THE IMPACT OF NATIONALLY DETERMINED CONTRIBUTIONS ON THE ENERGY SECTOR

IMPLICATIONS FOR ADB AND ITS DEVELOPING MEMBER COUNTRIES

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ABBREVIATIONS

ADB	Asian Development Bank
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
ASEAN	Association of Southeast Asian Nations
BAU	business as usual
CCS	carbon capture and storage
CO_2	carbon dioxide
DMC	developing member country
ETS	emissions trading schemes
GCF	Green Climate Fund
GHG	greenhouse gas
HELE	high efficiency low emission
HVDC	high-voltage direct current
IGCC	integrated gasification combined cycle
IRENA	International Renewable Energy Agency
NDC	nationally determined contribution
OECD	Organisation for Economic Co-operation and Development
PRC	People's Republic of China
REN21	Renewable Energy Policy Network for the 21st Century
SREP	Scaling up Renewable Energy Programme
TPES	total primary energy supply
UNFCCC	United Nations Framework Convention on Climate Change
WEO	World Energy Outlook

WEIGHTS AND MEASURES

EJ	exajoule
gCO_2	gram of carbon dioxide
Gt	gigaton
$GtCO_2$	gigaton of carbon dioxide
GW	gigawatt
km	kilometer
kV	kilovolt
kWh	kilowatt-hour
kWh/m^2	kilowatt-hour per square meter
$MtCO_2$	million tons of carbon dioxide
MW	megawatt
tCO_2	tons of carbon dioxide
TJ	terajoule (1 joule x 10^{12})
toe	ton of oil equivalent
TWh	terawatt-hour
TWh/y	terawatt-hour per year

EXECUTIVE SUMMARY

The Paris Agreement sets long-term goals to limit temperature rise to below 2 degrees centigrade (°C) and to pursue efforts to limit the temperature increase to 1.5°C. The core building blocks of the Paris Agreement are the nationally determined contributions (NDCs). NDCs contain a wide range of emissions targets, expressed in different forms and against different years, accompanied by targets in the form of renewable energy, nonfossil fuel energy, energy intensity, regulatory policies, and so on.

Many countries have specified targets for renewable energy as a key strategy to ensure achieving their NDC commitments. Around half of developing member countries (DMCs) of the Asian Development Bank (ADB) in the Asia and Pacific region have explicitly stated targets for the share of renewables in their NDCs, of which six countries in the Pacific (the Cook Islands, Fiji, Papua New Guinea, Samoa, Tuvalu, and Vanuatu) have set targets to achieve 100% renewable electricity generation, and another 16 countries are implementing or planning to implement clean energy policies to support their commitments. Twenty-seven DMCs anticipate power generation from renewable sources to account for more than 20% of the power generation mix by 2030.

This report assesses the impact of NDCs on the energy sectors of ADB's DMCs in terms of projected changes to the power mix, anticipated investment in energy technologies, as well the resulting emissions and emissions intensity of the power sector.

Implementation of NDCs reduces the degree of dependence on coal in power mix

Implementation of the NDCs (in 32 DMCs) will drive up the share of renewables and reduce the share of fossil fuels overall. An overall trend is to significantly reduce dependence on coal in the power mix by replacing it with renewables, nuclear, and gas.

The share of coal is projected to decrease from 67% in 2014 to 49% in 2030, and gas to increase from 8% to 11% over the period. The renewable share in power mix will increase to 31% in 2030 from 21% in 2014. Nuclear power will increase from 2% to 8%.

East Asia will show the largest drop in coal from 72% to 51% of generation by 2030. The People's Republic of China (PRC) contributes to this drop and its share of coal will fall from 73% in 2014 to 51% in 2030. This is mainly due to an increase in the share of renewables, gas, and nuclear in the PRC.

South Asia has the highest share of coal generation in 2030, though it is expected to decrease from 71% in 2014 to 56% in 2030. India is the key contributor to this given that the 58% of India's power is expected to be supplied through coal generation by 2030. By 2030, renewable generation is projected to supply 25% of power in South Asia from 15% in 2014.

Southeast Asia is projected to increase its renewable generation share by 8% to 27%; increase the share of coal from 36% to 42%; and see a decline in the share of gas from 40% to 30% in 2030.

In Central and West Asia, gas is projected to overtake coal to become the largest source of power generation by 2030. Coal will decline from 27% to 21% of total generation and gas will also fall from 30% to 25%. Kazakhstan contributes significantly to the fall in coal generation from 82% in 2014 to 44% in 2030. Renewable generation rises by almost 12 percentage points to 40%. The subregion has the highest share of nuclear generation among all subregions. The nuclear share sees a significant increase to 13% of generation due to the operation of new nuclear power plants in Armenia, Kazakhstan, and Pakistan.

In the Pacific, five countries (the Cook Islands, Fiji, Papua New Guinea, Samoa, and Tonga) are projecting to provide almost 100% of power by 2030 with generation from renewables, with oil generation in particular dropping to zero.

Renewable energy is the largest contributor to growth in electricity generation under the NDCs

By looking at the generation output of each source of energy between 2014 and 2030 in Figure 1, it can clearly be seen that the most significant share of the growth in power supply by 2030 will come from renewable energy. Renewable energy generation in ADB's DMCs is set to grow from 1,752 terawatt-hours (TWh) in 2014 to 4,470 TWh in 2030 under NDCs, more than doubling the current generation output. The growth of 2,715 TWh is the single largest contributor to the overall growth in the Asia and Pacific region's power supply by 2030.

The bulk of additional renewable generation will come from East Asia, but very significant growth will be seen in the Pacific, Southeast Asia, and South Asia, with an increase of 641%, 295%, and 267%, respectively.

Nuclear power generation projects the highest growth rate of all energy sources in DMCs by 2030

Currently, only four countries in the region (Armenia, the PRC, India, and Pakistan) produce nuclear power. In the PRC, India, and Pakistan, nuclear only represents a small share of the power mix (2.3% in the PRC, 2.8% in India, and 5% in Pakistan). In Armenia, nuclear represents 32% of total power generation.

Under the NDC scenarios for 2030, nuclear shows the highest growth rate of all generation sources, increasing from 176 TWh in 2014 to 1,118 TWh in 2030, to represent around 8% of the region's power generation. Most of this growth is accounted for by the PRC, but Pakistan, Kazakhstan, and Viet Nam see the most marked increases.

Pakistan sees nuclear capacity rising to 9 gigawatts (GW) from less than 1 GW in 2014. In Kazakhstan and Viet Nam, nuclear generation increases from almost zero in 2014 to reach 8% and 6% in 2030.

Coal will significantly increase its dominance in Southeast Asia and sees growth in generation of 218 % in the subregion by 2030

Overall, there is a fall in the dependence on coal in the region's power mix, but an absolute increase in generation from coal is still projected under the NDC scenarios, with an increase of 32% by 2030 compared to 2014. This is shown to be particularly significant in Southeast Asia and South Asia.

Southeast Asia is the only subregion to see rising share of coal in power generation. Its coal-fired generation is set to grow faster than every other source of energy, increasing by 218% in 2030 compared to 2014. From 2016 to 2030, 135 GW of coal capacity will be added in six key energy consumers, namely, Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam. Viet Nam leads with a coal generation increase of 544% against 2014. Cambodia and Indonesia show the next highest growth at well over 200%. This is contrary to the trend seen in other regions, and as a result, coal will increase its share in the power generation mix of these key energy consumers. The Philippines will overtake Indonesia and have the highest share of coal in the power mix for Southeast Asia in 2030 at 50%.

The substantial addition of coal capacity will result in locking in high emission assets for the long term. As such, a set of coordinated policies and the technologies are needed to satisfy short-term objectives while being consistent with longer-term ambitions. Governments must enhance support to investment in renewable technologies, emphasize the importance of investing in a diverse generation mix, as well as promote higher efficiency coal technologies and investment in carbon capture and storage (CCS).

Significant growth rates are also expected for natural gas in Indonesia, Thailand, and Viet Nam.

$4.8 trillion will be required for implementing the NDCs of DMCs, a third of which is for power grids and another third for renewables

In order to meet the power demand set out in the NDCs, it is estimated that an investment of at least $321 billion per year is required for the power sector in the 32 DMCs assessed in this report. This totals to $4.8 trillion between 2016 to 2030, 92% of which will need to occur in the PRC, India, Indonesia, Kazakhstan, Pakistan, and Viet Nam.

Roughly one-third of the investment will be in the power grid, another third will be in renewable energy capacity, and the rest for generation capacity from other sources. Around 18% will be invested in fossil fuels and 8% in new nuclear. Investment in coal will still represent 15% of the total investment, mainly in the PRC, India, Southeast Asia, and Pakistan.

Investment in the power grid is needed to achieve many different priorities, including reducing high power losses, increasing access to energy, enabling decentralized energy generation as well as interconnections in the region, and enabling better management of variable renewable resources through smart grids.

NDCs will substantially reduce the carbon intensity of power generation and energy intensity of GDP

Although emissions from power sector will still increase, by 2030 compared to 2014, the carbon intensity of power generation in the region will significantly decrease by 29% on average for the PRC; India; and for Asian economies that are not members of the Organisation for Economic Co-operation and Development (OECD), namely, Bangladesh; Brunei Darussalam; Cambodia; Indonesia; the Democratic People's Republic of Korea; Malaysia; Mongolia; Myanmar; Nepal; Pakistan; the Philippines; Singapore; Sri Lanka; Taipei,China; Thailand; Viet Nam; and other Asian economies and territories. The PRC will lead the drop of 32% in carbon intensity of power generation while other DMCs will see a decrease of around 27%.

By looking at the reduction trend in energy intensity of gross domestic product (GDP) in 11 selected DMCs (namely, Bangladesh, Brunei Darussalam, the PRC, India, Indonesia, Kazakhstan, Malaysia, the Philippines, Thailand, Turkmenistan and Viet Nam), where data are available, the energy intensity of GDP will be reduced by 22% on average from 2014 to 2030, showing a strong decoupling of energy and GDP growth. The most significant reductions will be made in the PRC and India, which is consistent with their commitments under the Paris Agreement.

Significant additional reductions in emissions can be achieved with enhanced low carbon actions

This report analyzes six countries (the PRC, India, Indonesia, Kazakhstan, Pakistan, and Viet Nam) based on their emissions and the projected investment required to achieve their NDCs. In each of these six countries, a scenario is elaborated on, which builds on the NDC to achieve more ambitious goals for future emissions.

Table A shows a summary of the emissions, carbon intensity of generation, and total investment required under the NDC; and the enhanced low carbon action scenario, which is an aggressive strategy to increase use of renewable energy in the overall generation mix.

The enhanced scenarios generally include a higher ambition for renewable energy, and in the PRC, India, and Viet Nam, there is a strong emphasis on energy efficiency. In India, this means an accelerated program of old coal plant closures, investment in high-efficiency technologies, and improvements to the efficiency of existing coal plants.

Importantly in India, an aggressive program to reduce the dependency on coal through these measures could massively bring down emissions by 46%, compared to the NDC, with an increased cost of only 3%, and would have a major impact on the coal dependency of the region.

It can be seen from Table A that only in Viet Nam will the enhanced scenario come at a negative cost relative to the NDC. This is primarily due to a focus on energy efficiency in end-use sectors in order to reduce power demand.

Similarly, an ambitious plan to increase the share of renewables in Pakistan could result in a 37% reduction in emissions compared to the NDC for a 16% increase in costs. Pakistan should therefore be a priority country for international climate finance to support this goal.

In the PRC, as the largest emitter, in addition to the increased investment in renewables and in light of the economic restructuring of the industry sectors as well as improvement of energy efficiency, more can be done to reduce energy consumption overall, and so this is reduced by 5% compared with the NDC. The scenario also leads to a peaking of emissions from the power sector by 2020 rather than 2030, which would be consistent with the pathway to achieve net zero emissions by the second half of the century.

In Indonesia, the focus of the enhanced scenario is predominantly investment in renewable generation technologies such as hydropower, geothermal, solar, and biomass, as well as implementation of a program to retire coal plants after 25 years and replace them with high efficiency, low emission (HELE) units.

Kazakhstan has the potential to generate 30% of its power from solar and wind. Therefore, the enhanced low carbon action scenario sees a major transformation of the power system in Kazakhstan to 41% of power generated from renewables and no generation from nuclear before 2030.

The analysis in this report has highlighted six key areas for ensuring that the region can meet its targets set out under the NDCs, and to try to surpass these.

1. **Meeting the needs of renewable energy growth** by investing in advanced smart grid technologies, promoting decentralized solutions, enhancing connectivity of the power grid, and increasing the application of renewable energy in the demand sector.

2. **Reducing the growth of coal and its impact** through a diversified power mix, increased efficiency of coal generation, driving forward CCS, and pricing carbon.

3. **Improving energy efficiency in demand sectors** through improved energy efficiency in industry, a program of energy efficiency in buildings, and low-emissions transport.

Table A: Emissions and Total Investment to Achieve the Nationally Determined Contributions Scenario and Enhanced Low Carbon Goals in Selected Countries

Country	Power Sector Emissions in 2014 ($MtCO_2$)	Power Sector Emissions in 2030 ($MtCO_2$)			Carbon Intensity of Generation in 2030 (gCO_2/kwh)			Total Investment ($ billion)		
		NDC Scenario	Enhanced Low Carbon Scenario	% Change	NDC Scenario	Enhanced Low Carbon Scenario	% Change	NDC Scenario	Enhanced Low Carbon Scenario	% Change
PRC	4,382	4,563	4,297	-6	519	465	-10	2,550	2,890	13
India	1,045	1,719	930	-46	594	404	-32	1,230	1,266	3
Indonesia	168	496	431	-13	606	526	-13	298	330	11
Viet Nam	50	299	264	-12	537	503	-6	209	194	-7
Pakistan	45	72	45	-37	252	158	-37	98	114	16
Kazakhstan	96	77	69	-10	562	506	-10	33	37	12

gCO_2 = grams of carbon dioxide, kWh = kilowatt-hour, $MtCO_2$ = million tons of carbon dioxide, NDC = nationally determined contribution.

Source: Consolidated based on figures of section IV.

4. **Promoting low carbon technology transfer and deployment** through technology promotion and financing mechanisms, diverse approaches for technology transfer, building domestic technological capacity, and enhancing South-South cooperation among DMCs.

5. **Promoting access to climate finance** by supporting project pipeline development, establishing risk mitigation instruments, building innovative financing platforms, and building capacity for access to international climate finance.

6. **Establish enabling regulatory and policy frameworks** by removing fossil fuel subsidies, reforming electricity markets for renewable power integration, and providing risk-sharing mechanisms and capacity-pricing mechanisms.

I. INTRODUCTION

This report analyzes the implication of the Paris Agreement for the energy sector, assesses the impact of nationally determined contributions (NDCs) on the energy sectors of developing member countries (DMCs) of the Asian Development Bank (ADB), and explains the challenges and opportunities faced by DMCs in the implementation of their NDCs. The report identifies what technology solutions, financing needs, and policy frameworks are required for accelerating energy transition and reaching NDC targets; and explains how ADB operations could support the effective implementation of these NDCs.

The report is structured into six sections. Section I introduces the background of the report; section II provides an overview of NDCs of DMCs; section III analyzes the impact of NDCs for the energy sector and challenges for DMCs to implement NDCs; section IV contains case studies to illustrate the energy sector impact of NDCs and implications for enhanced low carbon actions in selected countries; section V develops recommendations for DMCs to implement their NDCs; and section VI draws implications for ADB operations.

A. Key Outcomes of the Paris Agreement

The Paris Agreement entered into force on 4 November 2016, 30 days after 55 countries, representing 55% of global emissions, deposited their instruments of ratification, acceptance, or accession with the Secretary-General of United Nations.

The Paris Agreement sets ambitious long-term mitigation goals to limit temperature rise to below 2 degrees centigrade (°C) and to pursue efforts to limit the temperature increase to 1.5°C. It calls for a peaking of greenhouse gas emissions as soon as possible and for a balance between anthropogenic emissions by sources and removals by sinks in the second half of the century; in other words, net-zero emissions. The agreement also sets out mechanisms to tighten these targets in the short and longer term.

The agreement commits that all financial flows consistent with a pathway toward low emissions and climate resilient development. Developed countries will continue the commitment of mobilizing $100 billion a year from 2020, and adopt a more ambitious financial goal beyond that, though it is still unclear exactly where this money will come from. However, developed countries are required every 2 years to communicate climate financing they have provided, and the projected levels of support they expect to provide in the future.

A technology framework is also established in the agreement that is intended to support the existing technology mechanism, including through financial support to developing countries.

The agreement establishes a voluntary cooperative mitigation mechanism to encourage countries to achieve NDCs through carbon trading (including emissions trading and credit trading) on a voluntary basis. But such a mechanism must ensure environmental integrity and transparency, as well as robust accounting to ensure the avoidance of double counting.

The core building blocks of the Paris Agreement are the NDCs. NDCs represent the national commitments that countries are willing to make in order to contribute to global climate change mitigation. The NDCs are based on a country's national circumstances and ability to reduce GHG emissions. Importantly, the principle of common but differentiated responsibilities remains in the Paris Agreement, which was a victory for developing countries.

All countries are required to prepare, communicate, and maintain successive NDCs, which are updated every 5 years taking into account the results of the "global stock-take." The global stock-taking will provide a regular update on the overall effect of the NDCs and the latest reports from the Intergovernmental Panel on Climate Change, among other things, with a view to guiding NDC updates.

The first global stock-taking will be implemented in 2023 in order to inform the 2025 NDC updates. An informal stock-taking will be implemented in 2018 ahead of the start of the Paris Agreement in 2020. Each country is also asked to formulate a long-term GHG emission development plan that is consistent with the overall aim of the agreement.

The NDCs contain a wide range of emissions targets, expressed in different forms and against different years, accompanied by targets in the form of renewable energy, nonfossil fuel energy, energy intensity, regulatory policies, and so on.

The agreement contains a transparency framework to ensure that countries will do what they have set out in their NDCs. This includes certain principles on flexibility, transparency, accuracy, consistency, comparability, double counting, duplication, and so on. While the NDCs are not legally binding, this transparency framework will hold countries to account on their mitigation targets. Failure to meet their targets will result in political embarrassment for countries on the global stage.

B. Implications for the Energy Sector Transition

The peaking of GHG emissions as soon as possible and net-zero GHG emissions in the second half of the century will have far-reaching implications for the energy sector. To achieve these goals, the global energy sector must decarbonize, and as such, there will be immediate changes in energy policy around the globe in order to develop and deploy low carbon energy technologies in the sector.

1. Driving the Global Energy Transition to Decarbonization

Energy-related GHG emissions contribute to two-thirds of global GHG emissions (IEA 2015i). As such, the targets contained in the Paris Agreement require this global energy transition. To achieve the shorter-term targets set out in the NDCs and the longer-term commitments to achieve net zero emissions in the second half of the century, investment and policy decisions must be taken now to decarbonize the energy sector and ensure sufficient momentum is maintained on technology innovation in order to achieve emissions cuts at scale.

2. Limits to the Production and Consumption of Fossil Fuels

Over 90% of energy-related GHG emissions are carbon dioxide (CO_2) emissions from the combustion of fossil fuels, and 80% of total primary energy consumption is from fossil fuels (IEA 2015i). Reduction of fossil fuels' production and use is the key to staying below the agreed 2°C limit or indeed 1.5°C. However, the potential emissions from oil, gas, and coal in all of the world's fields and mines currently operating would take us beyond 2°C (Oil Change International 2016). A decline in production and consumption is therefore needed over the coming decades if we are to meet our climate goals.

The Paris Agreement will provide additional stimulus to the development of carbon pricing mechanisms and regional approaches to carbon markets to curb fossil fuel use. Currently, carbon pricing policies are planned or have already been introduced in 39 countries globally (World Bank and Ecofys 2015). In Asia, this includes the national carbon market in the People's Republic of China (PRC) due to commence in 2017, as well as the regional pilots already under way; the Republic of Korea carbon market that began in 2015; a number of schemes in Japan (including the Tokyo Cap and trade scheme that began in 2010, and the carbon tax that was introduced in 2012); and the emissions trading scheme in Kazakhstan that began in 2013. Other forms of carbon trading policies to discourage fossil fuel use are also under consideration in Indonesia, Thailand, and Viet Nam.

Investors around the world are now responding to this need by starting to divest from fossil fuels on the basis that an international agreement on climate change would result in fossil fuel investments becoming worthless (so called "stranded assets"). The types of institutions divesting from fossil fuels are investment banks, pension funds, foundations, universities, and local authorities.

Similarly, countries are also responding to the need to shut down fossil fuel capacity. In September 2016, the Government of the Netherlands voted to shut down the remaining five coal plants still in operation, having already closed five plants in 2015. Likewise, the PRC is intent on building a low carbon energy system through implementation of a number of measures, including limits on total coal consumption and increased share of cleaner coal technologies.

Over the coming years, we are therefore likely to see countries implement various policies to curb production and consumption of fossil fuels. Tightened standards and regulations will be applied to energy production and consumption, as well as industrial sources of GHG emissions. Carbon capture and storage will also need to move beyond demonstration to deployment by creating the right incentives and policy frameworks.

3. Accelerating Clean Energy Investment

It is clear from the NDCs that there will be a greater focus on renewable energy and we will see more incentive policies that drive renewable energy technology development on both the supply and demand sides. For example, India is implementing an ambitious strategy for renewable energy development that includes a number of initiatives such as the Green Generation for Clean & Energy Secure India that aims to deliver a fivefold increase in renewable energy generation capacity from 35 GW in March 2015 to 175 GW by 2022.

In order to deliver this transition to renewable energy, reliable and affordable technical solutions are urgently needed. Mobilizing the large amounts of financial resources necessary for clean energy investment will depend on cost reduction of renewable energy and attractive business models for renewable energy investment.

Various communities are now shifting their interests to clean energy investment. During the negotiation of the Paris Agreement, it was notable that many cities, states, companies and investors announced clean energy investment initiatives. Bill Gates and 27 other investors from 10 countries launched the Breakthrough Energy Coalition to channel private capital into deployment of clean energy technologies. A group of 20 governments (including the United States) launched the Mission Innovation Initiative, which commits to double public investment in clean energy research and development over the next 5 years. ADB committed to double its climate finance, of which half is to be allocated to clean energy investment.

C. Impact of Nationally Determined Contributions on Emission Reductions

The Paris Agreement sets out the overarching aim to hold the increase in the global average temperature to well below 2°C. Achieving this goal is dependent on the national commitments contained in all of the NDCs. Some 162 NDCs have been submitted representing 189 countries covering 95.7% of global emissions (including the European Union as one NDC). Globally, the unconditional commitments contained within the NDCs would lead us to a warming of around 2.7°C by 2100. This value is derived from a full range of model projections ranging from 2.2°C to 3.4°C (Climate Change Tracker 2015).

Many developing countries have set out unconditional commitments as well as targets that might be achieved if the right level of support and finance is provided by developed countries. If these so-called conditional targets can also be met, then the emissions gap (15 gigatons of carbon dioxide [so called $GtCO_2$] in 2030 to be on course for a 2°C pathway) can be partially closed by roughly 17% (Climate Action Tracker 2015).

Implementation of NDCs needs to translate commitments and plans into concrete actions. Asia will consume almost half of global energy in 2035 as the energy sector accounts for two-thirds of emissions. The energy sector must therefore be the central pillar for action.

II. OVERVIEW OF NATIONALLY DETERMINED CONTRIBUTIONS AND THEIR ENERGY COMPONENTS IN ADB'S DEVELOPING MEMBER COUNTRIES

A. Emission Reduction Commitments

In Asia and the Pacific, 38 DMCs have committed to take mitigation actions through NDCs under the Paris Agreement. Only Timor-Leste and Uzbekistan are the exceptions and had not submitted NDCs as of December 2016.

The commitments of DMCs to reduce emissions as set out in their NDCs take various forms, typically a percentage reduction from a defined baseline based on projections of emissions in a set year or base year. This approach is generally adopted by developed countries to provide an absolute quantification of the GHG emission reductions.

In developing countries, specifically in DMCs, the baseline is typically a projection of a business as usual (BAU) scenario for 2030. The BAU scenario would account for economic and industrial growth and might show an increase in emissions over time. Given that the accuracy of economic growth projections may be questioned, some of the larger developing countries have opted to link emission reductions directly to gross domestic product (GDP). The emission reduction is therefore relative to actual economic growth.

A large proportion of DMCs have set emission reduction targets based upon BAU projections (15 countries), and all of these targets are set to be achieved in 2030. Interestingly, both Georgia and Viet Nam have also expressed these targets relative to GDP and therefore show two sets of targets (Table 1).

The PRC, India, Malaysia, and Viet Nam have all set their primary targets in their NDCs in the form of emission reductions relative to GDP. This is the second such target set by the PRC, having already set a target of 40%–45% reduction by 2020 that it is on course to meet. Notably, the India NDC is the only one to not set a target on an unconditional basis.

Some DMCs have also set absolute emission reduction targets in their NDCs. These countries have adopted targets based on percentage emission reductions against a base year. These countries are mainly located in Central and West Asia (Azerbaijan, Kazakhstan, Tajikistan) and the Pacific (the Cook Islands, the Federated States of Micronesia, the Marshall Islands, Palau, Solomon Islands, Tuvalu). All Central and West Asia countries have adopted a 1990 base year, whereas Pacific island countries have used various baseline years.

Table 1: Specified Emission Reduction Targets in Developing Member Countries

	Target Type	Base Year	Target Year	Unconditional Target	Conditional Target (%)
Central and West Asia					
Afghanistan	% of BAU	n/a	2030		13.6
Armenia	Emissions cap	2015	2050	633 $MtCO_2$ in aggregate between 2015 and 2050	
Azerbaijan	% of base year	1990	2030		35

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Table 1 *continued*

	Target Type	Base Year	Target Year	Unconditional Target	Conditional Target (%)
Georgia	% of BAU	2013	2030	15%	25
	% relative to GDP	2013	2030	34%	43
Kazakhstan	% of base year	1990	2030	15%	25
Kyrgyz Republic	% of BAU	2010	2030	11.49%–13.75%	35.06–36.75
Pakistan	% of BAU	n/a	2030		20
Tajikistan	% of base year	1990	2030	10%–20%	25–35
Turkmenistan	Emissions cap (Emissions/GDP also used as indicator)	2000	2030		Zero growth in emissions, or even reduced emissions, by 2030
Uzbekistan	No INDC				
East Asia					
People's Republic of China	% relative to GDP	2005	2030	60%–65%	
Mongolia	% of BAU	n/a	2030		14
Pacific					
Cook Islands	% of base year	2006	2020	38% in power sector	81% in power sector
Federated States of Micronesia	% of base year	2000	2025	28%	35
Fiji	% of BAU	n/a	2030	10%	30
Kiribati	% of BAU	n/a	2030	12.8%	48.8
Marshall Islands	% of base year	2010	2025	32%	
Nauru	No emissions target				
Palau	% of base year	2005	2025		22% reduction in power sector
Papua New Guinea	Emissions cap				Zero emissions from power sector
Samoa	No emissions reduction target				
Solomon Islands	% of base year	2015	2030	30%	45
Tonga	No emissions reduction target				
Tuvalu	% of base year	2010	2025	60% in energy sector	
Vanuatu	% of BAU	n/a	2030		30 in energy sector

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Table 1 *continued*

	Target Type	Base Year	Target Year	Unconditional Target	Conditional Target (%)
South Asia					
Bangladesh	% of BAU	n/a	2030	5%	15
Bhutan		n/a	n/a	Remain carbon neutral (GHG emissions< sequestration)	
India	% relative to GDP	2005	2030		33–35
Maldives	% of BAU	n/a	2030	10%	24
Nepal	No emissions reduction target				
Sri Lanka	% of BAU	n/a	2030	4% in energy sector and 3% in other sectors	16% in energy sector and; 7% in other sectors
Southeast Asia					
Brunei Darussalam	No emissions reduction target				
Cambodia	% of BAU		2030		26.7% in energy and industries
Indonesia	% of BAU	2005	2030	29%	41
Lao People's Democratic Republic	No emissions target				
Malaysia	% relative to GDP	2005	2030	35%	45
Myanmar	No emissions reduction target				
Philippines	% of BAU	2000	2030		70
Thailand	% of BAU	2005	2030	20%	25
Viet Nam	% of BAU	2010	2030	8%	25
	% relative to GDP	2010	2030	20%	30

BAU = business as usual, GDP = gross domestic product, GHG = greenhouse gas, $MtCO_2$ = million tons of carbon dioxide, n/a = not available.

Source: UNFCCC (2016).

There are also a few countries that do not provide emission reduction targets but have indicated their broad intentions as follows:

(i) Bhutan has committed to remain carbon-neutral with GHG emissions, with emissions by source balanced by removals by sinks.

(ii) Armenia commits that its aggregate emissions will not exceed 633 $MtCO_2$ between 2015 and 2050, and that in 2050 emissions will be carbon-neutral, with GHG emissions by source balanced by removals by sinks.

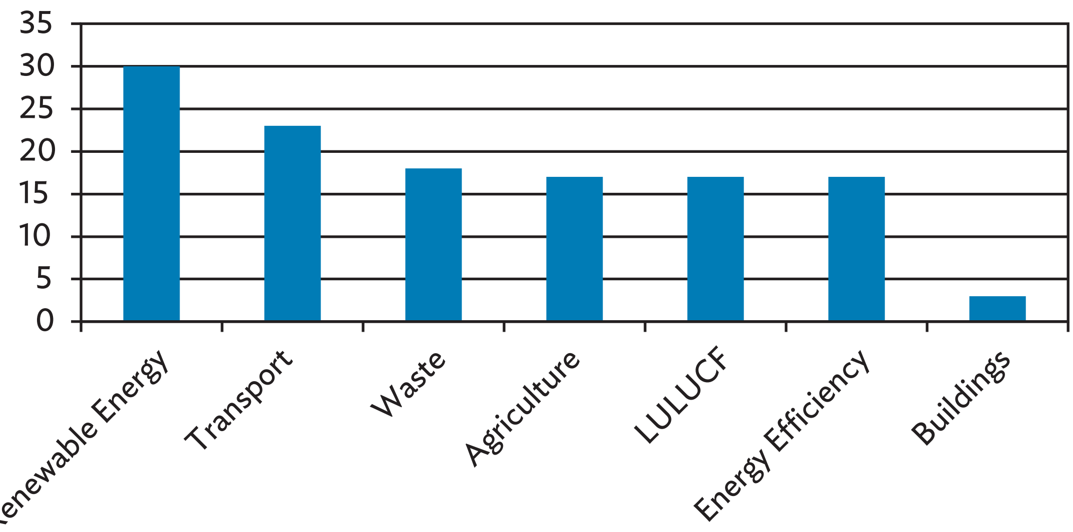
(iii) Turkmenistan pledges to achieve zero growth in GHG emissions by 2030, primarily through domestic action, but with some international support.

In addition to the targets set out in the table above, many countries have opted for specific targets for the energy sector, either as well as the emissions target or instead of (see section II-B below).

B. The Energy Transition to Achieve Nationally Determined Contribution Targets

Overall, the NDCs show a major commitment to renewable energy. The energy sector is consistently identified as a priority for emission reduction to meet the commitments on climate change. Figure 1 summarizes the priorities identified by DMCs in their NDC commitments.

Figure 1: Sector Priorities of Developing Member Countries for Climate Change Mitigation as Set out in Nationally Determined Contribution Scenarios



LULUCF = land use, land use change, and forestry.
Note: Aggregate information from various countries.
Source: UNFCCC (2016).

Given the importance of the renewable energy sector in meeting emission reduction targets, many countries have focused solely on this sector in putting forward their contributions to tackling climate change, rather than in setting explicit emission reduction targets. As such, Table 2 below lists the remaining targets for DMCs not covered in section II-A above.

1. Clean Energy and Renewable Energy Targets

In addition to the targets listed above, many countries that have specified emission reduction commitments have also specified targets for renewable energy as a key strategy to ensure achievement of their NDC commitments. Overall, around half of DMCs have established quantified actions for clean energy in different forms. For example, the PRC intends to increase its share of nonfossil fuels in primary energy consumption to around 20%. Similarly, India has also set the target to achieve 40% nonfossil fuel-based capacity for power generation in 2030. Bangladesh will reduce energy intensity by 20% in 2030 (this includes targets for renewables capacity of 400 megawatts (MW) wind and 1,000 MW of utility-scale solar).

Table 2 summarizes all the renewable energy targets set out in DMCs' NDCs. The table shows that in the Pacific, six countries (the Cook Islands, Fiji, Papua New Guinea, Samoa, Tuvalu, and Vanuatu) have set out ambitions to achieve 100% renewable electricity generation. Only 16 countries in the Asia and Pacific region have explicitly stated targets for the share of renewables in the NDC.

Table 2: Summary of Clean Energy Targets Set out in Nationally Determined Contributions Scenario by Developing Member Countries

	Target Type	Target Year	Unconditional Target	Conditional Target
Central and West Asia				
Afghanistan	No energy target			
Armenia	New RE generation capacity	2025	540 MW HPP 200 MW Wind	
Azerbaijan	No energy target			
Georgia	No energy target			
Kazakhstan	No energy target			
Kyrgyz Republic	No energy target			
Pakistan	No energy target			
Tajikistan	No energy target			
Turkmenistan	No energy target			
Uzbekistan	No energy target			
East Asia				
People's Republic of China	% share nonfossil fuel in PEC	2030	20%	
Mongolia	% share RE in generation capacity	2030	30%	
Pacific				
Cook Islands	% share RE in power mix	2020		100%
Federated States of Micronesia	No energy target			
Fiji	% share RE in power mix	2030	100%	
Kiribati	No energy target			
Marshall Islands	No energy target			
Nauru	Investment target	2030	$5 million in PV	$50 million in DSM
Palau	% share RE in power mix	2025	45%	
Papua New Guinea	% share RE in power mix	2030		100%
Samoa	% share RE in power mix	2025		100%

continued on next page

Table 2 *continued*

	Target Type	Target Year	Unconditional Target	Conditional Target
Solomon Islands	No energy target			
Tonga	% share RE in power mix	2030	70%	
Tuvalu	% share RE in power mix	2025	100%	
Vanuatu	% share RE in power mix	2030	100%	
South Asia				
Bangladesh	RE generation capacity	2030	400 MW wind 1,000 MW utility solar	
Bhutan	No energy target			
India	% share nonfossil fuel installed capacity	2030	40%	
Maldives	No energy target			
Nepal	% share RE in power mix	2050	80% RE 50% reduction in FFD	
Sri Lanka	No energy target			
Southeast Asia				
Brunei Darussalam	% share RE in power mix % reduction in TEC	2035 2035	10% 63%	
Cambodia	No energy target			
Indonesia	No energy target			
Lao People's Democratic Republic[a]	% share small-scale RE	2025	30%	
Malaysia	No energy target			
Myanmar	Hydropower generation capacity	2030	9.4 GW	
Philippines	No energy target			
Thailand	% share RE in power mix % share renewables in TEC	2036 2036	20% 30%	
Viet Nam	No energy target			

DSM = demand side management, FFD = fossil fuel dependency, GW = gigawatt, HPP = heat power plant, MW = megawatt, PEC = primary energy consumption, RE = renewable energy (for power generation), TEC = total energy consumption.

[a] The Lao People's Democratic Republic already uses almost 100% renewable energy and plans to increase capacity from small-scale renewables.

Note: Aggregate information from various countries.

Source: UNFCCC (2016).

2. Energy Sector Priorities

Many DMCs have specified priorities in energy sector for mitigation in their NDCs. DMCs each have unique situations in terms of energy resources, energy supply infrastructure, energy consumption patterns, and economic drivers. As such, the climate change mitigation potential differs by country as do the technology priorities. In general terms, DMCs identified the following priorities in their NDCs:

(i) high efficiency and low emissions fossil fuel power plant,

(ii) increased use of renewable energy,

(iii) retrofitting existing power plants,

(iv) improvements to the existing transmission and distribution network, and

(v) increased access to energy (renewable energy).

Table 3 sets out the regional energy technology priorities stated in the NDCs. In terms of renewable energy, wind, solar, and bioenergy technologies are the most common energy technologies identified in NDCs.

Table 3: Summary of Regional Energy Technology Priorities Set out in Nationally Determined Countries Scenario by Developing Member Countries

Region	Summary of Sector Priorities
East Asia	**People's Republic of China** • Clean use of coal; increased share of concentrated and highly efficient power generation • Lower coal consumption of power generation for new units • Expand the use of natural gas • Develop renewable and nuclear power, distributed energy, and smart grids **Mongolia** • Increase renewable electricity capacity • Reduce electricity transmission loss • Improve power plant efficiency
South Asia	**India** • Introduce more efficient and cleaner coal technologies for power generation • Renovate existing plants • Increase the share of alternative fuels in overall fuel mix • Improve efficiency of transmission and distribution networks • Construct Green Energy Corridor **Other Countries** • High-efficiency coal technology for new power generation • Develop renewable energy (solar, wind, biomass, large and small hydropower and waste-to-power plants) • Construct power grid • Increase access to energy
Southeast Asia	• Use high-efficiency coal-fired technology for new power plants • Raise efficiency of existing power production • Expand power grid • Develop renewables (solar, wind, hydropower, biofuel, biogas, biomass, waste-to-energy, etc.) • Increase access to energy
Central and West Asia	• Retrofit existing power plants (e.g., single cycle to combined cycle) • Improve the distribution networks and transmission line • Develop renewables (wind, large and small hydro, solar, biomass) • Develop renewable energy in the heating system for residential use • Apply modern high technologies in the production and processing of fossil fuels
Pacific	• Develop grid-connected and off-grid renewables (solar, wind, geothermal, wave, biofuel, biomass) • Use renewable energy to replace diesel • Construct grids with storage • Develop hybrid energy supply systems, distributed energy system, micropower grid etc.

Note: Aggregate information from various countries.
Source: UNFCCC (2016).

Many countries in the region have a high dependence on fossil fuels, hence, improving the efficiency of their use is a high priority. In general, countries are prioritizing two types of technological solutions:

(i) Implement high efficiency low emissions technologies (HELE) for new coal power plants, including supercritical coal, ultrasupercritical coal, integrated gasification combined cycle, and pressurized circulating fluidized bed combustion.

(ii) Improve the efficiency of existing power plants, including reduced coal consumption, single cycle to combined cycle conversion, and modernizing existing plants.

Bangladesh, the PRC, India, Indonesia, Malaysia, Mongolia, and Viet Nam all mandate that newly built power plants should be built using high-efficiency technologies.

In terms of efficiency improvements in existing power plants, according to the PRC's NDC, it has implemented policies to reduce coal consumption to around 310 grams coal equivalent per kilowatt-hour through technology upgrades. Bangladesh and Mongolia are adopting combined cycle for existing power plants and India will renovate and modernize existing power stations and extend their life of service.

In Central and West Asia, where gas is more prevalent, Armenia, Azerbaijan, and Turkmenistan plan to replace existing gas turbine power generation with combined cycle.

So far, only the PRC is working on the demonstration of carbon capture, utilization storage technology, and only the PRC and India are interested in the deployment of concentrated solar power due to its high cost. The PRC and India intend to deploy various low carbon technologies to accommodate their large energy demands.

Small-scale renewables are a priority for certain countries particularly where energy demands are relatively low and access to energy is a priority. Countries such as Cambodia, the Kyrgyz Republic, Myanmar, Nepal, and Tajikistan as well as the Pacific island countries see small-scale renewables as a solution to increase energy access in rural and remote areas. Technologies such as microhydro, small-scale wind, roof-top solar power, solar home systems, distributed solar, and minigrids are technologies sought by these countries.

Given that most of the Pacific island countries have set a target for renewable energy at 100% of the power mix, hybrid technologies are being looked at to optimize the required level of power storage and need for peaking plant. Solomon Islands has identified wind–solar hybrid systems, and Tuvalu has identified solar–biodiesel hybrid systems for power generation.

Many countries have indicated the need to increase power grid connections and improve existing transmission and distribution infrastructure. Mongolia and the Philippines intend to upgrade existing transmission lines and reduce transmission losses. Armenia, Azerbaijan, the Cook Islands, Nauru, Palau, Samoa, Tajikistan, and Thailand plan to improve transmission and distribution networks as well as enhance power grid connection through construction of additional lines. Bangladesh, Cambodia Fiji, Nepal, and Solomon Islands intend to increase grid-connected renewables through extension of the grid.

India has launched the National Smart Grid Mission for enhancing efficient transmission and distribution networks, as well as the Green Energy Corridor project to improve the grid uptake of renewable energy.

A few countries (the PRC, India, Thailand, and Tonga) are considering the deployment of smart grids and many other countries are also interested in minigrids and distributed generation, particularly the Pacific DMCs, Cambodia, and Myanmar. This reflects the need for flexible power grids to accommodate high shares of renewable energy in the power mix.

Likewise, energy storage has been identified as a need for some countries including the Pacific DMCs. India has also highlighted the need for energy storage technologies for renewable energy integration.

C. Technology Transfer and Financial Support for Nationally Determined Contributions

National mitigation commitments and mitigation actions set out in the NDCs are largely dependent on available technology and level of financial (as well as technical) support as well as capacity building for DMCs. Although many DMCs do not specify financing amount to implement their NDCs, most (36 DMCs) clearly require external support in terms of technology transfer, finance, and capacity building as a precondition for meeting their commitments.

Some countries (such as Afghanistan, Kazakhstan, Kiribati, the Marshall Islands, Mongolia, Tonga) stress that access to climate finance from international climate financing mechanisms, as well as capacity building to facilitate direct access to these mechanisms, is necessary to achieve their targets.

Only Azerbaijan and the PRC did not specify the need for international support. However, the PRC requires developed countries to provide new, additional, adequate, predictable, and sustained financial support to developing countries for the implementation of their NDCs.

D. Use of Market Mechanisms

The PRC, most of Southeast Asia, South Asia, and three Pacific DMCs are considering or intend to use international market-based mechanisms to support the implementation of their NDCs. Central Asian countries generally do not specify whether they would back market-based mechanisms, with the exception of Afghanistan and Kazakhstan.

A few countries have introduced or are considering carbon pricing mechanisms. Kazakhstan has begun its national emission trading market. The PRC has piloted emission trading in five cities and two provinces and is going to enter into national implementation in the second half of 2017. Indonesia, Thailand, and Viet Nam are developing their carbon trading schemes either as emissions trading or offset credit schemes.

India has introduced two market-based mechanisms to promote renewable energy development and energy saving in the country. The Renewable Energy Certificate (REC) was established for incentivizing uptake of renewable energy through trading renewable energy certificates, and the performance, achieve, trade has been created to improve energy efficiency in energy-intensive industries by trading energy savings certificates.

Aside from these market mechanisms, policies to incentivize clean energy are also set out in most NDCs. Subsidies, feed-in-tariffs, and tax exemption are the most common incentives employed to support renewable energy and energy efficiency. See section III-A7 below.

III. ENERGY CHALLENGES IN IMPLEMENTING THE NATIONALLY DETERMINED CONTRIBUTIONS

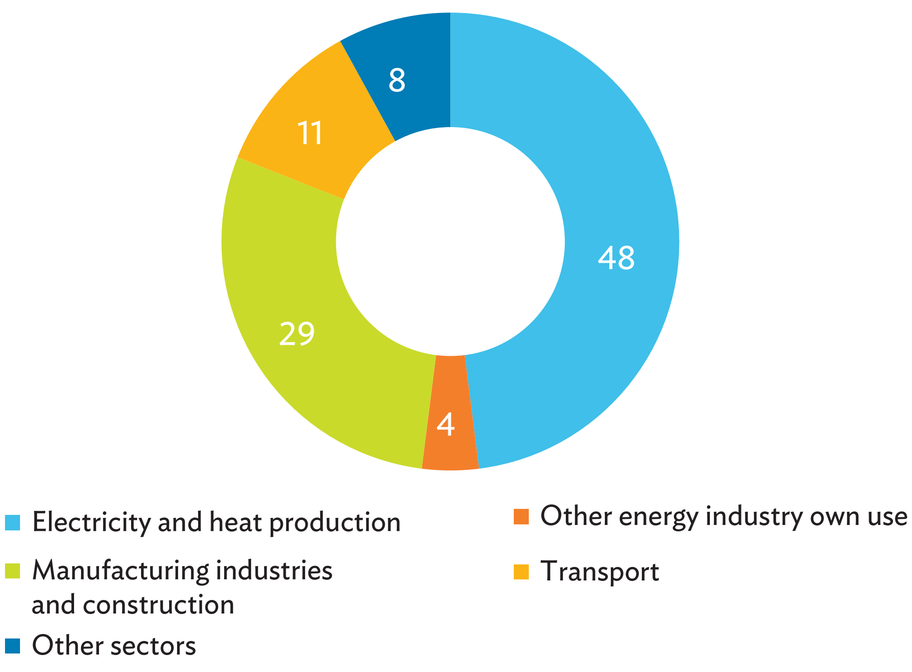
Energy demand is projected to almost double in the Asia and Pacific region by 2030. There is an urgent need for innovative ways to generate power in a socially, economically, and environmentally sustainable manner. Compounding the problem is widespread energy poverty across Asia, with almost a billion people still without access to electricity.

A. Overview of the Energy Sector in Asia and the Pacific

1. Energy and Carbon Dioxide Emissions in Asia and the Pacific

In 2014, total primary energy supply in DMCs was 3,207 million tons of oil equivalent (Mtoe), accounting for 36% of global primary energy supply, while energy-related CO_2 emission was 13.4 $GtCO_2$, accounting for 41% of global energy-related CO_2 emissions. The PRC represents more than 68% of DMCs' CO_2 emissions. Power and heat generation is the largest emission source, with CO_2 emissions representing 48% of CO_2 emissions in DMCs (Figure 2).

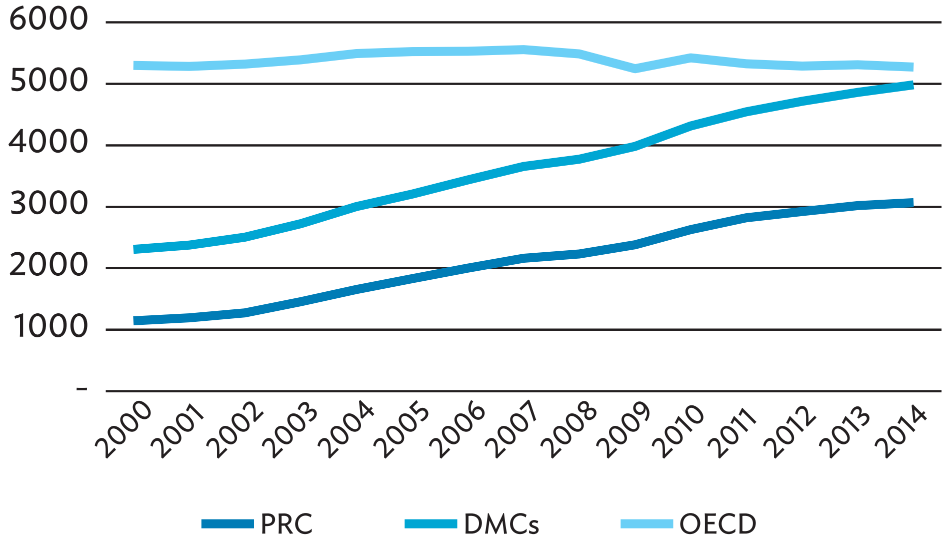
Figure 2: Carbon Dioxide Emissions by Sector in Developing Member Countries, 2014 (%)



Source: IEA (2016b).

Figure 3 and Figure 4 clearly indicate that both energy consumption and CO_2 emissions show a strong growth trend alongside GDP growth in DMCs since 2000. The opposite trends have been observed in countries of the Organisation for Economic Co-operation and Development. DMCs' total primary energy supply (TPES) increased by 110% between 2000 and 2014 while CO_2 emissions grew by 136%. The PRC's TPES and related CO_2 emissions increased by 167% and 192% during this period.

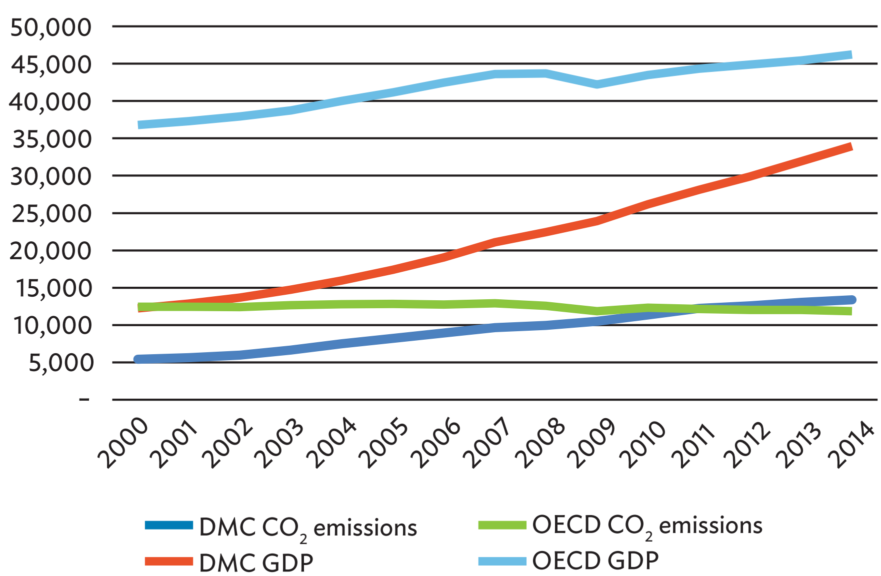
Figure 3: Historic Total Primary Energy Supply Trend in the People's Republic of China, Developing Member Countries, and Organisation for Economic Co-operation and Development, 2000–2014 (Mtoe)



PRC=People's Republic of China, DMCs=Developing Member Countries; OECD=Organization for Economic Co-operation and Development.

Source: IEA (2016b).

Figure 4: Historic Carbon Dioxide Emission and Gross Domestic Product Growth Trend in Developing Member Countries and Organisation for Economic Co-operation and Development, 2000–2014



GDP=gross domestic product, PRC=People's Republic of China, DMCs=Developing Member Countries; OECD=Organization for Economic Co-operation and Development.

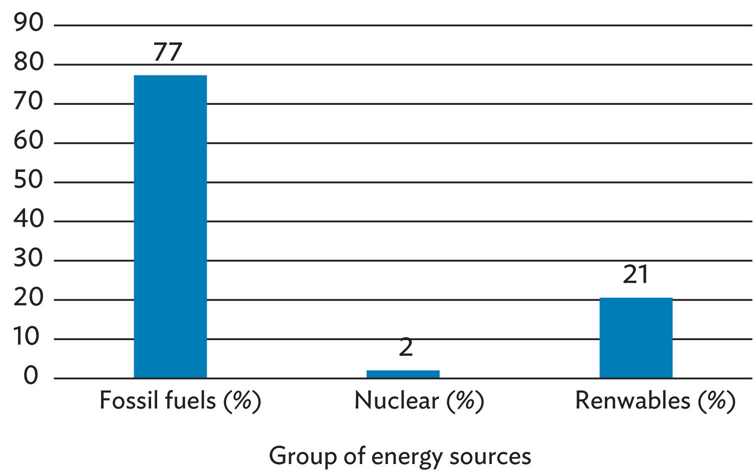
Source: IEA (2016b).

2. Current Power Mix in Asia and the Pacific

Fossil fuels remain the major energy source for power generation in DMCs and coal-fired power is dominant in power generation across the region despite the rising share of renewables. In 2014, in 33 DMCs, fossil fuel generation accounted for 77% of total power generation, 21% is from renewable power, and the remaining is from nuclear. Of this, the share of coal is 68% of the total generation and hydropower is the major renewable energy source at 17% of total power generation (Figure 5).

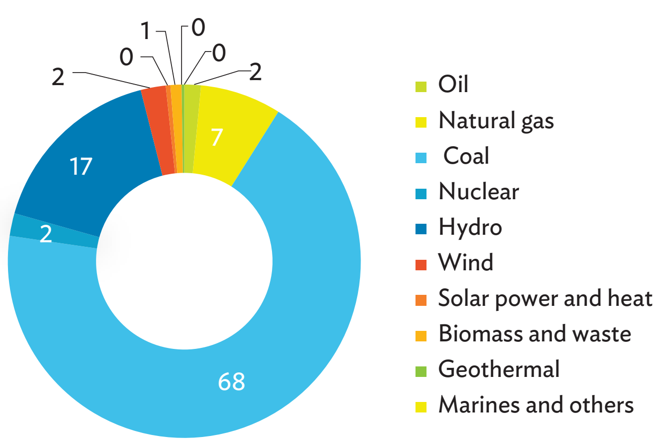
The region has seen rapid growth in renewable generation, in particular wind and solar. With the exception of hydropower, other renewable energy sources only provide a small amount of power at around 4% (Figure 6).

Figure 5: Generation Mix in Developing Member Countries, 2014 (%)



Source: Enerdata (2016).

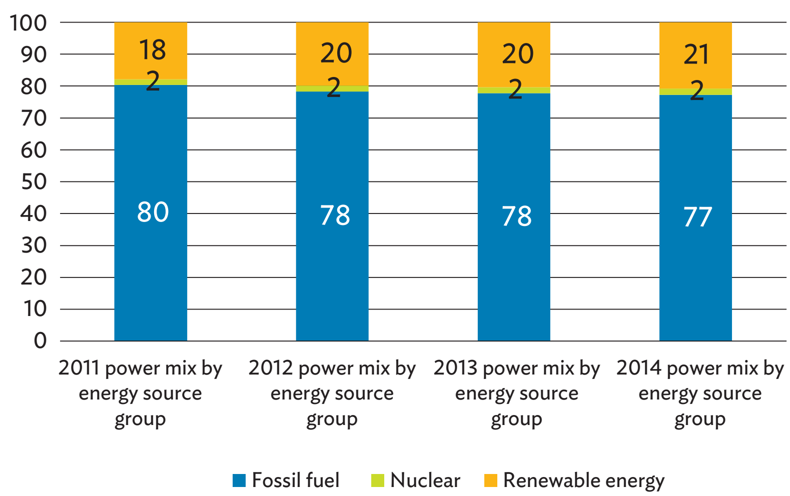
Figure 6: Renewable Generation Composition in Power Mix of Developing Member Countries, 2014 (%)



Source: Enerdata (2016).

Figure 7 shows the power mix from 2011 to 2014. In 2011–2014, the total share of fossil fuel generation has fallen from 80% to 77%, with renewable energy accounting for most of this change. Hydropower contributes the most to the growth in renewable generation, accounting for more than 70% of renewable power rise.

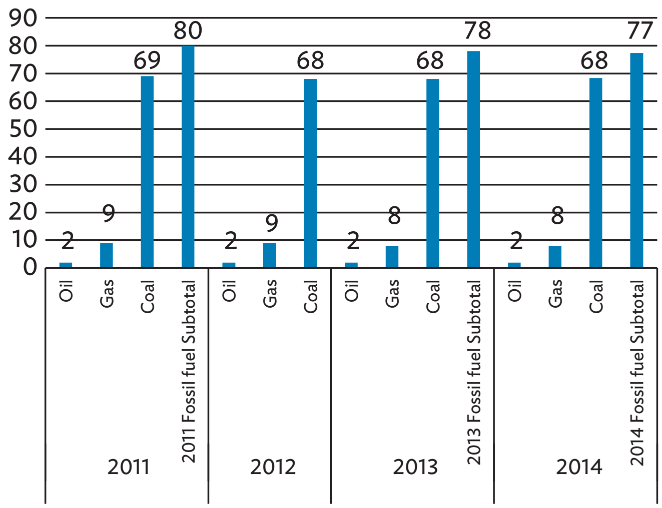
Figure 7: Changes in Power Generation Mix by Energy Type in Developing Member Countries, 2011–2014 (%)



Source: Enerdata.

Figure 8 shows the trend in fossil fuel generation in DMCs. Overall, coal generation fell 1% between 2011 and 2014, with the PRC as the major contributor to this decrease. Over the period, PRC's coal generation has decreased by more than 6%, and in India it rose by more than 8%. India is mostly responsible for the falling gas generation, and its gas share has decreased by almost 6% overall.

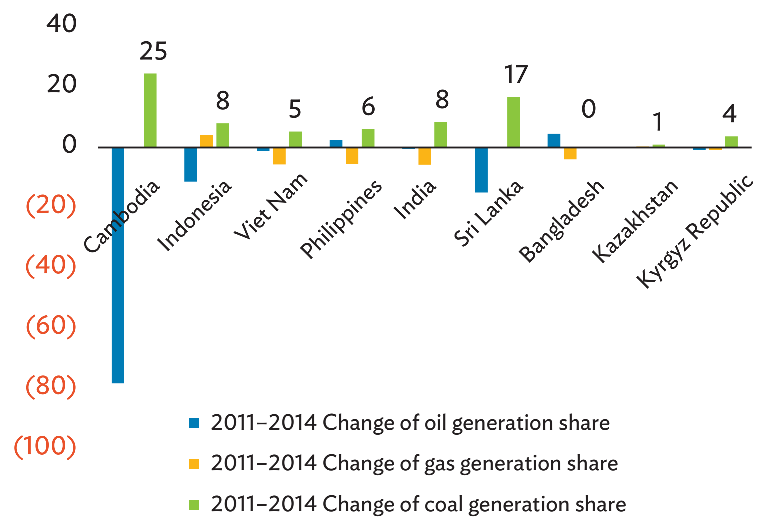
Figure 8: Fossil Fuel Share in Power Mix of Developing Member Countries, 2011–2014 (%)



Source: Enerdata.

Overall, most countries have reduced oil in power generation. In South Asia and Southeast Asia, coal and gas replace this reduction. Nine countries in Southeast Asia and South Asia have significantly increased their coal generation share between 2011 to 2014. Figure 9 shows the increased percentage of coal generation in these countries. Cambodia has the highest growth in the share of coal generation at 25%. Sri Lanka ranks second at 17%. Only Indonesia increased both coal and gas generation shares in its power mix. Bangladesh and the Philippines have increased power generation from oil.

Figure 9: Change of Fossil Fuel Share in Selected Developing Member Countries, 2011–2014 (%)



Source: Enerdata (2016).

3. Regional Trends in the Power Generation Mix across Developing Member Countries

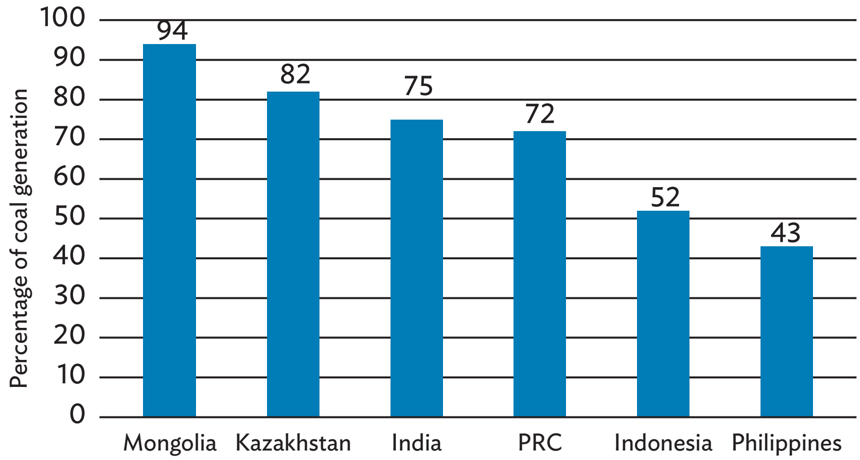
The power generation mix in DMCs may be broadly categorized into four groups according to dominance of coal, oil, gas, and hydropower.

(i) Coal-Dominant

The PRC, India, Indonesia, Kazakhstan, Mongolia, and the Philippines are all dominated by coal-fired power generation, with 43%–94% coal in the mix (Figure 10). These six countries alone account for 98.5% of coal-fired power generation in the region and emit almost 94% of CO_2 emissions from energy generation. Mongolia has the highest share of coal generation at 94%.

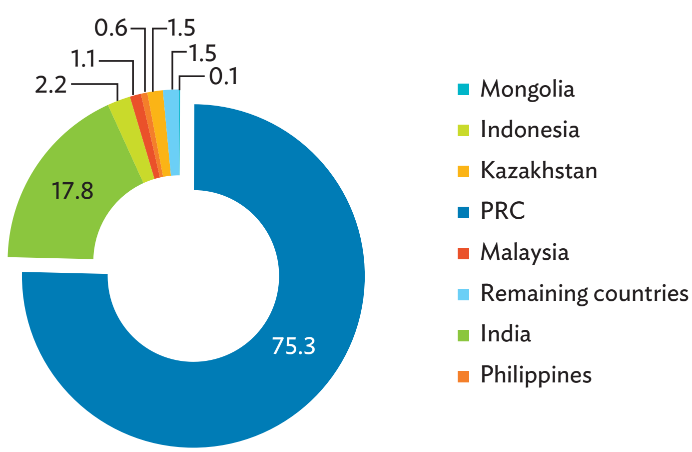
Figure 11 shows that although the PRC does not have the highest share of coal at 72%, it represents 75% of the region's coal generation, with India ranking second at 18% of total coal generation in the region.

Figure 10: Coal Generation in the Top Six Coal-Dependent Developing Member Countries, 2014 (%)



PRC=People's Republic of China.
Source: Enerdata (2016).

Figure 11: Coal Generation Share in Developing Member Countries, 2014 (%)

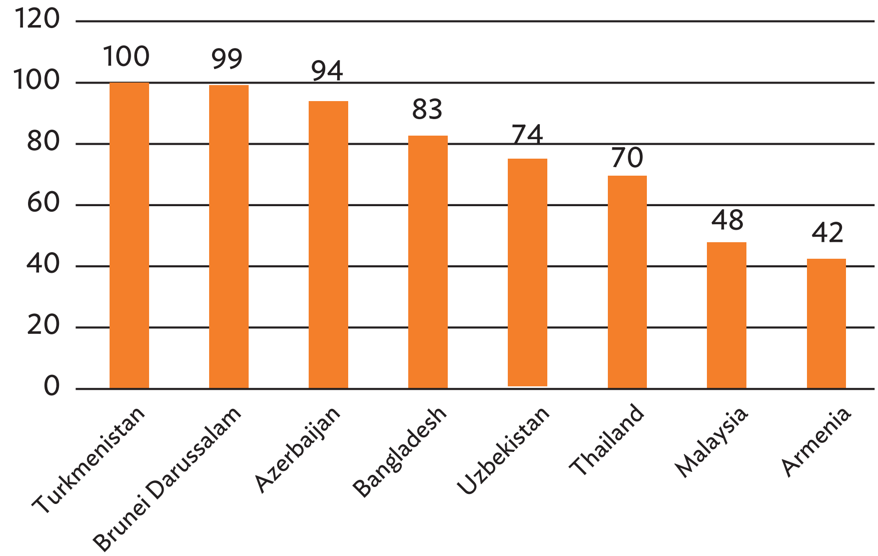


PRC = People's Republic of China.
Source: Enerdata (2016).

(ii) Natural Gas-Dominant

Central and West Asia and Southeast Asia are typically dependent on gas in their power mix. In Turkmenistan, almost 100% of power is generated from gas, and in Brunei Darussalam, it is 99%. Figure 12 shows the share of gas in the power mix for the top eight countries in the region in 2014.

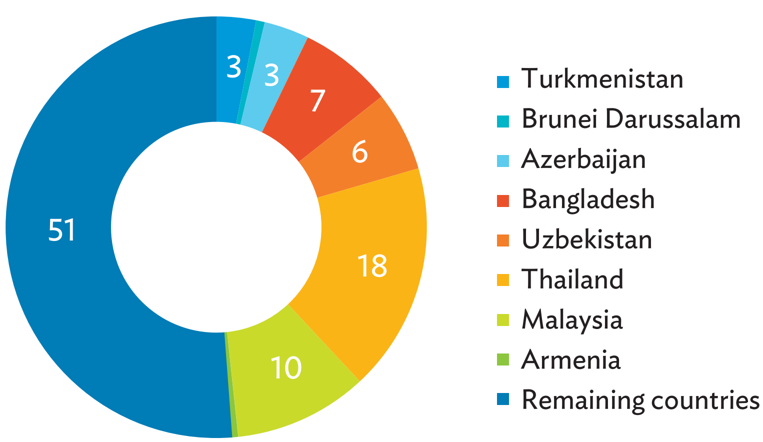
Figure 12: Gas Generation in Power Mix in the Top Eight Gas-Dependent Developing Member Countries, 2014 (%)



Source: Enerdata (2016).

Gas-fired power generation from these eight countries accounted for 49% of total gas generation across the region in 2014. In Southeast Asia, Thailand represented 18%, and Malaysia represented 10% of gas generation for the whole region (Figure 13).

Figure 13: Gas Generation Share by Country in Total Gas Generation of Developing Member Countries, 2014 (%)

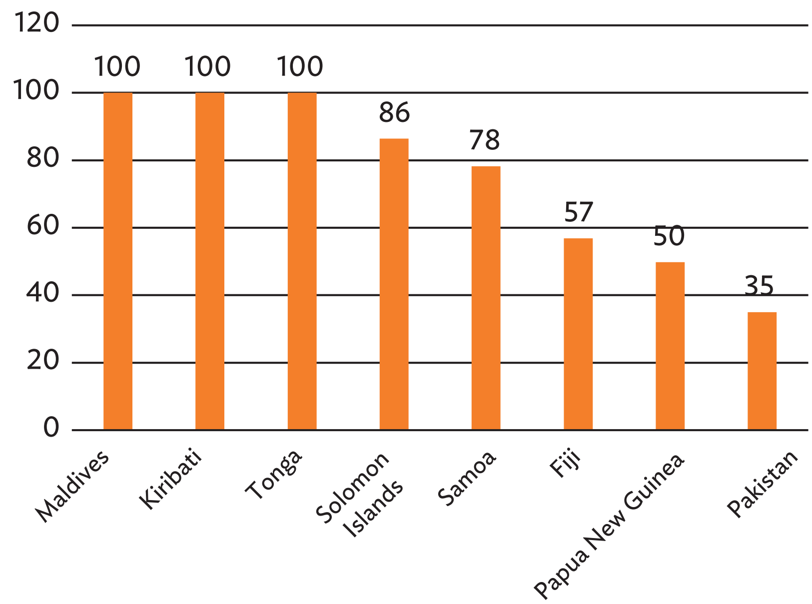


Source: Enerdata (2016).

(iii) Oil-Dominant

In Asia and the Pacific with the highest oil dependence are the Pacific DMCs, Maldives, and Pakistan. Pakistan is the only non-island DMC with a dominance of oil in the generation mix (Figure 14). Oil dependency in the Pacific DMCs has a significant cost burden as well as energy security issues, which is why there is such a strong desire to deploy renewable energy technologies to meet their energy demands.

Figure 14: Oil Generation in Power Mix in the Top Eight Oil-Dependent Developing Member Countries, 2014 (%)

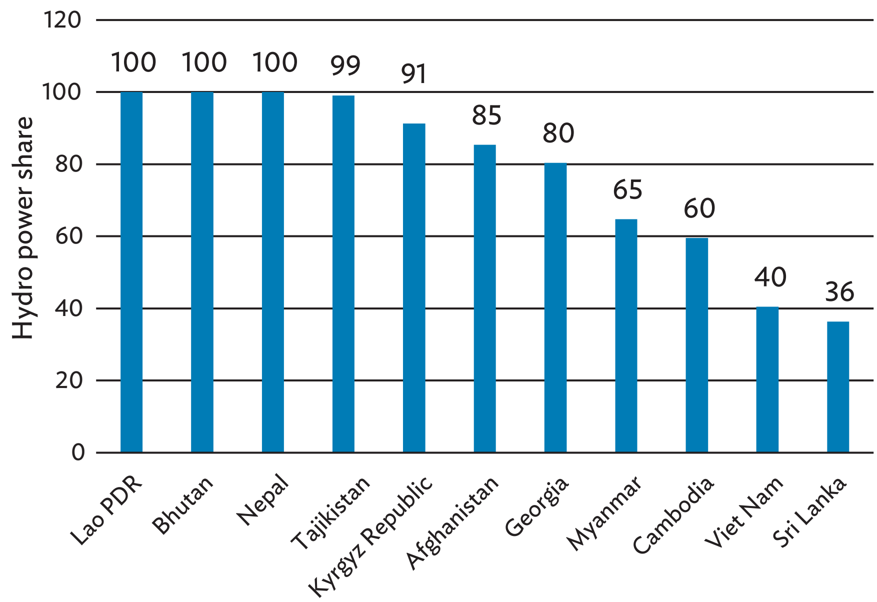


Source: Enerdata (2016).

(iv) Hydropower-Dominant

Hydropower plays a significant role in many countries in the region. Eleven countries from Central and West Asia, Southeast Asia, and South Asia are dominated by hydropower. Nine of these countries have a share of hydropower in excess of 60% in their power generation mix. Bhutan, the Kyrgyz Republic, the Lao People's Democratic Republic, Nepal, and Tajikistan produce almost 100% of their power from hydro. Hydropower has low emissions, but is affected by weather patterns such that diversification in energy supply should also be sought for energy security.

Figure 15: Hydropower Generation in the Power Mix of Hydropower-Dependent Developing Member Countries, 2014 (%)



Lao PDR = Lao People's Democratic Republic.
Source: Enerdata (2016).

Only four DMCs in the region (Armenia, the PRC, India, and Pakistan) produce nuclear power. In the PRC, India, and Pakistan, nuclear only represents a small share of the power mix (2.3% in the PRC, 2.8% in India, 5% in Pakistan). In Armenia, nuclear represents 32% of total power generation.

4. Aging Infrastructure in the Power Sector

Existing coal-fired power plants in the region typically operate at low efficiencies (34% in India, 37% in the PRC, and 33% on average in Southeast Asia) (IEA 2015i, 2015g). The low efficiency of power plants results in increased coal consumption and higher carbon emissions. Table 4 shows how the efficiency of power plants alters the carbon emissions factor.

Table 4: Efficiency of Power Plants and Corresponding Carbon Dioxide Emission Factors

Efficiency (%)	26	27	28	29	30	31	32	33	34	35	36	37	38
CO_2 (g/kWh)	1,252	1,215	1,180	1,145	1,112	1,079	1,048	1,018	988	960	933	908	883
Efficiency (%)	39	40	41	42	43	44	45	46	47	48	49	50	
CO_2 (g/kWh)	859	837	815	795	775	757	740	724	709	695	682	670	

CO_2 = carbon dioxide.
Source: Barnes (2014).

Small improvements in efficiency of coal-fired power plants can reduce emissions that are disproportionately higher than might be achieved through other technologies for the same costs. As such, there is significant potential to reduce CO_2 emissions through these improvements.

Additionally, an aging and inefficient power grid infrastructure is creating significant losses in electricity with associated impacts on emissions. In many cases, the inefficiencies result from old lines and equipment, but they also result from inefficiencies in grid management. Transmission and distribution losses are a key problem faced by many DMCs. In 2013, average losses for 23 of the DMCs (excluding the Pacific) amounted to 13%, compared to 6% in OECD countries. Only three of the 23 DMCs (the PRC, Malaysia, and Thailand) have a loss rate at or below 6% (Table 5).

Table 5: 2014 Transmission and Distribution Losses in Developing Member Countries Power Transmission and Distribution

	Losses (% of output)
East Asia	**11**
People's Republic of China	6
Mongolia	15
South Asia	**18**
Bangladesh	13
India	18
Nepal	31
Sri Lanka	10
Southeast Asia	**13**
Brunei Darussalam	9
Cambodia	28
Indonesia	10
Lao People's Democratic Republic	not available
Malaysia	4
Myanmar	27
Philippines	10
Thailand	6
Viet Nam	9
Central and West Asia	**13**
Afghanistan	not available
Armenia	12
Azerbaijan	14
Georgia	8
Kazakhstan	12
Kyrgyz Republic	20
Pakistan	18
Tajikistan	15
Turkmenistan	13
Uzbekistan	9

Note: Only 23 countries' power loss is available.

Sources: IEA (2014b), IEA Statistics.

India serves as a good example of the significance of these losses in terms of emissions. In 2014, India's total power losses in transmission, transformation, and distribution amounted to 232 TWh, which was almost 18% of that year's total available electricity (CEA 2016). This is equivalent to additional carbon emissions of 188 $MtCO_2$. There is an urgent need for countries to retrofit existing power grids, enhance their management, and reduce power losses by using smart grid technologies.

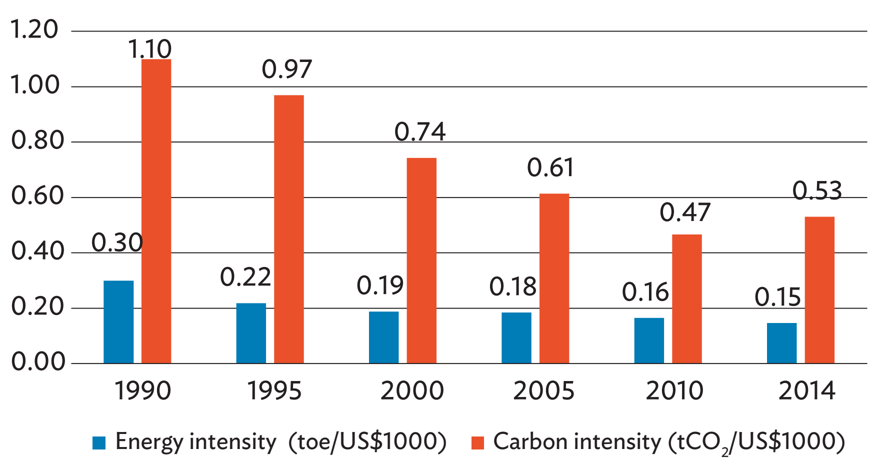
Increasing integration of variable renewable sources in power generation also adds a huge pressure on power grids. The PRC is facing increasing issues of wind and solar curtailment, and only 85% of wind capacity was connected in 2015 (NEA 2016). If targets for renewable energy set out in the NDCs are to be achieved, investment in grid infrastructure must become the priority. ADB has recently had approval from the Green Climate Fund (GCF) for a program in the Pacific DMCs to look at these issues and to make investment in battery storage in the Cook Islands for exactly these reasons.

Furthermore, power grids are increasingly required to have additional capacity to meet increasing demand for access to power. Existing grid infrastructure is designed and managed with a centralized system, whereas decentralized renewable power systems may require micro grid, off-grid in place, which is more suitable for renewable energy and rural power access. Therefore, diversifying power grid solutions including extension and enhancement of power grids, smart grids, microgrids, and off-grid solutions also need to be considered for the future.

5. Energy and Carbon Intensity

Most DMCs have seen a reduction in the energy and carbon intensity of GDP since 2000 (Figure 16). Energy intensity and carbon intensity of GDP declined 21% and 28% between 2000 and 2014. The reduction reflects DMCs' efforts in both energy conservation and climate actions, as well as changes in economic structure.

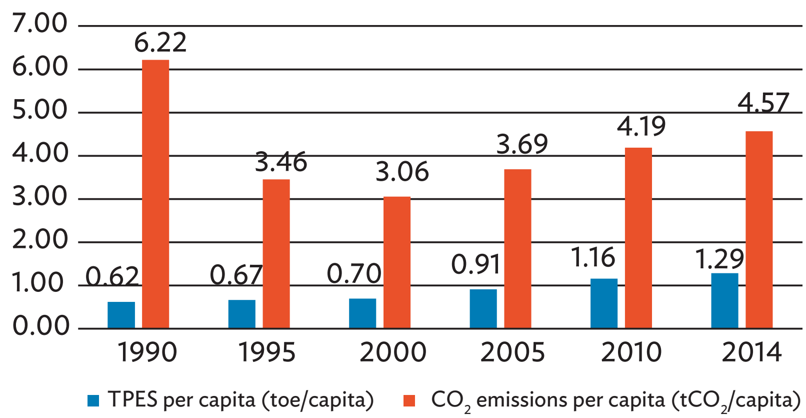
Figure 16: Energy Intensity and Carbon Intensity of Gross Domestic Product in Developing Member Countries, 2000–2014



toe = ton of oil equivalent, tCO_2=ton of Carbon Dioxide.
Note: Aggregate information from International Energy Agency.
Source: IEA (2016a).

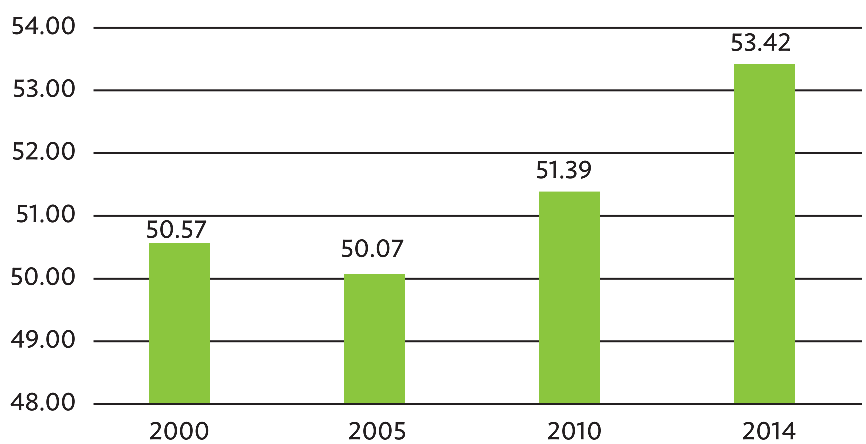
By contrast, energy and CO_2 emissions per capita and CO_2 emissions of the energy sector (CO_2/total primary energy supply [TPES]) have increased by 84% and 50%, respectively, from 2000 to 2014 (Figure 17). This mirrors DMCs' strong growth in energy demand and associated CO_2 emissions along with the economic development. CO_2 emissions of the energy sector (CO_2/TPES) grew significantly over the same period (Figure 18), reflecting the reliance on fossil fuels in the energy mix. As such, while the carbon intensity of GDP has been falling as the energy intensity of GDP falls, emissions in the energy sector continue to increase, along with the energy requirements of economic growth. Emissions and economic growth are certainly not decoupled.

Figure 17: Energy and Carbon Dioxide Emission per Capita in Developing Member Countries, 2000–2014



TPES = Total Primary Energy Supply, toe = tonnes of oil-equivalent, tCO_2 = tonnes of carbon dioxide.
Source: IEA (2016a).

Figure 18: Carbon Dioxide Emissions in the Energy Sector of Developing Member Countries, 2000–2014 (tCO_2/TJ)



tCO_2= tonnes of carbon dioxide.
Source: IEA (2016a).

Although energy intensity and carbon intensity have improved in DMCs, both are still almost double that of OECD countries. However, TPES per capita and CO_2 emissions per capita remain much lower than in OECD countries as shown in Table 6, suggesting that DMCs will face tremendous challenges with increasing energy demand, and associated emissions with rapid economic growth and increased energy access. Given the large share of energy-related CO_2 emissions in global GHG emissions, peaking CO_2 emissions in the energy sector in DMCs will be crucial to the global peaking of CO_2 emissions.

Table 6: Comparison of Key Energy and Carbon Dioxide Indicators in Developing Member Countries and Organisation for Economic Co-operation and Development, 2000–2014

	2000		2005		2010		2014	
Indicator	**DMC**	**OECD**	**DMC**	**OECD**	**DMC**	**OECD**	**DMC**	**OECD**
Energy intensity (toe/$1,000)	0.19	0.14	0.18	0.13	0.16	0.12	0.15	0.11
Carbon intensity (tCO_2/$1,000)	0.74	0.34	0.61	0.31	0.47	0.28	0.53	0.26
TPES per capita (toe per capita)	0.70	4.59	0.91	4.62	1.16	4.38	1.29	4.16
CO_2 emissions per capita (tCO_2 per capita)	3.06	10.79	3.69	10.74	4.19	9.95	4.57	9.36

DMC = developing member country, OECD = Organisation for Economic Cooperation and Development, toe = tonnes of oil of equivalent, tCO_2 = tonnes of carbon dioxide.
Source: IEA (2016a).

6. Access to Modern Energy

While the region is seeking low carbon solutions for power generation, a large population of people are still struggling with access to modern energy. There are 1.8 billion people (43%) in Asia and the Pacific without access to clean energy for cooking. There are 480 million people (24%) that do not have access to electricity.

The table 7 gives the shares of population without access to power and clean energy in the DMCs. The issues of electricity and energy access are most magnified in the Pacific DMCs, South Asia, and Southeast Asia. The Pacific DMCs are fully reliant on oil for primary energy, and Southeast and South Asia show increasing fossil fuel combustion for power generation.

Table 7: Share of Population without Access to Electricity and Nonsolid Fuels in Developing Member Countries (%)

Country	Share of Population without Access to Electricity	Share of Population without Access to Nonsolid Fuels for Cooking
People's Republic of China	0.20	33
Mongolia	10	63
East Asia Subtotal	**5.10**	**48.00**
Bangladesh	39	89
Bhutan	24.40	37.30
India	19	67

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Table 7 *continued*

Country	Share of Population without Access to Electricity	Share of Population without Access to Nonsolid Fuels for Cooking
Maldives	0	7.60
Nepal	24	80
Sri Lanka	6	74
South Asia Subtotal	**18.73**	**59.15**
Brunei Darussalam	0	0
Cambodia	66	88
Indonesia	20	39
Lao PDR	13	65
Malaysia	0	0
Myanmar	68	93
Philippines	21	54
Thailand	1	23
Viet Nam	3	47
Southeast Asia Subtotal	**19.00**	**45**
Afghanistan	57	80.50
Armenia	0	7.50
Azerbaijan	0	7.30
Georgia	0	46.20
Kazakhstan	0	9.90
Kyrgyz Republic	0	26.80
Pakistan	27	58
Tajikistan	0	31.40
Turkmenistan	0	0.00
Uzbekistan	0	12.20
Central and West Asia Subtotal	**8**	**27.98**
Cook Islands	not available	not available
Fiji	40.70	40.30
Kiribati	40.70	45.80
Marshall Islands	40.70	32.20
Micronesia	40.70	51.70
Palau	40.70	1.60
Papua New Guinea	81.90	68.30
Samoa	0.00	61.60
Solomon Islands	77.20	91.30
Tonga	4.10	54.60
Vanuatu	73	85
Tuvalu	55.40	17.80
Timor–Leste	58.80	92.20
Pacific Subtotal	**46**	**54**

Lao PDR = Lao People's Democratic Republic.

Sources: Global Tracking Framework (2017); REN21 (2016).

The region faces tremendous challenges in satisfying energy demand while providing affordable access to modern energy. Climate change and environmental pressures require the reduction of fossil fuel consumption and increased investment in renewable energy to enable renewable energy to become a competitive option for the consumer.

7. Energy Policy Frameworks

Many DMCs have implemented complex policy packages to encourage clean energy development, reduce the use of fossil fuels, and improve energy efficiency over time. The increase in the share of renewable energy and the reduction in energy and carbon intensity of GDP are proving to be positive outcomes of these policy efforts. Table 8 summarizes clean energy and energy efficiency policies in selected countries.

Table 8 shows the breadth of policies that are being implemented in support of renewable energy and energy efficiency. Many of these policies take the form of mandatory targets, taxes, and fiscal and investment incentive policies. The PRC has the most policies and measures in place to encourage renewable energy and energy efficiency.

Despite the region's reliance on fossil fuels for power generation, only three DMCs have implemented carbon pricing schemes to constrain their use. The PRC is implementing seven pilot emission trading schemes (ETS) at the provincial and city level and plans to start a national scheme in 2017. Kazakhstan's ETS is also in its pilot phase. India imposes carbon taxes on coal, petrol, and diesel.

DMCs from Southeast Asia still provide some subsidies to the use of fossil fuels, though they have made progress in reform of certain subsidies (IEA 2015g). While countries provide incentives to support investment in clean energy, there are often no policies to limit the use of cheaper coal, and no cost of carbon is therefore reflected in the coal price. The International Monetary Fund (IMF) estimates that the external costs resulting from fossil fuels consumption (air pollution, climate change, health and so on) amounted to $5.3 trillion globally (or 6.5% of global GDP) in 2015 (IMF 2015). This is equivalent to $5.3 trillion in subsidies being provided for the use of fossil fuels.

Around 25% of these global subsidies contribute to global warming and 75% of the subsidies resulted in health impacts from exposure to outdoor air pollution etc. (IMF 2015). The subsidies provided to fossil fuels are half the annual investment required for the energy sector under the 2°C scenario, given that the investment required is estimated at $10.3 trillion per year from 2016 to 2050 under the 2°C scenario (IEA 2015d).

Table 8: Energy Policy Frameworks in Selected Countries

Renewable Energy Policy													
Country	Renewable Target	Feed-in Tariff/ Premium	Electric Utility Quota/ RPS	Net Metering/ Net Billing	Transport Mandate	Heat Mandate	Tradable REC	Tendering	Subsidies/ Grants/ Rebates	Production Tax Credits	Tax Reductions	Energy Production Payment	Public Investment/ Loan/Grant
PRC													
IND													
BAN													
CAM													
INO													
LAO													
MAL													
MYA													
THA													
VIE													
PHI													
KAZ													
PAK													

Energy Efficiency Policy									
Country	Target	Tax Credit/ Reduction	Subsidy/ Investment/ Grant	Performance Standards/ Labelling	Carbon Pricing	Tax on Fossil Fuel	Trading of Energy-Saving Certificates	Energy Auditing	Subsidy on Fossil Ffuels
PRC									
IND									
BAN									
CAM									
INO									
LAO									
MAL									
MYA									
THA									
VIE									
PHI									
KAZ									
PAK									

BAN = Bangladesh; CAM = Cambodia; IND = India; INO = Indonesia; KAZ = Kazakhstan; LAO = Lao People's Democratic Republic; MAL = Malaysia; MYA = Myanmar; PAK = Pakistan; PHI = Philippines; PRC = People's Republic of China; REC = Renewable Energy Certificate, RPS = Renewable Portfolio Standard, THA = Thailand; VIE = Viet Nam.

Sources: REN21 (2016), IEA (2016f).

B. Development Trends in the Energy Sector from Nationally Determined Contributions

1. Renewable Energy Share in the Power Sector to 2030

As described in section above, many DMCs have clearly specified renewable energy targets and commitments to increase power generation from renewable sources in their NDCs.

Table 9 exhibits the progression of renewable energy in the power generation mix to 2030 according to the NDCs and latest national energy policies adopted to support implementation of the NDC commitments. Most DMCs show a high aspiration to increase power generation from renewables. A few countries (the Kyrgyz Republic, the Lao People's Democratic Republic, Myanmar, Sri Lanka, and Viet Nam) see a decrease in renewable generation share in power mix. This reduction of renewable power is principally a reduction in the share of hydropower that will be mostly be taken over by natural gas and coal. In Myanmar and Sri Lanka, it is likely that both coal and natural gas will supplement hydropower to meet increased energy demands. In the Kyrgyz Republic, the supplemental power will come from coal. In Viet Nam, the share of renewables will be replaced by generation from coal and nuclear to deal with the increased energy demand.

By 2030, 27 DMCs anticipate power generation from renewable sources to account for more than 20% of the power generation mix.

Table 9: Renewable Generation Target or Share in Developing Member Countries, 2014–2030

Region	Country	2014 RE Share in Power Mix (%)	2020 RE Share in Power Mix (%)	2025 RE Share in Power Mix (%)	2030 RE Share in Power Mix (%)	Change in RE Share between 2014 and 2030 (%)	Source
East Asia	**PRC**	6	28		33	27	International Energy Agency. 2016. World *Energy Outlook* 2016. Paris.
	Mongolia	2			14	12	Calculated based on SREP investment plan
South Asia	**Bangladesh**	1	10		10	9	Calculated based on NDC and SREP Investment plan
	Bhutan	100	100		100	0	NDC
	India	15	19		25	10	International Energy Agency. 2016. World *Energy Outlook* 2016. Paris.
	Maldives	0	30		30	–	IRENA 2016 Renewable energy roadmap for the Republic of Maldives
	Nepal	100	100		100	0	Estimated based on NDC, SREP investment plan
	Sri Lanka	39	60	44	38	(1)	National Energy Development plan and Ceylon Electricity Board 2016.

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Table 9 continued

Region	Country	2014 RE Share in Power Mix (%)	2020 RE Share in Power Mix (%)	2025 RE Share in Power Mix (%)	2030 RE Share in Power Mix (%)	Change in RE Share between 2014 and 2030 (%)	Source
Southeast Asia	**Brunei Darussalam**	0	3	5	8	8	Calculated based on NDC
	Cambodia	50	56	62	67	17	Estimated based on IRENA & ACE: Renewable *Energy Outlook* for ASEAN
	Indonesia	11	19	25	27	16	National Electrification Plan (RUKN) 2015-34, and IRENA 2016; IEA 2016
	Lao PDR	100	94	86	86	(14)	Estimates based on NDC and IRENA & ACE: Renewable *Energy Outlook* for ASEAN
	Malaysia	8	13		16	7	NDC, IRENA & ACE: Renewable Energy Outlook for ASEAN, Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.
	Myanmar	62	60	59	38	-24	NDC and IRENA & ACE: *Renewable Energy Outlook* for ASEAN
	Philippines	26		28	33%	7	Calculated based on National Renewable Energy Plan and Program (2011–2030) and Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.
	Thailand	9	12		17	8	Calculated based on NDC, National Power Development Plan (PDP), Alternative Energy Development Plan (AEDP) and Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.

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Table 9 continued

Region	Country	2014 RE Share in Power Mix (%)	2020 RE Share in Power Mix (%)	2025 RE Share in Power Mix (%)	2030 RE Share in Power Mix (%)	Change in RE Share between 2014 and 2030 (%)	Source
	Viet Nam	41	36		29	(12)	Revised Master Plan for Power Development in Viet Nam 2011–2020 with Outlook to 2030 (Revised PDP VII)
Central and West Asia	**Armenia**	26	31	34	41	15	3rd NC report
	Azerbaijan	6	20		32	26	3rd NC report
	Georgia	80	85		93	13	3rd NC and Biennial Update Report of Georgia to the UNFCCC
	Kazakhstan	8	14		23	15	Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013)
	Kyrgyz Republic	91	83	83	83	(8)	3rd NC
	Pakistan	32		35	39	7	NDC and Pakistan vision 2025, latest announced program, National Power System Expansion Plan 2011-2030
	Tajikistan	99			99		Estimate 3rd NDC, SREP investment plan
	Turkmenistan	0			1	1	3rd NC report
Pacific	**Fiji**	43	64		100	57	NDC
	Kiribati	0					
	PNG	38	61		100	62	NDC
	Samoa	22	51		100	78	NDC
	Solomon Islands	14					
	Tonga	0	50		70	70	NDC
	Cook Islands	50	100		100	50	NDC
	Tuvalu	50	75	100	100	50	NDC
	Vanuatu	67	65		100	33	NDC
	Palau	0	0	45	45	45	NDC
	Marshall Islands	0	20			20	2nd NC report

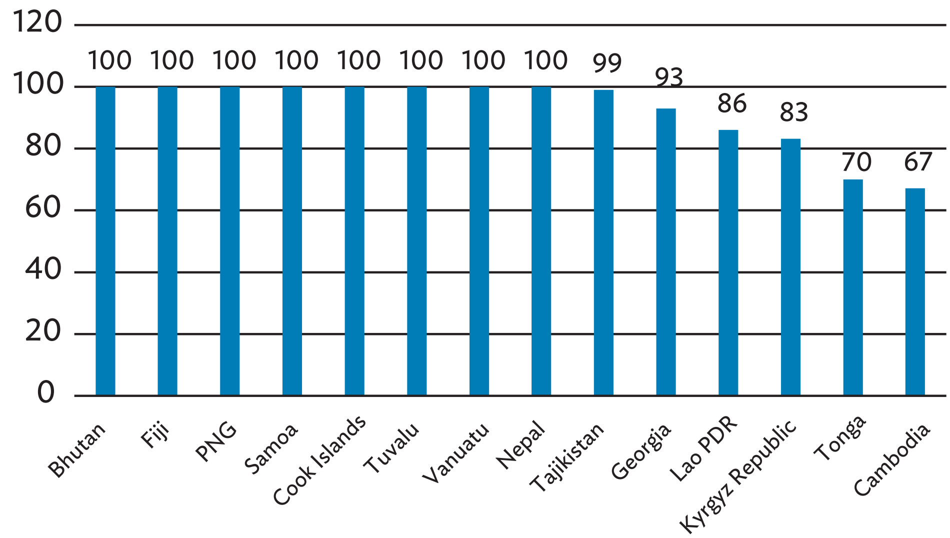
ACE = ASEAN Center of Energy; APEC = Asia-Pacific Economic Cooperation; ASEAN= Association of Southeast Asian Nations; IRENA = International Renewable Energy Agency; Lao PDR = Lao People's Democratic Republic; NC = National Communication; NDC = nationally determined contribution; PRC = People's Republic of China; PNG = Papua New Guinea; RE = Renewable Energy; SREP = Scaling up Renewable Energy Programme; UNFCCC = United Nations Framework Convention on Climate Change; WEO = World Energy Outlook.

Note: The renewable share of each country is calculated from NDCs, latest National Communication Reports on Climate Change under UNFCCC, and national energy development plans.

Sources: Author's estimates.

DMCs with an abundance of hydro resources and the Pacific DMCs generally commit to a high share of renewable energy in the power generation mix. Figure 19 shows the DMCs that have committed to targets and anticipate renewable generation shares above 60%.

Figure 19: Countries with 2030 Renewable Generation Targets and Anticipated Share above 60% (%)



Lao PDR = Lao People's Democratic Republic, PNG = Papua New Guinea.

Note: The figure is based on data in Table 9.

Source: Author's estimates.

2. Growth of Renewables and Fossil Fuels to 2030

Table 10 gives the anticipated growth of renewable generation and fossil fuel generation by country in 2030. Based on the 2030 renewable generation shares, it is estimated that total annual renewable power supply in 32 DMCs will increase 2.5 times from approximately 1,747 terawatts per year (TWh/y) in 2014 to 4,467 TWh/y in 2030. On the other hand, over the same period, fossil fuel power generation is expected to increase around 1.5 times from 2014 levels. As such, the growth rate of renewable power generation is much higher than that of fossil fuel generation in the region.

Table 10: Renewable Generation and Fossil Fuel Generation Growth in Developing Member Countries, 2014–2030

Country	2030 RE Growth (%)	2030 Fossil Growth (%)	Source
People's Republic of China	120	19	Estimates based on International Energy Agency. 2016. *World Energy Outlook 2016*. Paris.
Mongolia	2724	187	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
East Asia	**120**	**19**	
Bangladesh	1,511	98	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Bhutan	0	-100	No change between 2014 and 2030
India	271	88	Estimates based on International Energy Agency. 2016. *World Energy Outlook 2016*. Paris.
Maldives		4	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Nepal	159	3597	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Sri Lanka	72	80	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
South Asia	**267**	**89**	
Brunei Darussalam	25,429	37	Estimates based on 2030 power generation from Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.
Cambodia	247	96	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Indonesia	768	195	Estimates based on *2030 Generation from National Electrification Plan 2015–34*
Lao PDR	423	0	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Malaysia	231	65	Estimates based on 2030 power generation from Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.
Myanmar	209	825	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Philippines	151	75	Estimates based on 2030 power generation from Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.

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Table 10 *continued*

Country	2030 RE Growth (%)	2030 Fossil Growth (%)	Source
Thailand	208	44	Estimates based on 2030 power generation from Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.
Viet Nam	174	329	Estimates based on 2030 generation from Revised Master Plan for Power Development in Vietnam 2011–2020 with Outlook to 2030 (Revised PDP VII).
Southeast Asia	**295**	**143**	
Armenia	185	-54	Estimates based on 2030 generation from 3rd NC report
Azerbaijan	639	0	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Georgia	28	-60	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Kazakhstan	310	6	Estimates based on 2030 generation from Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013)
Kyrgyz Republic	147	253	Estimates based on 2030 generation from 3rd NC.
Pakistan	234	68	Estimates based on 2030 generation from NDC, Pakistan Vision 2025, latest announced programs
Tajikistan	53	2,129	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Turkmenistan		47	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Central and West Asia	**177**	**31**	
Cook Islands	150	-100	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Fiji	219	-100	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Palau			Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Papua New Guinea	757	-100	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.

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Table 10 *continued*

Country	2030 RE Growth (%)	2030 Fossil Growth (%)	Source
Samoa	488	-100	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Tonga		-62	Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Vanuatu			Estimates based on 2030 power generation from ADB. 2013. *Energy Outlook for Asia and the Pacific*. Manila.
Pacific	641	-98	
Total	156	45	

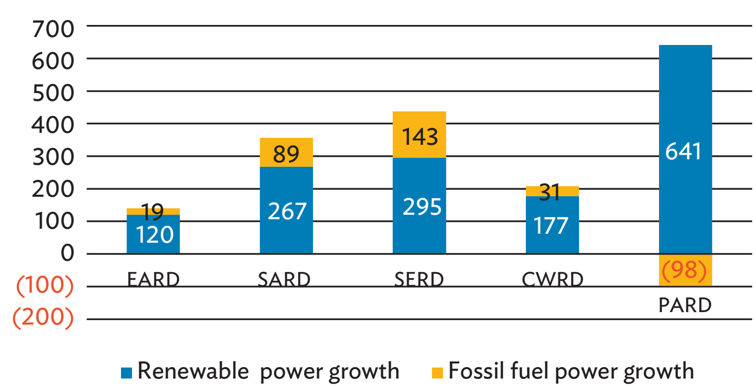
IRENA = International Renewable Energy Agency, Lao PDR = Lao People's Democratic Republic, NC = national communication, NDC= nationally determined contribution, RE = renewable energy.

Note: Renewable and fossil fuel power generation are calculated based on the RE share in Table 9 and power generation information from sources as listed.

Source: Author's estimates.

Figure 20 summarizes the regional differences in renewable and fossil fuel power generation between 2014 and 2030.

Figure 20: Renewable and Fossil Fuel Power Generation Growth by Region, 2014–2030 (%)



Source: Author's estimates.

Under the NDCs, the Pacific DMCs show the largest decrease in fossil fuel generation (–98%) and the highest increase in renewable power (641%).

East Asia sees the lowest regional growth rate in renewable power (120%) and a relatively low growth rate of fossil fuels (19%). This is mainly because of the PRC's controls on the growth of coal generation, which will show an increase of 8% by 2030 alongside a growth in nuclear power over 500%.

Central and West Asia will increase renewable generation by 177% over the period and has a relatively low growth in fossil fuels generation at 31%, owing mainly to significant cuts in the use of fossil fuels in

Armenia and Georgia (over 50%). In Armenia, fossil fuels are replaced by renewables and new nuclear. In Georgia power generation from hydro will replace fossil fuels.

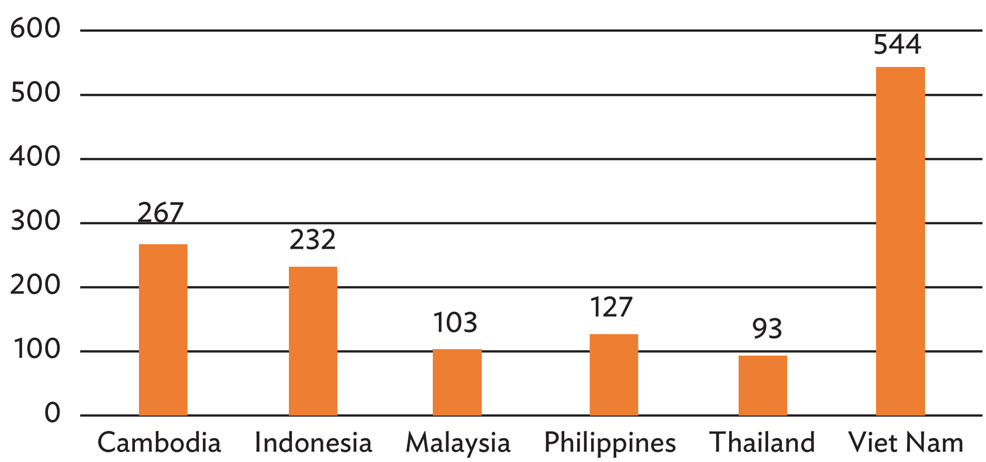
South Asia will increase both renewable power (267%) and fossil fuel generation (89%). In India, the increase in fossil fuels will come from coal, while in Bangladesh, increase in fossil fuels will come from both coal and gas.

Southeast Asia sees the highest growth in fossil fuel power (143%) and ranks the second in renewable power increase (295%) in the region. This is due to a few countries increasing their use of coal for power generation (Indonesia, Malaysia, the Philippines, Thailand, Viet Nam).

3. Growth of Coal in Southeast Asia

Coal-fired generation is set to grow faster than every other source of energy in Southeast Asia. Viet Nam leads the coal generation growth among six countries, with an increase of 544% against 2014. Cambodia and Indonesia show the next highest growth at well over 200%. A full overview is provided in Figure 21. Significant growth rates are also expected for natural gas, particularly in Indonesia, Thailand, and Viet Nam as shown in Figure 22.

Figure 21: Coal Generation Growth in Southeast Asia under the Nationally Determined Contributions Scenario, 2014–2030 (%)

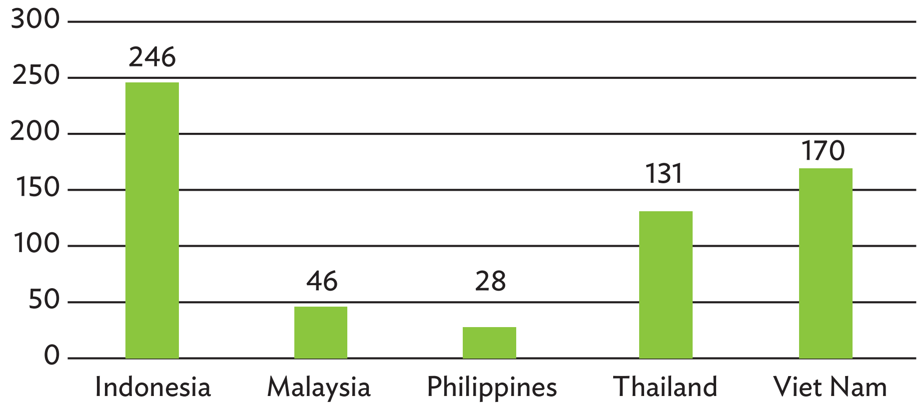


NDC = nationally determined contribution.

Note: Coal generation growth is calculated based on information in NDCs and national energy plans.

Source: Author's estimates.

Figure 22: Gas Generation Growth in Southeast Asia under the Nationally Determined Contributions Scenario, 2030



NDC = nationally determined contribution.

Note: Gas generation growth is calculated based on information in NDCs and national energy plans.

Source: Author's estimates.

Dominance of hydropower in the renewable generation share

Table 11 shows that less than 10 countries have a variable renewable generation share (including wind and solar) above 9%. Most countries rely on hydro, biomass, biogas, and geothermal as major resources to generate power. This is consistent with the fact that countries with abundant hydro resources have committed to high increases in renewable power generation and as such this is likely to contribute to most of the renewable power growth.

In the island DMCs, variable renewable power generation has a major role in achieving the renewable power generation growth. In these cases, variable renewable power accounts for more than 30% of the power mix.

Table 11: Variable Renewable Generation Share in Power Mix in Selected ADB Developing Member Countries (%)

Country	2014 Variable Renewable Power in Power Mix	2020 Variable Renewable Power in Power Mix	2030 Variable Renewable Power in Power Mix	Source
Mongolia (oil)	2%	–	10%	Taken from IRENA report
China, People's Republic of	4%	9%	15%	IEA. 2016. World *Energy Outlook 2016*. Paris.
India	3%	8%	14%	IEA. 2016. *World Energy Outlook 2016*. Paris.
Maldives	0%	>30%	>30%	IRENA. 2016.
Viet Nam	0%	1%	9%	National power plan
Azerbaijan	0%	14.4%	23%	3rd NC report

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Table 11 *continued*

Country	2014 Variable Renewable Power in Power Mix	2020 Variable Renewable Power in Power Mix	2030 Variable Renewable Power in Power Mix	Source
Kazakhstan	0%	3%	11%	Kazakhstan Concept for Green Growth
Cook Islands	–	–	100%	NDC
Palau	–	–	45%	NDC and IRENA
Vanuatu	–	>10%	>10%	IRENA report

IEA=International Energy Agency, IRENA = International Renewable Energy Agency, NC = National Communication, NDC = nationally determined contribution, PRC = People's Republic of China, RE = renewable energy.

[a] Only list the countries where the information is available.

[b] Renewable and fossil fuel power generation are calculated based on the RE share, fossil fuel share, and generation forecast in sources as cited.

Source: Author's estimates.

4. Power Generation Mix under the Nationally Determined Contributions

Table 12 indicates that implementation of the NDCs will drive up the share of renewables and reduce the share of fossil fuels overall. In 30 DMCs, the renewable share in power mix will decrease to 31% in 2030 from 21% in 2014 while fossil fuel generation in power mix will decrease to 62% in 2030 from 76% in 2014. Nuclear power will increase from 2% to 8%.

Coal is set to continue to be the largest source of fossil fuels for power generation in the region, but over the period, the share of coal decreases from 67% to 49%, and gas increases from 8% to 11%.

Using the data from Table 12, Figure 23 exhibits an overall power generation mix in DMCs and Figure 24 and Figure 25 show power generation mixes in five sub-regions in 2014 and 2030 respectively.

Table 12: Power Generation Share by Source by Region, 2014–2030 (%)

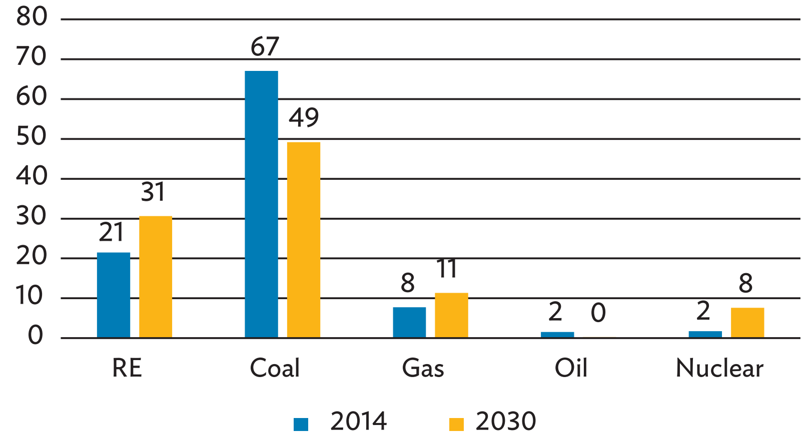
Region	RE 2014	RE 2030	Coal 2014	Coal 2030	Gas 2014	Gas 2030	Oil 2014	Oil 2030	Nuclear 2014	Nuclear 2030
East Asia	23	33	72	51	2	7	0	0	2	10
South Asia	15	25	71	56	8	9	2	1	0	5
Southeast Asia	19	27	36	42	40	30	5	0	0	1
Central and West Asia	28	40	27	21	30	25	13	0	3	13
Pacific	42	100	0	0	0	0	58	0	0	0
Asia and Pacific Region	21	31	67	49	8	11	2	0	2	8

NDC = nationally determined contribution, RE = renewable energy.

Note: Estimates based on Enerdata, national energy plans, NDCs, IEA, and IRENA reports.

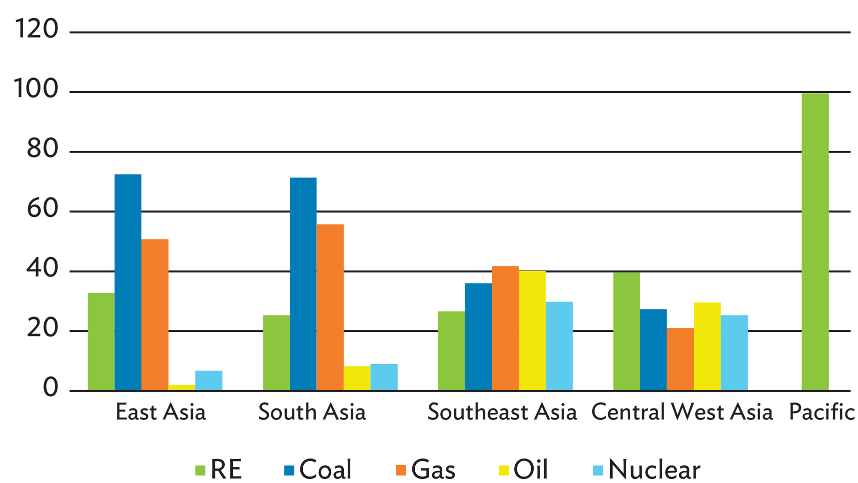
Source: Author's estimates.

Figure 23: Power Generation Mix in ADB Developing Member Countries, 2014–2030 (%)



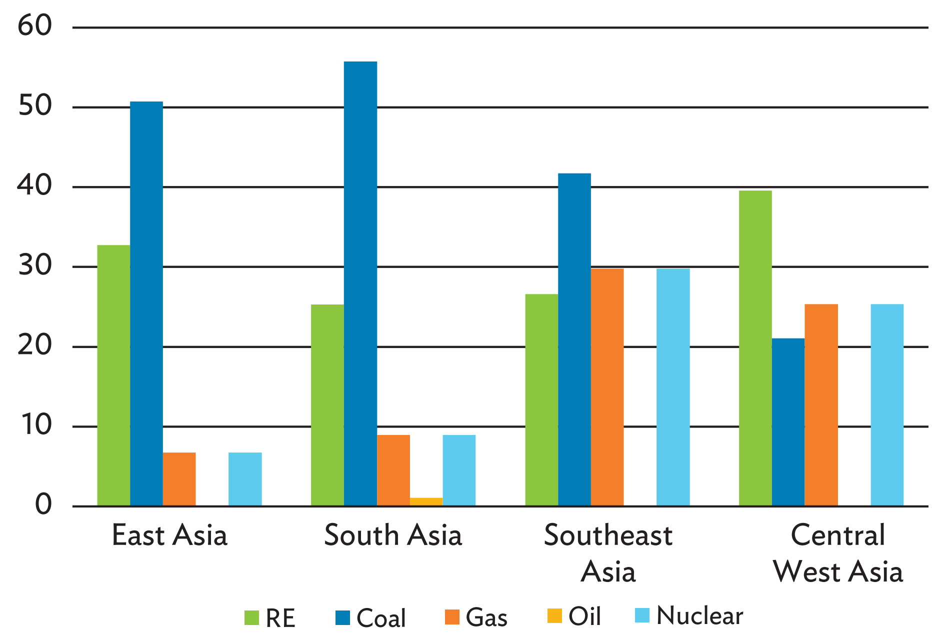
RE = renewable energy.
Note: The figure is produced based on data in Table 12.
Source: Author's estimates.

Figure 24: Power Generation Mix by Region, 2014 (%)



RE = renewable energy.
Note: The figure is produced based on data in Table 12.
Source: Author's estimates.

Figure 25: Power Generation Mix by Region, 2030 (%)



RE = renewable energy.

Note: The figure is produced based on data in Table 12.

Source: Author's estimates.

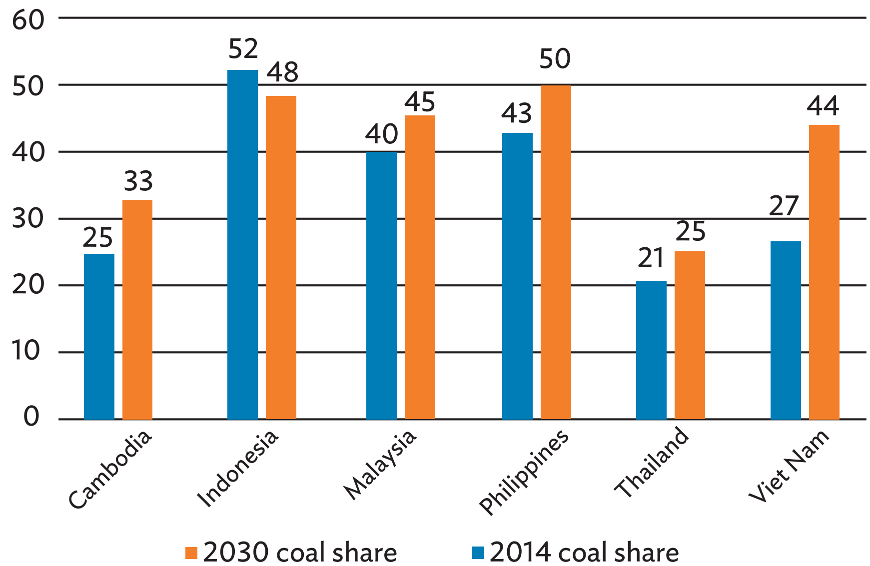
East Asia will show the largest drop in the share of coal from 72% to 51% by 2030, mainly due to the PRC where the share of renewables is projected to rise by 10% to 33% by 2030; gas generation share is expected to rise from 2% to 7%; and nuclear is expected to increase to 10%. As such, its share of coal will fall from 73%in 2014 to 51% in 2030.

South Asia has the highest share of coal generation in 2030, though it is expected to decrease from 71% in 2014 to 56% in 2030. India is the key contributor to this given that the 58% of India power is expected to be supplied through coal generation by 2030. By 2030, renewable generation is projected to supply 25% of power from 15% in 2014.

Southeast Asia is projected to increase renewable generation share by 8% to 27%. By contrast, Southeast Asia sees an increase in the share of coal from 36% to 42%, while the share of natural gas declines from 40% to 30%.

As indicated in Figure 26, Southeast Asia's key energy consumers, Indonesia, Cambodia, Malaysia, the Philippines, Thailand, and Viet Nam plan to expand their use of coal for power generation. Viet Nam shows the highest growth in coal generation and the Philippines will overtake Indonesia and have the highest share of coal in the power mix by 2030 at 50%.

Figure 26: Share of Coal in Power Mix in Southeast Asia, 2014–2030 (%)



APEC = Asia-Pacific Economic Cooperation, IEA = International Energy Agency, NDC = nationally determined contribution.
Note: The share of coal is estimated based on information from NDCs, national energy plans, including IEA and APEC reports.
Source: Author's estimates.

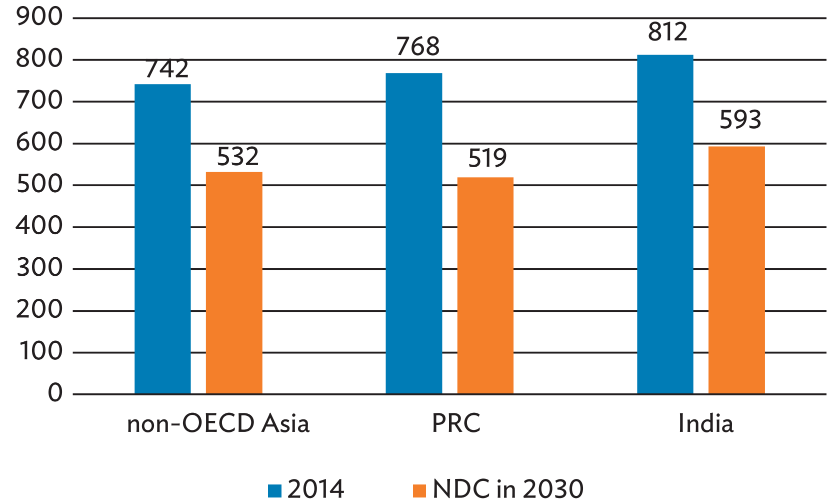
In Central and West Asia, gas is projected to overtake coal to become the largest source of power generation in 2030 given the abundance of natural gas in the region. Coal will decline from almost 27% to 21% of total generation, while gas will also fall from 30% to 25% in the power mix. Kazakhstan contributes significantly to the drop in coal generation, from 82% in 2014 to 44% in 2030. Renewable generation rises by almost 12 percentage points to 40%. The region has the highest share of nuclear generation among others. The nuclear share sees significant increase to 13% of the generation due to operation of new nuclear power plants in Armenia, Kazakhstan, and Pakistan.

In the Pacific, five countries (the Cook Islands, Fiji, Papua New Guinea, Samoa, and Tonga) are projecting to provide almost 100% of power by 2030 with generation from renewables, with oil generation in particular dropping to zero.

5. Carbon Intensity of Power Generation in Developing Member Countries

Under the NDCs, the carbon intensity of power generation decreases overall in DMCs. Figure 27 reflects changes in carbon intensity in the PRC, India and other non-OECD Asia under the NDCs. In the PRC, the carbon intensity of power generation would drop by 32% in 2030 compared to 2014 while in India, carbon intensity would decrease by 27%. For non-OECD Asian countries, NDCs could reduce the carbon intensity of power generation by 28% against the level of 2014.

Figure 27: Carbon Intensity of Power Generation in the Nationally Determined Contributions Scenario in Developing Asia Countries



NDC = nationally determined contribution, PRC = People's Republic of China, OECD = Organisation for Economic Co-operation and Development

Note: Carbon intensity is reaggregated based on information from World Energy Outlook (IEA 2016h).

Sources: IEA (2016h). World Energy Outlook 2016; author reaggregates.

6. Energy Intensity of Gross Domestic Product under the Nationally Determined Contributions Scenario

Improving energy efficiency and reducing energy consumption are key priorities for implementation of NDCs in DMCs. More specifically, improving energy efficiency in power generation, industry, buildings, and the transport sector have been set out as priorities in most NDCs. Some DMCs set energy intensity targets in their NDCs and some have set these targets in their national communication reports under the United Nations Framework Convention on Climate Change (UNFCCC). Table 13 presents energy intensity of GDP in 2014 and 2030 in selected countries where data are available.

Table 13: Energy Intensity of Gross Domestic Product in the Nationally Determined Contributions Scenario, 2014–2030

Country	Energy Intensity (toe/$1000)		Reduction from 2014 (%)	NB
	2014	**2030**		
PRC	0.18	0.10	(42)	IEA WEO 2016
India	0.12	0.07	(42)	IEA WEO 2016 and NDC
Bangladesh	0.08	0.06	(20)	NDC

continued on next page

Table 13 *continued*

Country	Energy Intensity (toe/$1000)		Reduction from 2014 (%)	NB
Indonesia	0.09	0.08	(11)	Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.
Malaysia	0.13	0.09	(30)	Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo.
Thailand	0.14	0.12	(14)	National Energy Efficiency Plan
Viet Nam	0.14	0.11	(21)	NDC
Philippines	0.07	0.05	(35)	National Energy Efficiency and Conservation Roadmap(2015)
Brunei	0.13	0.11	(14)	NDC
Armenia	0.13	0.19	46	3rd NC
Kazakhstan	0.20	0.17	(15)	Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013)
Turkmenistan	0.35	0.21	(40)	3rd NC report
Average	0.15	0.11	(22)	

APEC = Asia-Pacific Economic Cooperation; DMC = developing member country; IEA = International Energy Agency; NC = National Communication; NDC = nationally determined contribution; RE = renewable energy; WEO = World Energy Outlook

[a] Information is available only for 12 DMCs.

[b] Data are extracted from IEA and APEC reports; NDCs; NC reports; national energy development reports, etc. as indicated in the sources column in the table.

Source: Author's estimates.

Table 13 shows that energy intensity of GDP is estimated to decrease by 22% on average in these countries by 2030, with annual average reduction of 1.4%. This reduction is slightly lower than the average annual growth of 1.8% in the same countries over the period 2000–2014. The average annual energy intensity improvement to 2030 in these countries is also lower than the world average annual reduction of 1.9% to 2030 as set out in the NDCs (IEA 2016h). The PRC, India, and the countries from Central and West Asia show a strong reduction trend in energy intensity. The annual reduction of energy intensity to 2030 in Armenia, the PRC, India, and Turkmenistan are above 2.5%, which is higher than the world average. These countries have all implemented policies on energy efficiency and energy conservation across sectors as well as clear energy intensity targets and structural changes to their industrial base.

C. Investment Required for Implementing Nationally Determined Contributions

In order to meet the power demands and renewable power targets set out in the NDCs, it is estimated that at least an investment of $321 billion per year is required for the power sector in 32 DMCs. This totals $4,817 billion between 2016 to 2030, of which 92% will need to occur in the PRC, India, Indonesia, Kazakhstan, Pakistan, and Viet Nam. Much of this required investment will be used for the construction of additional clean energy power plants; retrofitting aging infrastructure (coal-fired and gas-fired power plants, electricity transmission and distribution system, gas pipelines); and extending and enhancing the power grid and gas distribution networks. Roughly one-third of the investment will be in the power grid, another third will be in renewable energy capacity, and the rest for generation capacity from other sources. Around 18% will be invested in fossil fuels and 8% in new nuclear. Investment in coal will still represent 15% of the investment, mainly in the PRC, India, Southeast Asia, and Pakistan. Table 14 shows the estimated investment by subregion and in six countries with the most investment in the subregion.

Table 14: Estimated Investment in the Power Sector in Developing Member Countries under the Nationally Determined Contributions Scenario

Country	Power Generation ($ million)					Power Grid ($ million)	Total ($ million)	NB
	Renewable	Gas	Coal	Fossil fuel	Nuclear			
East Asia	812,507	40,500	257,490	297,990	243,000	1,200,000	2,553,497	
People's Republic of China	810,000	40,500	256,500	297,000	243,000	1,200,000	2,550,000	Estimates based on information from Energy and Climate 2015 (IEA 2015g)
South Asia	**499,744**	**45,630**	**227,036**	**272,666**	**60,000**	**497,073**	**1,329,483**	
India	420,000	45,000	210,000	255,000	60,000	495,000	1,230,000	Estimates based on information from Energy and Climate Special Report(IEA 2015g)
Southeast Asia	**316,541**	**46,547**	**215,254**	**261,902**	**13,800**	**148,024**	**740,286**	
Indonesia	121,852	17,581	108,080	125,661		50,195	297,70	Estimates based on information from NDC and Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo., IEA information on unit capital costs in Southeast Asia

continued on next page

Table 14 *continued*

Country	Power Generation ($ million)					Power Grid ($ million)	Total ($ million)	NB
Viet Nam	62,357	8,152	71,293	79,455	13,800	53,797	209,399	Estimates based on information on new addition under NDC and Asia Pacific Energy Research Centre. 2016. *Energy Demand and Supply Outlook*. 6th ed. Tokyo., IEA information on unit capital costs in Southeast Asia
Central and West Asia	**60,510**	**4,966**	**23,714**	**28,679**	**52,687**	**14,031**	**156,945**	
Kazakhstan	11,702	3,110	4,182	7,292	12,247	1,387	32,629	Estimates based on information from Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013)
Pakistan	39,901	41	18,604	18,645	34,140	4,982	97,668	Estimates based on information on new addition under Pakistan vision 2025, latest announced program, National Power System Expansion Plan 2011–2030
Pacific	3,871					2,618	6,489	
Total	1,693,282	139,892	737,743	877,738	382,987	1,861,746	4,816,803	
% of Total	35	3	15	18	8	39		

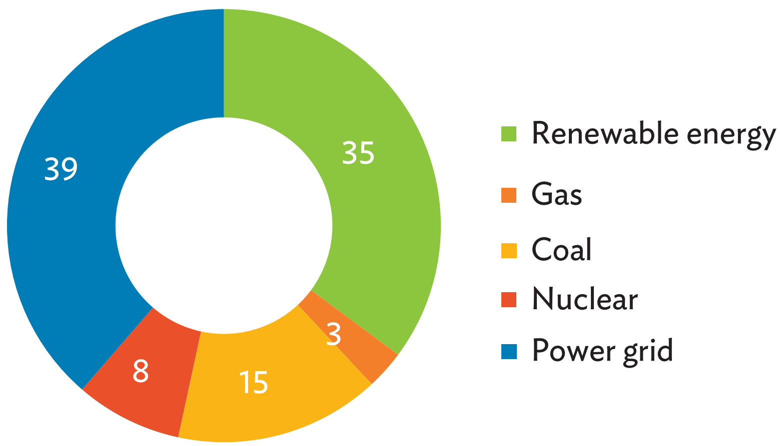
APREC = Asia Pacific Energy Research Centre; IEA = International Energy Agency; NC = National Communication; NDC = nationally determined contribution; RE = renewable energy; WEO = World Energy Outlook.

Note: Investment is estimated based on information from NDC; NC report; national energy plan; economic growth plan; and IEA, IRENA, and APREC reports.

Source: Author's estimates.

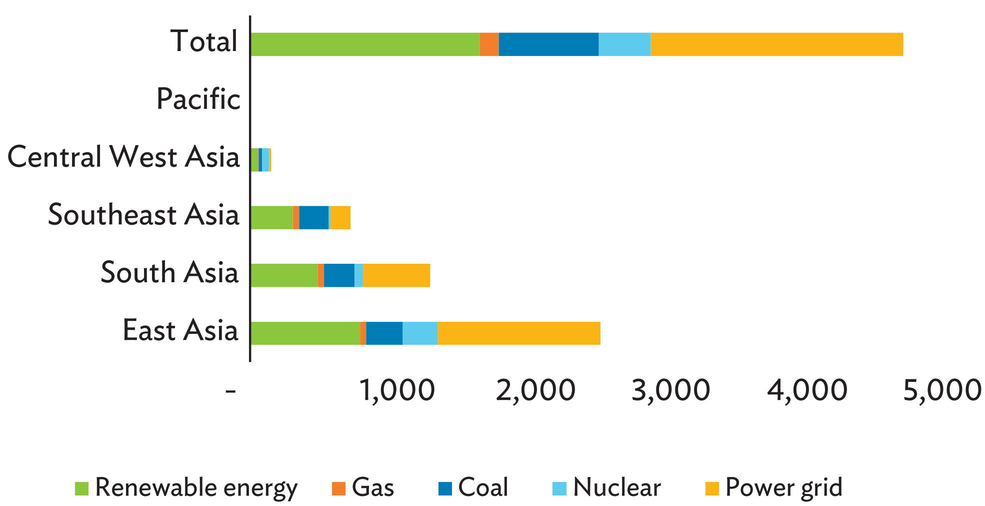
Using the data from table 14, Figure 28 presents an overall investment mix by generation source in DMCs under NDCs and Figure 29 gives more specific investment share by source in sub-regions under NDCs.

Figure 28: Investment Share by Source in the Power Sector of Developing Member Countries under the Nationally Determined Contributions Scenario (%)



Source: Author's estimates.

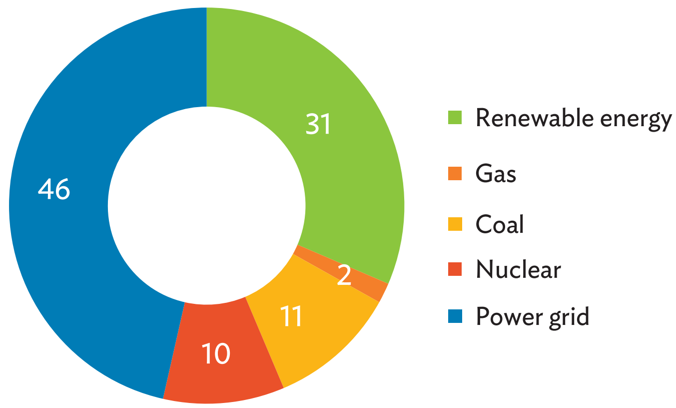
Figure 29: Power Sector Investment by Region and Source under the Nationally Determined Contributions Scenario ($ billion)



Source: Author's estimates.

As shown in Figure 30, East Asia is projected to invest over $2.5 trillion in the power sector under the NDCs, accounting for 54% of the region's investment. Most of this will be invested in the PRC in renewables and grid infrastructure.

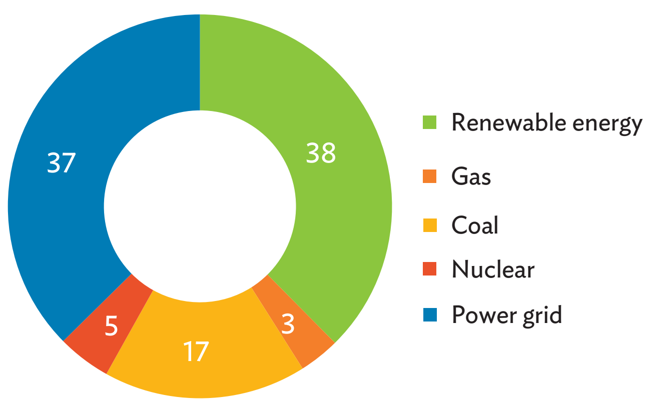
Figure 30: Power Sector Investment by Source under the Nationally Determined Contributions Scenario in East Asia (%)



Source: Author's estimates.

Figure 31 indicates that South Asia will need to invest $1.3 trillion over the next 15 years, accounting for 28% of total investment in the region. Transmission and distribution networks and renewable generation account for most of this investment (37% and 38%, respectively). Fossil fuel investment still makes up 22% in the region, while only 3% of the investment is for nuclear generation (in India). India accounts for 93% of the investment in South Asia.

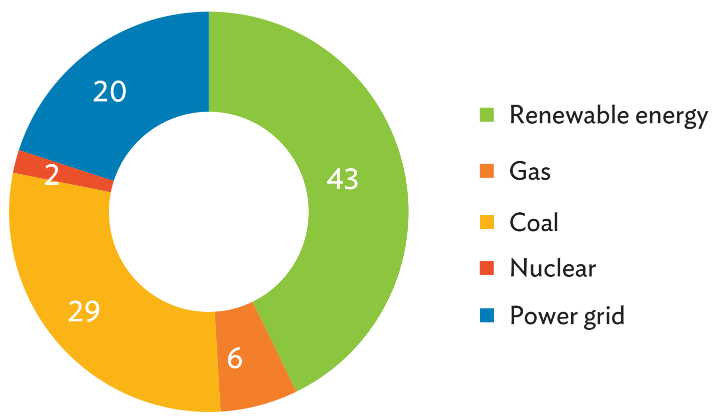
Figure 31: Power Sector Investment by Source under the Nationally Determined Contributions Scenario in South Asia (%)



Source: Author's estimates.

It is seen in Figure 32, in Southeast Asia, investment in the power sector is expected to be over $0.7 trillion, accounting for 15% of the region's investment. Indonesia and Viet Nam make up 69% of this total investment. Investment in renewables accounts for 43%, but fossil fuel investment comes in second at 35%. Investment in coal remains a priority, accounting for 29% of the investments in Southeast Asia. Indonesia and Viet Nam account for 50% and 33% of coal investment in Southeast Asia.

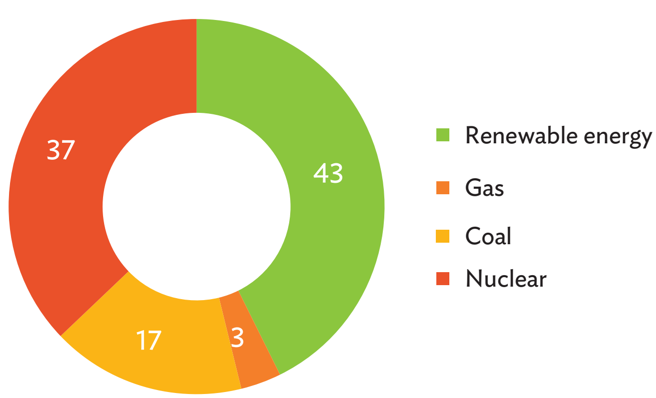
Figure 32: Power Sector Investment by Source under the Nationally Determined Contributions Scenario in Southeast Asia (%)



Source: Author's estimates.

In Central and West Asia, NDCs will lead to an investment of $157 billion in the power sector, accounting for 3% of the region's investment. As shown in Figure 33, most investment will take place in Pakistan and Kazakhstan, accounting for 62% and 21% of total investment in the region. Most countries from Central and West Asia will be investing in efficiency of thermal power plants, power grids, and heat and gas pipelines.

Figure 33: Power Sector Investment by Source under the Nationally Determined Contributions Scenario in Central and West Asia (%)



Source: Author's estimates.

An investment of $6.5 billion is needed in the Pacific DMCs to meet the targets set out in their NDCs, most of which will be for renewable power generation and storage. Papua New Guinea represents most of this investment at 85%.

D. Global Climate Battle: Keeping within 2°C

1. Emissions Gap in the Energy Sector between the Nationally Determined Contributions and the 2°C target

Implementation of the NDCs is expected to slow down emissions growth, but the NDCs will not reduce emissions to the level required to hold the temperature rise to below 2°C. According to analysis from IEA (2016c), under the NDCs, global energy related and process-related GHG emissions will rise to 42 $GtCO_2$ equivalent in 2030, of which more than 83% (35 $GtCO_2$) are CO_2 emissions from combustion of fossil fuels. Given that energy-related emissions will account for about 70% of the global GHG emissions by 2030, the emissions trend in the energy sector has the greatest influence on global emissions, and would put the world on track for an average global temperature increase of 2.7°C by 2100 (IEA 2015i and 2016c). In order to hold the temperature rise below 2°C, energy-related emissions must peak before 2020.

Driven by fast economic growth, the total primary energy supply in DMCs in Asia and the Pacific is projected to increase to half of global energy consumption in 2035 from 36% in 2014. Overall, in Asia and the Pacific, energy-related CO_2 emissions will account for about 50% of global CO_2 emissions in 2035 from 41% in 2014 (ADB 2013). Emissions from developing Asia would reach 40 $GtCO_2$ in 2050, which would be above the global emissions budget of 30 $GtCO_2$ required to keep the temperature rise below 2°C (ADB 2016b). Asia and the Pacific is the main battlefield to combat climate change, and reduction of CO_2 emissions in energy sector is critical to global climate mitigation goals.

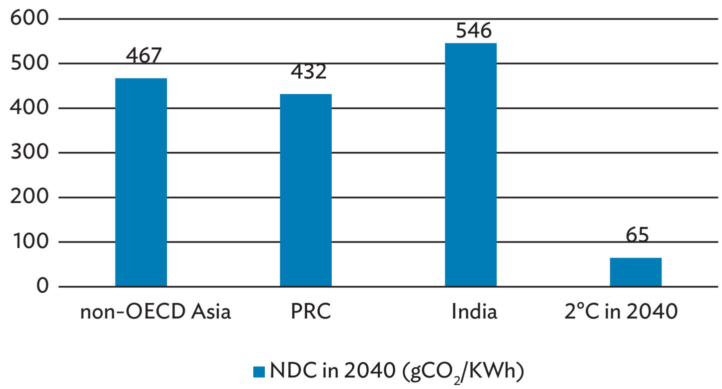
Overall, the implementation of NDCs would reduce emissions by less than 50% by 2050, which is lower than the 70% reduction required under the 2°C scenario (ADB 2016b). Furthermore, no emissions peak can be seen before 2020 in the DMCs' NDCs. Emissions from the top three emitters, namely the PRC, India, and Indonesia would increase to 10.1 Gt CO_2, 4 $GtCO_2$, and 0.8 $GtCO_2$ in 2030 (IEA 2016h). This represents increases of 3%, 90%, and 6%, respectively, compared to their 2014 levels.

2. Emissions Gap in the Power Sector between the Nationally Determined Contributions and the 2°C target

Currently, CO_2 emissions from the power sector account for about 40% of energy sector emissions globally. Burning of coal and gas generates around 90% of CO_2 emissions from power generation. According to IEA (2016c), 39% of energy emissions reductions need to take place in the power sector in order to limit global temperature increase to 2°C. As such, the carbon intensity of power generation will need to fall to 65 gCO_2/kWh in 2040 in order to meet global targets. However, the carbon intensity of power generation in the NDCs in the PRC, India, and non-OECD Asia would reach 432 gCO_2/kWh, 546 gCO_2/kWh, and 467 gCO_2/kWh in 2040 (see Figure 34).

According to IEA (2016c), abated coal generation needs to overtake unabated generation by 2040. This means that coal-fired power plant would need to be equipped with CCS to lower the carbon intensity of generation by 85-95% in order to stay consistent with a 2°C pathway.

Figure 34: Projected Carbon Intensity under the Nationally Determined Contributions Scenario and Requirement to Reach 2°C in 2040 (gCO_2/kWh)



PRC = People's Republic of China, OECD = Organisation for Economic Co-operation and Development.
Note: Reaggregates are based on information from World Energy Outlook 2016 (IEA 2016g).
Source: Author's estimates.

Existing coal-fired power plants are operating with carbon-intensive technologies, such as subcritical, supercritical, ultrasupercritical, integrated gasification combined cycle (IGCC). The average carbon intensity of IGCC and ultrasupercritical coal is 700 gCO_2/kWh, and for subcritical power plants it is 800 gCO_2/kWh. Currently, most coal-fired power plants are subcritical and only the PRC is working on the demonstration of carbon capture, utilization storage technology.

To close the gap between the NDCs and the 2°C scenario, much more will need to be done to reduce emissions from coal.

IV. CASE STUDIES: ASSESSMENT OF NATIONALLY DETERMINED CONTRIBUTIONS IN SELECTED COUNTRIES

This section presents case studies on the highest-emitting countries, those with the highest dependency on coal, as well as countries with the highest levels of anticipated power sector investment in each subregion (the PRC, India, Indonesia, Viet Nam, Kazakhstan, and Pakistan, respectively). For each country, the current situation in the power sector is summarized and the projected scenarios under the NDC as well as under enhanced low carbon actions is elaborated on.

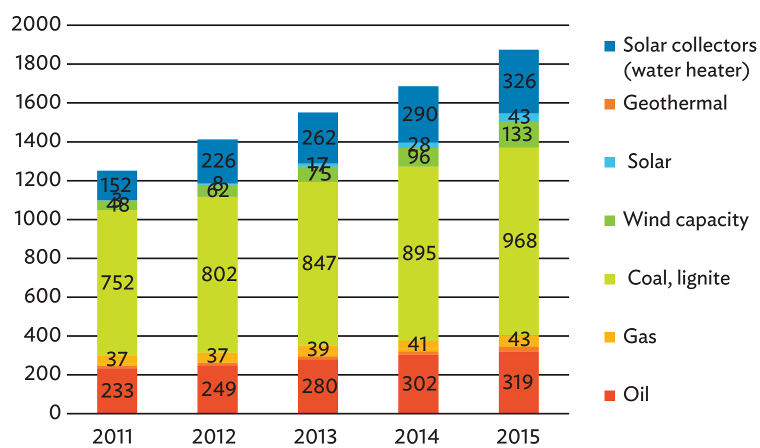
A. People's Republic of China

According to the data in section III-C, the PRC will see the largest investment in the power sector, accounting for 54% of the total investment required under the NDCs. The PRC is also the top emitter in the region (and globally) with projected emissions of 10.1 $GtCO_2$ by 2030. This compares to 4 $GtCO_2$ in India and 0.8 $GtCO_2$ in Indonesia, the second and third highest emitters, respectively.

1. Current Situation and Recent Developments in the Power Sector

In 2015, total generation capacity rose to 1,548 GW from 1,048 GW in 2011. Wind and solar capacity increased 126 GW from 2011 to 2015, with its share rising from 5% in 2011 to 11% in 2015. Coal capacity increased by 216 GW but its share dropped 5% from 68% in 2011 to 63% in 2015 (see Figure 35). The remaining capacity additions of 158 GW was mainly from hydropower, gas, and nuclear.

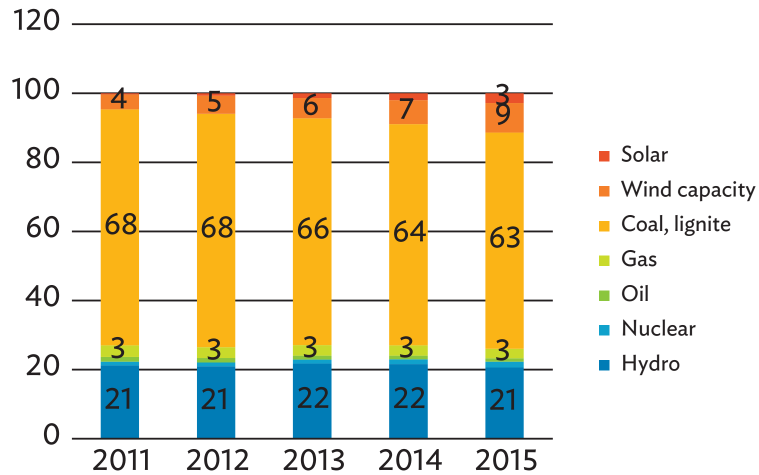
Figure 35: People's Republic of China—Generation Capacity by Source, 2011–2015 (GW)



GW = gigawatt.
Source: Enerdata (2016).

Figure 36 presents changes in power generation mix from 2011 to 2015 in 2015, the PRC's power generation rose to 5,696 TWh from 4,716 TWh in 2011. Over this period, its coal share decreased in power mix to 70% from 79% in 2011. Power generation from renewable sources rose to 25% from 17% in 2011. Nuclear generation increased by 1% and the gas generation share remains almost unchanged.

Figure 36: People's Republic of China—Power Generation Share by Source, 2011–2015 (%)



Source: Enerdata (2016).

2. Power Mix under Nationally Determined Contributions Scenario Projections

Under its NDC, the PRC has committed to peak its carbon emissions by 2030 and make best efforts to peak earlier; lower its carbon emissions per unit of GDP to 60% from 65% by 2030 from 2005 levels; and increase the share of nonfossil fuels in primary energy consumption to around 20%.

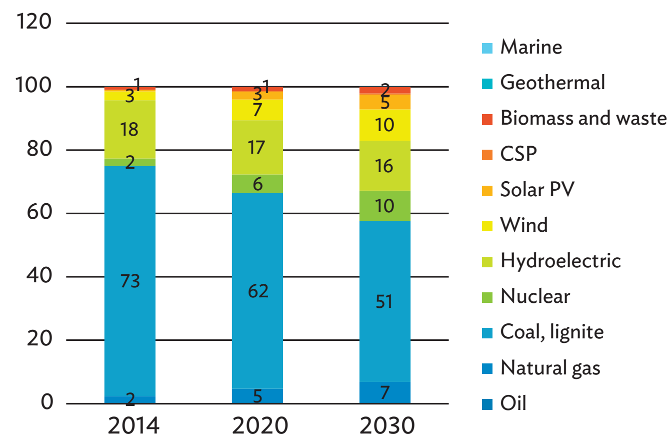
In order to achieve its NDC target, the PRC will implement a comprehensive policy package including developing a low carbon energy system; structural changes in industry; improving energy efficiency in industry, buildings, and transportation; pursuing an innovative low carbon development growth pattern; establishing a national emissions trading market; developing a green electricity trading market, and so on.

Figure 37 and 38 reflect generation mix and generation capacity in PRC under NDC. Under the NDC, the PRC's electricity generation is projected to increase 3,080 TWh to reach 8,786 TWh in 2030. Energy-related emissions are expected to reach 9.3 Gt, of which the power sector contributes 4.6 Gt. Of the additional 3,080 TWh, nonfossil fuels provide 75% (51% coming from renewables and 24% from nuclear), and fossil fuels contribute 25%.

Renewable generation is projected to expand to more than double the exiting level, increasing to 33% of power generation. Hydro remains a dominant source of renewable generation despite its share dropping to 16% from 18% in 2014. Wind and solar contribute to much of the new renewable generation capacity, accounting for 69%. As such, the share of wind and solar rises to 15% of the power mix.

Over the period 2014–2030, nuclear increases more than fivefold to 10% of total power generation. Coal generation will not see such rapid growth and is projected to rise 8% overall by 2030. Coal will still dominate the power supply, accounting for 51% of the generation mix, down from 73% in 2014. Gas generation also expands nearly fourfold to 7% of generation in 2030.

Figure 37: People's Republic of China—Generation Share by Source under the Nationally Determined Contributions Scenario, 2014–2030 (%)



IEA =International Energy Agency, PV = photovoltaic, CSP = concentrating solar power.

Note: Estimates based on information from IEA new policy scenario in World Energy Outlook 2016 (IEA 2016h) and Pursuing an Innovative Development Pathway: Understanding China's INDC (Technical Summary) (NCSC 2015).

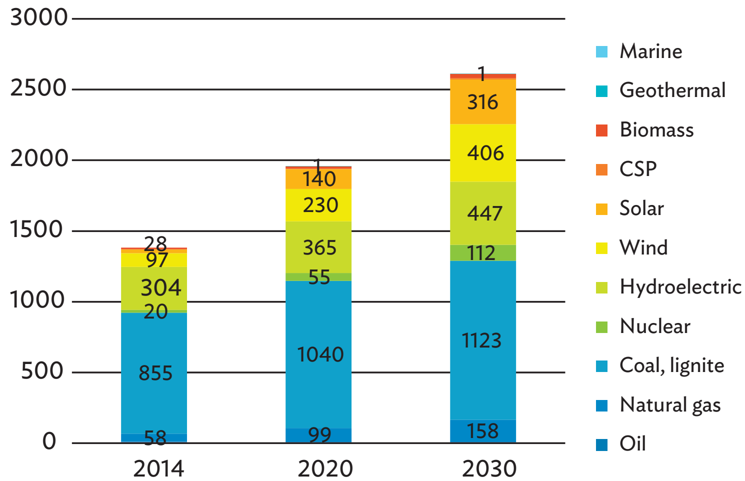
Source: Author's estimates.

In 2030, total generation capacity in the PRC is estimated to reach 2,612GW, increasing from 1,230 GW from 2014. The increase in nonfossil fuel capacity represents more than 70% of the 1,230 GW increase (63% for renewables and 7% for nuclear). This means that renewable capacity will more than double, reaching 1,210 GW and accounting 46% of total installed capacity. Wind and solar account for 78% of renewable capacity growth and solar capacity in particular sees the fastest growth than any other source. By 2030, solar capacity is expected to increase 11 times that in 2014, and wind capacity will increase more than 4 times. Wind and solar capacity is estimated to reach 406 GW and 316 GW, respectively, in 2030.

By 2030, 268 GW of new coal capacity is projected to be installed. Coal capacity will reach 1,123 GW and will continue to dominate the generation fleet (43%) despite slow growth. Gas capacity has an increase of 100 GW, to make up 6% of total capacity.

The PRC expands its nuclear capacity more than sixfold from 2014 levels, to 4% of generation capacity.

Figure 38: People's Republic of China—Generation Capacity under the Nationally Determined Contributions Scenario, 2014–2030 (GW)



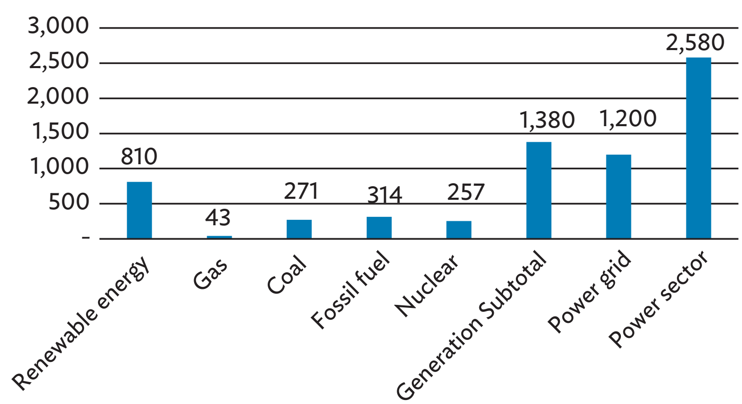
CSP = concentrating solar power, GW = gigawatt.

Note: Estimates based on information from IEA new policy scenario in World Energy Outlook 2016 (IEA 2016h) and Pursuing an Innovative Development Pathway: Understanding China's INDC (Technical Summary) (NCSC 2015).

Source: Author's estimates.

To achieve the NDC commitment, the PRC needs an investment of $2,558 billion in the power sector over the next 15 years. As shown in Figure 39, more than 47% of the investment is used in power grid construction and renovation, 32% would be used for additional renewable generation capacity and 10% would be for new coal and nuclear.

Figure 39: People's Republic of China—Investment Estimation under the Nationally Determined Contributions Scenario, 2016–2030 ($ billion)



Note: Estimates based on information from World Energy Outlook Special Report: Energy and Climate Change (IEA 2015i).

Source: Author's estimates.

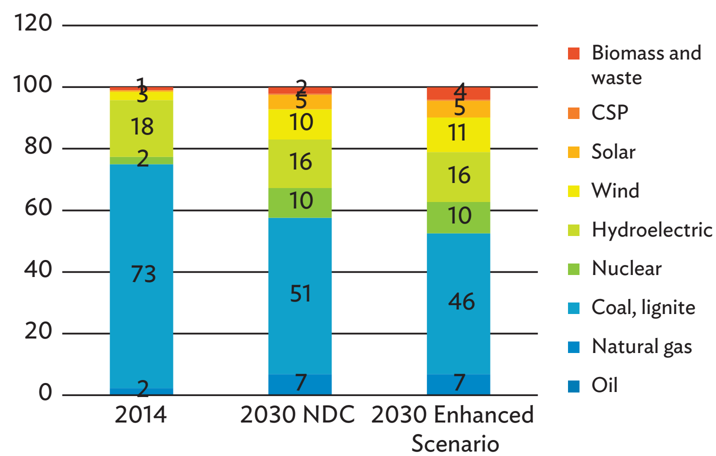
3. Power Mix under an Enhanced Low Carbon Action Scenario

The PRC has committed to peaking emissions by 2030 and making best efforts to peak earlier. This power mix scenario looks at the opportunity to support the PRC in peaking its emissions before 2020. The PRC is also facing multiple challenges around economic and industrial transformation, and environmental degradation, particularly regarding the serious air pollution across the country. An enhanced low carbon scenario must therefore also address these priorities.

In the scenario projections set out below, there is a focus on improving the energy efficiency of end users as proposed by the IEA bridge scenario. Improvement of energy efficiency reduces power consumption and would lower power generation by 5% compared to NDC (IEA 2015i), to 8,331 TWh in 2030. It is assumed that the reduction in power demand would reduce power generation from fossil fuels and consequently increase the share of nonfossil fuels. Coupled with the reduction in power generation from fossil fuels, there is also an increase in renewable capacity.

Figure 40 and 41 respectively project generation mix and generation capacity under enhanced low carbon scenario. Under this scenario, coal generation decreases by 5% to 46%, down from 51% in the NDC. Around 47% of generation will come from nonfossil fuels (37% from renewables and 10% from nuclear) and gas generation remains the same as in the NDC.

Figure 40: People's Republic of China—Power Generation Share by Source under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (%)



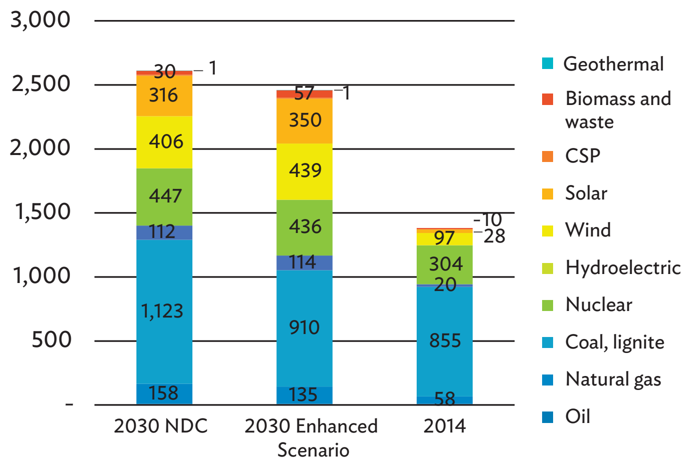
CSP = concentrating solar power, NDC = nationally determined contribution.

Note: Estimates based on information from IEA bridge scenario in Energy and Climate Change 2015 report (IEA 2015i).

Source: Author's estimates.

The associated generation capacity is estimated to be 2,382 GW in 2030, 153 GW less than the installed capacity required for the NDC. Renewables capacity increases by 82 GW and accounts for 53% of total installed capacity. Wind, solar, and biomass show the most growth in this scenario and there is a small decline in hydropower capacity. Coal sees a fall in capacity of 213 GW and the share of capacity is reduced to 37%. Gas also decreases 23 GW to only 5%, while nuclear increases 2 GW to share 3% of generation capacity compared with the NDC.

Figure 41: People's Republic of China—Generation Capacity under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios (GW)



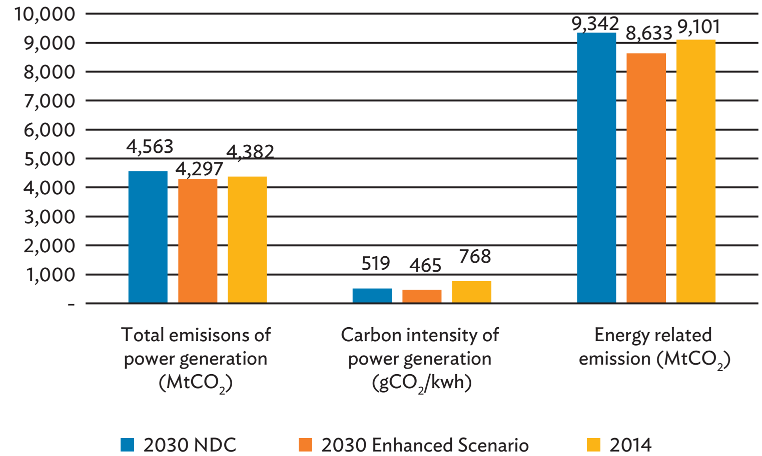
CSP = concentrating solar power, GW = gigawatt, NDC = nationally determined contribution.
Note: Estimates based on information from IEA bridge scenario in Energy and Climate Change 2015 report (IEA 2015i).
Source: Author's estimates.

Given that emissions are set to peak by 2020 under this scenario, from 2020, coal generation starts to decline and coal capacity decreases further. In 2030, the coal generation and installed capacity are 659 TWh and 213 GW less than in the NDC scenario. Gas generation and capacity also declines over time through to 2030.

Between 2020 and 2030, renewables grow rapidly and their capacity exceeds fossil fuels. Both renewable generation and capacity are higher than in the NDC. Given this increased generation efficiency, lesser installed capacity is needed in 2030 under enhanced low carbon action scenario.

Figure 42 presents the changes in carbon intensity of power generation under the NDC and enhanced low carbon scenario. Under the enhanced low carbon scenario, carbon emissions from the power sector are estimated at 4.3 Gt, decreasing 6% compared to the NDC scenario. Carbon intensity of power generation is 419 gCO_2/kWh, 9% lower than under the NDC. Energy-related CO_2 emission is reduced by 8%.

Figure 42: People's Republic of China—Emissions and Carbon Intensity of Power Generation under the Nationally Determined Contributions and Enhanced Low Carbon Scenario



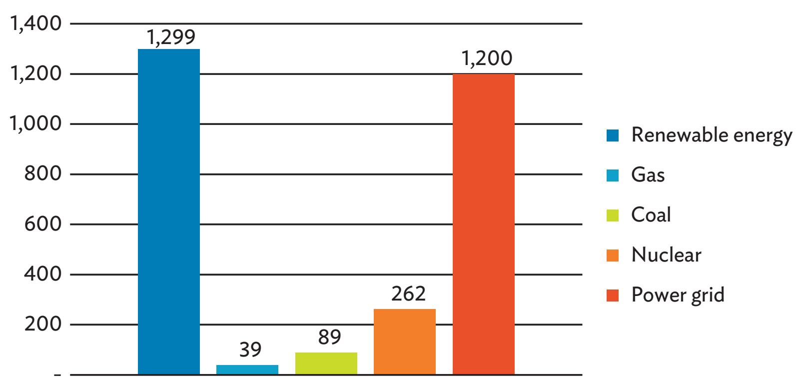
gCO_2 = grams of carbon dioxide, kWh = kilowatt-hour, $MtCO_2$ = million tons of carbon dioxide, NDC = nationally determined contribution.

Note: Estimates based on information from IEA bridge scenario in Energy and Climate Change 2015 report (IEA 2015i) and World Energy Outlook 2016 (IEA 2016h).

Source: Author's estimates.

Under the enhanced scenario, total investment increases by 12% compared to the NDC, reaching $2,890 billion over 15 years (see Figure 43). Renewables investment rises by 60% and nuclear investment increases by 2%. Fossil fuels investment drops by 59% and investment in coal generation falls by 67%. Investment in grid infrastructure is projected to be the same as under the NDC at $1,200 billion.

Figure 43: People's Republic of China—Investment Estimation under Enhanced Low Carbon Scenarios, 2016–2030 ($ billion)



Note: Estimates based on information from Energy and Climate Chang (IEA 2015i) and Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016).

Source: Author's estimates.

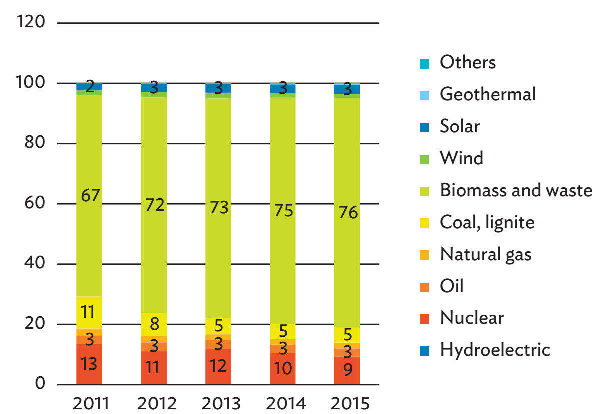
B. India

India is the second largest investor and emitter in the power sector, with 26% of the regional investment required under the NDC.

1. Current Situation and Recent Developments in the Power Sector

Figure 44 and 45 show changes of generation mix and capacity from 2011 to 2015. India's electricity output was 1,368 TWh in 2015, up from 1,074 TWh in 2011. This increase came from coal generation, which rose to 76% of the generation mix in 2015 from 67% in 2011. At the same time, the share of hydropower and gas generation has decreased over the same period. Natural gas is down to 5% from 11% in 2011 and the share of hydropower is down to 9% from 13%. Generation from other renewable sources (wind, solar, biomass and waste, geothermal, etc.) has slowly increased, but only represent 1%–3% of the power mix. The share of nuclear and oil remain at 3% and 2%, respectively.

Figure 44: India—Generation Share by Source, 2011–2015 (%)



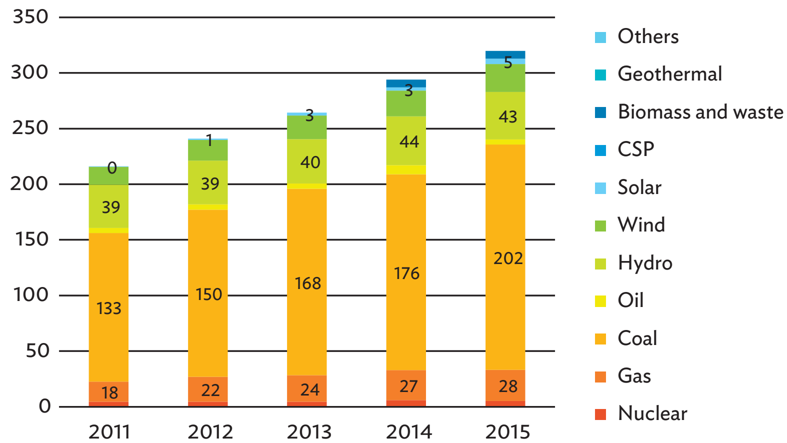
Sources: Enerdata (2016) and IEA (2016h).

In 2014, India had 313 GW of generation capacity, 97 GW more than in 2011. Coal capacity increased 69 GW, accounting for 71% of the capacity additions, while renewables accounted for 18%. Renewables capacity increased by 31% from 2011 compared to 52% for coal. Coal makes up by far the largest share with 65% of total installed capacity in 2015, followed by hydropower (14%), natural gas (9%), and wind (8%). Solar, biomass, and nuclear each had a 2% share.

The heavy dependence on coal and the use of inefficient subcritical plants to burn low-quality coal has increased the carbon intensity of power generation in India to 754 gCO_2/kWh, which is much higher than a world average of 567 gCO_2/kWh (IEA 2016h).

India has the second highest projected share of generation from coal in the region to 2030 (after Mongolia). Given the scale of coal generation in India, raising the efficiency of this generation is critical to achieving emission reduction in the power sector. Around 85% of existing coal generation units are operating with subcritical technology, and India's average efficiency of coal-fired generation units is below 34% (IEA 2015e and 2015i). Outages on the power grid causes high power losses during

Figure 45: India—Power Generation Capacity, 2011–2015 (GW)



CSP = concentrating solar power, GW = gigawatt.
Sources: Enerdata (2016) and IEA (2016h).

transmission, and inadequacies of transmission lines also mean that the generation units cannot run at full load. The load factors of coal-fired power plants was only 60% in 2014, down from 80% in 2007 (CEA 2015). Meanwhile, there is still a large population (about 2.4 million) without access to electricity. These challenges must also be dealt on the way toward low carbon power system.

2. Power Mix under Nationally Determined Contributions Scenario Projections

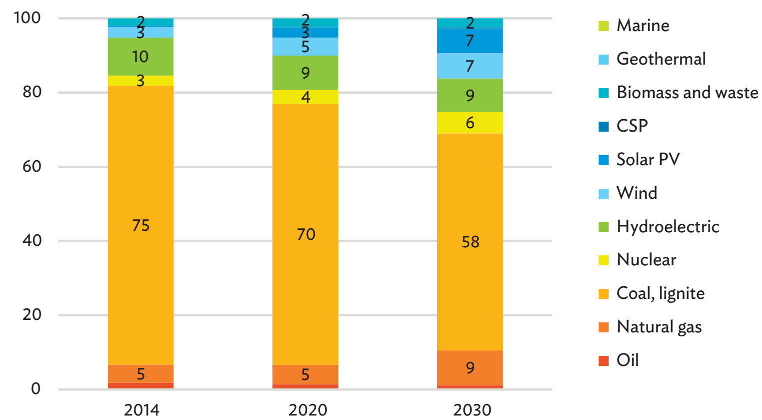
India aims to achieve 40% installed capacity from nonfossil fuel-based energy resources by 2030, with the help of technology transfer and low-cost international finance, including from the GCF.

India has set ambitious renewable targets that aim to increase renewable capacity to 175 GW by 2022. India has also mandated the use of supercritical technology in new coal-fired power generation, and is seeking to strengthen the national grid infrastructure in order to reduce losses to 15%. Meanwhile, India has implemented energy efficiency programs in industry, buildings, and transport sectors by adopting mandatory standards, market-based instruments (e.g., performance, achieve, trade), and fiscal support. These policies and measures will support India to achieve its NDC commitments.

Under the NDC, India's power demand is projected to more than double from 2014 levels in 2030 reaching 2,896 TWh (an increase of 1,609 TWh). This is a result of population growth, economic growth, and increased access to electricity. Under the NDC, coal still provides most of the increased power demand (45% of the additional power), whereas 33% comes from renewables and 8% from nuclear.

Coal generation maintains the dominant share at 58%, down from 75% in 2014. Gas generation increases by 4%–9% and oil drops to 1%. Nonfossil fuel generation has the largest growth and is expected to provide 31% of the generation in 2030, up from 18% in 2014, of which 25% is from renewables and 6% from nuclear. Solar generation has the highest growth in power mix: its share rises by 7% to 7% of the total power output, whereas wind only rises by 4% to achieve the same share as solar of 7%. Hydropower maintains a similar share in 2030 of 9%, down slightly from 10% in 2014.

Figure 46: India—Power Generation Share by Source under the Nationally Determined Contributions Scenario, 2014–2030 (%)



CSP = concentrating solar power, NDC = nationally determined contribution, PV = photovoltaic.

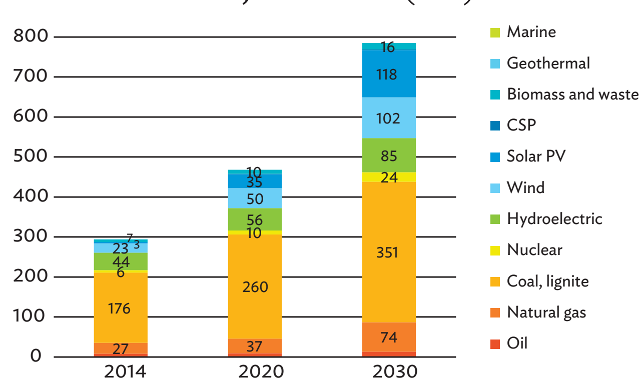
Note: Generation share under NDC is recalculated based on the information from World Energy Outlook 2016 (IEA 2015i, 2016h).

Sources: Author's estimates; Enerdata (2016)

Figure 46 and 47 show the development of power generation share and capacity under the NDC. Under the NDC, India's generation capacity is projected to increase 491 GW to 789 GW in 2030, which is almost triple the capacity in 2014. Coal generation capacity is expected to double over this period with 175 GW additional capacity, which is equivalent to the coal capacity in 2014. The increase of nonfossil fuel capacity is greater than that of fossil fuels, accounting for 54% of capacity additions. Renewables play an increasingly important role with 50% of capacity additions, of which solar and wind are the most significant. Solar capacity increases almost 40 times by 2030; wind increases 2 times from 2014.

Coal still has the largest generation fleet generation capacity, with a capacity of 351GW, accounting for 45% of installed capacity. Gas will expand 74 GW but its share remains unchanged.

Figure 47: India—Generation Capacity under the Nationally Determined Contributions Scenario, 2014–2030 (GW)



CSP = concentrating solar power, NDC = nationally determined contribution, PV = photovoltaic.

Note: Generation share under NDC is recalculated based on information from World Energy Outlook 2016 (IEA 2015i and 2016h).

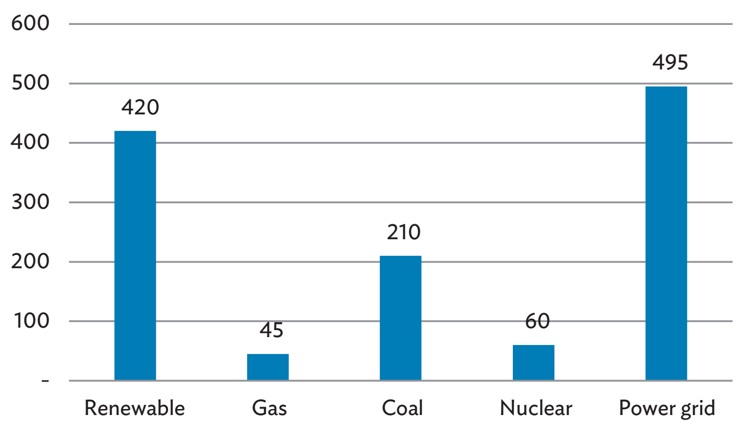
Sources: Author's estimates.

Nonfossil fuels are projected to reach 41% of the installed capacity. Solar overtakes hydro and takes second place with 118 GW (15%), followed by wind with 105 GW (13%). Hydropower has declining role and its capacity falls to 11% of generation capacity. Nuclear rises to 24 GW with 3% of total capacity.

Under India's NDC, energy-related CO_2 emissions will increase by 88% relative to 2014, to reach 3.79 $GtCO_2$ up from 2.0 $GtCO_2$ in 2014. Despite the growth in absolute emissions, the carbon intensity of power generation is 594 gCO_2/kWh, a decrease of 27%.

To implement the NDC, India's total investment in the power sector is projected to be $1,230 billion. The bulk of the investment is directed toward the power grid infrastructure and renewable generation capacity, which account for 40% and 34%, respectively (see Figure 48).

Figure 48: India—Investment Estimation under the Nationally Determined Contributions Scenario, 2016–2030 ($ billion)



Note: Estimates based on information from Energy and Climate Change 2015 (IEA 2015i), and unit cost data from IEA (2015f) and IRENA (2015e).

Source: Author's estimates.

3. Power Mix under an Enhanced Low Carbon Action Scenario

As discussed, India's power demand is expected to increase rapidly driven by economic growth, urbanization, and an increased population with access to power. Improving energy efficiency and increasing investment in renewable energy is vital to provide for this strong power demand. The power mix under enhanced action scenario is based on the assumption of improving energy efficiency and increasing investment in renewables from the IEA bridge scenario. Several enhanced measures need to be taken by India in enhanced low carbon action scenario:

(i) increase investment in renewable, in particular solar energy;

(ii) invest in hydropower and gas to increase flexibility of capacity to accommodate integration of variables;

(iii) accelerate the closures of older and inefficient plants and use high efficiency and low emissions technology such as ultra-super critical and IGCC, which are capture-ready for new coal power plants. About 86% of existing coal capacity or 160 GW of inefficient coal capacity is retired (IEA 2015i) and an additional 144 GW is installed with IGCC, ultra-super critical, or super critical technologies, which is 32 GW less than NDC;

(v) replace old generation units with gas and renewables; and

(vi) improve efficiency of the remaining coal fleet.

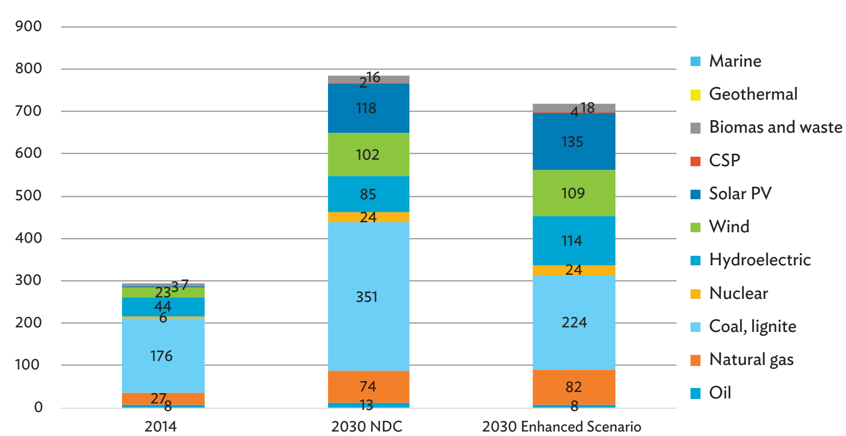
IEA (2015i) estimates that the actions to improve energy efficiency in industry, buildings, and transportation would reduce the power demand to 2,312 TWh, 20% lower than the NDC scenario. This would reduce generation capacity by 67 GW.

Figure 49 and 50 estimate generation capacity and generation share to 2030 under enhanced low carbon scenario through increased investment, nonfossil fuels add 57 GW against the NDC scenario to reach 404 GW and account for 56% of installed capacity. Hydropower increases by 29 GW to 114 GW; solar photovoltaic and concentrated solar power increase by 19 GW to 135 GW; and wind capacity reaches 109 GW.

Coal and oil capacity is reduced by 127 GW and 19 GW due to both increased nonfossil fuel capacity and reduced power demand, as well as speeding up the closure of inefficient coal. Gas capacity is increased by 8 GW to 82 GW.

Under the enhanced low carbon scenario, hydropower and natural gas capacity see a substantial increase as they are used in a flexible capacity to accommodate variable renewable generation.

Figure 49: India—Power Generation Capacity under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (GW)



CSP = concentrating solar power, NDC = nationally determined contribution, PV = photovoltaic.

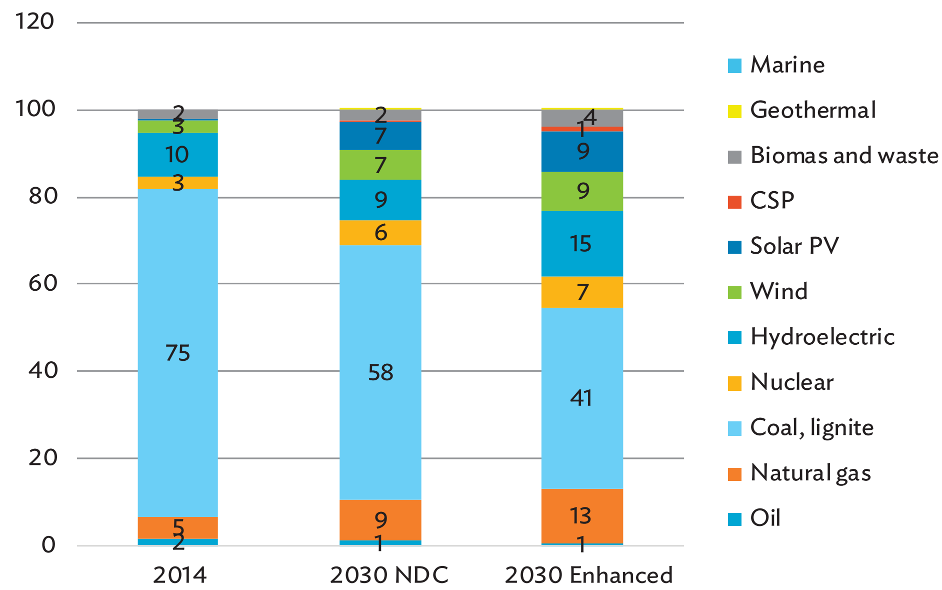
Note: Estimates based on information from bridge scenario in Energy and Climate Change 2015 (IEA 2015i) and data from Central Energy Authority (CEA 2017).

Source: Author's estimates.

Under the enhanced scenario, nonfossil fuel would provide 45% (38% from renewables and 7% from nuclear) rising by 14% relative to the NDC scenario. Solar (including concentrated solar power) and wind account for 18% of the generation, and hydropower is 15%. The remaining 4% is from biomass.

Coal generation is reduced by 17% compared to NDC, falling to only 41% in the power mix. Gas generation increases by 4% relative to the NDC, to reach 13%.

Figure 50: India—Power Generation Share by Source under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (%)



CSP = concentrating solar power, NDC = nationally determined contribution, PV = photovoltaic.

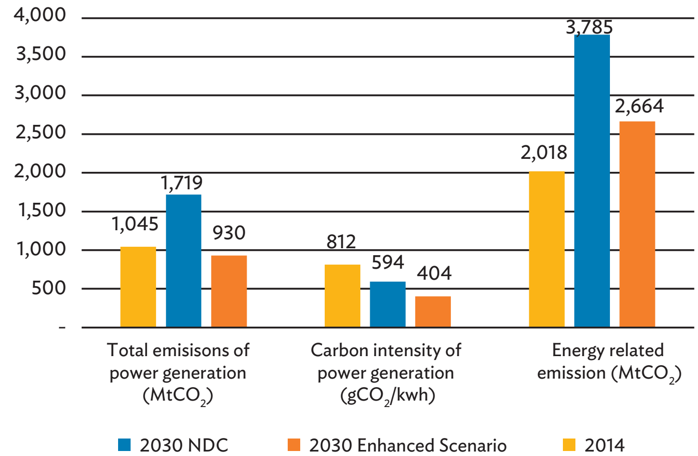
Note: Estimates based on information from IEA bridge scenario in Energy and Climate Change 2015 (IEA 2015i) and data from Central Energy Authority (CEA 2017).

Source: Author's estimates.

Under the enhanced low carbon action scenario, coal capacity and generation rise through to 2020 and then decrease as nonfossil and gas capacity growth strengthens. The overall power generation efficiency increases as about 160 GW of inefficient coal capacity is retired through to 2030 (IEA 2015h).

Given the reduction in electricity demand and coal generation, and increasing efficiency of power generation, carbon emission from the power sector under the enhanced scenario is reduced significantly compared to the NDC, and the reduction is estimated at 0.93 Gt or 46% lower than the. The carbon intensity of power generation drops to 404g CO_2/kWh, which is 32% lower than under the NDC (see Figure 51).

Figure 51: India—Emissions and Carbon Intensity in the Power Sector under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios



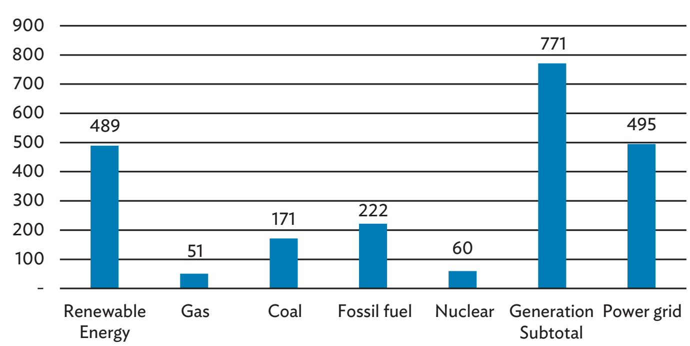
gCO_2 = grams of carbon dioxide, kWh = kilowatt-hour, $MtCO_2$ = million tons of carbon dioxide, NDC = nationally determined contribution.

Note: Estimates based on information from bridge scenario in Energy and Climate Change 2015 (IEA 2015i) and data from Central Energy Authority (CEA 2017), World Energy Outlook 2016 (IEA 2016h).

Source: Author's estimates.

Figure 52 shows the projected investment for taking enhanced low carbon actions. Under the enhanced low carbon action scenario, the total investment is projected to be $1,266 billion for the power sector, $36 billion higher than under the NDC. Investment in coal capacity is reduced by $39 billion and investment in renewables is increased by $69 billion. The share of renewable investment rises to 38%, increasing by 4% while coal investment falls to 14% from 17% under the NDC. Investment in solar is more than any other generation source, accounting for 20% of the total investment. The power grid again has the highest accounting for 39% of total investment in the sector.

Figure 52: India—Investment Estimation under Enhanced Low Carbon Action Scenario, 2016–2030 ($ billion)



Note: Estimates based on information in bridge scenario of in Energy and Climate Change 2015 (IEA 2015i), and unit cost data from by IEA (IEA 2015f) and IRENA (IRENA 2015e).

Source: Author's estimates.

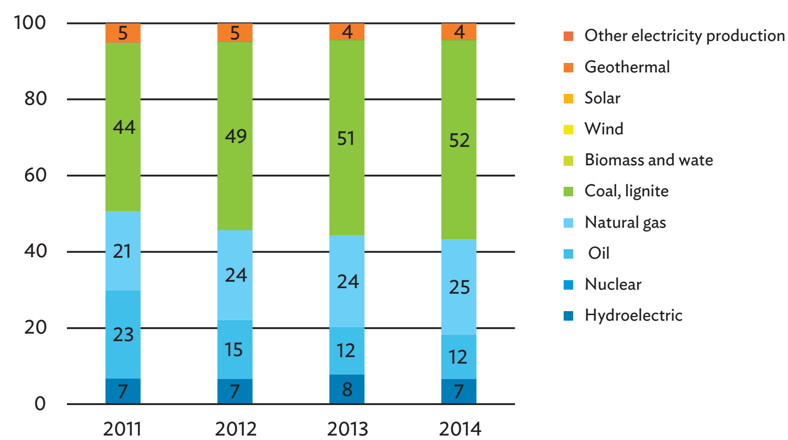
C. Indonesia

Indonesia has the third largest projected investment in power sector in the region, accounting for 6% of total investment. Indonesia is also the third highest emitter in the region and is the only country projected to increase both coal and gas generation in its power mix.

1. Current Situation and Recent Developments in the Power Sector

Indonesia's total power generation was 228 TWh in 2014. The key change recently in Indonesia's power sector is the rise of fossil fuel generation and decrease of renewables generation. Figure 53 and Figure 54 respectively show changes of power generation mix and generation capacity by sources from 2011 to 2015. Between 2011 and 2014, Indonesia cut its share of oil-fired power generation by 11%–12% of the total generation share. However, the reduction in oil was largely replaced by coal and gas. The share of coal generation rose by 8% over the last 4 years to 52% of the power mix in 2014, while the share of gas generation rose by 4% to 25% in 2014. The share of renewable generation declined by 1% to 11% in 2014. Hydro is the largest renewable source for power generation with a share of 7% of total generation, followed by geothermal with 4%.

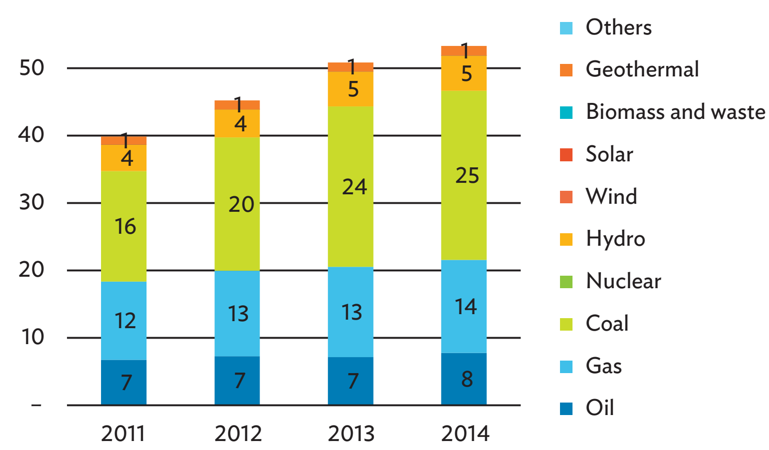
Figure 53: Indonesia—Generation Share by Source, 2011–2014 (%)



Source: Enerdata (2016).

Indonesia had 53 GW of generation capacity in 2014 and fossil fuels accounted for 47 GW or 89% of the total installed capacity. Coal capacity has increased substantially over the last 4 years, rising by 56% compared to 2011 to represent 64% of total installed capacity. Gas and oil follow with 14% and 12% of installed capacity, and renewables have only a small generation capacity of 7 GW.

Figure 54: Indonesia—Generation Capacity, 2011–2014 (GW)



GW = gigawatt.
Source: Enerdata (2016).

Energy-related CO_2 emissions were 437 $MtCO_2$ in 2014. Given the increasing generation from coal, emissions from power generation reached 168 $MtCO_2$ in 2014, 22% higher than in 2011 (APERC 2016). The 2014 carbon intensity of power generation was 738 gCO_2/kWh, significantly higher than the world average of 567 g CO_2/kWh. The carbon intensity is particularly high because 91% of coal capacity employs subcritical technology (IEA 2016g).

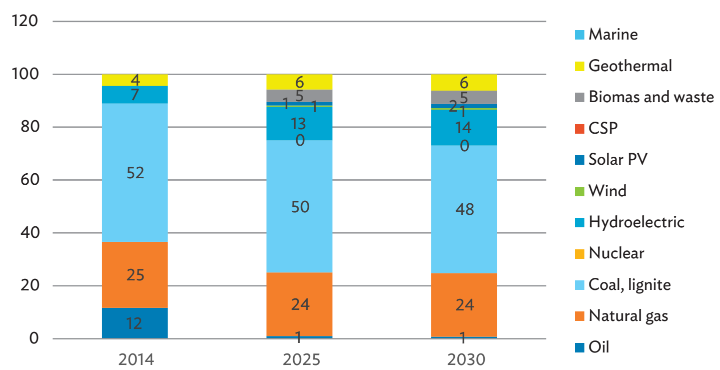
2. Power Mix under Nationally Determined Contributions Scenario Projections

Indonesia pledged an unconditional target to reduce its GHG emissions by 29% below business as usual scenario, and also pledged to increase this to up to 41% with international support. Indonesia's NDC stated that the implementation of existing energy policy will support Indonesia to achieve this commitment. The Indonesia National Energy Plan (Kebijakan Energi Nasional.) sets a target of at least 23% of energy from new and renewable energy by 2025.

The General Plan for National Electricity Development and Electricity Supply Business Plan of Indonesian State Electricity Company have adopted a higher target of a 25% share in renewable generation in the power mix. According to the both plans, 50% of power will be generated from coal, 24% from gas, and 1% from oil by 2025. As such, the targets in both plans have been used to assess the power mix development trend under the NDC. It is expected that extension of the existing policies would achieve 27% of power from renewables in 2030.

Figure 55 and 56 shows the development of power generation and generation capacity under the NDC. Under the NDC, power generation is projected to more than triple by 2030 reaching 819 TWh. Most of the additional generation will be met by coal and gas, and renewables will account for 30% of the additional generation (with 16% from hydro and 7% each from geothermal and bioenergy). Although coal still dominates under the NDC, its share is down to 48% from 52% in 2014, and renewables show an increase. Hydropower rises by 7% to 14%, geothermal rises to 6%, and biomass to 5%. Solar and wind account for 2% and 1% of the generation mix, respectively.

Figure 55: Indonesia—Generation Share by Source under the Nationally Determined Contributions Scenario, 2014–2030 (%)



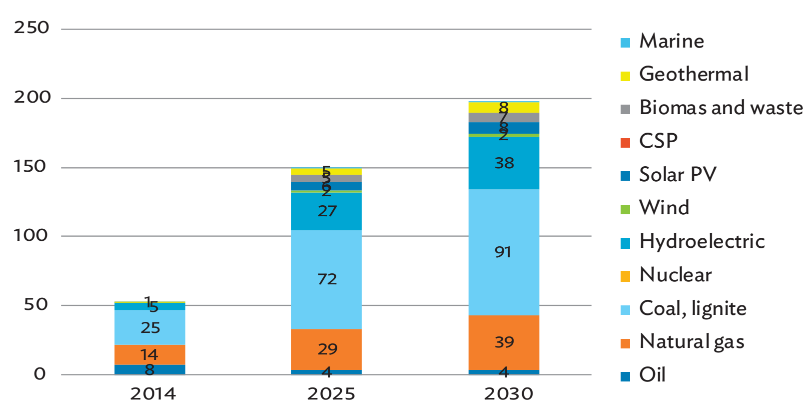
CSP = concentrating solar power, GW = gigawatt, NDC = nationally determined contribution.

Note: Estimates based on information from Indonesia National Electricity Development Plan; Electricity Supply Business Plan of Indonesian State Electricity Company; Renewable Energy Outlook for ASEAN: a REmap Analysis (IRENA and ACE 2016); and Reducing Emissions from Fossil-Fired Generation: Indonesia, Malaysia, and Viet Nam (IEA 2016g).

Source: Author's estimates.

Generation capacity is projected to increase by 144 GW, reaching 197 GW in 2030. Coal increases by 66 GW to account for 46% of the generation capacity, natural gas increases by 25 GW to account for 20%, and hydro expands by 33 GW to account for 19% of generation capacity. Other renewables only have a small increase and minor shares in the installed capacity.

Figure 56: Indonesia—Generation Capacity under the Nationally Determined Contributions Scenario, 2014–2030 (GW)



CSP = concentrating solar power, GW = gigawatt, NDC = nationally determined contribution.

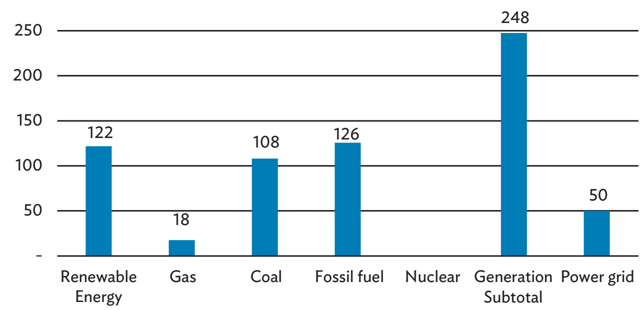
Note: Estimates based on information from Indonesia National Electricity Development Plan; Electricity Supply Business Plan of Indonesian State Electricity Company; Renewable Energy Outlook for ASEAN: a REmap Analysis (IRENA and ACE 2016); and Reducing Emissions from Fossil-Fired Generation: Indonesia, Malaysia, and Viet Nam (IEA 2016g).

Source: Author's estimates.

Indonesia's carbon emissions from power generation are projected to rise to 496 $MtCO_2$ in 2030 from 168 $MtCO_2$ in 2014 despite carbon intensity declining to 606 gCO_2/kWh from 738 gCO_2/kWh.

Figure 57 shows that investment needed for the power sector is estimated at $298 billion from 2015 to 2030 under the NDC. Of this, 41% is directed to renewables, 36% to coal, and 17% to the power grid. Investment in gas only makes up 6% of the total investment. Given that magnitude of investment in coal generation, adopting high efficiency technologies such ultrasupercritical and IGCC will be critical to lower the impact of emissions from coal generation.

Figure 57: Indonesia—Investment Estimation under the Nationally Determined Contributions Scenario, 2015–2030 ($ billion)



Note: Estimates based on information unit cost for power generation from Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016); Southeast Asia Energy Outlook (IEA 2015h); and Renewable Energy Outlook for ASEAN: A REmap Analysis (IRENA and ACE 2016).

Source: Author's estimates.

3. Power Mix under an Enhanced Low Carbon Action Scenario

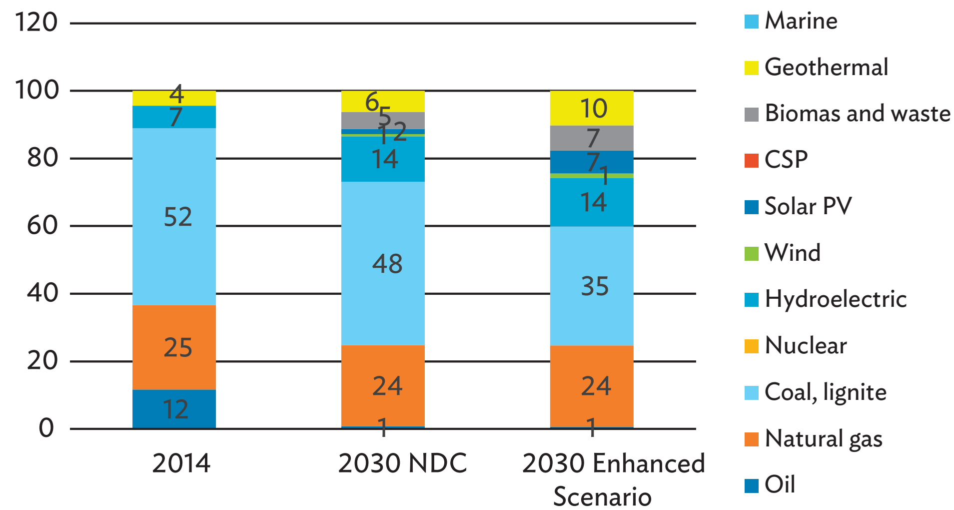
Indonesia has the potential to increase its power generation from renewables given its abundant resources. It is estimated that Indonesia has the potential for 75 GW of hydropower, 9.3 GW of wind, 32.7 GW of biomass, and 28 GW of geothermal. Indeed, Indonesia has around 40% of the world's geothermal potential (IEA 2015c) and considerable year-round potential for solar energy. Indonesia has an average solar radiation of 4.8 kilowatt-hours per square meter (kWh/m^2) per day. Geothermal power in Indonesia also benefits from the lowest levelized cost compared to other renewable energy sources, including large hydropower (BREE 2014).

The enhanced policy scenario suggests an increase in investment in renewable generation technologies such as hydropower, geothermal, solar, and biomass, leading to a share of power generation from renewables of 40%. At the same time, reduced generation from coal and increased efficiency of coal generation (through retirement after 25 years and replacement with HELE units) would be implemented. These measures could significantly reduce total emissions from the power sector.

Under these assumptions, electricity generation from renewables reaches 329 TWh in 2030, from 221 TWh under the NDC. Geothermal, solar, and biomass would contribute to the increased share of renewables in the power mix. In 2030, geothermal accounts for 10% of total generation compared with 8% under the NDC. Solar and biomass each make up 7%. Solar PV generation is the fast runner in terms of growth, rising by 5% in the power mix relative to the NDC, and biomass increases 2%. Wind and hydropower maintain the same share as in the NDC.

Figure 58 and 59 represent the potential development of power generation and its capacity under enhanced low carbon scenario. Generation from fossil fuel falls to 491 TWh from 598 TWh in the NDC scenario and its share drops to 60% in the power mix, compared to 73% in the NDC. Electricity from coal is reduced by 27%, accounting for 35% of total generation (48% in NDC). No changes are made to gas and oil generation.

Figure 58: Indonesia—Generation Share by Source under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (%)



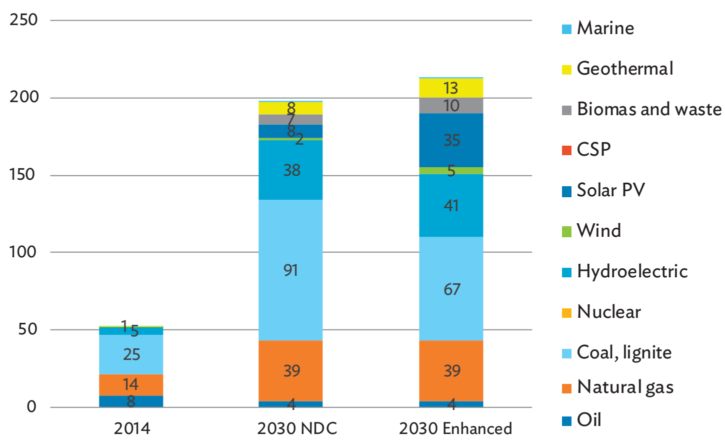
CSP = concentrating solar power, GW = gigawatt, NDC = nationally determined contribution.

Source: Author's estimates.

Generation capacity reaches 213 GW under the enhanced low carbon action scenario, increasing 16 GW from the NDC scenario. Renewable capacity increases by 40 GW, accounting for almost half of generation capacity. This is mostly due to an increase in solar of 27 GW to 35GW in 2030. Hydro capacity remains the largest source of renewable capacity with 41 GW (38GW in NDC).

Fossil fuel generation capacity is reduced to 110 GW from 134 GW under the NDC. The reduction is attributed to a reduction in coal capacity. Coal capacity decreases 24 GW to 67 GW and gas and oil remain unchanged.

Figure 59: Indonesia—Generation Capacity under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (GW)



CSP = concentrating solar power, GW = gigawatt, NDC = nationally determined contribution.

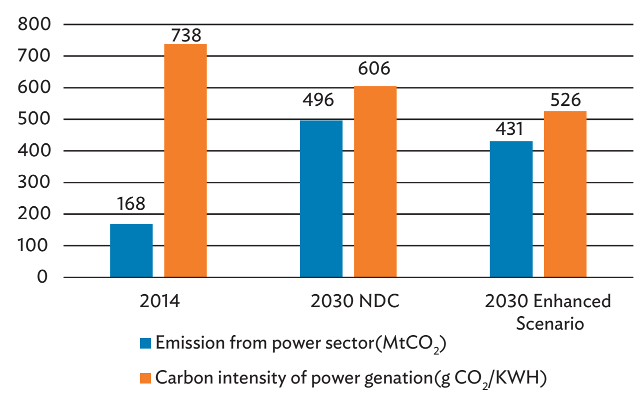
Note: Estimates based on information from Indonesia National Electricity Development Plan; G20 Toolkit for Renewable Energy Deployment: Country Options for Sustainable Growth Based on Remap (IRENA 2016b); Renewable Energy Outlook for ASEAN: A REmap Analysis (IRENA and ACE 2016); and Reducing Emissions from Fossil-Fired Generation: Indonesia, Malaysia, and Viet Nam (IEA 2016g).

Source: Author's estimates.

As described above, the key assumptions are that old coal capacity will be retired and all new capacity will be HELE technologies. According to IEA (2016h), the implementation of a 25-year retirement plan in existing subcritical generation units would avoid 23 $MtCO_2$ emissions per year on average in Indonesia.

Overall, the increased generation from renewables and raising the efficiency of coal under this scenario would reduce power sector emissions by 65 $MtCO_2$ from 496 $MtCO_2$ to 431 $MtCO_2$, and the carbon intensity of power generation from 606 gCO_2/kWh to 526 gCO_2/kWh when compared to the NDC (Figure 60).

Figure 60: Indonesia—Emissions and Carbon Intensity of the Power Sector under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios



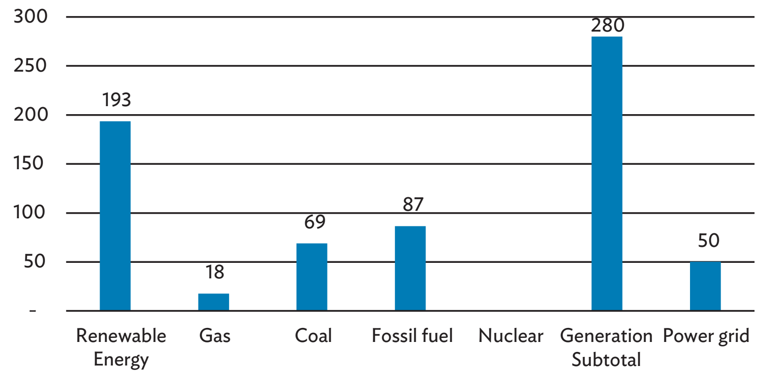
gCO_2 = grams of carbon dioxide, kWh = kilowatt-hour, $MtCO_2$ = million tons of carbon dioxide, NDC = nationally determined contribution.

Note: Estimates based on information from Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016); and Reducing Emissions from Fossil-Fired Generation: Indonesia, Malaysia, and Viet Nam (IEA 2016g).

Source: Author's estimates.

As shown in Figure 61, the enhanced low carbon scenario would increase investment by $32 billion against the NDC scenario. Renewables investment rises to $193 billion from $122 billion in the NDC. Investment in coal falls to $69 billion, 16% lower than in the NDC.

Figure 61: Indonesia—Investment Estimation under the Enhanced Low Carbon Action Scenario, 2016–2030 ($ billion)



Note: Estimates based on information unit cost for power generation from Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016); Southeast Asia Energy Outlook (IEA 2015g); and Renewable Energy Outlook for ASEAN: A REmap Analysis (IRENA and ACE 2016).

Source: Author's estimates.

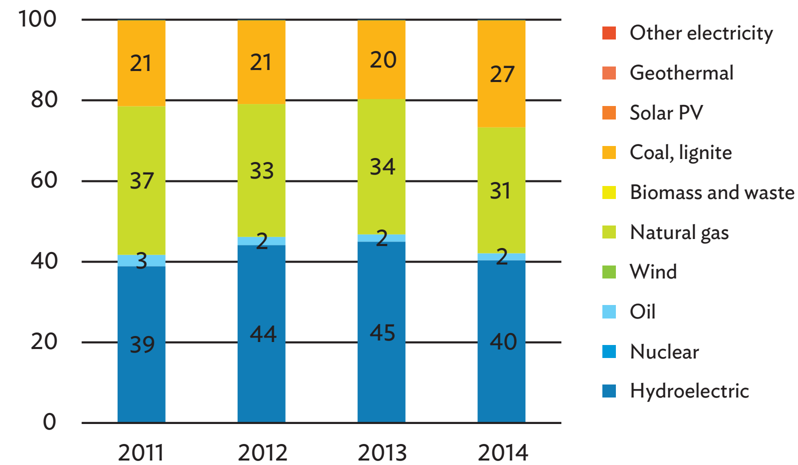
D. Viet Nam

Viet Nam has the fourth largest projected investment in power sector in the region, accounting for 4% of total investment. Viet Nam also shows the highest projected growth in coal generation in the region, building on a growth of over 50% in just 3 years up to 2014.

1. Current Situation and Recent Developments in the Power Sector

Viet Nam's total power generation was 143 TWh in 2014. Figure 62 shows that between 2011 and 2014 there has been significant recent growth of coal generation in Viet Nam's power sector, increasing 6% to 27% of the power generation mix. This has directly replaced gas in the mix, which fell 6% to 31% over the same period. Hydropower experienced a 2-year growth during 2012–2013 and then dropped to 40% in 2014. Other forms of renewable power generation represent less than 0.5% of total power generation.

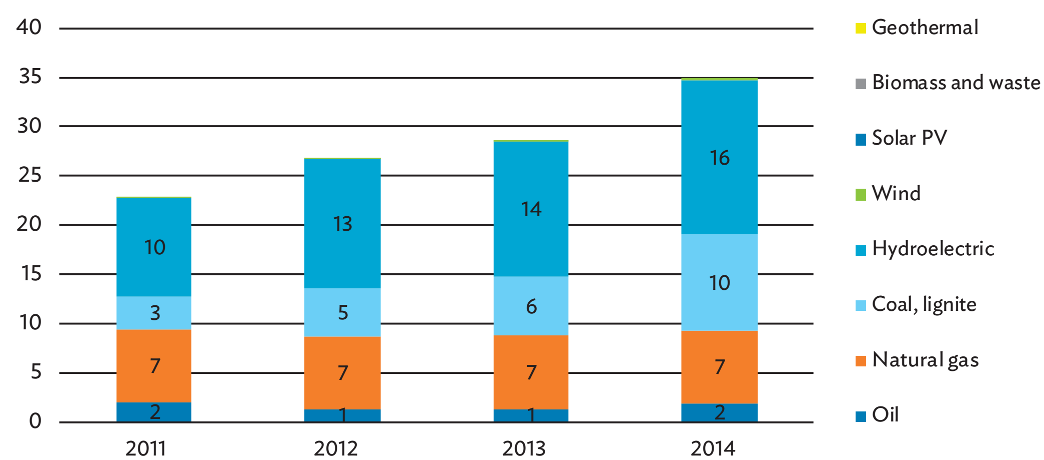
Figure 62: Viet Nam—Generation Share by Source, 2011–2014 (%)



Source: Enerdata (2016).

Viet Nam had 35 GW of generation capacity in 2014. Fossil fuels accounted for 19 GW and coal saw a rapid increase of 7 GW from 3 GW in 2011 to account for 30% of total capacity in 2014 from 15% in 2011. Renewable capacity was 16 GW in 2014, 99% of which comes from hydro. Hydropower increased by 6 GW to 16 GW in 2014 (Figure 63).

Figure 63: Viet Nam—Generation Capacity by Source, 2011–2014 (GW)



GW = gigawatt, PV = photovoltaic.

Source: Enerdata (2016).

CO_2 Emissions from the power sector were 50 $MtCO_2$ in 2014, accounting for 39% of energy-related emissions. Given that its 40% of power is generated from hydropower, Viet Nam's carbon intensity of power generation was relative low at 349 gCO_2/KWh in 2014 and lower than the world average level of 567g CO_2/kWh(IEA 2016b). However, emissions from the power sector rose 53% in only 3 years from 32.7 $MtCO_2$ in 2011. Carbon intensity grew 12% from 310 gCO_2/kWh in 2011. This is due to the increased generation from coal over the period.

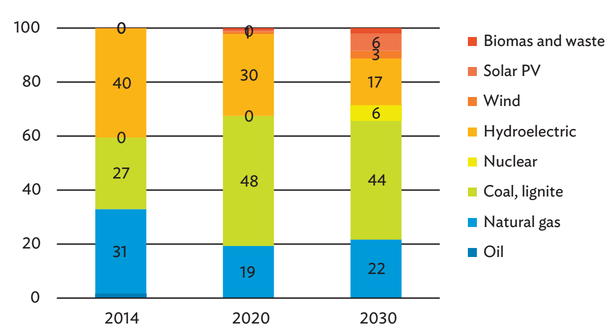
2. Power Mix under Nationally Determined Contributions Scenario Projections

In the NDC, Viet Nam pledges to reduce GHG emissions by 8% compared to the business as usual scenario, and emission intensity per unit of GDP will be reduced by 20% compared to 2010. The target could be increased to 25% with international support, and the corresponding emission intensity per unit of GDP will be reduced by 30% compared to 2010.

Viet Nam approved an adjustment of the 7th Viet Nam Power Development Planning 2011–2020 period with an outlook up to 2030 (MOIT 2015b). The plan revises the GDP growth rate between 2016 and 2030 downward by about 1.5% per year to of 7.0% per year over the period. This adjustment reduces the demand for electricity by 20% in 2020, and 18% in 2030. The plan also reduces the assumed coal generation capacity from 76 GW to 55 GW by 2030. This is a significant move to address climate change mitigation and support the goals of the Paris Agreement.

Figure 64 and 65 gives estimation of power mix and generation capacity under the NDC. Under the NDC scenario, power demand increases fourfold from 2014 to reach 557 TWh in 2030. Fossil fuels still heavily dominate the power generation mix. Although the revised power plan reduces coal generation capacity, Viet Nam anticipates a major shift in its power system from hydro to coal for baseload power generation. In 2030, coal will overtake hydropower to become the dominant generation source, rising to 44% of the power mix from 27% in 2014. Hydropower and gas generation fall to 17% and 22%, respectively, in 2030 (from 40% and 31% in 2014). Viet Nam intends to invest in nuclear generation to provide 6% of generation by 2030.

Figure 64: Viet Nam—Generation Share by Source under the Nationally Determined Contributions Scenario, 2014–2030 (%)



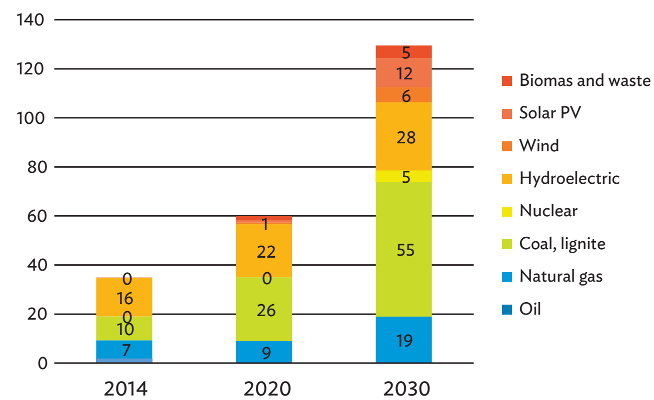
PV = photovoltaic.

Note: Estimates based on information for Viet Name NDC and Adjusted Vietnam Power Development Plan (MOIT 2015), Viet Nam's Renewable Energy Development Strategy up to 2020 with an Outlook to 2050 (Government of Viet Nam 2015).

Source: Author's estimates.

Total generation capacity increases to 130 GW in 2030 from 35 GW in 2014 with most of the increase coming from coal. Coal generation capacity increases by 45 GW, to reach 55 GW in 2030 (a 450% increase). Hydropower shows moderate growth to 28 GW, gas climbs to 19 GW, and solar and nuclear both grow from almost nothing to a significant share of the power capacity with 12 GW and 5 GW, respectively.

Figure 65: Viet Nam—Generation Capacity by Source under the Nationally Determined Contributions Scenario, 2014–2030 (GW)



GW = gigawatt, PV = photovoltaic.

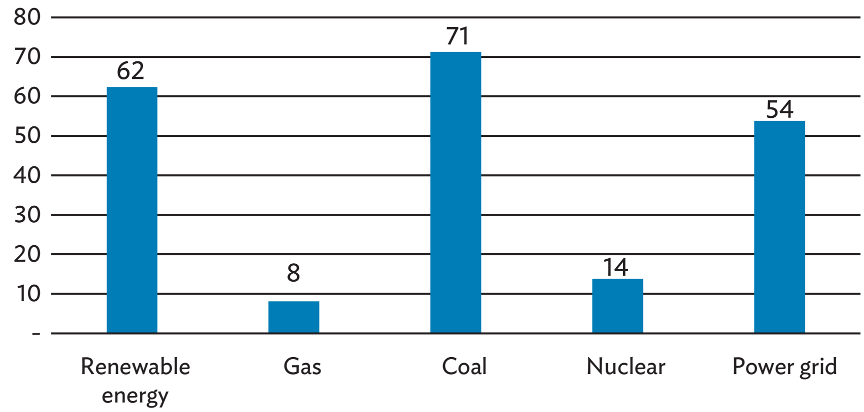
Note: Estimates based on information from National Energy Development Strategy: Revision of Power Master Plan No. VII (MOIT 2015); and Viet Nam's Renewable Energy Development Strategy up to 2020 with an Outlook to 2050 (Government of Viet Nam 2015).

Source: Author's estimates.

Alongside this growth in coal, carbon emissions from the power sector are projected to increase five times to 299 $MtCO_2$ by 2030 from only 50 $MtCO_2$ in 2014. The carbon intensity of generation also rises to 537 gCO_2/kWh from 349 gCO_2/kWh in 2014. Energy-related CO_2 emissions also increase to 496 $MtCO_2$ in 2030, or 3.5 times that of the 2014 level.

It is seen in Figure 66 that investment needed for implementation of the NDC scenario is estimated at $209 billion, with coal accounting for 34% of this investment. Renewables and the power grid make up 30% and 26%, respectively.

Figure 66: Viet Nam—Investment Estimation under the Nationally Determined Contributions Scenario, 2016–2030 ($ billion)



Note: Estimates based on information unit cost for power generation from Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016); Southeast Asia Energy Outlook (IEA 2015q); and Renewable Energy Outlook for ASEAN: A REmap Analysis (IRENA and ACE 2016).

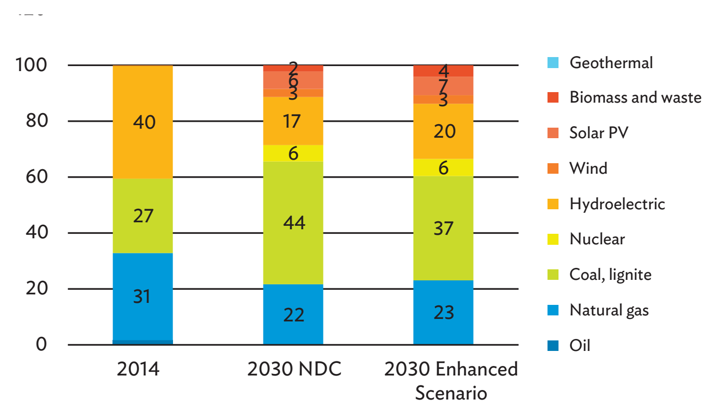
Source: Author's estimates.

3. Power Mix under an Enhanced Low Carbon Action Scenario

The enhanced low carbon action scenario explores opportunities both in improving energy efficiency in end-use sectors that leads to reduction of power demand and increasing investment in renewable power generation. According to an Asia Pacific Energy Research Centre (APERC) study in 2016, improving energy efficiency in end-use sectors could reduce power demand by 6% compared to the NDC, reaching 524 TWh in 2030, and reducing the need for generation capacity by 9 GW in 2030.

Figure 67 and 68 draw development of power mix and generation capacity under the NDC and Enhanced low carbon action scenario. Lower power demand provides the opportunity to reduce generation from coal. Hence, under this scenario, coal generation decreases to 37% in 2030 from 44% in the NDC scenario. This is coupled with increased investment in renewable generation from small hydropower, solar, and biomass in particular. Generation from renewables increases to 33% from 29%. Hydropower increases to 20% of power generation, while solar and biomass increase to 7% and 4%, respectively. Variable renewables increase their share to 10% of total generation. Gas generation shows small increases of 1% to 23%, and nuclear remains the same.

Figure 67: Viet Nam—Power Generation Share by Source under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (%)



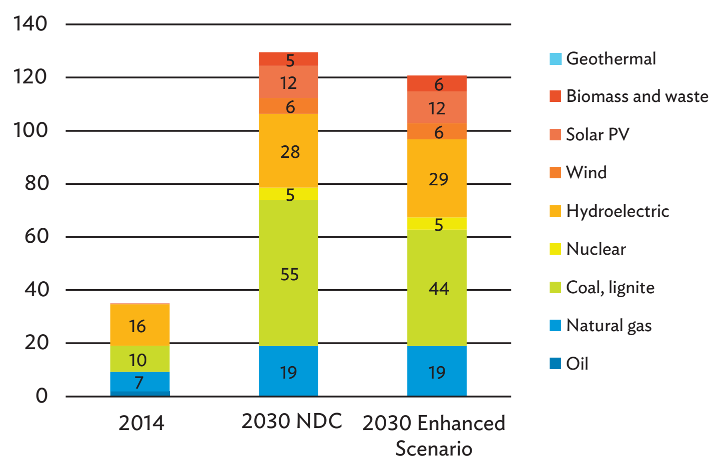
NDC = nationally determined contribution, PV = photovoltaic.

Note: Estimates based on available information from NDC; Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016); Renewable Energy Outlook for ASEAN: A REmap Analysis (IRENA and ACE 2016); and Reducing Emissions from Fossil-Fired Generation: Indonesia, Malaysia, and Viet Nam (IEA 2016g).

Source: Author's estimates.

Total generation capacity decreases to 121 GW given the focus on energy efficiency, and coal capacity is reduced by 11 GW to 44 GW. Renewable generation capacity increases by 3 GW.

Figure 68: Viet Nam—Generation Capacity by Source under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (GW)



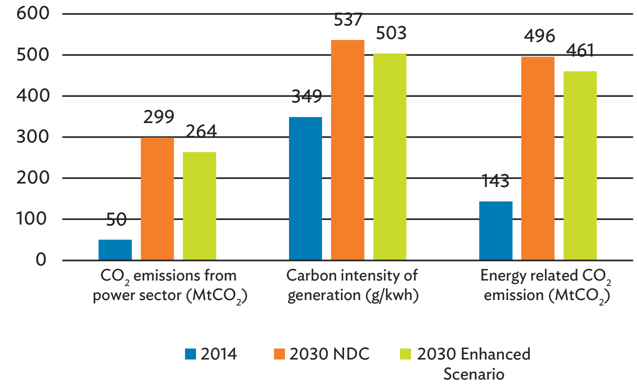
GW = gigawatt, NDC = nationally determined contribution, PV = photovoltaic.

Note: AnalyzeEstimates based on the available information from NDC, Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016); APEC Energy Demand and Supply Outlook (6th edition)(APERC 2016); Renewable Energy Outlook for ASEAN: a REmap Analysis(IRENA & ACE 2016); Reducing emissions from fossil-fired generation: Indonesia, Malaysia and Viet Nam (IEA. 2016g).

Source: Author's estimates.

As shown in Figure 69, under the enhanced scenario, an emission reduction of 35 $MtCO_2$ is expected compared with the NDC scenario in 2030. Carbon emissions intensity of generation is reduced to 503 gCO_2/kWh from 537 gCO_2/kWh.

Figure 69: Viet Nam—Emissions and Carbon Intensity of the Power Sector under the Nationally Determined Contributions and Enhanced Low Carbon Scenario



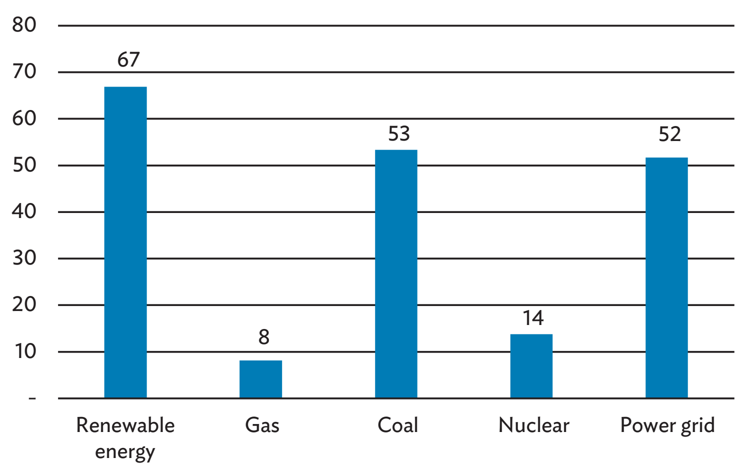
gCO_2 = grams of carbon dioxide, kWh = kilowatt-hour, $MtCO_2$ = million tons of carbon dioxide, NDC = nationally determined contribution.

Note: Estimates based on available information from Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016); and Reducing Emissions from Fossil-Fired Generation: Indonesia, Malaysia, and Viet Nam (IEA 2016g).

Source: Author's estimates.

Figure 70 gives a projection of investment for power sector under enhanced low carbon scenario. The focus on energy efficiency in demand sectors means that the enhanced scenario could lead to investment savings of $16 billion compared to the NDC scenario. Investment in renewables increases by $5 billion while investment in coal is reduced by $18 billion compared with the NDC.

Figure 70: Viet Nam—Investment Estimation under Enhanced Low Carbon Action Scenario, 2016–2030 ($ billion)



Note: Estimates based on information unit cost for power generation from Energy Demand and Supply Outlook (Asia Pacific Energy Research Centre 2016); Southeast Asia Energy Outlook (IEA 2015q); and Renewable Energy Outlook for ASEAN: A REmap Analysis (IRENA and ACE 2016).

Source: Author's estimates.

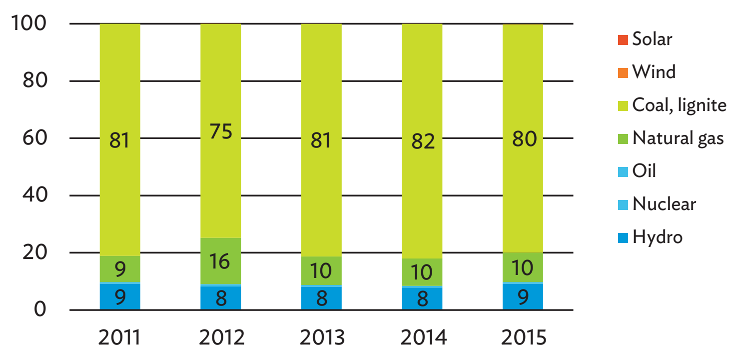
E. Kazakhstan

Kazakhstan has the second largest projected investment in the power sector in Central and West Asia. It also has the second highest share of coal in the power mix in Asia and the Pacific.

1. Current Situation and Recent Developments in the Power Sector

Kazakhstan's total power generation was 94 TWh in 2015. Fossil fuels provided 91% of generation. Figure 71 and 72 reflect the development of the power mix and generation capacity. The majority of fossil generation comes from coal, which has maintained around 80% of total generation from 2011 to 2015. Gas generation accounts for around 10%, and oil 1%. Renewables and specifically hydro provided 8%–9% of generation consistently over the period. The power generation mix has seen little change since 2011.

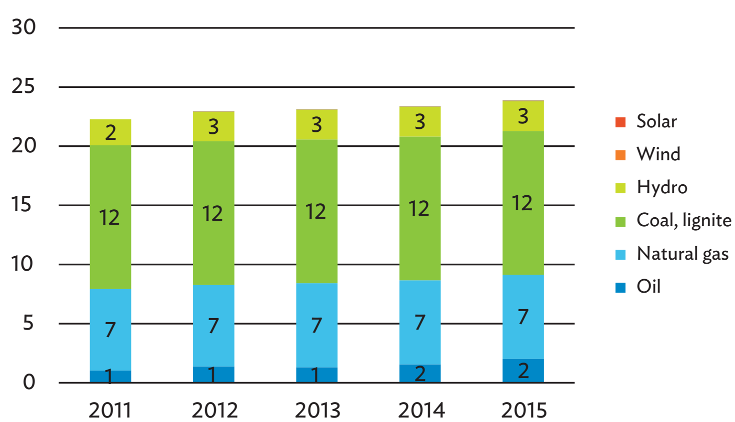
Figure 71: Kazakhstan—Generation Share by Source, 2011–2015 (%)



Source: Enerdata (2016).

Generation capacity has increased 2 GW since 2011 to 24 GW in 2015. The increased capacity has come from coal (1 GW) and hydro (1 GW). Coal has the highest installed capacity with 12 GW, followed by gas (7 GW), hydropower (3 GW), and oil (2 GW).

Figure 72: Kazakhstan—Generation Capacity, 2011–2015 (GW)



Source: Enerdata (2016).

CO_2 Emissions from the power sector were 96 $MtCO_2$ in 2014, accounting for 43% of energy-related emissions. The carbon intensity of power generation is very high at 985g CO_2/kWh (IEA 2016b), which is almost double the world average.

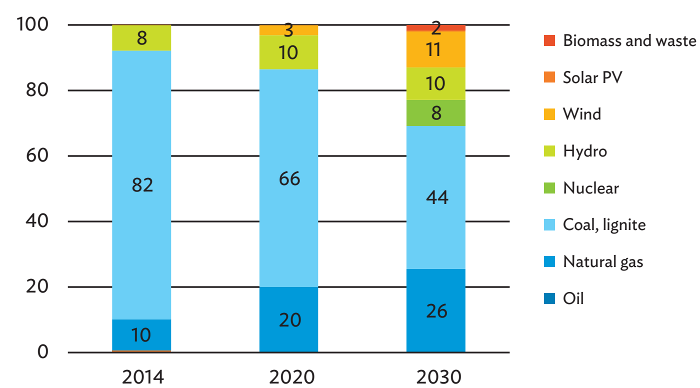
2. Power Mix under NDC Scenario Projections

Kazakhstan has committed to reduce GHG emissions by 15% compared to 1990 by 2030. This target would be raised to 25% with international support through access to low carbon technologies, technology transfer, the GCF, and other flexible market mechanisms.

Kazakhstan's "Concept for Transition of the Republic of Kazakhstan to Green Economy" sets a target of providing 50% of total energy supply by alternative and renewable energy sources (including nuclear) by 2050, and decreasing energy intensity of GDP by 50% by 2050 compared to a 2008 baseline (Government of the Republic of Kazakhstan 2013). By 2030, the share of alternative sources in electricity production and reduction of the energy intensity of GDP should achieve 30%. Kazakhstan's NDC emphasizes that implementation of the concept will be a significant contribution to achieving its GHG emission reduction commitments. As such, the concept provides important background for the analysis of the Kazakhstan power mix under the NDC.

Figure 73 and 74 outline the development of power mix and generation capacity under the NDC scenario. In this scenario, power demand is projected to approach 137 TWh in 2030, increasing 41% from 2014. The power sector sees a gradual shift from coal to gas and renewables. Coal is still the major generation source but its share drops to 44% in 2030 from 82% in 2014, and generation from gas rises 16% to 26% of total generation. Renewables provide 23% of generation, increasing by 15%, with wind seeing a significant increase in power generation from almost zero in 2015 to 11% in 2030. Nuclear also increases from almost zero to reach 8% in 2030. No generation from oil is seen in 2030.

Figure 73: Kazakhstan—Generation Share by Source under the Nationally Determined Contributions Scenario, 2014–2030 (%)



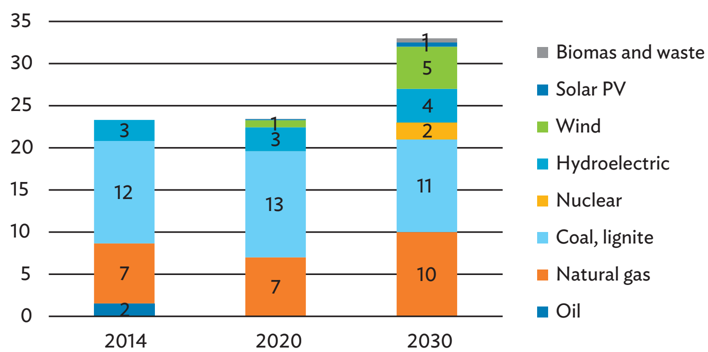
Note: Estimates based on information from Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013).

Source: Author's estimates.

Kazakhstan's generation capacity increases to 33 GW in 2030 from 23 GW in 2015. The majority of new capacity comes from renewables, which increase to 10 GW from only 3 GW in 2014. Wind reaches 5 GW in 2030 from zero in 2014. Hydropower increases by 1 GW to 4 GW. Biomass and waste, as well as solar, only see a slow increase in capacity with less than 1 GW for each in 2030. 1.5 GW of nuclear capacity is put into use by 2030.

The majority of existing coal-fired generation capacity (about 6 GW by 2030) is refurbished and only 0.6 GW will be built under the NDC. Coal capacity falls to 11 GW as old fleets retire. Gas generation capacity increases by 3 GW to 10 GW. Increased gas capacity satisfies the growing power demand and substitutes for the retired coal capacity while providing back-up for renewables.

Figure 74: Kazakhstan—Generation Capacity by Source under the Nationally Determined Contributions Scenario, 2014–2030 (GW)



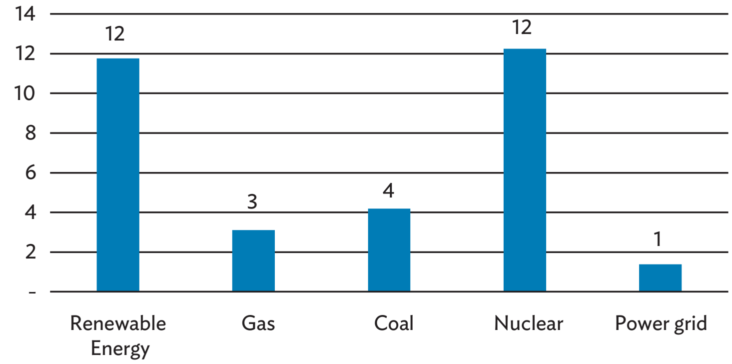
Note: Estimates based on information from Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013).

Source: Author's estimates.

Under this scenario, emissions from the power sector decline to 77 $MtCO_2$ in 2030 from 96 $MtCO_2$ in 2014 due to the reduced generation from coal. Carbon intensity of power generation falls substantially to 562 gCO_2/kWh from 985 gCO_2/kWh in 2014.

As shown in Figure 75, investment needed to achieve these commitments is estimated at $33 billion. Nuclear takes the largest share of this investment, accounting for 38%, followed by renewables at 36%. 86% of the investment in coal is used to retrofit existing coal generation units and investment in gas is for the addition of new generation units.

Figure 75: Kazakhstan—Investment Estimation under the Nationally Determined Contributions Scenario, 2016–2030 ($ billion)



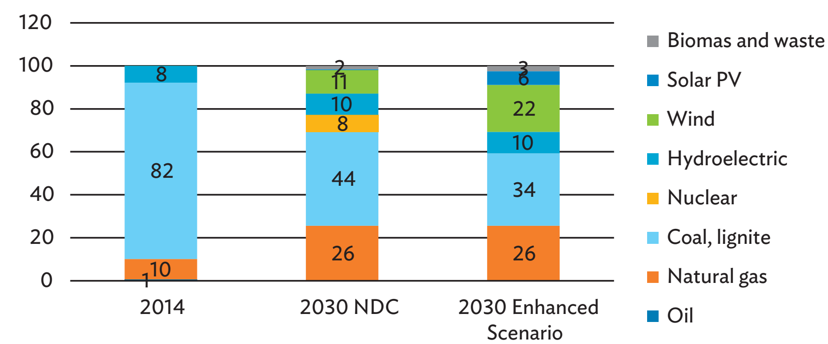
Note: Estimates based on information from *Lower Carbon Strategy for the Electricity Sector of Kazakhstan to 2030/50: Scenarios for Generation and Network Development* (Egerer et al. 2014); and Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013).

Source: Author's estimates.

3. Power Mix under an Enhanced Low Carbon Action Scenario

According to Lower Carbon Strategy for the Electricity Sector of Kazakhstan to 2030/50: *Scenarios for Generation and Network Development* (Egerer et al. 2014), Kazakhstan has the potential to generate 30% of its power from solar and wind. Therefore, the enhanced low carbon action scenario sees a major transformation of the power system in Kazakhstan to 41% of power generated from renewables and no generation from nuclear before 2030. Coal generation in the power mix is further reduced to 34% from 44% under the NDC scenario, and gas generation is expected to be the same. Under the enhanced scenario, wind and PV are assumed to have a low capacity factor requiring additional back-up. Gas and hydropower are expected to be the same as under the NDC scenario.

Figure 76: Kazakhstan—Generation Share by Source under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (%)



NDC = nationally determined contribution, PV = photovoltaic.

Note: Estimates based on information from *Lower Carbon Strategy for the Electricity Sector of Kazakhstan to 2030/50: Scenarios for Generation and Network Development* (Egerer et al. 2014); Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013); and Clean Energy Technology Assessment Methodology Pilot Study: Kazakhstan (IEA 2016b).

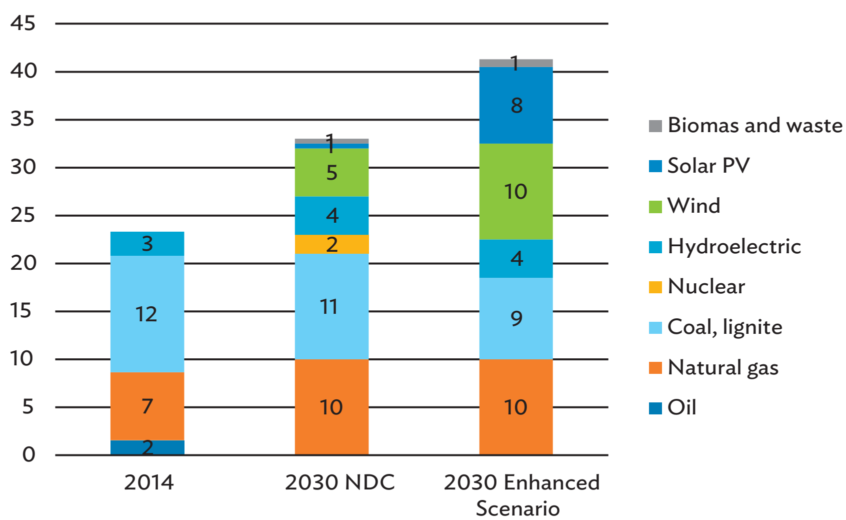
Source: Author's estimates.

Figure 76 and 77 reflect the development of the power mix and generation capacity under the NDC scenario. Generation from wind and solar increases to 22% and 6% of total generation in 2030, compared to 11% and almost zero under the NDC scenario. Biomass and waste provide 3% of generation output.

The shift from extensive coal and nuclear power to more renewables results in increase of generation capacity of 8 GW in 2030 relative to 33 GW under the NDC scenario. The additional capacity is entirely from renewables, which increase to 23 GW, accounting for more than half of total generation capacity, of which wind and solar capacity counts for 18 GW, double the level in the NDC.

Coal capacity is reduced to only 9 GW (11 GW in NDC scenario) and gas still maintains the same capacity as in NDC. No nuclear units are built.

Figure 77: Kazakhstan—Generation Capacity under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (GW)



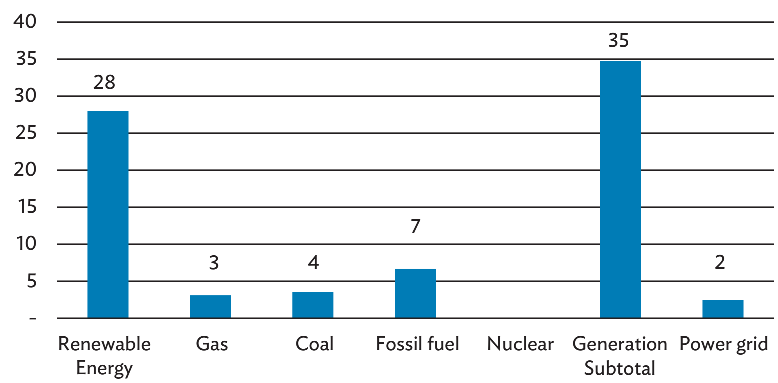
NDC = nationally determined contribution, PV = photovoltaic.

Note: Estimates based on information from *Lower Carbon Strategy for the Electricity Sector of Kazakhstan to 2030/50: Scenarios for Generation and Network Development* (Egerer et al. 2014); and Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013); and Clean Energy Technology Assessment Methodology Pilot Study: Kazakhstan (IEA 2016b).

Source: Author's estimates.

Figure 78 shows that the total investments for refurbishments and new capacity under the enhanced action scenario is $37 billion, increasing by $7 billion compared to the NDC scenario. Reduced investment in nuclear and coal is directed toward a renewable capacity and extension of the power network. 75% of the investment is in renewables and mainly in wind, solar, and hydropower technologies.

Figure 78: Kazakhstan—Investment Estimation under the Enhanced Low Carbon Action Scenario, 2016–2030 ($ billion)

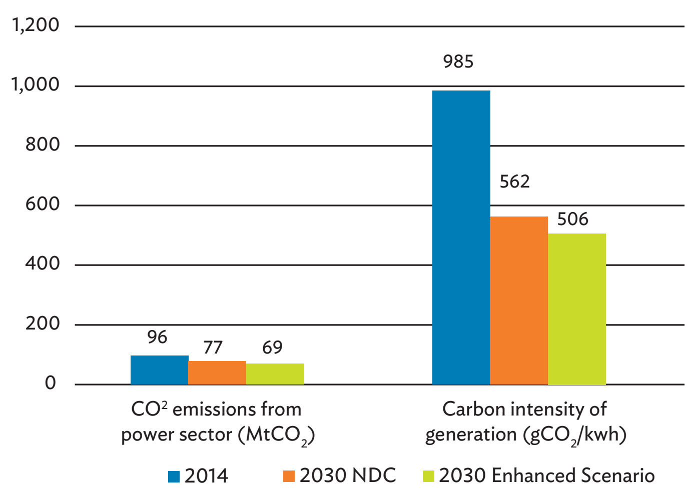


Note: Estimates based on information from *Lower Carbon Strategy for the Electricity Sector of Kazakhstan to 2030/50: Scenarios for Generation and Network Development* (Egerer et al. 2014); and Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013).

Source: Author's estimates.

Given the further reduction of coal generation, the emissions from the power sector decreases to 69 $MtCO_2$ from 77 $MtCO_2$ under the NDC, and the corresponding carbon intensity of generation also falls to 506 gCO_2/kWh from 562 gCO_2/kWh (see Figure 79).

Figure 79: Kazakhstan—Emissions and Carbon Intensity of the Power Sector under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios



gCO_2 = grams of carbon dioxide, kWh = kilowatt-hour, $MtCO_2$ = million tons of carbon dioxide, NDC = nationally determined contribution.

Note: Estimates based on information from Concept for Transition of the Republic of Kazakhstan to Green Economy (Government of the Republic of Kazakhstan 2013); and Biannual Emissions Report 2014: Third-Sixth National Communications to UNFCCC 2013 (Government of Kazakhstan 2014).

Source: Author's estimates.

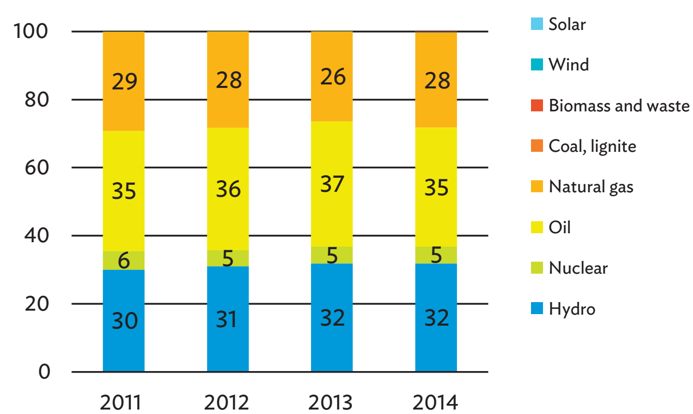
F. Pakistan

Pakistan has the largest investment projection in Central and West Asia and is the only continental country to have a power sector dominated by oil.

1. Current Situation and Recent Developments in the Power Sector

Figure 80 and 81 gives recent development of power sector. Pakistan's total power generation was 105 TWh in 2014 and is reliant upon imported fossil fuels. Oil provides 35% of total generation followed by hydropower (32%) and gas (28%). Nuclear provides about 5% of generation and coal generation is currently negligible.

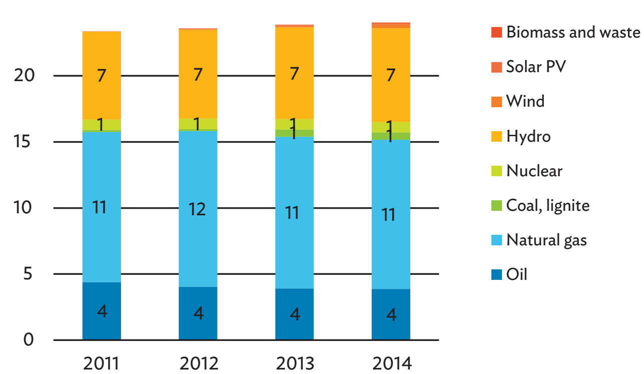
Figure 80: Pakistan—Power Generation Share by Source, 2011–2014 (%)



Source: Enerdata (2016).

Pakistan had a capacity of about 25 GW in 2014 that is comprised of 11 GW gas, 7 GW hydropower, and 4 GW oil. Natural gas power plants do not run at full capacity due to the availability of gas.

Figure 81: Pakistan—Generation Capacity, 2011–2014 (GW)



PV = photovoltaic.
Source: Enerdata (2016).

Energy-related emissions were 137 $MtCO_2$ in 2014, of which 45 $MtCO_2$ came from the power sector. The carbon intensity of power generation was 430 gCO_2/kWh in 2014 (IEA 2016c).

Pakistan faces several key challenges with its energy supply. Firstly, there is a lack of domestic energy resources with both gas and oil imported for power generation. Secondly, there is a huge power deficit of peak demand at about 5.6 GW in 2015. Thirdly, transmission and distribution losses were at 18% in 2015. Finally, there is a large population without access to power (27% in 2014).

2. Power Mix under Nationally Determined Contributions Scenario Projections

Under the Pakistan Vision 2025, targets are set out for the power sector to address the gap in demand and supply as well as the energy security issues. Specifically, Pakistan aims to

(i) eliminate the current electricity supply–demand gap by 2018, and cater to growing future demand by addition of 25,000 MW by 2025;

(ii) increase electricity access from 67% to over 90% of the population;

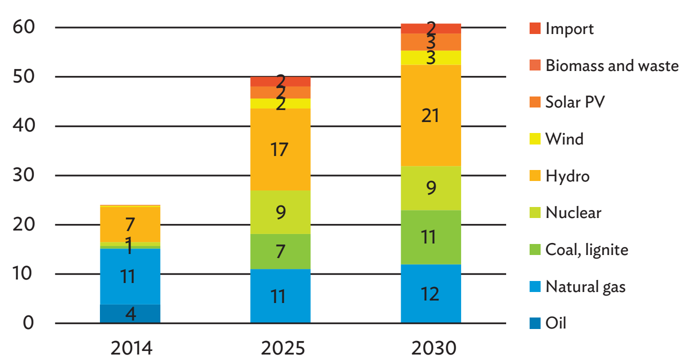
(iii) reduce average cost per unit by over 25% by improving generation mix (15%) and reducing distribution losses (10%); and

(iv) increase percentage of indigenous sources of power generation to over 50%;

The Pakistan Vision 2025 specifies key activities to achieve these targets, including two major hydropower projects (Diamer Bhasha and Dasu dams); one major coal project (6,600 MW Gaddani Energy Park); as well as new nuclear power generation plants and improvements in energy efficiency and distribution losses.

The Pakistan Vision 2025 is the basis for the projections under the NDC. Under this framework, Pakistan is expected to more than double its existing generation capacity by 2030 to reach 61 GW, with most capacity additions from hydropower, coal, and nuclear. By 2030, renewable generation capacity will surpass fossil fuels, accounting for 44% compared with 34% in 2014. Despite the significant growth in coal capacity, overall, the share of fossil fuels falls from 63% to 38%. Nuclear capacity rises to 9 GW from less than 1 GW in 2014, representing 15% of generation capacity. Figure 82 shows the complete breakdown by fuel between 2014 and 2030.

Figure 82: Pakistan—Generation Capacity by Source under the Nationally Determined Contributions Scenario, 2014–2030 (GW)



PV = photovoltaic.

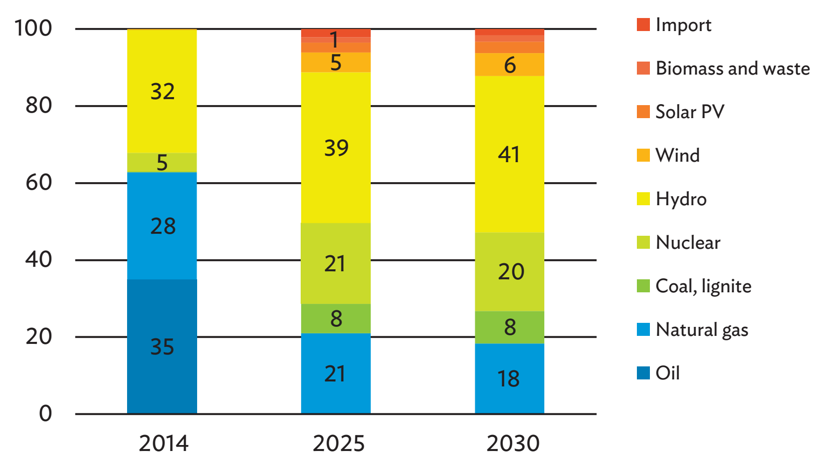
Note: Estimates based on information from Pakistan Vision 2025 (Government of Pakistan 2014).

Source: Author's estimates.

With the increased generation capacity, power generation is anticipated to rise to 287 the TWh in 2030, which is almost triple existing generation. Figure 83 gives corresponding power mix under NDC. Notably, coal has the highest growth in generation share, from zero in 2014 to 20% by 2030. Generation from oil is phased out and generation from gas falls to 18% in 2030 from 28% in 2014. The share of nuclear generation rises by 15% in line with the growth in capacity.

Hydropower provides the most power generation among all others, at 35% of total generation, despite its share only expanding by 3%. The share of renewables other than the hydropower remains quite low in the power mix by 2030, but there is still significant growth from 2014.

Figure 83: Pakistan—Power Generation Share by Source under the Nationally Determined Contributions Scenario, 2014–2030 (%)



PV = photovoltaic.

Note: Estimates based on information from Pakistan Vision 2025 (Government of Pakistan 2014).

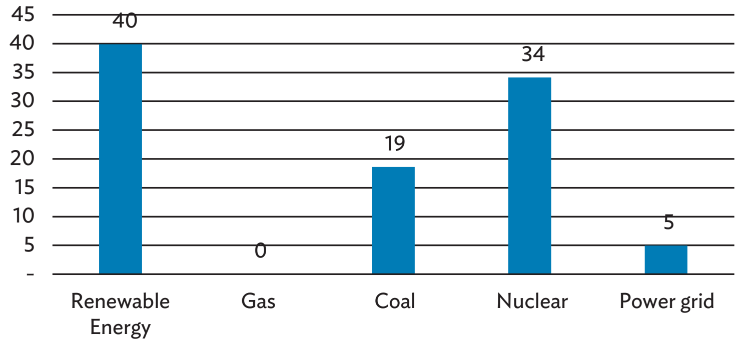
Source: Author's estimates.

Under this scenario, total emissions from the power sector are projected to rise to 72 $MtCO_2$ in 2030 from 45 $MtCO_2$ in 2014, with most of the increase in emissions coming from the growth in coal. On the other hand, the carbon intensity of power generation substantially falls to 252 gCO_2/kWh from 430 gCO_2/kWh in 2014 owing to the growth in nuclear and renewables.

To achieve the growth set out in this scenario, the total investment needed for the power sector is estimated at $98 billion by 2030. Renewables account for 41% of this, nuclear for 35%, and coal for 19%. Investment in the power grid accounts for about 5% (see Figure 84). [1]

[1] Investment in power grid is only for the period up to 2020 based on the available information.

Figure 84: Pakistan—Investment Estimation under the Nationally Determined Contributions Scenario, 2016–2030 ($ billion)



Note: Estimates based on information from Pakistan Vision 2025 (Government of Pakistan 2014) and The Long-Term Forecast of Pakistan's Electricity Supply and Demand: An Application of Long Range Energy Alternatives Planning (Perwez et al. 2015).

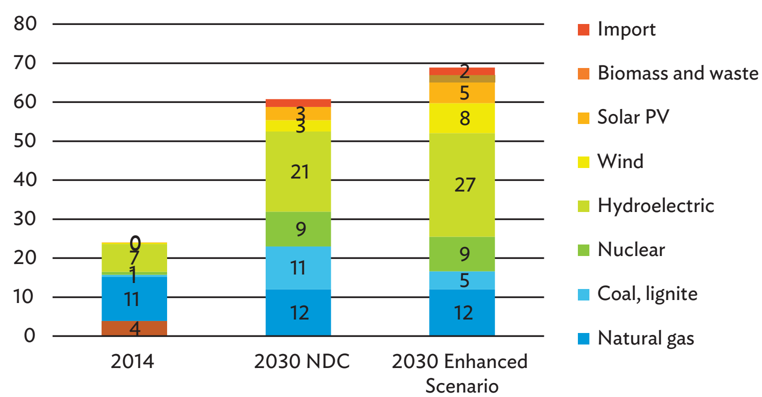
Source: Author's estimates.

3. Power Mix under an Enhanced Low Carbon Action Scenario

The enhanced low carbon action scenario is an aggressive strategy to increase use of renewable energy in the overall generation mix. It explores the opportunities for energy independence and reduced fuel costs. It would also require better infrastructure for its advancement and for the procurement of renewable energy technologies and affordable costs.

Pakistan has abundant renewable energy resources that remain unexploited. The hydropower potential is approximately 100 GW with 50 GW of sites already identified (Farooqui 2014). The potential for solar and biomass energy is about 169 GW and 15 GW by 2030 (Farooq and Kumar 2013).

Figure 85: Pakistan—Generation Capacity by Source under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030 (GW)



NDC = nationally determined contribution, PV = photovoltaic.

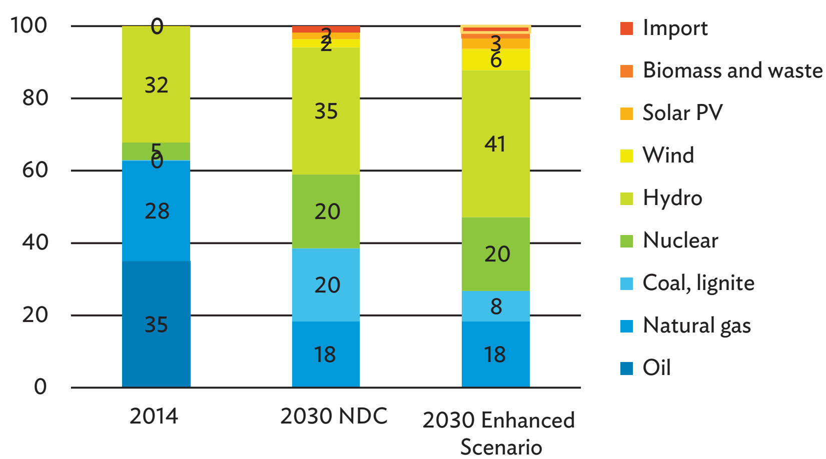
Note: Estimates based on information from Pakistan Vision 2025 (Government of Pakistan 2014); Pakistan Low Carbon Scenario Analysis: GHG Reference Case Projection Report (IISD and ECN 2016); Pakistan's Electricity Supply and Demand: An Application of Long Range Energy Alternatives Planning (Perwez et al. 2015); and Analysis of Pakistan's Electric Power Sector (Khan and Ashraf 2015).

Source: Author's estimates.

Compared to the NDC scenario, generation capacity increases by 8 GW to reach 69 GW, with much of the increase coming from renewables. Figure 85 and 86 draw development of the power sector under enhanced low carbon scenario. Renewables' capacity increases by 15 GW while fossil fuel (coal) capacity drops by 6 GW compared to the NDC scenario. Hydropower and wind make up most of the additional capacity expanding by 6 GW to 5 GW each. Solar and biomass each increase by 2 GW and nuclear capacity remains the same as under the NDC.

Generation shows a similar trend, with renewables overtaking fossil fuels, accounting for 51%, as fossil fuel generation drops to 27% in the power generation mix (39% in NDC). Coal falls by 12% compared to the NDC, to only 8% of generation. Hydropower provides 41% of the generation. Wind and solar contributes to 9%, and biomass generates 2% of power. There is no change in the shares of gas and nuclear.

Figure 86: Pakistan—Generation Share by Source under the Nationally Determined Contributions and Enhanced Low Carbon Scenario, 2014–2030 (%)



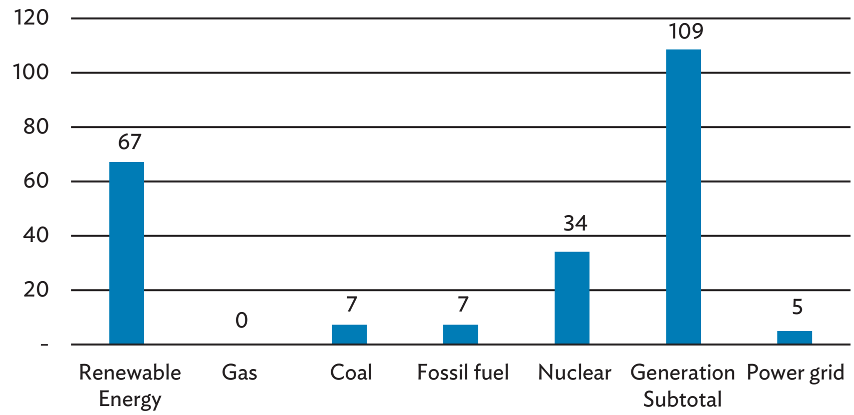
NDC = nationally determined contribution, PV = photovoltaic.

Note: Estimates based on information from Pakistan Vision 2025 (Government of Pakistan 2014); Pakistan Low Carbon Scenario Analysis: GHG Reference Case Projection Report (IISD and ECN 2016); Pakistan's Electricity Supply and Demand: An Application of Long Range Energy Alternatives Planning (Perwez et al. 2015); and Analysis of Pakistan's Electric Power Sector (Khan and Ashraf 2015).

Source: Author's estimates.

As shown in figure 87, the total investment for the enhanced scenario is $16 billion higher than for the NDC, with most of the increased investment for renewables.

Figure 87: Pakistan—Investment Estimation under the Enhanced Low Carbon Action Scenario, 2016–2030 ($ billion)

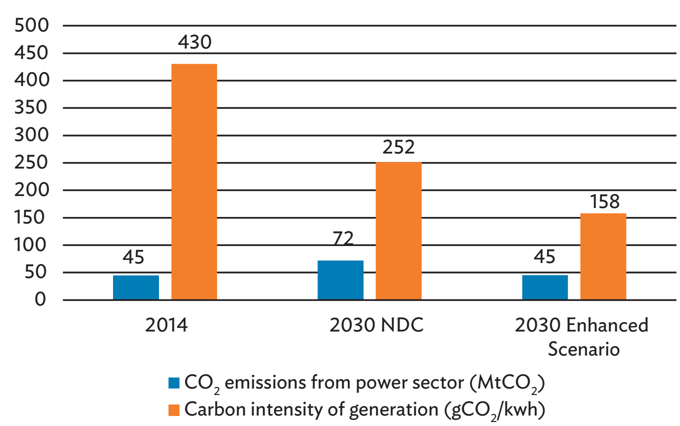


Note: Estimates based on information from Pakistan Low Carbon Scenario Analysis: GHG Reference Case Projection Report (IISD and ECN 2016); and Pakistan's Electricity Supply and Demand: An Application of Long Range Energy Alternatives Planning (Perwez et al. 2015).

Source: Author's estimates.

Given the reduction in generation from coal under this scenario, emissions from the power sector remain at the 2014 level of about 45 $MtCO_2$ (27 $MtCO_2$ lower than NDC), and the carbon intensity of generation falls to 158 gCO_2/kWh from 252 gCO_2/kWh in the NDC (Figure 88).

Figure 88: Pakistan—Power Sector Emissions and Carbon Intensity under the Nationally Determined Contributions and Enhanced Low Carbon Scenarios, 2014–2030



gCO_2 = grams of carbon dioxide, kWh = kilowatt-hour, $MtCO_2$ = million tons of carbon dioxide, NDC = nationally determined contribution.

Note: Estimates based on Intergovernmental Panel on Climate Change default emission factors (IPCC 2006).

Source: Author's estimates.

V. RECOMMENDATIONS

This report has set out an analysis of each NDC in the DMCs and what the implications are for the energy sector both in terms of changes to the power sectors as well as the investments required to achieve these targets. Case studies have been presented that show how the power sectors will evolve in some of the most carbon-intensive countries in the region, and the countries with the highest projected investment that is required to achieve the goals of the NDC. The recommendations in this section focus on what will be required to achieve these goals—and in some cases surpass what has been set out in the NDCs—to achieve a transformation in this sector that is consistent with the 2°C pathway agreed in Paris.

A. Address the Needs of Renewable Energy Growth

The projected growth in renewable generation capacity for the region is colossal, with renewable energy generation increasing from 1,747 TWh/y in 2014 to 4,467 TWh/y in 2030. This is a 156% growth compared with a growth in fossil fuel generation of 45%. The investment required to implement the NDCs is estimated to be at least $321 billion per year in 30 of the DMCs. This totals $4,817 billion between 2016 to 2030, with roughly one-third being directed to investment in power grids, and another third to new renewable energy generation capacity. Given the scale of investment required, it is critical to ensure that this investment is directed to the right technologies and supporting infrastructure that will enable the effective growth of this sector. Investment in compatible power grid and storage technologies as well as increasing electrification by renewable power generation in the end-use sector will be essential to ensure that renewable power can be delivered and consumed when generated.

1. Invest in Advanced Smart Grid Technology

Without efficient, reliable, and flexible transmission and distribution networks to deliver the electricity to the consumers, adding renewable generation capacity may not result in increased generation on the grid, particularly in countries with outdated grid infrastructure with high power losses. Grid infrastructure has been highlighted as a priority in most DMCs, and as described, above one-third of investment in the region's power sector is expected to be for the power grid infrastructure. This investment must be compatible with the large-scale deployment of renewable power generation.

Advanced smart grid technologies can support centralized and distributed generation for both grid-connected and off-grid power systems. Smart grids can also increase systemwide efficiency and reliability. Countries may prioritize the investments in suitable and advanced technologies based on local conditions. For example, high voltage direct current (VSC-HVDC) transmission can improve the management of transmission networks to optimize power transfer and reduce losses. This technology is suitable for connecting large-scale renewable power such as wind and solar farms, and is useful to improve the efficiency of power transfer from remote energy sources. High voltage direct current can also be used for long-distance transmission for grid interconnections to enable more flexibility.

There are a few examples for application of high voltage (HV) transmission technologies in DMCs. The PRC installed a 5,000 kilometer (km) ultra-high voltage direct current(U-HVDC) transmission lines to connect remote, resource centers in the west with demand centers on the east coast. ADB supported India's Green Energy Corridor and Grid Strengthening by installing real-time measurement and monitoring equipment, and constructing 800 kV HVDC terminals and 320 kV HVDC terminals.

Advanced metering infrastructure (AMI) will also provide flexibility by enabling two-way flow of information, providing customers and utilities with data on electricity price and consumption in real time. AMI offers systemwide benefits for power producers to understand where, when, and how much electricity is needed and at what price. Smart meters are perhaps the easiest AMI technology that can be deployed in many DMCs. ADB has supported Pakistan, Sri Lanka, and Uzbekistan in the deployment of smart meters. More work needs to be done on the development of business models for scaled-up deployment of AMI.

2. Promote Decentralized Solutions

Decentralized distributed generation, minigrids, and off-grid solutions are also needed to expand the use of renewable energy and increase access to electricity in remote and rural areas. Decentralized energy can also reduce power losses from long distance transmission and voltage transformation. Distributed generation should be encouraged for islands, rural areas, and in regions that are a long distance from major load centers.

Mini grids with battery storage are particularly important for islands and off-grid areas in order to improve power supply reliability. Currently, most islands and off-grid areas are powered by diesel generation. Diesel generation is expensive and has high emissions. As such, minigrids or off-grid systems with battery technology offers the opportunity for integration of variable renewable energy with reduced fuel costs and increased energy independence. ADB is supporting a solar-based mini grid project in Maldives to support the country's 100% renewable energy ambition. Innovations from this pilot can be used a reference in other DMCs.

Distributed generation and off-grid applications is the most economic option for electrification in most rural and remote areas (IRENA 2014b). With large populations without access to power, investment in off-grid systems must continue to be a key solution to achieve universal electricity access. As such, it is important to explore sustainable business models that promote the application of these technology solutions.

3. Enhance Connectivity of Power Grids

Cross-border interconnections are important for an effective transmissions and distribution network, as they can enhance the flexibility and security of power systems by balancing the gap between supply and demand across geographical borders. This also supports the integration of renewable energy.

Interconnections are necessary in Bhutan, the Kyrgyz Republic, the Lao People's Democratic Republic, Nepal, and Tajikistan where hydropower dominates electricity generation and surpluses of power (which can be exported) are produced during the wet seasons. Interconnection is particularly important in Southeast Asia as the export of hydropower from Cambodia, the Lao People's Democratic Republic, and Myanmar to neighboring countries Thailand and Viet Nam could help to reduce investment in coal there. Opportunities for interconnection also exist in South Asia and Central and West Asia.

4. Increase Application of Renewable Energy in Demand Sectors

The potential for renewable energy in the end-use sector is underestimated since it is often easier to identify opportunities in the power sector. Heating and cooling technologies in the building sector offer extensive opportunities for the increased uptake of renewable energy. Renewable heating can also serve as a storage solution for the integration of renewables on the power grid so that when wind and solar supply is in excess, electricity can be converted to heat for use in buildings or the industry sector.

Renewable heating technologies include all forms of modern bioenergy, solar water heaters, solar thermal, geothermal heat pumps, and renewables-based electricity. Energy demand for space heating and water heating in either buildings sector or industrial production process is high in the northern areas of Asia, such as in the PRC, Mongolia, and DMCs in Central and West Asia.

There is growing demand for space cooling demand in the region particularly in South and Southeast Asia as more people are able to afford air-conditioning. In Mumbai, electricity demand for space cooling requires 40% of peak power demand (IRENA 2016c). In these regions, cooling demand peaks when the greatest amount of electricity is generated from solar PV. Solar PV could be a technology solution to meet energy demand for cooling.

Although there is huge potential to deploy renewable heating and cooling in buildings, the challenge is that in most cases, modification and retrofit of existing buildings will be required. Southeast Asia and South Asia are experiencing rapid urbanization with fast-growing building stocks and new urban areas. In order to avoid future costs of modification and retrofit, renewable heating and cooling systems need to be fully integrated into urban infrastructure development.

B. Reduce Growth of Coal and Its Impact

The analysis in section III shows that dependence on coal for power generation will continue through to 2030 in East Asia and South Asia (India). It also shows that Southeast Asia will see a shift to coal by 2030 from existing energy sources. The substantial addition of coal capacity will result in locking in high emission assets for the long term. A set of coordinated policies and the technologies are needed to satisfy short-term objectives that will be consistent with longer-term ambitions. Governments must enhance support to investment in renewable technologies and emphasize the importance of investing in a diverse generation mix that, while meeting demand growth, also satisfies the need for affordability, environmental protection, and energy security.

1. Diversify Power Mix

Diversifying the generation mix supports emission reductions by slowing down coal-fired capacity additions. Increasing ambition for renewable generation should be a priority to reduce coal growth in countries with an existing dependence on coal, as well as in countries where substantial coal growth is anticipated.

There is significant potential for countries to expand the penetration of renewables in their power mix. This potential has been illustrated in the enhanced low carbon action scenarios in six countries (the PRC, India, Indonesia, Kazakhstan, Pakistan, and Viet Nam), which have a high dependence on coal in their power system. Increasing generation from renewables, combined with improving energy efficiency in these six countries would reduce coal generation by 1,602 TWh and reduce coal capacity by 385 GW (31% less than under the NDCs). This reduction on coal would lead to an emission reduction of 2 billion tons CO_2 emissions.

In addition to increased ambition from renewables, gas generation should also be prioritized as a near-term option for the energy transition in the region. Gas-fired power generation is a cleaner fuel relative to coal and oil and provides the flexibility of power generation at a lower cost. With its quicker construction time and lower construction cost, gas-fired power generation technology is a near-term option for a fuel switch from coal and oil, supporting the integration of variable renewable energy. Many countries are moving away from gas due to concerns over energy security, but the recent low gas prices have led to some countries reconsidering this, although pipeline infrastructure must be developed.

2. Raise the Efficiency of Coal Generation

The overall efficiency of coal generation analyzed in section 3 is a very attractive, cost-effective option to reduce emissions and fuel consumption while generating additional power. A plant operating at 44% efficiency would emit 25% less CO_2 per MWh than one operating at 33% (IEA 2016g). Investment in improving efficiency of coal generation fleet and deployment of higher-efficiency technologies will be extremely important to reduce emissions from coal-fired generation.

The first priority is to retire inefficient old generation units at the end of their economic life and replace them with high efficiency low emissions technologies. This would yield a substantial emission reduction. For example, in Indonesia, on average, approximately 23 $MtCO_2$ could be avoided every year by retiring subcritical units after 25 years (when plants have already recovered their investment costs) rather than after 50 years, and replacing them with high efficiency low emissions technologies (IEA 2016h).

High efficiency low emissions technologies include ultrasupercritical coal (USC) and integrated gasification combined cycle. Regular maintenance and effective operation can also help keep plant performance from deteriorating over time.

3. Drive Forward Carbon Capture and Storage

Carbon capture and storage plays a vital role in decarbonization of the power sector in a 2°C scenario given that emissions must peak in 2020 and be net-negative in the second half of the century. Coal generation with CCS must therefore overtake unabated generation by 2040 to achieve the 2°C (IEA 2016c). IEA also estimates that around 56% of all coal-fired CCS power generation will come from the PRC, India, and the Association of Southeast Asian Nations (ASEAN) in 2050. Under the NDCs, unabated coal capacity will increase by 483GW in the PRC, India, and Southeast Asia alone. Typically, an unabated coal-fired unit might emit annually 5,000–6,000 tCO_2/MW, which for 483 GW of unabated capacity would lead to 2.4–2.9 $GtCO_2$ emissions annually. These coal plants are expected to continue to operate after 2040.

This highlights the importance of being able to retrofit coal plants with CCS to prevent stranding of coal assets such that they are fit for purpose into the future. All new coal-fired power plants must therefore seek to be capture-ready. Building new coal-fired plants and modifying existing plants to be CCS-ready reduces the risk of carbon emissions lock-in and future stranding of assets.

For coal plants to be CCS-ready, they must consider space requirements for the installation of additional capture-related equipment; identify sites for CO_2 storage; and identify possible routes for transportation of CO_2 to the storage site. Governments need to play a role to ensure CCS regulations are in place to ensure all new plants are capture-ready.

Deployment of CCS remains expensive and challenging today. There are only a few large-scale CCS projects operating so far. There is an urgent need to establish a regional CCS hub in the PRC, Southeast Asia, and India to address the economic, financing, technology, policy, social, technology, and information issues in order to speed up commercialization of CCS in the region. Governments must also prioritize resources to support the development of CCS pilot projects. ADB is currently supporting a CCS center in the PRC and Indonesia. Linking these two centers will support wider development in the region.

4. Formulate Carbon Pricing Schemes

Given the impacts of climate change becoming more apparent, and the political drivers to reduce emissions and achieve the ambitions set out in the Paris Agreement, high carbon assets are being increasingly viewed as high-risk. Indeed, investors are pulling out of investment in coal around the world and governments are shutting down their coal-fired generation fleet in order to achieve their commitments on GHG emissions.

Under this backdrop, more and more companies and governments around the world are internalizing the carbon transition risk by applying a carbon price to their investment decisions. According to CDP, in 2015, there were more than 1,000 companies around the world who have an internal price of carbon or intend to establish one in the next 2 years (CDP 2015). Internalizing a carbon price will drive investment away from coal and toward clean energy technologies.

In addition to carbon pricing by companies, there are also many carbon pricing schemes implemented by governments around the world. Carbon pricing is being implemented through instruments such as carbon taxes and emissions trading schemes (ETS). There are currently about 40 countries implementing some form of carbon pricing at the national level (including the European Union ETS as 31 countries) and over 20 subnational governments have carbon pricing schemes (World Bank and Ecofys 2015). These schemes cover only about 12% of global emissions.

In Asia and the Pacific, carbon pricing mechanisms are emerging in the form of ETS. As of 2015, there were 11 ETS operating in Asia and the Pacific at various administrative levels (city to national level). In 2017, the PRC plans to begin its national ETS and will start pricing industrial emissions sources. The jurisdictions with ETS in operation or under consideration account for about 38% of global carbon emissions, and more are being planned (ADB 2016a). Prices are typically below $10 per ton. A substantial carbon price on average of $57.5 per tCO_2 is needed to enable a shift away from coal and fossil fuels for the top 20 emitters (IMF 2014).

When implementing new carbon pricing schemes, it is critical to ensure that there is a long-term ambitious cap to create the demand to drive emission reductions, and for carbon pricing policy needs to be complemented by policy instruments to address other barriers not influenced by price. The consistency of long-term policies is also required to maintain the momentum for increasing climate mitigation ambitions.

C. Improve Energy Efficiency in Demand Sectors

The two drivers of energy-related emissions are carbon intensity of energy supply and amount of energy consumed by end users. Analysis by the International Energy Agency indicates that energy efficiency contributes to the largest share of emissions reductions needed to limit temperature increases to 2°C, surpassing the contribution of renewables (IEA 2016c).

The enhanced low carbon scenario for the case studies demonstrates that energy efficiency in the end-use sector can reduce power consumption by 1072 TWh and therefore generation capacity by 229 GW in the PRC, India and Viet Nam. This could cut emissions from coal generation in the power sector by 1.09 $GtCO_2$ in these three countries. This suggests the importance of improving energy efficiency in DMCs

1. Energy Efficiency in Industry

In the industry sector, about 88% of emission reductions will be achieved by improving energy efficiency of industrial processes and switching to low carbon fuels by 2030 (IEA 2015d). Importantly, focus should be given to the application of advanced technology in industry. Employing current best available technologies can reduce energy use by 18% in the cement sector, 26% in pulp and paper, and 11% in aluminum (IEA 2015d).

The PRC and India are the two largest producers of iron and steel and therefore have the greatest potential for energy efficiency improvement in this sector. However, with the PRC's low carbon transition and changes to industrial structures, it is anticipated that energy and emissions-intensive production will shift from the PRC to India and other ASEAN countries. It is estimated that those regions will see a more than fivefold increase in crude steel production, growing by 571 Mt by 2050. Meanwhile, cement production will increase by 180% in India and the ASEAN region production to reach 1348 Mt in 2050 (IEA 2015d).

It is critical for India and ASEAN countries to adopt high efficiency low carbon technologies and production processes in these sectors from the beginning. The PRC should take this shift as an opportunity to transfer low emission technologies to these developing countries. In the long term, the industry sector must also look at the integration of carbon capture into their process, particularly where there is the opportunity to produce a concentrated CO_2 stream.

Some DMCs have also benefited and gained experience from integrated energy management in their energy-intensive sectors. These valuable experiences and knowledge on improvement of energy efficiency can be shared and applied by other DMCs. The PRC is implementing a pilot program to encourage recycling, resource efficiency, and life-cycle approaches to reduce the overall impacts of industrial products. India is also implementing a market-based mechanism, The Perform Achieve and Trade (PAT) program to reduce energy consumption in energy-intensive sectors. The most notable energy management program implemented in the PRC was the Top 10,000 Programme in the Twelfth Five-Year Plan, 2011–2015. The program actually covered 15,000 of the highest energy-consuming industrial enterprises and aimed to reduce energy consumption by 7.3 EJ by 2015 by requiring enterprises to implement energy audits and energy management systems, and set energy saving targets.

2. Energy Efficiency in Buildings

Energy consumption in buildings includes main components: space heating and cooling, lighting, and associated appliances and facilities. Small energy technology solutions or design improvements can significantly improve energy savings and emission reductions. The application of advanced lighting technologies through a 2-year LED lighting program could reduce 109 TWh of electricity per year in India and 864 TWh (or 2,700 TWh of primary energy) for water heating (Clasp 2015). Adopting high efficiency water heating technology in the PRC (e.g., instantaneous condensing gas water heaters, heat pump water heaters, and solar thermal collectors) could save 2,700 TWh of primary fossil energy in the PRC for the period 2015–2035 and reduce CO_2 by 660 $MtCO_2$.

Space heating and cooling accounts for around 40% of global building energy consumption and is a critical area of needed action in the buildings sector (IEA 2016d). The largest energy savings potential in buildings could be from cooling in Asia and the Pacific (ADB 2013).

Improved air sealing technologies to reduce air leakage (i.e., infiltration and exfiltration) can bring down heating, cooling, and ventilation energy consumption by up to 30% (IEA 2016d). In South and Southeast

Asia where there is a large space cooling demand, improved air sealing technologies should be considered as a high priority.

To scale up the deployment of high efficiency technologies, governments must formulate and enforce stringent building codes, including minimum energy performance for equipment, products and buildings to ensure rapid market penetration. In addition to this, governments are also required to provide the incentive policies and fiscal support, but also ban inefficient products sold in the market.

3. Low Emissions Transport

Transport is the fastest growing sector in terms of final energy demand, among others. Its share will increase from 16.0% in 2010 to 18.6% in 2035. The road transport subsector's energy consumption accounts for the bulk of the energy demand (ADB 2013). Improving vehicle efficiency, fuel switching, and shifting to other forms of transport can significantly reduce GHG emissions from transport sector.

Electric vehicles provide the opportunity for renewable energy integration and emissions reduction. Emissions can be reduced by more than 50% compared to conventional gasoline internal combustion engine vehicles (ICE) (JHFC 2006). On average, energy consumption (kWh/km) of electric buses is 75% less compared to diesel buses, and 65% less compared to hybrid electric buses (IEA 2014a). The PRC and India have witnessed fast development of electric vehicles. The PRC has provided strong financial incentives to encourage the deployment of electric vehicles, offering tax exemptions on vehicle purchase of $6,000 to $10,000 (Lutsey 2015). The PRC has set ambitious targets of 5 million electric vehicles deployed, 4.3 million electric vehicles outlets, and 0.5 million public charging stations for cars (EVI 2016). In India, year-on-year sales growth for electric cars also exceeded 75% (IEA 2016e).

There is a huge potential to develop electric vehicles in other DMCs, particularly in urban areas. Two-wheelers could be suitable option for small cities and rural area in Southeast Asia, South Asia, and part of the Pacific. Two-wheel electric vehicles are one option for Southeast Asian countries to replace existing diesel motorcycles. Electric buses can be applicable to any size of city as main public transportation to replace existing diesel buses. The incentive policies and intensive infrastructure development (e.g., battery and charging stations, etc.) are required to support market penetration of electric vehicles.

Biofuels offer the ability to shift to low carbon and nonpetroleum fuels with minimal change in the current vehicle stocks. The table below shows mitigation potentials for different types of biofuels.

Table 15: Mitigation Potential of Different Biofuels (%)

Type of Fuel	**Greenhouse Gas Reduction Potential** (%)
Ethanol (cereal)	30–65
Ethanol (sugar)	79–87
Biodiesel	47–78
Advanced biofuel (cellulosic ethanol)	70–95

Source: Intergovernmental Panel on Climate Change default emission factors (IPCC 2006).

Conventional biofuel technologies (crop-based biofuels) are already commercially available and dominate biofuel production today. Advanced biofuel technologies are still in the research, development, and demonstration (RD&D) stage and are not expected to be cost-competitive in 2030 (IEA 2016d).

Policies are needed to encourage people to travel through public transportation such as bus rapid transit (BRT) and mass rapid transit (MRT). In addition, countries need to impose mandatory fuel economy standards on new light-duty vehicles, and adopt fuel efficiency standards for new freight trucks that can reduce fuel consumption and emission from road transport.

D. Promote Low Carbon Technology Transfer and Deployment

The Paris Agreement prompted countries to integrate their low carbon technology (LCT) needs into national development planning through their NDCs. In many cases, international cooperation on technology transfer is needed to bring down technology costs in DMCs. In order to promote and enable such transfer of technologies, the following specific recommendations are made.

1. Establish Technology Promotion and Financing Mechanisms

Systematic approaches are needed to encourage both the public and private sectors to accelerate technology transfer, deployment, and investment in LCTs. Such approaches must include the development of an enabling policy environment to promote technology transfer and create market demand, mobilization of financial resources, and building of business models to ensure that investments are robust and sustainable.

For technology transfer to be successful, a mechanism is needed that integrates policy, technology, investment, finance, and markets. ADB's CTFC has developed a wealth of experience in integrating approaches to build technology and promote financing mechanisms. The public sector can create enabling frameworks by providing support to

(i) formulate incentive policies to stimulate technology diffusion and investment;

(ii) build marketplaces, trading platform, and centers for information-sharing to reduce transaction costs and increase transparency;

(iii) provide technology-matching services for technology providers and technology adopters;

(iv) set up technology incubators and accelerators that foster LCT businesses and entrepreneurs (supporting business model development and networks);

(v) establish VC and equity funds to raise capital through public and private partnerships; and

(vi) support capacity building and encourage diffusion of technology expertise and knowledge.

ADB is already providing support to pilot a technology financing mechanism in Hunan province in the PRC. The mechanism aims to build a link between technology, market, policy, and investment; and to provide a platform for technology and solution providers, entrepreneurs, and investors for networking.

ADB is also supporting the Beijing Energy Club to establish a Technology Assessment and Dissemination Platform that aims to accelerate diffusion and deployment of new low carbon technologies. The platform provides objective and comprehensive assessment for a given new technology in terms of technology attractiveness, market potential, regulatory and policy environment, health, safety and environment, prospects, and risk. The assessment builds confidence in technologies and enhances interactions between stakeholders and the market.

2. Promote Diverse Approaches for Technology Transfer

Technology transfer can take many forms such as international trade in components and equipment (technology diffusion), international collaborative RD&D, operational learning through joint ventures, mergers and acquisitions of technology companies, and so on. Technology transfer should therefore be promoted through diverse approaches such as international trade, foreign direct investment (FDI), joint ventures, licensing, and intellectual property.

International trade requires a country to fully open its market to foreign investment and would ensure the country has access to the best available technologies. FDI can transfer both capital and technologies needed by recipient countries and hence be a means to acquire desired technologies and financing for low carbon technology investment. Joint ventures are a means for a technology provider to gain market entry through a local firm, and as such can provide capacity building in the recipient country as well as market knowledge to the technology provider. Both FDI and Joint ventures approaches require the recipient country has certain technology capability and market size. For those countries that are facing capital rationing, FDI can be an alternative for acquisition and diffusion of low carbon technology.

Transfer of intellectual property enables a firm that acquires the license to access the know-how to be able to use and develop the technology. For example, Goldwind (one of the PRC's largest wind technology manufacturers) initially acquired access to wind technology by purchasing licenses from German wind turbine maker Vensys. However, there are very large upfront costs associated with this approach.

3. Strengthen Domestic Technological Capacity

Domestic technological capability (absorptive capacity, manufacturing capacity, and RD&D) is essential to absorb imported technologies. Important technologies will require this capacity to be able to install, operate, and adapt technologies to local circumstances. The PRC is the top technology importer, manufacturer, and inventor of low carbon technologies among developing countries.

Technological capacity can be fostered during technology transfer (through FDI, joint venture and international trade, transfer of licensing, intellectual property) and will result in greater technology deployment. Building technological capacity can also be achieved through targeted training, education, and cooperation activities, which is one of the reasons for the PRC's success in having invested heavily in education, research infrastructure, and manufacturing capacity.

Building domestic manufacturing capacity will also lower the cost of low carbon technology, while at the same time fitting the local requirements and increasing the competitiveness of Asia's developing countries. To achieve this, countries must develop effective regulation, incentives, and standards to ensure the transfer of a manufacturing base that is resource-efficient and environment-friendly.

4. Enhance Cooperation Among DMCs

Domestic manufacturing capacity and innovation are increasing in Asian developing countries. The PRC and India are leading the way and have demonstrated their capacity to reorient their manufacturing base and labor markets, leveraging human capacity, investment, and technology toward a stronger, more dynamic, and competitive low carbon economy. They are developing, manufacturing, deploying, and exporting clean energy technologies such as solar panels and wind turbines. A large share of the growth has been seen in the PRC, especially in wind power, heating, insulation, solar power, and transmission and distribution. India has also developed multiple business models and technological capabilities for biomass gasifiers that are now enabling India to transfer these technologies and capacities to Africa. These technologies could also be applied in other Southeast and South Asian countries.

The PRC has announced a contribution of $3 billion (CYN 20 billion) for a South–South initiative on climate change. This could be a catalyst for regional cooperation on clean energy technology and investment among Asian developing countries and result in partnerships among DMCs for climate change mitigation and adaptation. Technology providers and adopters would benefit from this regional technology cooperation through the creation of markets and increasing competitiveness in the region.

E. Access Climate Finance

Energy transition requires shifting investments from high emissions technologies to low carbon technologies. According to the analysis set out in this report, DMCs will need at least $4.8 trillion to meet the targets set out in the NDCs. Many of the DMCs specifically seek international finance in their NDCs and will be looking to attract foreign investment to meet their commitments. DMC governments will need to take the lead by establishing regulations, incentives, and other policy measures that reduce the investment risks for the private sector associated with low carbon technology, as well as build capacity to access international climate finance.

1. Support Project Pipeline Development

A concrete understanding of which projects are in the pipeline is an important aspect of building confidence in leveraging private investment. Countries should implement targeted public finance programs to support the development of a project pipeline for investment.

Grants can be used to finance RD&D and to provide funding for project development and document preparation (such as feasibility studies and environmental impact assessments). This will increase the investment deal flow and increase the pipeline of bankable projects ready for investment. Grants may also be used to finance policy and institutional reforms to overcome barriers to low carbon technology investment.

ADB has several facilities available for development in the project pipeline, such as the Clean Energy Financing Partnership Facility and the Climate Change Fund. Both use public funding to support cost-effective investments, especially in technologies that result in GHG mitigation. They target increased deal flow by addressing the gap in early-stage financing. The facilities also provide technical assistance along with grants.

2. Establish Risk Mitigation Instruments

For private investors, the central challenge of low carbon technology investment is delivering an attractive commercial return for the risks taken, which come in various forms. Risk mitigation is especially important in leveraging private capital for low carbon investment.

Risk mitigation instruments use public finance to reduce perceived risks associated with investments. The most common risk mitigation instrument is a guarantee, which are able to leverage additional investment better than grants or direct loans can.

Risk mitigation instruments can reduce the incremental cost of a low carbon technology investment, which in turn increases the return expected for private investors. Guarantees may also be used to support seed funds that have expertise in managing early-stage risks, or help new emerging technology sectors to reach markets quicker, thereby making the sector more attractive to traditional venture capital/private equity investors.

3. Introduce Innovative Financing Platforms

Small amounts of public funding can be used to build dedicated financing platforms to catalyze significant private investment. Some government agencies and international organizations have established financing platforms through partnership with private funds. The PRC has used state funding to encourage venture capital to establish the National Fund for Technology Transfer and Commercialization.

ADB's partnership with the PRC has established a green financing platform (GFP) to mobilize finance for air quality improvements in the Greater Beijing–Tianjin–Hebei region. The GFP aims to leverage private capital for green investment and provide debt financing, credit enhancement, losses guarantee, mezzanine financing, subordinate debt, or preference shares for promising small and medium enterprises. Capital raised is used for energy efficiency in the buildings sector, establishment of low-emission fuel standards and improvement of fuel efficiency of vehicles, leveraging additional finance, and facilitating access to capital for small and medium enterprises.

In addition to the above tools to catalyze private investment, government should mobilize capital through green bonds, climate bonds, etc.

4. Build Capacity for Access to International Climate Finance

Under the Paris Agreement, it was agreed that developed countries would jointly mobilize $100 billion per year from 2020 for climate change mitigation and adaptation in developing countries. A share of this would be channeled through the GCF established under the UNFCCC. There are several dedicated climate funds available for developing countries. These include the Climate Investment Funds, the Global Environment Facility, the Clean Investment Funds of the World Bank, and most recently, the GCF.

The GCF will be an important instrument for DMCs to access finance for low carbon technologies. ADB is accredited as an operational entity of the fund. The GCF provides grants, loans, guarantees, and equity for climate change projects. Two projects in the region have already received funding from the GCF through ADB. This will build regional experience for other DMCs. The Pacific Islands Renewable Energy Investment Program was recently approved by GCF to build the renewable energy project pipeline in the Pacific DMCs through technical assistance and a grant to fund battery storage in the Cook Islands.

The GCF's Private Sector Facility may also be used to de-risk investments and catalyze private capital once it is fully operational.

Countries must build their own capacity for access to these finance mechanisms. In particular, governments should allocate the resources to develop project pipelines that are eligible for access to these international finance mechanisms, and which can support the document preparation required for fund application, among others.

F. Establish Enabling Regulatory and Policy Frameworks

Most DMCs have adopted renewable energy targets under their NDCs. Translating these broad aspirations into concrete technology-specific deployment and attracting investment must be supported by corresponding regulatory and policy frameworks as well as market environment.

1. Remove Fossil Fuel Subsidies

Initially, there was conflict with renewable energy objectives when the use of fossil fuels was still subsidized in the region, particularly in Southeast Asia. Pricing carbon can help to contain the use of fossil fuels, but such subsidies incentivize the excessive use of fossil fuels and hinders the development of low carbon technologies.

Fossil fuel production subsidies act as a negative carbon tax, artificially lowering the cost of producing more oil, coal, and gas. This is passed through in lower energy prices and encourages more fossil fuel consumption and emissions. Subsidies in fossil fuels provide a false confidence in their long-term attractiveness, which can lead to lock-in of fossil fuel dependency through long-lived infrastructure projects (IISD 2017). Fossil fuel subsidies must therefore be phased out.

Energy prices should reflect the full economic costs of production including the external costs of fossil fuels in terms of social and environmental impacts. Subsidies to fossil fuels are counter to this and act as a perverse incentive to increase GHG emissions. Subsidy reform can include the removal of direct subsidies as well as implementation of carbon pricing, so that energy prices start to reflect the full economic cost of the use of fossil fuels. Implementation of both fossil fuel subsidy reform and carbon pricing policies needs to be supplemented by a broader range of policy instruments such as standards and codes for buildings or vehicles, and fuels to address other barriers not influenced by price.

2. Reform Electricity Market for Renewable Power Integration

The existing design of power markets gives more attention to promoting low carbon technology investment and low carbon power production. Less highlight is given to demand-side market and consumption. Such market framework might not be able to provide the right price signals to trigger the investment needed to achieve the long-term decarbonization of the power system.

As variable renewable energy and distributed generation are integrated into the power system, transformation to low carbon power systems requires the power market being able to reflect characteristics of variable energy resources and distributed resources. Incentivizing new low carbon investment while maintaining power supply security and affordability are equally important. As such, the consideration needs to be taken care in reforming power markets, including power investment markets, carbon markets, and demand-side market.

3. Establish Risk-Sharing Mechanism and Capacity Pricing Mechanism

Existing electricity prices cannot recover the full investment costs of low carbon energy technologies. Reflecting a carbon price in energy prices can strengthen the competitiveness of renewable energy, encourage low carbon technology investment, and contain the growth of fossil fuels, particularly coal.

Given high up-front capital costs of renewable energy technologies, long-term carbon price signals and long-term purchase agreements are necessary to hedge investment risks. Introducing risk-sharing mechanisms among investors, consumers, and governments could improve the effectiveness of supporting the shift to a competitive investment market.

With the increasing integration of renewable energy on power grids, some generation capacity reserve is needed for operation when renewable generation cannot supply sufficient power to the grid. A capacity price mechanism can be introduced to promote reliability. Under this mechanism, compensation would be provided to cover investment and operation costs of the reserved generation capacity.

VI. ADB ROLES IN SUPPORTING IMPLEMENTATION OF NATIONALLY DETERMINED CONTRIBUTIONS IN DEVELOPING MEMBER COUNTRIES

In line with the Midterm Review of Strategy 2020: Meeting the Challenges of a Transforming Asia and Pacific, which is focused on addressing regional energy challenges in energy access, clean energy, and energy efficiency, ADB needs to enhance its engagement in the implementation of NDCs, and support DMCs to achieve long-term energy transformation. Opportunities to support ADB operations could be as follows:

- improve energy efficiency in both energy supply and energy use;
- deploy new renewable technologies and solutions;
- demonstrate strategic low carbon energy technologies and solutions;
- facilitate acquisition of low carbon energy technologies; and
- pilot new financing and business models.

A. Upgrading Existing Transmission and Distribution Networks with Smart Technologies

Most DMCs are facing issues of technical and commercial loss due to aging transmission networks. Existing transmissions networks cannot meet the needs of power demand and renewable energy integration and this is a key reason why one-third of power sector investment to achieve the goals of the NDCs is needed for upgrading and extending the power grid infrastructure.

ADB needs to enhance its investment in transmission and distribution networks by investing in cross-border interconnections, advanced smart technologies such as HV transmission, advanced metering infrastructure, and integration measures. The investment will help the countries to increase the efficiency of power transportation, reduce power losses, and meet the need of renewable energy growth.

In addition, ADB could support network planning in order for DMCs to meet the growing needs of variable renewable power integration.

B. Upgrading Existing Coal and Gas Power Generation Unit

Increasing energy efficiency can lower the costs of energy supply, increase the availability of energy, and avoid emissions from increased power generation. This is an important near-term option to meet DMCs' growing energy needs and reduce GHG emissions.

The majority of coal-fired power generation units, particularly in India and Southeast Asia, employ subcritical technology with low efficiency and high emissions. Investment in retrofits can be a short-term solution to reduce emissions. ADB could support countries to identify the priorities for renovation, find appropriate technology measures, and finance retrofit opportunities. However, ADB needs to assess the future low carbon transition risk of the coal assets in the investment decision making.

Some DMCs in Central and West Asia, Southeast Asia, and Bangladesh are still using aging gas-turbine or open cycle turbines with low efficiency. ADB may provide assistance to these countries to retrofit existing gas-fired power plants by converting them to combined cycle and cogeneration power plants in order to reduce fossil fuel consumption and reduce emissions.

C. Application and Deployment of New Low Carbon Energy Technologies and Solutions

1. Renewable Power Integration

Increasing renewable power integration through the targets set out under the NDCs, and surpassing these will require flexibility of the power system. There are emerging options to increase power flexibility, and ADB should support DMCs in identifying the most cost-effective options for renewable power integration and support the deployment of identified solutions.

2. Mini Grids with Battery Storage Technologies, Off-Grid Solutions

Mini grids with battery storage and off-grid solutions are emerging technologies that can increase the use of renewable energy, improve energy efficiency, and expand energy access in the Pacific island countries and rural areas. Supporting the application and deployment of these new technologies can provide DMCs with affordable and sustainable energy, while helping DMCs transform their energy systems. ADB already supports such applications, and this needs to extended to more countries.

3. Integrated Solution for Urban Energy Systems

The combination of heating, cooling and electricity through renewable energy sources and waste can increase the uptake of renewable energy in the demand sector while increasing energy efficiency and resource utilization efficiency. ADB has the opportunity to mobilize energy and urban community resources to deploy such smart solutions in DMCs.

4. Support Development and Demonstration of Strategic Clean Energy Technologies

Strategic technologies such as CCS and large-scale energy storage technologies (rather than pumped-storage hydropower and compressed air energy storage) are necessary for long-term energy decarbonization but are not currently economically viable. Supporting the development and demonstration of these technologies can build a country's capacity for long-term energy transformation For example, in addition to the PRC, ADB could support interested countries in developing a CCS road map that includes strategy, approaches, priority areas, assessment of storage resources, policy and regulatory framework, and so on.

5. Low Carbon Energy Technology Transfer

Technology transfer is an essential need of DMCs for achieving their NDC targets. ADB has established a Climate Technology Financing Center (CTFC) to support climate technology transfer in the regions. Based on the experience on operation of CTFC, ADB should continue supporting low carbon energy technology transfer through CTFC, with focus on

- region-specific priority technologies for achieving energy transition,
- integrated approaches to facilitate technology transfer and investment by piloting technology-promoting mechanisms similar to that in Hunan, PRC
- build DMCs' capacity for adopting and absorbing new low carbon technologies, and
- facilitate regional cooperation on technology transfer, in particular cooperation among DMCs.

D. Innovation in Financing Model and Business Model

In order to achieve the goals set out under the NDCs as well as to mobilize the international climate finance agreed in the Paris Agreement, the public sector will need to work with the private sector to mobilize the required investment. ADB should therefore pilot different forms of public–private partnership financing models to attract private investors.

ADB can establish risk mitigation instruments to remove barriers to investment from the private sector. Low carbon energy technologies are generally capital-intensive with high uncertainties around regulatory frameworks, tariffs, performance, and so on. ADB could use its financial resources to pilot a risk mitigation instrument. ADB would bear technology risks or cover part of the incremental cost. This is critical to mobilize adequate private finance for promising low carbon technologies that could be taken forward.

ADB can also support innovative approaches to reduce transaction and financing costs for low carbon energy projects. For example, aggregation or programmatic approaches to small-scale investments in low carbon energy projects would enable the scale required by financiers.

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The Impact of Nationally Determined Contributions on the Energy Sector

Implications for ADB and Its Developing Member Countries

In Asia and the Pacific, 38 developing member countries (DMCs) of the Asian Development Bank (ADB) have committed to take mitigation actions through nationally determined contributions (NDCs) under the Paris Agreement. The Agreement aims to cap the increase in global average temperature to below 2°C. Country signatories have made NDCs to reduce greenhouse gas emissions under the Agreement. This paper analyzes implications of the Agreement for the energy sector; assesses the impact of NDCs on the energy sectors of DMCs; and explains the challenges and opportunities in implementing NDCs. The paper examines technology solutions, financing needs, and policy frameworks to accelerate energy transition and reach the NDC targets; and how ADB could support implementation of these NDCs.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to a large share of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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