Energy Transition Pathways for the 2030 Agenda

SDG 7 Road Map for Pakistan

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

NEXSTEP
National Expert SDG Tool for Energy Planning

Energy Transition Pathways for the 2030 Agenda

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Developed using the National Expert SDG7 Tool for Energy Planning (NEXSTEP)

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United Nations publication

ST/ESCAP/3054

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Acknowledgements

The preparation of this report was led by the Energy Division of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) in collaboration with Murdoch University, Australia, Private Power and Infrastructure Board (PPIB) Pakistan, Ministry of Energy (Power Division) and Sustainable Development Policy Institute (SDPI), Pakistan.

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The review and valuable suggestions were provided by Hongpeng Liu, Director of the Energy Division, ESCAP, Michael Williamson, Section Chief of the Energy Division, ESCAP and David Ferrari, ESCAP consultant.

Robert Oliver edited the manuscript. The cover and design layout were created by Xiao Dong and Qi Yin.

Administrative and secretariat support was provided by Prachakporn Sophon, Sarinna Sunkphayung, Nawaporn Sunkpho and Thiraya Tangkawattana.

Foreword: ESCAP

The continued development of the energy sector in Pakistan is key to the country's ongoing prosperity. Pakistan is well-positioned to progress on the path of sustainable energy development. It is richly endowed with renewable energy resources such as solar and wind, while hydroelectric power already contributes substantially to the national energy mix. However, more progress is required towards achieving universal access to modern energy. Around six per cent of the population still has no access to electricity. More efforts are also needed to provide access to clean cooking fuel by more than half of the population that is still reliant on unclean cooking fuels and technologies. Improving energy efficiency also should be given high priority, particularly in the industry and transport sectors, which need to shift away from independence on imported fossil fuels.

This Road Map for achieving the Sustainable Development Goal 7 (SDG 7) targets presents a detailed assessment of the energy system of Pakistan. It offers a least-cost pathway to providing universal access to clean cooking fuels and technologies, increasing the share of renewable energy across all sectors, and doubling the historic rate of energy efficiency improvement. Taking a holistic approach to the energy system by using the National Expert SDG Tool for Energy Planning (NEXSTEP), the Road Map was developed in close consultation with national policymakers and experts with a deep understanding of the country's energy system. The Road Map has been developed to help in planning an energy transition that reflects national development strategies and is aligned with global goals and targets.

The Road Map presents a range of opportunities to achieve the SDG 7 targets, while improving energy security and improving the health of its citizens through reduced indoor air pollution. It sets out four key policy recommendations – to increase access to clean cooking technology, improve efficiency in all economic sectors, electrify the transport sector and decarbonize the power sector.

The success of this collaboration between ESCAP, the Private Power and Infrastructure Board, Ministry of Energy (Power Division), Government of Pakistan and the Sustainable Development Policy Institute is a testament to the shared ambition to deliver on the vision for energy in the Sustainable Development Goals. The Road Map presents a pathway for Pakistan to continue to prosper in the next phase of its development as it builds back better in the recovery from COVID-19. It also provides an example for other countries to better understand the opportunities to develop sustainable energy.

I look forward to the implementation of the Road Map by Pakistan and its continued success in delivering a secure, sustainable and healthy energy future as we move forward.

Hongpeng Liu
Director, Energy Division, ESCAP

Foreword: Pakistan

At the outset, I would like to appreciate UN-ESCAP, SDPI and other key stakeholders for providing valuable support to the Government of Pakistan (GoP) in developing UN Sustainable Development Goal 7 (SDG7) roadmap for Pakistan. Supply of reliable, secure, efficient, and affordable electricity is one of the primary drivers for sustainable growth of a nation's economy. Pakistan is endowed with abundant indigenous and renewable energy resources by the Allah Almighty and the GoP has been emphasizing on utilization of these resources while keeping country's GHG emissions within the limits, in line with SDG7 i.e. Ensure Access to Affordable, Reliable, Sustainable and Modern Energy to all by 2030.

The GoP is endeavoring to increase the share of renewable energy in its energy mix to 20% by 2025 and up to 30% (excluding hydropower) by 2030. Overall, Pakistan is targeting to achieve more than 60% share of clean and green energy including electricity generation through hydropower, in its energy mix by 2030.

Pursuant to the updated Nationally Determined Contributions (NDCs) 2021, Pakistan is considering emission reduction target of 50% by 2030 including 15% emission reductions using country's own resources and an additional 35% subject to availability of international financial support. Total required investment is estimated to be $101 Billion by 2030 and $165 Billion by 2040, for the clean energy transition actions mentioned in the NDCs 2021. To achieve sustainability in power sector on long term basis, the GoP is working on various policies, plans and structural reforms for effective utilization of indigenous, renewable and environmentally clean energy generation sources in line with UN SDGs and the Paris Agreement.

UN-ESCAP in collaboration with PPIB and SDPI through its National Expert SDG Tool for Energy Planning (NEXSTEP) has developed a road map for Pakistan in close consultation with key stakeholders having deep insight of country's energy and environment sectors, to achieve SGD7 targets as well as energy transition objectives in line with country's international environmental commitment pursuant to the Paris Agreement. The SDG7 Road Map for Pakistan carries in-depth assessment of country's energy sector offering increasing share of renewable energy across sectors, least-cost solution for achieving universal access to clean cooking fuels and technologies and doubling the energy efficiency rate.

I am hopeful that SDG7 Roadmap for Pakistan will help the GoP in making informed policy decisions for achieving clean energy targets, universal access of electricity and carbon emission reduction targets pursuant to NDCs 2021. It will also provide a holistic and integrated approach towards development and modernization of Pakistan's energy and environment sectors.

Shah Jahan Mirza
Managing Director PPIB

Abbreviations and acronyms

AEDB	Alternate Energy Development Board
BAU	business-as-usual
CBA	cost benefit analysis
BOI	Board of Investment
CO_2	carbon dioxide
CPS	current policy scenario
DISCOs	distribution companies
EE	energy efficiency
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EV	electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt
GWh	gigawatt-hour
ICS	improved cooking stove
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
$MTCO_{2\text{-}e}$	million tonnes of carbon dioxide equivalent
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Low Emissions Analysis Platform
LPG	liquified petroleum gas
MCDA	Multi-Criteria Decision Analysis
MEPS	minimum energy performance standard
MJ	megajoule
MTF	Multi-Tier Framework
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatt-hour
NDC	nationally determined contributions
NEECA	National Energy Efficiency and Conservation Authority
NEMO	Next Energy Modelling system for Optimization
NEPRA	National Electric Power Regulatory Authority
NEXSTEP	National Expert SDG Tool for Energy Planning
NTDC	National Transmission and Despatch Company.
OECD	Organisation for Economic Co-operation and Development
PP	power plant
PPIB	Private Power and Infrastructure Board
RE	renewable energy
SDG	Sustainable Development Goal
TFEC	total final energy consumption
TPES	total primary energy supply
USD	United States dollar
WHO	World Health Organization

Executive Summary

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth as well as respond to increasing energy demand, reduce emissions, and consider and capitalize on the interlinkages between SDG 7 and other SDGs. To address this challenge, ESCAP has developed the National Expert SDG Tool for Energy Planning (NEXSTEP).[1] This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as nationally determined contributions (NDCs). The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9, which endorsed its outcome. NEXSTEP also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool.

The key objective of this SDG 7 Road Map[2] is to assist the Government of Pakistan to develop enabling policy measures to achieve the SDG 7 targets. This Road Map contains a matrix of technological options and enabling-policy measures for the Government of Pakistan to consider. It presents three core scenarios (BAU, CPS and SDG scenarios) and two ambitious scenarios that have been developed using national data, and which consider existing energy policies and strategies and reflect on other development plans. These scenarios are expected to enable the Government to make an informed decision to develop and implement a set of policies to achieve SDG 7 by 2030, together with the NDC.

A. Highlights of the road map

In 2021, 93.6 per cent of Pakistan's population had access to electricity (Pakistan Bureau of Statistics, 2021). However, only 77 per cent of the population had access to grid electricity. Based on the historical trend, it is estimated that Pakistan will achieve universal access to electricity by 2027. Universal access to clean cooking technology and fuel, however, has been and is likely to remain very low under the current policy scenario (it was 49.3 per cent in 2021, and estimated to increase to 59.2 per cent by 2030). It remains a challenge for the country's 40.8 per cent of the population who will still rely on polluting cooking fuels and technology in 2030. Well-planned and concerted efforts will be needed to achieve universal access to clean cooking by 2030.

Pakistan has abundant renewable energy resources. In addition to its large hydropower resources, it also has significant potential for solar PV, wind and biomass. Pakistan has a target of 20 per cent on-grid renewable generation by capacity (excluding hydropower) by 2025 and at least 30 per cent by 2030. In terms of petroleum resources, Pakistan has limited petroleum fuel resources and thus requires imports of oil products and natural gas to meet its increasing demand in the transport, industry and power sector. The NEXSTEP analysis has examined the potential for diversifying the energy sources, e.g., by increasing renewable energy technologies, both on the demand and supply sides.

Energy intensity, the indicator used to measure energy efficiency, decreased from 5.1 MJ/USD_{2017} in 2010 and reached 4.8 MJ/USD_{2017} in 2021 (ESCAP, 2022). To achieve the SDG 7 target for energy efficiency, this needs to be reduced to 4.1 MJ/USD2017 by 2030, which will require energy efficiency measures to be implemented across the entire demand sectors. With comprehensive power demand planning, Pakistan has the potential to provide carbon-free electricity to fuel its society by leveraging its abundant hydropower and rich renewable energy potential.

1 The NEXSTEP tool has been specially designed to perform analyses of the energy sector in the context of SDG 7 and NDC, with the aim that the output will provide a set of policy recommendations to achieve the SDG 7 and NDC targets.

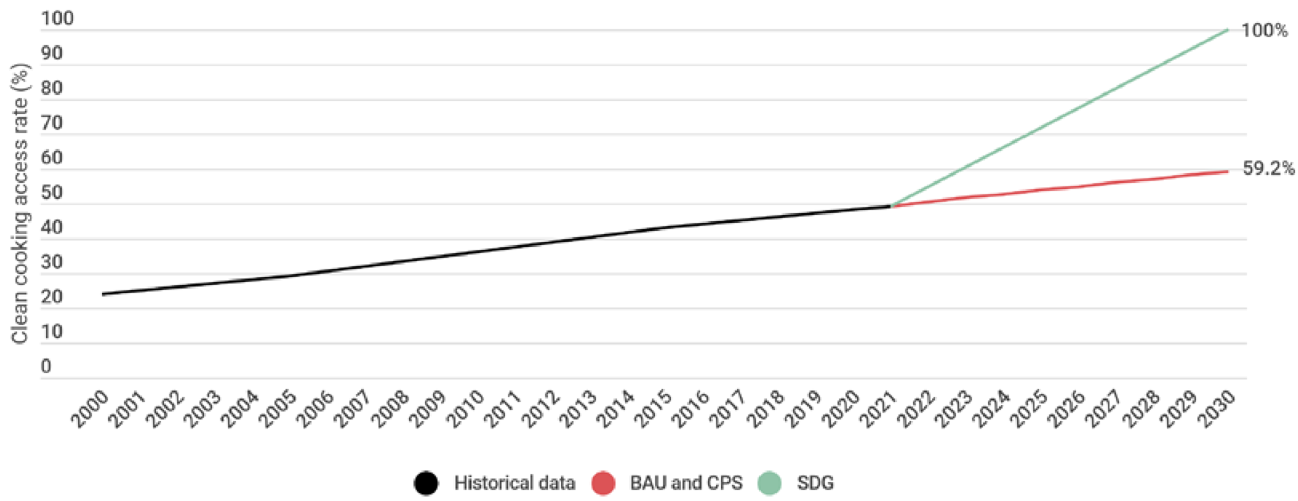
2 This Road Map examines the current status of the national energy sector and existing policies, compares them with the SDG 7 targets, and presents different scenarios highlighting technological options and enabling policy measures for the Government to consider.

B. Achieving Pakistan's SDG 7 and NDC targets by 2030

1. Universal access to modern energy

Pakistan has yet to achieve universal access to electricity. Based on the historical trend, however, it is estimated that Pakistan will achieve universal access to electricity by 2027. On the other hand, more than 50 per cent of the population in Pakistan relied on polluting cooking fuel and technology in 2021. This exposes the population to negative health impacts, including non-communicable diseases such as stroke, ischaemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer, particularly among women and children (World Health Organization, 2022a). As there are currently no governmental policies or initiatives for progressing clean cooking, based on the historical improvement trend between 2000 and 2020, it is projected to reach 59.2 per cent by 2030 (figure ES 1). This leaves around 40.8 per cent of households still relying on polluting solid fuel stoves (assuming biomass as the primary fuel) in 2030. The NEXSTEP analysis suggests that electric cooking stoves would be the most suitable long-term solution to closing the remaining gap in urban areas, while improved cooking stove would be appropriate for rural areas.

Figure ES 1. Pakistan's access to clean cooking under the BAU, CPS and SDG scenarios[3]



2. Renewable energy

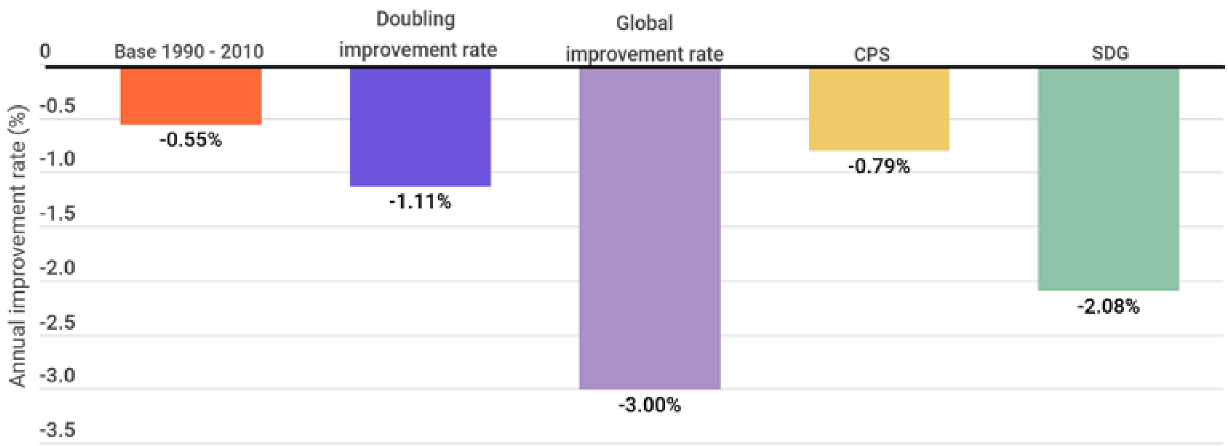
The share of renewable energy (excluding traditional biomass usage in residential cooking and heating) the total final energy consumption (TFEC) was 3.2 per cent in 2021. Based on current policies, the share of renewable energy is projected to increase to 6.8 per cent by 2030. The increase is due to the projected increase both in renewable electricity and other renewable energy consumption (excluding traditional use of biomass). In the SDG scenario, the share of renewable energy is projected to improve to 23.5 per cent of TFEC in 2030. This improvement is largely due to the phasing out of traditional biomass usage in cooking and heating, which will substantially decrease TFEC, enabling the share of renewable energy (RE) to rise.

3. Energy efficiency

Pakistan's energy intensity in 2021 is estimated to have been 4.80 MJ/USD_{2017}. Energy intensity in Pakistan declined at an average annual rate of 0.55 per cent between 1990 and 2010. A doubling of the 1990-2010 improvement rate is required in order to achieve the SDG 7.3 target, which requires an average annual rate increase of 1.11 per cent between 2010 and 2030. This corresponds to a 2030 energy intensity target of 4.08 MJ/USD_{2017} (figure ES 2).

3 Historical trend projection based on the year 2000 access rate data provided by ESCAP, 2022 as well as the 2021 access rate provided by the national consultant.

Figure ES 2. **Pakistan energy efficiency target**



Source: Calculated based on data from the Asia-Pacific Energy Portal (ESCAP, 2022)

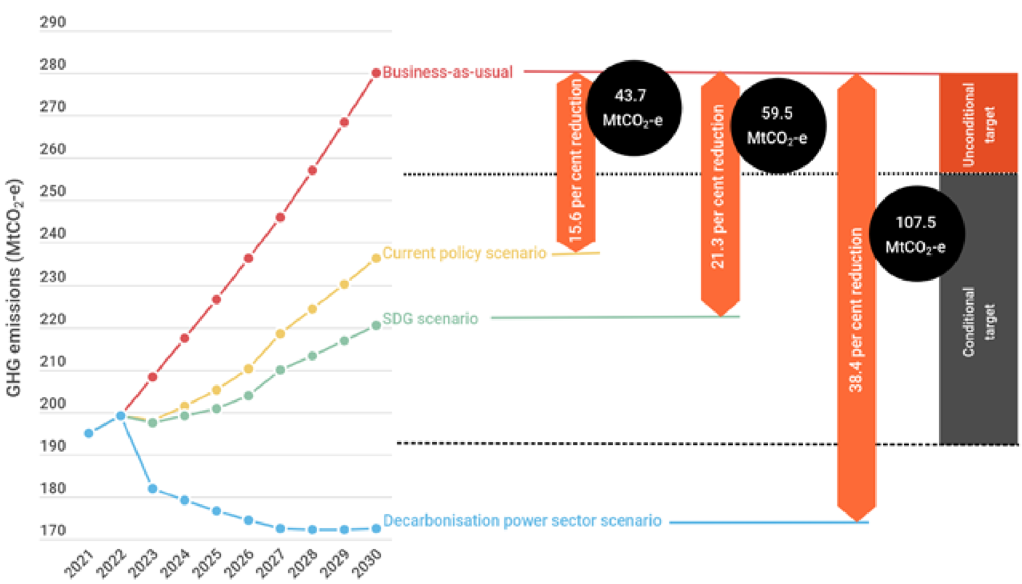
Under the current policy settings, the energy intensity is projected to drop to 4.47 MJ/USD$_{2017}$. The energy efficiency target is met under the SDG scenario, reaching 3.97 MJ/$_{2017}$ by 2030. This is primarily due to the phase-out of inefficient cooking and heating technologies and replaced with more efficient electric cooking stoves, improved cooking stoves and cleaner heating stoves. In addition, further energy intensity reduction can be realised through increased adoption of minimum energy performance standards (MEPS), encouragement of public transport use, improvement of passenger car fuel economy and adoption of the zig-zag brick kiln.

4. Nationally determined contribution

Pakistan's updated nationally determined contribution (Government of Pakistan, 2021a) sets a target of an overall 50 per cent reduction of greenhouse gas emissions below BAU between 2015 and 2030, with a 15 per cent reduction using the country's own resources (known as the unconditional target), and an additional 35 per cent subject to international financial support (known as the conditional target).

Using the energy sector emissions projection for 2030 from the INDC document (56 per cent), the unconditional and conditional targets for the energy sector are estimated to be 8.4 per cent and 28 per cent respectively. Figure ES 3 shows that this reduction in emissions is set to be achieved through an improved energy mix, green transportation, a pledge to build no new coal power plants and a ban on the use of imported coal for energy generation. The unconditional NDC target is met in CPS and SDG scenarios while the conditional NDC target is met in the decarbonization of power sector scenario.

Figure ES 3. **Comparison of emissions, by scenario, 2021-2030**



C. Important policy directions

The Road Map sets out the following four key policy recommendations to help Pakistan achieve the SDG 7 targets as well as reduce reliance on imported energy sources:

(1) **Strong policy measures are required to address the large gap in clean cooking by 2030.** Achieving access to clean cooking fuels and technologies is one of the biggest challenges for Pakistan. Adoption of electric cooking stoves in the urban areas and improved cooking stoves (ICS) in the rural areas of the country is needed to provide clean cooking access to 50.7 per cent of population (18.3 million households). ICS can play an intermediary role until cleaner options become more affordable. The cost of deploying electric cooking stoves to the urban areas would require US$ 8.7 million, whereas the deployment of ICS in the rural areas would need USD 161 million. Therefore, the total cost of clean cooking access would be US$ 169.7 million by 2030.

(2) **An increase in the efficiency of energy use in all economic sectors should be pursued.** The residential sector is also the highest energy consuming sector in Pakistan when traditional biomass (non-commercial biomass) use is considered. Therefore, utilization of improved High Efficiency, Low Emission (HELE) heaters for space heating in the rural areas will significantly help to improve energy efficiency with an energy saving potential of 2,427 ktoe as well as reduce emissions by 1.02 MtCO2-e. HELE can play an intermediary role until cleaner options become more affordable. Targets to double the minimum energy performance standard (MEPS) adoption rate and thermal insulation improvement in the residential sector can be implemented to achieve a more sustainable target. Together, these can reduce energy consumption by 1,719 ktoe by 2030. In addition to the residential sector, the industry and agriculture sectors would have a significant emission reduction potential of 2,631 ktoe through the adoption of efficient machinery and energy audit. Very high consumption of fossil fuel in the industry sector will pose a major challenge should the country wishes to pursue carbon neutrality by 2050. Therefore, fuel switching options, including electrification of end uses need to be further considered. The Road Map has identified the fact that the fuel switching options in different areas across the entire economy have the potential to reduce energy consumption by 95.5 Mtoe in 2050.

(3) **Transport electrification strategies provide multi-fold benefits.** With the absence of fuel efficiency standards and requirements to remove old vehicles from the road, the transport sector contributes to severe air pollution, GHG emissions (the second highest emitting sector after the industry sector) and inefficient use of energy resources. Vigorous adoption of electric vehicles by 2030 is highly recommended. Increasing the sales of electric vehicles by 30 per cent for passenger cars and freight trucks, and 50 per cent for other vehicles, by 2030 has the potential to save 1,031 ktoe of energy and reduce emissions by 4.22 MtCO2-e. This will also reduce the demand for oil products, hence reducing Pakistan's reliance on imported petroleum fuels. At the same time, it will contribute to climate mitigation and improve the local air quality. Electrification of transport is critical to decarbonize the transport sector by 2050. Simultaneously, the promotion of mass transportation and the improvement of fuel efficiency standards using a hybrid model can be affordable pathways during the transition period before moving towards 100 per cent e-mobility.

(4) **Decarbonization of the power supply provides the highest potential for GHG emission reduction as well as improving energy security.** Decarbonization of the power sector is important in preventing the shifting of emissions from one sector to another when implementing policies on clean cooking and electric vehicles. This would be also needed if the country plans to move towards carbon neutrality or net zero by 2050. Realizing the decarbonization objective will require a substantial increase in renewable capacities, which could be challenging technically and economically; however, it will offer multiple benefits, including the reduction of emissions and improvement of the energy security through the utilization of indigenous resources, such as solar PV and wind. The decarbonization of the power sector by 2030 will need to substantially increase renewable energy in the generation mix. The required additional capacities to what have been already planned under the IGCEP are 4GW hydro, 4.6GW solar PV, 5.5GW wind and 1.6GW biomass with an investment of US$ 13.5 billion.

1. Introduction

1.1. Background

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure a sustained economic growth, respond to increasing energy demand, reduce emissions as well as consider and capitalise on the interlinkages between SDG 7 and other SDGs. In this connection, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as nationally determined contributions (NDCs) emission reduction targets. The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9 which endorsed the meeting's outcome. NEXSTEP also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool. The ministerial declaration advises ESCAP to support its member States, upon request, in developing national SDG 7 Road Maps.

The tool NEXSTEP has been specially designed to support policymakers in analysing the energy sector and developing an energy transition plan in the context of SDG 7. Further details of the NEXSTEP methodology are discussed in the next chapter. While this tool has been designed to help develop the SDG 7 road map at the national level, it can also be used for subnational energy planning.

1.2. SDG 7 targets and indicators

SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. It has three key targets, which are outlined below.

- Target 7.1. "By 2030, ensure universal access to affordable, reliable and modern energy services." Two indicators are used to measure this target: (a) the proportion of the population with access to electricity; and (b) the proportion of the population with primary reliance on clean cooking fuels and technology.
- Target 7.2. "By 2030, increase substantially the share of renewable energy in the global energy mix". This is measured by the renewable energy share in TFEC. It is calculated by dividing the consumption of energy from all renewable sources by total energy consumption. Renewable energy consumption includes consumption of energy derived from hydropower, solid biofuels (including traditional use), wind, solar, liquid biofuels, biogas, geothermal, marine and waste. Due to the inherent complexity of accurately estimating the traditional use of biomass, NEXSTEP focuses entirely on modern renewables for this target.
- Target 7.3. "By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the International Energy Agency (IEA), TPES is made up of production plus net imports, minus international marine and aviation bunkers, plus stock changes. For comparison purposes, GDP is measured in constant terms at 2017 PPP.

In addition to the above-mentioned targets, the SDG 7 goal also includes target 7.A – promote access, technology and investments in clean energy, and target 7.B – expand and upgrade energy services for developing countries. These targets are not within the scope of NEXSTEP.

1.3. Nationally Determined Contribution

NDCs represent pledges by each country to reduce national emissions and are the stepping-stones to the implementation of the Paris Agreement. Since the energy sector is the largest contributor to GHG emissions in most countries, decarbonizing energy systems should be given a high priority. Key approaches to reducing emissions f om the energy sector include increasing renewable energy in the generation mix and improving energy efficiency.

Pakistan's updated nationally determined contribution (NDC) (Government of Pakistan, 2021a) sets an economic-wide conditional target of an overall 50 per cent reduction below BAU of its projected emissions between 2015 and 2030, with (a) a 15 per cent reduction using the country's own resources (known as unconditional target), and (b) an additional 35 per cent subject to international financial support (known as conditional target). This reduction in emissions is set to be achieved through an improved energy mix, green transportation, and a pledge to build no new coal power plants and ban the use of imported coal for energy generation.

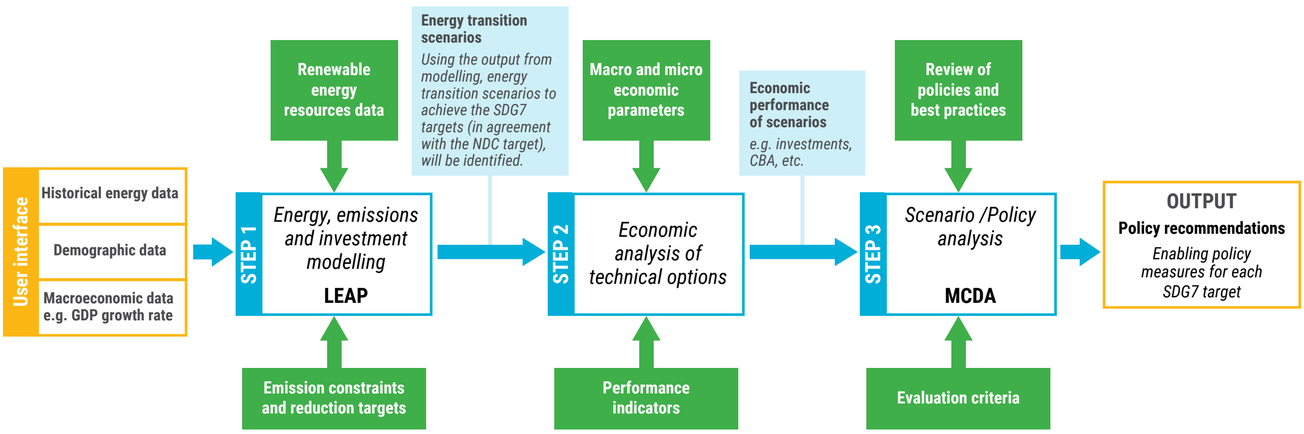
The energy sector emission is projected to account for 56 per cent of total emissions in 2030 in the Intended Nationally Determined Contribution (INDC) document (Government of Pakistan, 2016). NEXSTEP applies a *pro rata* share to calculate the emission reduction target in the energy sector. Therefore, the unconditional and conditional targets for the energy sector will be 8.4 per cent and 28 per cent, respectively.

1.4. NEXSTEP methodology

The main purpose of NEXSTEP is to help design the type and mix of policies that would enable the achievement of the SDG 7 targets and the emission reduction target (under NDCs) through policy analysis.

The tool helps modelling energy, emissions and economics to analyse a range of policies and options for their suitability. This tool is unique in a way that no other tools look at developing policy measures to achieve SDG 7. One key feature is a back casting approach to energy and emissions modelling, which is important in planning for SDG 7 where the trajectory is developed backwards from the (known) 2030 targets to the present day. Figure 1 shows different steps of the methodology.

Figure 1. Different components of the NEXSTEP methodology



1.4.1. Energy and emissions modelling

NEXSTEP begins by developing a model of the energy system for each scenario, defining the technical options in terms of the final energy (electricity and heat) requirement for 2030, possible generation/supply mix, emissions and the size of investment required. The energy and emissions modelling component uses the Low Emissions Analysis Platform (LEAP) tool. This proprietary software is used by many countries to develop scenarios for the energy sector, policy analysis and develop NDC targets.

1.4.2. Economic analysis

The second step builds on the selection of appropriate technologies through an economic optimisation process which identifies the least-cost energy supply options for the country. A comparative assessment of selected power generation technologies is done using the Levelized Cost of Electricity (LCOE) as an economic indicator. This provides policymakers with insights into the costs and benefits of the economically attractive technology options, allowing better allocation of resources and better-informed policy decisions. While the economic analysis has been kept at a simple level, it contains enough information to support policy recommendations in this Road Map. Some key cost parameters used in this analysis are (a) capital cost, including land, building, machinery, equipment and civil works, and (b) operation and maintenance cost, comprising fuel, labour and maintenance costs.

1.4.3. Scenario analysis

The scenario analysis evaluates and ranks scenarios, using the Multi Criteria Decision Analysis (MCDA) tool, with a set of criteria and weights assigned to each criterion. Although the criteria considered in the MCDA tool can include the following, stakeholders may wish to add/remove criteria to suit the local context:

- Access to clean cooking fuel;
- Energy efficiency;
- Share of renewable energy;
- Emissions targets in 2030;
- Alignment with the Paris Agreement;
- Fossil fuel subsidy phased out;
- Price of carbon;
- Fossil fuel phase-out;
- Cost of access to electricity;
- Cost of access to clean cooking fuel;
- Investment cost of the power sector;
- Net benefit from the power sector.

This step is performed using the NEXSTEP online portal[4] as a means to suggest the best way forward for the countries by prioritizing the scenarios. Stakeholders can update this scenario ranking by using a different set of criteria and their weights. The top-ranked scenario from the MCDA process is used to inform the Government on the best possible energy transition pathway for the country.

4 Available at https://nexstepenergy.org/

2. Country overview

2.1. Demographic and macro-economic profile

Geography and climate: Pakistan is located in South Asia and is bordered by India to the east, Afghanistan to the west, Iran to the south-west, and China to the north-east. It is separated narrowly from Tajikistan by Afghanistan's Wakhan Corridor in the north and shares a maritime border with Oman. The country occupies a land area of 881,913 km^2 and has a 1,046-kilometre coastline along the Arabian Sea and Gulf of Oman in the south.

The south of Pakistan is mainly determined by the tropical and humid sea climate. In the north, however, there is a continental climate. The winters are very cool, and the summers are hot. The differences in temperatures are enormous in Pakistan. During the monsoon season there is significant rainfall, especially in the mountains. In recent years, the country has observed intense droughts, accelerated melting of glaciers, heat waves and irregular rainfall patterns. The 2019 report of the Global Environmental Risk Index (GermanWatch, 2020) ranks Pakistan at the eighth position, recognizing the significant consequences faced due to climate change. In 2022, Pakistan has experienced intense heatwaves, causing temperatures to reach approximately 50 degrees Centigrade in some areas across the country (World Economic Forum, 2022). The high temperature has further resulted in both an increased demand for energy resources and acute water shortages.

Population and economy: In 2021, the country had a population of 225.22 million people, with an average of six (6) persons per household which amounted to an estimated 37,536,667 households. The annual population growth rate is around 2 per cent. The urbanization rate in 2020 was 37.2 per cent, which is projected to grow to 39.5 per cent in 2030.

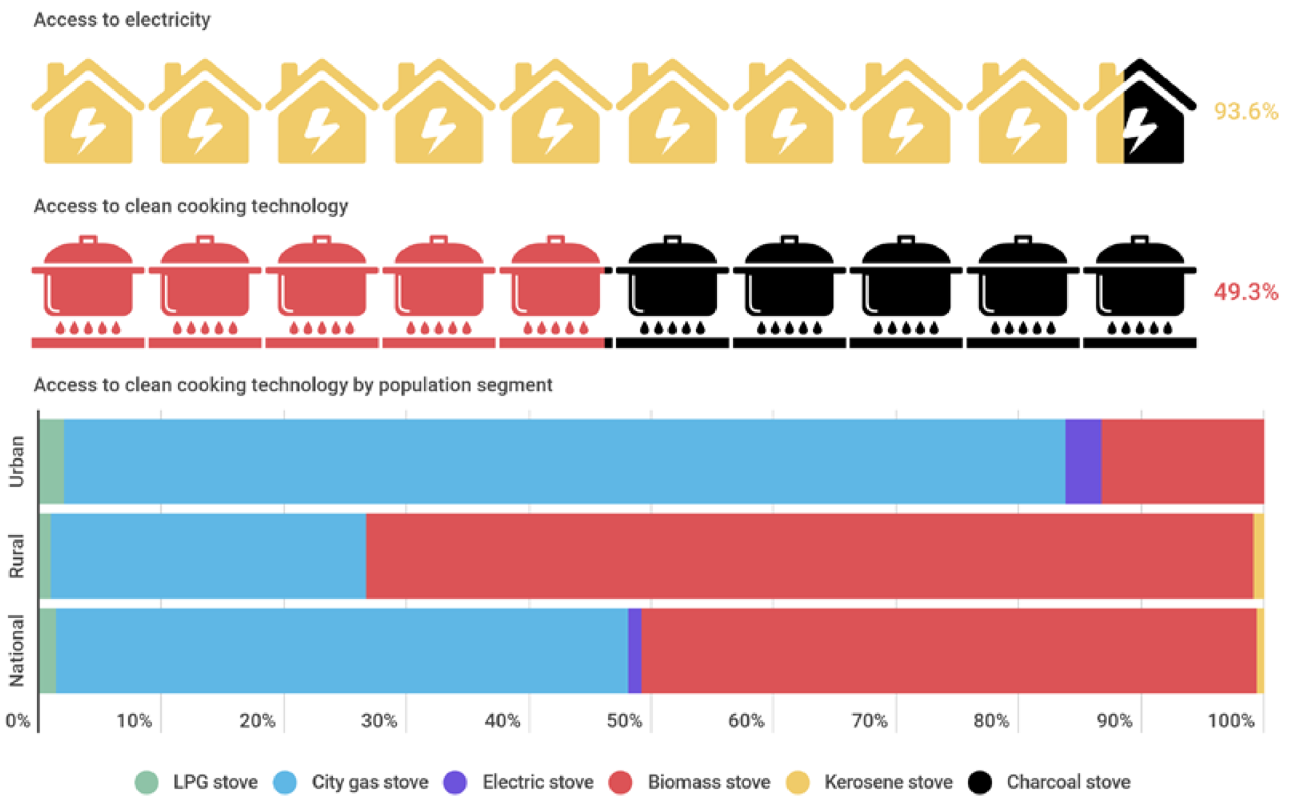
Pakistan's GDP in 2021 was estimated at 346 billion with a GDP growth rate of 6.03 per cent. Pakistan is classified as a lower-middle income economy (World Bank, 2022a) with GDP per capita was USD 1,507 in 2021 (World Bank, 2022b). Like other countries in the world, Pakistan's economy has been impacted by COVID-19.

2.2. Energy sector overview

2.2.1. National energy profile

The electrification rate in Pakistan was 93.6 per cent in 2021. However, only 77 per cent of the population had access to grid electricity. Therefore, there are opportunities to provide better electricity services to its citizens. The clean cooking access rate is estimated at 49.3 per cent.[5] The remaining 50.7 per cent of the population, which corresponds to 19 million households, still rely on polluting solid fuel stoves as their primary cooking technology. The natural gas stove is the most dominant primary clean cooking technology, with an estimated share of 46.7 per cent (figure 2). This is followed by the liquefied petroleum gas (LPG) cooking stove, which is estimated to be 1.3 per cent, and the electric cook stove, at 1.3 per cent.

Figure 2. Electricity and clean cooking access share



The following details describe the estimated national energy consumption using data[6] collected with a bottom-up approach, such as activity level and energy intensity for the different sectors. The bottom-up estimation is generally in agreement with the national energy statistics in terms of total energy supply and total final energy consumption by fuel type. The biomass consumption data have been estimated based on International Energy Agency data in 2022.

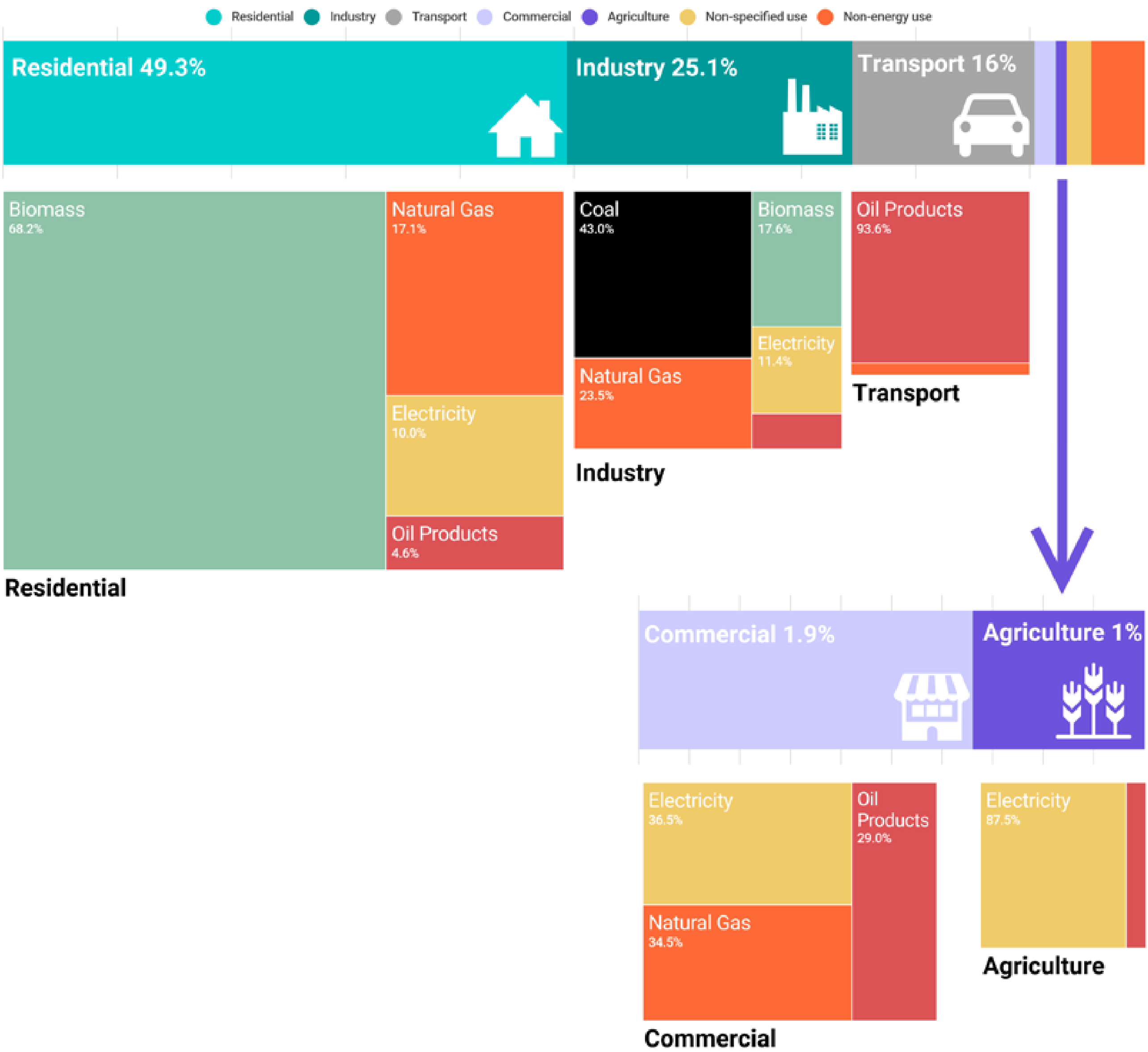
In 2021, TFEC was 94.1 Mtoe. As shown in figure 3, most of the demand came from the residential sector (49.3 per cent), of which 89.6 per cent of energy was consumed for cooking (69.2 per cent) and heating (20.9 per cent) purposes. Such a high

5 Estimated based on the cooking distribution data provided for urban and rural sectors in accordance with WHO (2020).

6 National data compiled by SDPI with reference to publicly available sources.

share of residential cooking energy demand was attributable to the widespread use of inefficient traditional biomass and solid fuels, particularly in rural households. In terms of electricity usage, 27.1 per cent was for electric fans, 25.3 per cent was used for televisions, 11.8 per cent was for lighting, 10.8 per cent was for refrigeration, 9.9 per cent for water pumps, 8.3 per cent for air conditioners, and the remainder for other appliances (ironing, washing machines etc).

Figure 3. Total final energy consumption by sector in 2021



The second-largest energy-consuming sector is the industrial sector, estimated at 25.1 per cent. Within the industrial sector, 58.9 per cent of energy was consumed by cement and brick kiln industries and 21.1 per cent by textile and wearing apparel industries. Food, beverages and tobacco industries accounted for 4.5 per cent of energy use while the fertilizer industry accounted for 3.4 per cent of energy use. The remaining percentage was for the other industrial types.

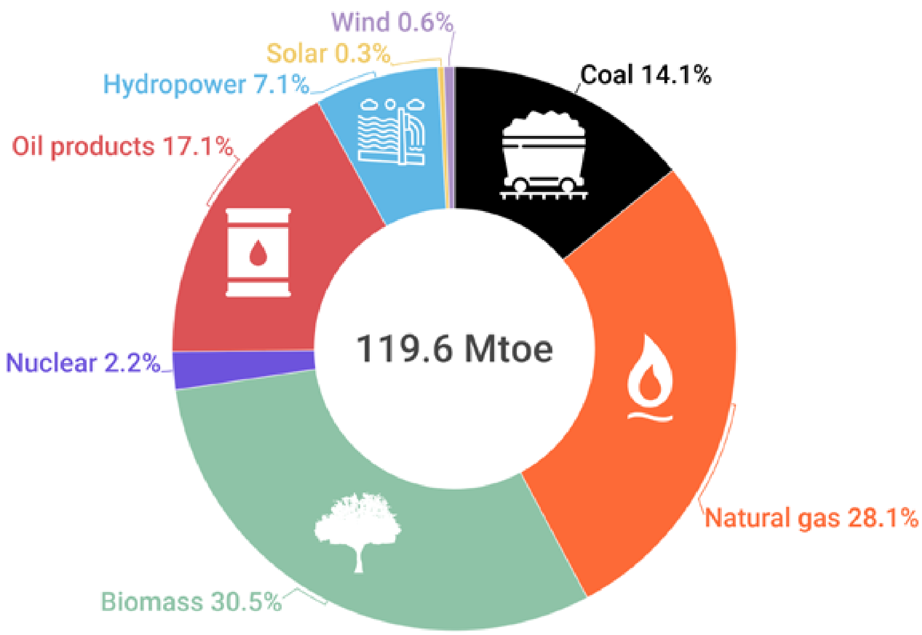
The transport sector consumed 16 per cent of TFEC, of which the road transport sector consumed around 92.2 per cent of energy in this sector. This was followed by non-energy use (4.7 per cent), non-specified use (2.1 per cent), the commercial sector (1.9 per cent) and the agricultural sector (1 per cent).

In terms of fuel usage in TFEC, biomass contributed the highest amount (38.1 per cent) followed by natural gas (21.1 per cent). Oil products (including petroleum, diesel and crude oil) made up around 19.9 per cent of TFEC. The transport sector, which operated predominantly with internal combustion engine vehicles, was the main consuming sector for oil products. Other fuel use included coal (10.8 per cent) and electricity (10.1 per cent). Coal was mainly used in the industrial sector, particularly in the cement and brick kiln industries.

Modern renewable energy delivered approximately 3.2 per cent of TFEC in 2021. This excludes traditional biomass usage in residential cooking and heating as well as in industry, which corresponds to an estimated 35.8 Mtoe (38.1 per cent of TFEC). While endowed with an abundance of hydropower potential, of which the installed hydropower capacity contributes around 27.6 per cent of the total electricity produced in 2021, Pakistan has a high reliance on imported fuels (i.e., coal and oil products) for meeting its stationary and mobile fuel demands.

Total primary energy supply in 2021 was 119.6 Mtoe. As shown in figure 4, biomass supplied the most energy, mainly in the residential sector for cooking and space heating. Renewable energy supplied only 8 per cent of primary energy of which 89 per cent came from hydropower.

Figure 4. Total primary energy supply by fuel type in 2021



The total installed electrical generation capacity in 2021 was 39.3 GW. Total electricity generation was 142,793 GWh, comprising 60.9 per cent fossil fuel (predominantly natural gas and coal), 27.6 per cent hydropower, 7.8 per cent nuclear, 2.5 per cent wind, 0.7 per cent bagasse and 0.5 per cent solar PV.

The energy sector emissions, from the combustion of fossil fuel, were calculated based on IPCC Tier 1 emission factors assigned in the LEAP model and expressed in terms of 100-year global warming potential (GWP) values. GHG emissions from the energy sector were estimated at 194.9 $MtCO_{2-e}$ in 2021. Emissions from the industry sector were the largest at 56.2 $MtCO_{2-e}$. It was followed by the transport sector at 44.1 $MtCO_{2-e}$ arising from direct fuel combustions in internal combustion engines. The residential sector accounted for 38.7 $MtCO_{2-e}$ coming from solid fuel combustion for cooking and heating. The total emissions attributable to electricity generation were estimated at 49.5 $MtCO_{2-e}$.

2.2.2. National energy policies, plans, strategies and institutions

The governance of Pakistan's energy sector is carried out by the Cabinet of Ministers and various government agencies. These include the Private Power Infrastructure Board (PPIB), the Alternate Energy Development Board (AEDB), the Board of Investment (BOI), National Energy Efficiency and Conservation Authority (NEECA), National Electric

Power Regulatory Authority (NEPRA), National Transmission and Dispatch Company (NTDC) and distribution companies (DISCOs).

Pakistan's energy sector development is guided by several national policies and articles of legislation. These have been used as guiding references for the NEXSTEP modelling in order to better understand the country context and to develop recommendations in adherence to the Government's overarching direction. Where applicable, the currently implemented and adopted policies or regulations are considered in the current policy scenario, in order to identify gaps in achieving the SDG 7 targets.[7] The key policies and strategic documents consulted are detailed below.

- **The National Electricity Policy 2021** (Government of Pakistan, 2021b) proposes a three-pronged goal for the power sector, namely access to affordable energy, energy security (uninterrupted supply) and sustainable energy. The policy does not set any specific targets or specific actions since the implementation of the policy is expected to take form under National Electricity Plans, prepared together with provincial governments. The document has the objectives and principles for establishing Competitive Trading Bilateral Contract Market (CTBCM). The CTBCM model will transition the market from a single buyer to a competitive wholesale electricity market. This transition will enable the Bulk Power Consumers (BPCs) (currently having 16 per cent share in the market) to choose a supplier of their own choice. This transition will also enable distribution companies (DISCOs), the System Operator, NTDC and other power sector entities to perform their role in an effective manner.
- **Power Generation Policy 2015** (Government of Pakistan, 2015). The objectives of the Power Policy include: (a) provision of sufficient power generation capacity at the least cost; (b) encouraging and ensuring exploitation of indigenous resources; (c) ensuring that all stakeholders are looked after in the process – a win-win situation; and (d) being attuned to safeguarding the environment. In particular, the policy offers profitable business opportunities, and the Government urges the local and international investors to participate in the development of power projects.
- **Transmission Line Policy Framework 2015** (Power Private and Investment Board, 2015). This document describes the policy framework and the package of incentives that will be available to prospective investors interested in bidding for AC and DC Extra High Voltage (EHV) power transmission lines, substations, and converter stations.
- **Alternative and Renewable Energy (ARE) Policy 2019** (Government of Pakistan, 2019) sets a target of at least 20 per cent on-grid RE generation by capacity by 2025 and at least 30 per cent by 2030. The alternative and renewable technologies covered in this policy are biogas, biomass, waste-to-energy, geothermal, hydrogen, synthetic gas, ocean/tidal/wave energy, solar, wind, hybrid and storage technology.
- **Indicative Generation Capacity Expansion Plan (IGCEP) 2022-31** (National Transmission and Despatch Company, 2022). The base case results show that a generation capacity of 69,372 MW is proposed, which includes the utilization of existing generation facilities, consideration of committed power plants, and optimization of candidate power plants. To meet the demand by 2031, the share from variable renewable energy (VRE) resources stands to be 8,350 MW, 4,928 MW and 394 MW of solar, wind and bagasse, respectively.
- **National Electric Vehicle Policy** (Ministry of Climate Change, 2020) seeks to capture 30 per cent of all passenger vehicle and heavy-duty truck sales by 2030, and 90 per cent by 2040 by electric vehicles. In addition, the Government seeks to capture 50 per cent of electric two- and three-wheelers as well as electric bus sales by 2030 and 90 per cent by 2040.
- **National Energy Efficiency and Conservation Authority (NEECA) Strategic Plan, 2020-2023** (Ministry of Energy, Power Division, 2020) is set to achieve the goal of 3 Mtoe of energy saving by 2023. The following are sectoral objectives of the Strategic Plan (2020-2023):

7 Only policies with concrete measures are considered in the scenario modelling for the current policy scenario. plan/strategy policy documents without concrete measures enforced are not considered, but are compared with scenario result findings in the "Revisiting Existing Policies" chapter.

  - In the industrial sector, a total saving up to 1.3 Mtoe will be achieved by improving energy efficiency in electrical systems, optimization of thermal utilities and carrying out mandatory industrial energy audits;
  - In the building sector, a total saving of up to 0.5 Mtoe will be achieved by the implementation of building codes, development of building energy management systems and the launch of mandatory appliances labelling regimes in the buildings;
  - In the transport sector, a total saving of up to 0.5 Mtoe will be achieved by developing vehicle examination system and regulations, establishing vehicle tune-up centres, developing fleet management mechanisms and supporting the implementation of electric vehicle policy;
  - In the power sector, a total saving up to 0.4 Mtoe will be achieved through the intervention of various energy efficiency (EE) programmes, which includes transformer and LT capacitor programmes, carrying out heat rate assessments and enforcement of mandatory energy audits in industries;
  - In the agriculture sector, a total saving up to 0.3 Mtoe will be achieved by replacing inefficient tube wells, establishing agricultural tractor tune-up centres and overall addressing the water-energy-food nexus.
- **Pakistan's Updated Nationally Determined Contribution (NDC)** (Government of Pakistan, 2021a) sets a cumulative conditional target of an overall 50 per cent reduction of its projected emissions between 2015 and 2030, with a 15 per cent reduction using the country's own resources, and an additional 35 per cent subject to international financial support. This reduction in emissions is set to be achieved through an improved energy mix, green transportation, and a pledge to build no new coal power plants and ban the use of imported coal for energy generation.

2.2.3. National energy resources and potentials

Pakistan depends on indigenous resources and energy imports to meet its energy needs. Pakistan is endowed with substantial hydropower potential, which supplied 27 per cent of its electricity requirements in 2021. As of 2021, there was 9,915 MW of hydropower capacity, generating a total of 39,384 GWh of electricity. The total hydropower potential from large- and medium-sized rivers is estimated at 50,000 MW. Most of the resources are in the north of the country, which offer sites for large-scale power projects (Bashir, 2022).

The country's geographical location and climatic conditions will allow broader development of solar energy. The annual direct normal solar radiation has a potential of 6.5 to 7.5 kWh/m^2/day in Baluchistan, 5 to 5.5 kWh/m^2/day in southern Punjab and northern Sindh, and 4.5 to 5 kWh/m^2/day in the remaining areas of Pakistan. In addition, exploitation of wind energy is also promising in Pakistan. The National Renewable Energy Laboratory (United States of America) has identified that wind with good to excellent speed is available in many parts of the country, establishing a total potential of about 340,000 MW (Bashir, 2022). The highest wind potential is mainly found in in the coastal belt of Sindh and Baluchistan (southern Pakistan).

There are proven reserves of accessible geothermal energy, comprising water at a temperature around 80°C, with some reserves found in Baluchistan and Sindh. However, the geothermal resources have yet to see significant development. Biomass also has considerable potential – Pakistan produces a huge amount of municipal waste (Karachi, 12,000 tons/day, and other cities about 1,000 to 6,000 tons/day) and agriculture waste in the form of bagasse, cotton sticks and rice husks. Converting this waste to energy could generate up to 5,000 MW of power (Bashir, 2022). Pakistan offers lucrative opportunities in this sector in which a number of projects are already underway. Table 1 presents a strength, weakness, opportunities and threats (SWOT) analysis of renewable energy resources in Pakistan.

Table 1. SWOT analysis of renewable energy resources in Pakistan

	Strength	Weakness	Opportunites	Threats
Solar energy	- Abundant resource availability - Potential to deliver sustainable energy (heat and electricity)	- The shortfall of industrial chain for the production of solar PV and assessory components - Lack of financial mechanism - Grid instability	- Huge potential to meet the supply and demand gap - Reduction in GHG emissions	- Low FIT - High capital cost
Wind energy	- Abundant resource - Widely distributed potential	- Grid instability	- Windy areas have an opportunity to install wind farm	- High capital cost - electricity off-take due to prioritisation of thermal generations
Hydro energy	- Endowed with enormous water resources - Already established technology	- Seasonal variability	- The key player in the current market - Huge potential for micro-scale hydropower	- Disturbance in biodiversity
Biomass energy	- Availability of energy crops - Huge agricultural areas - Abundant animal, forest, and organic waste.	- Lack of knowledge and competence - Limited application	- Opportunity to retrofit old thermal power plant	- Difficult to establish a suitable energy market
Geothermal energy	- Many hot water springs	- Lack of expertise - Low temperature	- Environmentally-friendly	- High capital cost

3. Modelling assumptions

This section presents an outline of the scenarios considered by NEXSTEP, together with the key demographic and economic assumptions used in modelling Pakistan's energy system.

3.1. Scenario definitions

NEXSTEP is designed for scenario analysis, using the LEAP modelling system to enable energy specialists to model energy system evolution based on current energy policies. The baseline year 2021 was chosen, as it is the most recent year with sufficient data information for modelling. In the NEXSTEP model for Pakistan, five scenarios have been modelled. These include three core scenarios: (a) business-as-usual (BAU) scenario; (b) current policy scenario (CPS); and (c) Sustainable Development Goal (SDG) scenario. In addition, two ambitious scenarios have been developed: (d) decarbonization of the power sector by 2030 scenario; and (e) decarbonization of whole economy by 2050 scenario.

3.1.1. BAU scenario

This scenario follows historical demand trends, based on growth projections, such as using GDP and population growth. It does not consider the emission limits or renewable energy targets set out in policy and legislation. For each sector, the final energy demand is met by a fuel mix reflecting the current shares in TFEC, with the trend extrapolated to 2030. Essentially, this scenario aims to indicate what will happen if enabling policies are not implemented or the existing policies fail to achieve their intended outcomes. The main purpose of this scenario is to be able to compare the emissions trend with the baseline and estimate the emissions reduction target.

3.1.2. Current policies scenario

Inherited from the BAU scenario, this scenario considers initiatives implemented or scheduled to be implemented during the analysis period of 2021-2030. These are, for example, the power development plan and energy efficiency programmes. Otherwise, the energy intensities from different demand sectors are assumed constant throughout the analysis period, with demand growth as detailed in Annex II. Only policies with concrete measures are considered in the scenario modelling for the current policy scenario. Plan/strategy/policy documents without concrete measures enforced are not considered but are compared with scenario result findings later in this Road Map.

3.1.3. SDG scenario

The SDG scenario builds on the current policy settings to provide recommendations for achieving the SDG 7 targets. This scenario aims to achieve the SDG 7 targets, including universal access to electricity and clean cooking fuel, substantially increasing the renewable energy share and doubling the rate of energy efficiency improvement. For clean cooking, different technologies (electric cooking stoves, LPG cooking stoves, natural gas stoves and improved cooking stoves) have been assessed, with subsequent recommendation of the uptake of the most appropriate technology. Energy intensity has been modelled to help achieve the SDG 7 target. It also allows the achievement of the country's unconditional NDC target.

In addition, it addresses the opportunities in phasing out unclean heating technologies in the residential sector. While clean heating is not specifically addressed in SDG 7 targets, it is an important issue in the region, which contributes towards indoor air pollution and associated health impacts. A substantial amount of Pakistan's population relies on the traditional solid fuel heating stove, particularly in low-income households, making them susceptible to the consequences of inadequate heating and increased risks of respiratory illness (Janjua and others, 2012).

3.1.4. Ambitious scenario

Like the SDG scenario, the ambitious scenario aims to achieve the SDG 7 targets. In addition, these scenarios also look to increasing the socio-economic and environmental benefits for the country from raising its ambition beyond just achieving the SDG 7 targets, such as by further improving its energy efficiency beyond the SDG 7.3 target and meeting its conditional NDC target.

Further analysis shows that there are ample opportunities for Pakistan to raise its ambition beyond just achieving the SDG 7 targets. More can be done from a whole-economy perspective for Pakistan to decarbonize its energy system and achieve a higher energy efficiency improvement rate. For example, additional energy efficiency measures can substantially increase energy savings and reduce fuel imports.

3.2. Assumptions

The energy demand is estimated by using the activity level and energy intensity in the LEAP model. The demand outlook throughout the

NEXSTEP analysis period is influenced by factors such as annual population growth and annual GDP growth. The assumptions used in the NEXSTEP modelling are further detailed in Annex II, while table 2 provides a summary of key modelling assumptions for the three main scenarios (i.e., BAU, CPS and SDG scenarios).

Table 2. Important factors, targets and assumptions used in NEXSTEP modelling

Parameters	Business as usual scenario	Current policy scenario	Sustainable Development Goal scenario
Economic growth	4.3 per cent per annum (Following the projected GDP on the Base Scenario under Indicative Generation Capacity Expansion Plan (IGCEP 2022-31)		
Population growth	2 per cent per annum		
Urbanization rate	37.4 per cent in 2021, growing to 39.5 per cent in 2030[8]		
Commercial floor space	Assumed annual energy consumption increasing at the same growth as GDP		
Industrial activity	Assumed annual energy consumption increasing at the same growth as GDP		
Transport activity	Passenger transport activities and freight transport activities are assumed growing at a rate similar to the growth in GDP per capita		
Residential activity	The appliance ownership for electrical appliances is projected to grow at a rate like the growth in GDP per capita.		
Access to electricity	Projected based on the historical penetration rate between the 2017-2020 period (CAGR 1.77 per cent). 100 per cent access to electricity in the urban area can be achieved in 2022 whereas in the rural area it can be achieved in 2027.		
Access to clean cooking fuels	Projected based on the historical penetration rate between the 2000-2020 period.[9] Clean cooking access rate is projected to reach 59.2 per cent in 2030.	Projected based on the historical penetration rate between the 2000-2018 period. Clean cooking access rate is projected to reach 59.2 per cent in 2030. There are no additional governmental measures planned.	In alignment with the SDG7 target, 100 per cent clean cooking access rate is considered through the promotion of electric cooking stove in urban area and ICS in rural area.
Energy efficiency	Additional energy efficiency measures not applied	Improvement based on current policies, including the one in the NEECA Strategic Plan, 2021-2023	Doubling the improvement in energy efficiency achieved
Power plant	Considers 2021 fuel mix in power generation and grid emissions	Considers capacity expansion in accordance with the Base Scenario under Indicative Generation Capacity Expansion Plan IGCEP, 2022-31	

8 This assumes that the urbanization rate grows with an annual rate of 0.61 per cent, with reference to the national historical urbanization growth from 2010 to 2020.

9 The clean cooking access rate is linearly projected based on the clean cooking improvement between 2000 and 2020. The clean cooking access rate is assumed at 24 per cent and 48.4 per cent in 2000 and in 2020, respectively (World Health Organization, 2022b).

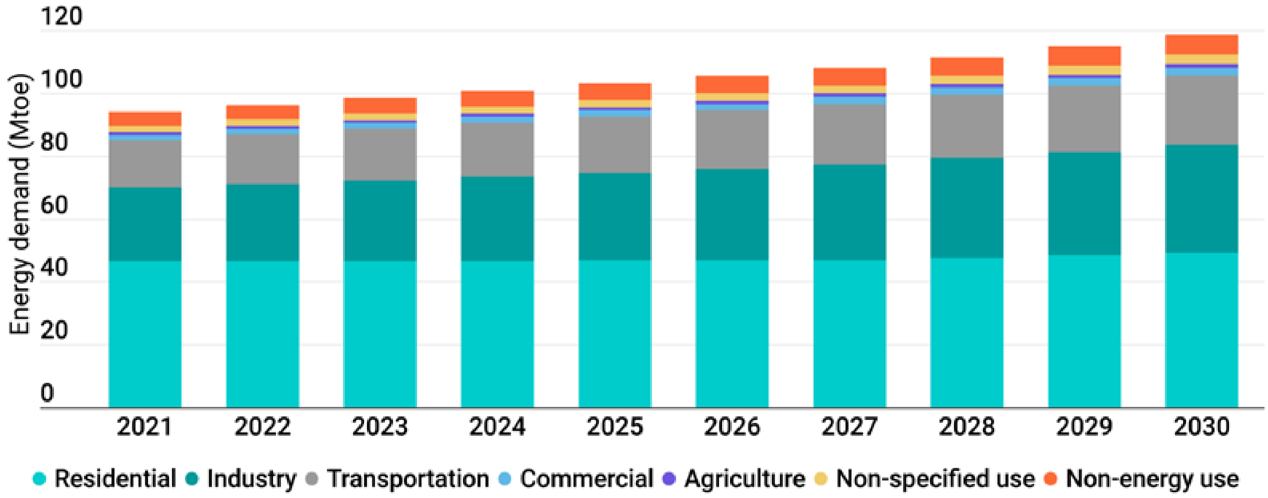
4. Energy transition outlook in the current policy scenario

This section presents the key results of modelling under the NEXSTEP's three main scenarios, focusing on impacts in key areas of the economy and the energy sector.

4.1. Demand

The total final energy consumption under the BAU scenario is expected to increase from 94.1 Mtoe in 2021 to 118.6 Mtoe in 2030 (figure 5), an average annual growth rate of 2.6 per cent. In 2030, the residential sector consumption will be, by far, still the largest at 41.4 per cent, followed by the industrial sector, 29.1 per cent, the transportation sector, 18.5 per cent, the commercial sector, 2.1 per cent and the agricultural sector, 1 per cent. The remaining 7.9 per cent accounts for non-specified energy use and non-energy use.

Figure 5. Energy demand outlook in the BAU scenario, 2021-2030



Under the current policy setting, the demand for total final energy is expected to increase from 94.1 Mtoe in 2021 to 114.6 Mtoe in 2030. The 4 Mtoe reduction in energy demand compared to the BAU scenario is due to the adoption of energy efficiency measures in the residential, industry, transport and agriculture sectors. The residential sector consumption will remain the largest at 42.3 per cent, followed by the industrial sector at 28.4 per cent, the transport sector at 18.3 per cent and the commercial sector at 2.1 per cent. The remaining 8.9 per cent is attributable to non-energy usage at 5.7 per cent, other non-specified use at 2.5 per cent and the agriculture sector at 0.7 per cent. The sectoral energy efficiency measures are described further below.

4.1.1. Residential sector

Under the current policy setting, the residential sector will continue to dominate Pakistan's TFEC, with a 42.3 per cent share in 2030. The residential sector will consume 48.4 Mtoe, an annual growth of 1.7 per cent, up from 46.4 Mtoe in 2021. The urban and rural split of energy consumption would be 29.3 per cent and 70.7 per cent, respectively. In terms of fuel, biomass will be the main energy source at just around 62 per cent, followed by natural gas at 23.1 per cent and electricity at 13.7 per cent. Biomass and natural gas are used for cooking and heating purposes.

In the building sector, NEECA targeted a total saving of up to 0.5 Mtoe by 2023 through the implementation of building codes, development of building energy management systems, and launching of mandatory appliances labelling regimes in the buildings. The Government of Pakistan has put effort into developing MEPS for most of those appliances for lighting, electric fans, refrigeration, electric motors and air conditioners. It appears that the Government may be able to achieve the 2023 targets for energy efficiency. However, the implementation must be significantly accelerated in the coming years. In terms of a green building code, the improvement of thermal efficiency would potentially reduce natural gas heater consumption in urban areas. Table 3 provides the details of energy and emissions savings by different measures under the CP scenario by 2023 and 2030 (forecast) in alignment with the targets set in the NEECA Strategic Plan, 2020-2023.

Table 3. **Energy saving and GHG emission reduction in the residential sector in the CP scenario, compared to the BAU scenario, by 2023 and 2030**

Sector	NEECA target	2023		2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*	Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*
Lighting	100 ktoe reduction by 2023 through MEPS for lighting (Ministry of Energy, Power Division, 2020) (modelled as 33 per cent adoption of energy-efficient lighting)	100.4	0.40	140.7	0.57
Air conditioners and refrigerators	100 ktoe reduction by 2023 through MEPS for air conditioners and refrigerators (Ministry of Energy, Power Division, 2020) (modelled as 33 per cent adoption of energy efficient AC and fridges)	96.9	0.39	135.8	0.55
Electric fans	100 ktoe reduction by 2023 through MEPS electric fans (Ministry of Energy, Power Division, 2020) (modelled as 30 per cent adoption of energy efficient fans)	104.7	0.42	146.7	0.59
Electric motors	100 ktoe reduction by 2023 through MEPS for electric motors (Ministry of Energy, Power Division, 2020) (modelled as 50 per cent adoption of energy efficient water pump)	101.4	0.41	142.1	0.57
Building Code (Thermal)	100 ktoe reduction by 2023 through building thermal efficiency (Ministry of Energy, Power Division, 2020) (modelled as 12 per cent of intensity reduction on natural gas for heating in urban areas)	106.8	0.25	128.0	0.29
Total		**510.3**	**1.87**	**693.3**	**2.57**

* GHG emission reduction for electrical appliances is calculated using the grid emission factor 0.346 kg CO_{2-e}/kWh. This emission factor is calculated from the power sector's emission and generation in Pakistan, from the modelling result.

4.1.2. Industrial sector

in the CPS, the industrial sector will consume 32.6 Mtoe in 2030, an annual growth of 4.1 per cent, up from 23.6 Mtoe in 2021. Within the industrial sector, 60.3 per cent of energy consumption will be by cement and brick kiln industries and 21.3 per cent by textile and wearing apparel industries. Food, beverages and tobacco industries will account for 4.4 per cent while the fertilizer industry will use 1.5 per cent of energy in 2030.

In the industrial sector, NEECA targeted a total saving up to 1.3 Mtoe to be achieved in 2023 by improving energy efficiency in electrical systems, optimization of thermal utilities, and carrying out mandatory industrial energy audits. It seems that the current effort has been made in these industries and the Government may be able to achieve the 2023 NEECA target. Table 4 shows energy and emissions saving by different measures, in accordance with the NEECA Strategic Plan, 2020-2023, by 2023 and 2030 (forecast) in the CPS compared to the BAU scenario. However, a significant effort must be made in the long term to decarbonize the industry, particularly to reduce the usage of coal.

Table 4. Energy efficiency measures in industrial sector – CP scenario compared to the BAU scenario by 2023 and 2030

Sector	NEECA targets	2023		2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*	Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*
Textiles	200 ktoe reduction by 2023 through energy meter and automatic control (Ministry of Energy, Power Division, 2020) (modelled as 24 per cent energy intensity reduction for electricity in textile industry)	267.6	1.08	359.3	1.45
Food and beverages	100 ktoe reduction by 2023 through heat recovery and co-gen in sugar mills (Ministry of Energy, Power Division, 2020) (modelled as 18 per cent energy intensity reduction for natural gas in F&B industries)	101.4	0.24	136.1	0.32
Brick Kiln	100 ktoe reduction by 2023 through zig-zag technology brick kiln through partial implementation (Ministry of Energy, Power Division, 2020) (modelled as 4 per cent energy intensity reduction for biomass and coal in brick kiln industry)	301.2	0.69	404.4	0.94

Sector	NEECA targets	2023		2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*	Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*
Cement	100 ktoe reduction by 2023 through overall energy efficiency (Ministry of Energy, Power Division, 2020) (modelled as 2.5 per cent energy intensity reduction for cement)	186.3	0.68	250.1	0.91
Wood and paper	100 ktoe reduction by 2023 through tuning up boiler burner (Ministry of Energy, Power Division, 2020) (modelled as 40 per cent energy intensity reduction for natural gas in the wood and paper industry)	47.3	0.11	63.6	0.15
Fertilizer	500 ktoe reduction by 2023 through energy efficient steam Haber Bosch (Ministry of Energy, Power Division, 2020) (modelled as 67 per cent energy intensity reduction for natural gas in the fertilizer industry)	495.3	1.16	665.1	1.56
Total		**1399.1**	**3.96**	**1,878.6**	**5.33**

* GHG emission reduction for electrical equipment is calculated using the grid emission factor 0.346 kg CO_{2-e}/kWh.

4.1.3. Transport sector

Pakistan's transport sector consists of road transport, rail transport and aviation. The total energy demand is projected to be 20.9 Mtoe in 2030, an increase from 15 Mtoe in 2021 under the CP scenario. While its growth is much greater than that of the residential and industrial sectors, it will continue to be the third-largest energy consuming sector in 2030. Among the passenger vehicle categories in 2030, motorcycles will consume the most at 4.2 Mtoe (25.4 per cent), followed by private cars at 4 Mtoe (24.5 per cent), buses at 2.8 Mtoe (17 per cent) and auto- rickshaws at 2.6 Mtoe (15.7 per cent). The remaining demand will be for taxis, minibuses, tractors and other vehicles.

The Government of Pakistan has set a target for reducing the energy demand in the transport sector. Analysis indicates that the Government may be able to achieve the emission reduction through a fleet management system. However, in terms of electric vehicles (EVs), the 200 ktoe energy saving target is unlikely to be achieved by 2023 since the progress of EV penetration is very slow. Table 5 presents energy and emissions saving by measures as stipulated in the NEECA Strategic Plan, 2020-2023 by 2023 and 2030 (forecast), in the CP scenario compared to the BAU scenario.

Table 5. **Energy efficiency measures in the transport sector in the CP scenario compared to the BAU scenario by 2023 and 2030**

Sector	NEECA targets	2023		2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*	Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*
ICE vehicle	300 ktoe Reduction by 2023 through tune up centre plus fleet management (Ministry of Energy, Power Division, 2020) (modelled as 3 per cent energy intensity reduction for all road transport)	303.9	0.90	408.1	1.20
Electric Vehicle	Electric Vehicle Policy of 30 per cent electric vehicle sales of cars and trucks in 2030, and 50 per cent electric two-and three-wheelers and electric buses share (Ministry of Climate Change, 2020) coupled with 200 ktoe reduction by 2023 through efficiency standards in EVs (Ministry of Energy, Power Division, 2020) (modelled as 10 per cent energy intensity reduction for all EV)	187.8	0.65	622.5	3.02
Total		**491.7**	**1.55**	**1,030.6**	**4.22**

* GHG emission reduction for electrical equipment is calculated using the grid emission factor 0.346 kg CO_{2-e}/kWh.

4.1.4. Commercial and agriculture sectors

Total energy consumption in the commercial sector under the CPS will increase from 1.7 Mtoe in 2021, at an average annual growth of 4.2 per cent, to 2.5 Mtoe in 2030. On the other hand, total energy consumption in the agriculture sector under the CPS will decrease from 0.9 Mtoe in 2021 to 0.8 Mtoe in 2030. In the agriculture sector, a total saving of up to 0.1 Mtoe will be achieved by replacing inefficient tube wells. The Government of Pakistan in 2022 has also planned to convert 1.2 million diesel-operated tube wells to solar electricity, with the aim of reducing the input cost, ensure food security, and saving the earnings of the local farmers (The News, 2022). To strengthen this initiative, the Government has decided to develop a taskforce that can develop the process and engage different financial units (banks etc.) to finance this facility. Under this facility, farmers would be allowed to repay the loans in instalments up to three years. The replacement of the tube wells with solar pumps will reduce the energy demand in the agricultural sector by 0.4 Mtoe and emissions by 0.26 $MtCO_{2-e}$ in 2030. Table 6 shows energy and emissions savings from the commercial and agriculture sectors by 2023 and 2030 (forecast), in alignment with the NEECA Strategic Plan, 2020-2023 in the CPS compared with the BAU scenario.

Table 6. Energy efficiency measures in the commercial and agricultural sectors – CP scenario compared with BAU scenario by 2023 and 2030

Sector	NEECA targets	2023		2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*	Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*
Commercial	100 ktoe reduction target by 2023 through building thermal efficiency (Ministry of Energy, Power Division, 2020) (modelled as 10 per cent of intensity reduction of natural gas for heating in commercial sector)	65.3	0.15	87.7	0.21
Agriculture	200 ktoe reduction by 2023 through efficient pumps (Ministry of Energy, Power Division, 2020) (modelled as: replacement of 1.2 million of tube wells with solar pumps**)	96.1	0.06	393.4	0.26
Total		**161.4**	**0.21**	**481.1**	**0.47**

* GHG emission reduction for electrical appliance is calculated using the grid emission factor 0.346 kg CO_{2-e}/kWh.

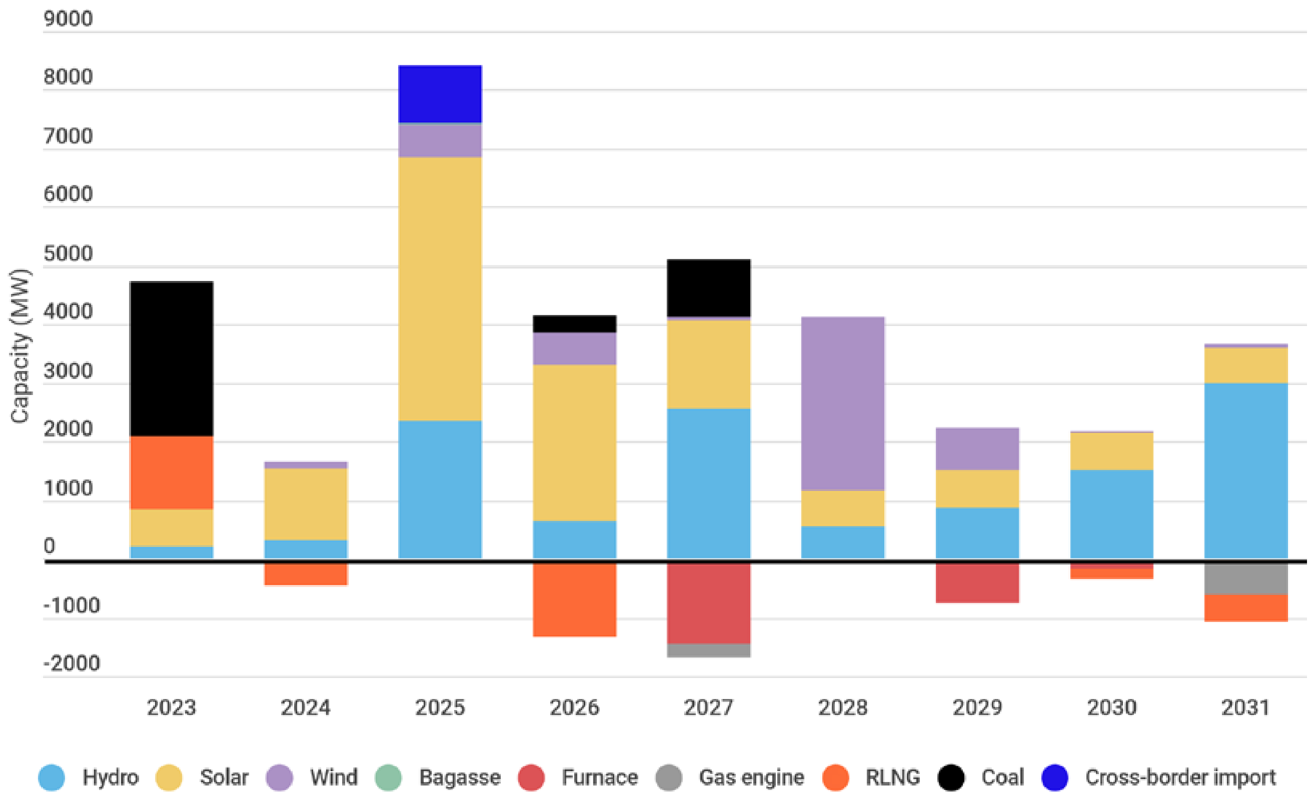
** Ministry of Energy announcement in July (The News, 2022).

4.2. Power sector

4.2.1. Capacity

Following approval by the National Electric Power Regulatory Authority (NEPRA), Pakistan's National Transmission and Despatch Company (NTDC) approved and put forward the updated iteration of the Indicative Generation and Capacity Expansion Plan (IGCEP) in late September 2022. The IGCEP is more focused towards the deployment of renewable energy (solar and wind) with the renewable energy share increasing to at least 30 per cent by 2031 (against 21 per cent in the previous iteration) (communication with SDPI and PPIB). The Government of Pakistan has also committed to retiring some thermal power plants. The power capacity expansion and retirement under the current policy scenario is as projected in figure 6. This assumes that the expansion plan is carried out according to the planned timeline.

Figure 6. Power capacity expansion and retirement plan



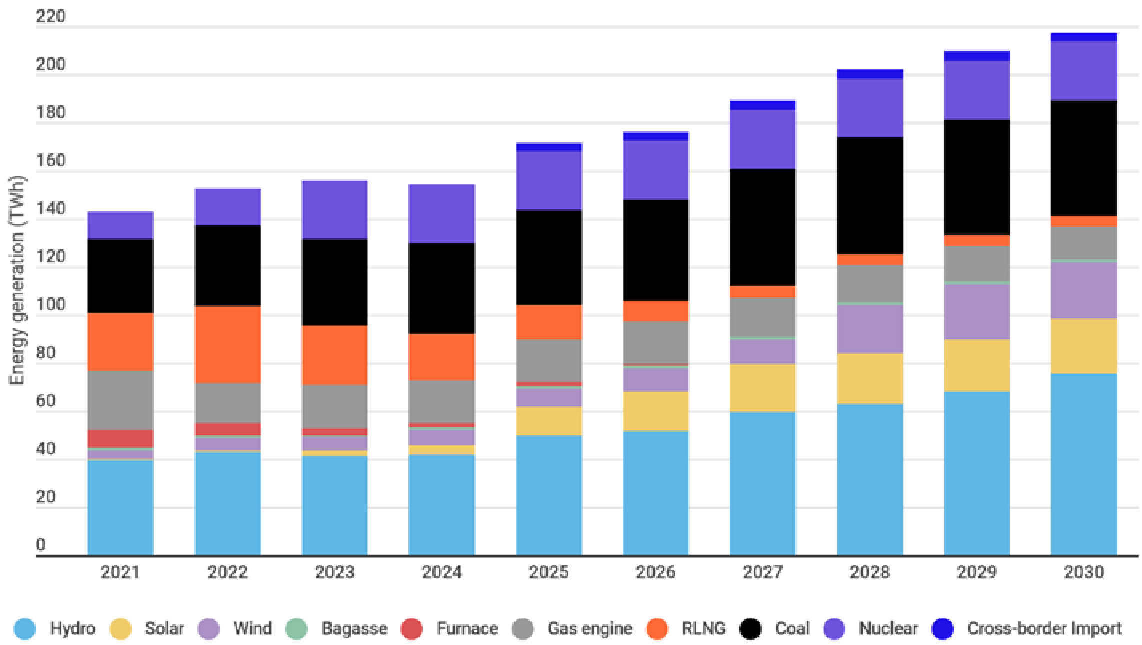
The given information on IGCEP, comprising both NTDC and K-Electric based systems, has been incorporated into the NEXSTEP model in both the CP and SDG scenarios. Therefore, there is no difference between the CP and SDG scenarios in terms of power generation, although the energy requirement is different. Electricity demand remains the same while demand for other energy sources decreases in the SDG scenario, compared with the CP scenario. Pakistan also has around 1.4 GW of captive power plants. These captive power plants are used occasionally and only generate around 136 GWh per annum. Due to the limited amount of technical data and information on these captive power plants, NEXSTEP does not incorporate them into the model. It must be noted that since the IGCEP is revised annually, the information provided here reflects the information on the 2022 IGCEP (2022-2031).

Pakistan also aims to establish a Competitive Trading Bilateral Contract Market (CTBCM). CTBCM model will transition the market from a single buyer to a competitive wholesale electricity market. This transition will enable the Bulk Power Consumers (BPCs) (currently having 16 per cent share in the market) to choose a supplier of their own choice. This transition will also enable DISCOs, the System Operator, NTDC, and other power sector entities to perform their role in an effective manner. This particular analysis is not within the scope of this SDG 7 Road Map; therefore, CTBCM is not incorporated into the model.

4.2.2. Generation

In both the CP and SDG scenarios, electricity generation is expected to rise from 142.8 TWh in 2021 to 217.2 TWh in 2030. The hydropower and renewable energy share of electricity supply (solar, wind, bagasse and cross-border marine generation) will increase from 31.3 per cent in 2021 to 61.8 per cent in 2030, with the remaining coming from thermal generation (figure 7). The increased share is due to the rapid increase in solar and wind capacities (as per the power capacity expansion plan) during the analysis period.

Figure 7. Electricity supply by fuel, 2021-2030, CP and SDG scenarios



The total electricity requirement (considering both final energy demand as well as transmission and distribution losses) in the CP and SDG scenarios by 2030 would be 196.4 TWh and 193.3 TWh, respectively. It is possible that Pakistan will meet its electricity requirements through domestic generation under the current expansion plan.

In the power sector, NEECA targeted a total saving up to 0.4 Mtoe to be achieved by 2023 through the intervention of various energy efficiency (EE) programmes which include transformer and LT capacitor installations, carrying out heat rate assessments, and enforcement of mandatory energy audits in the power sector. Table 7 shows energy and emissions savings from the power sector in the CP scenario compared to the BAU scenario.

Table 7. Energy efficiency measures in the power sector in the CP scenario compared to the BAU scenario by 2023 and 2030

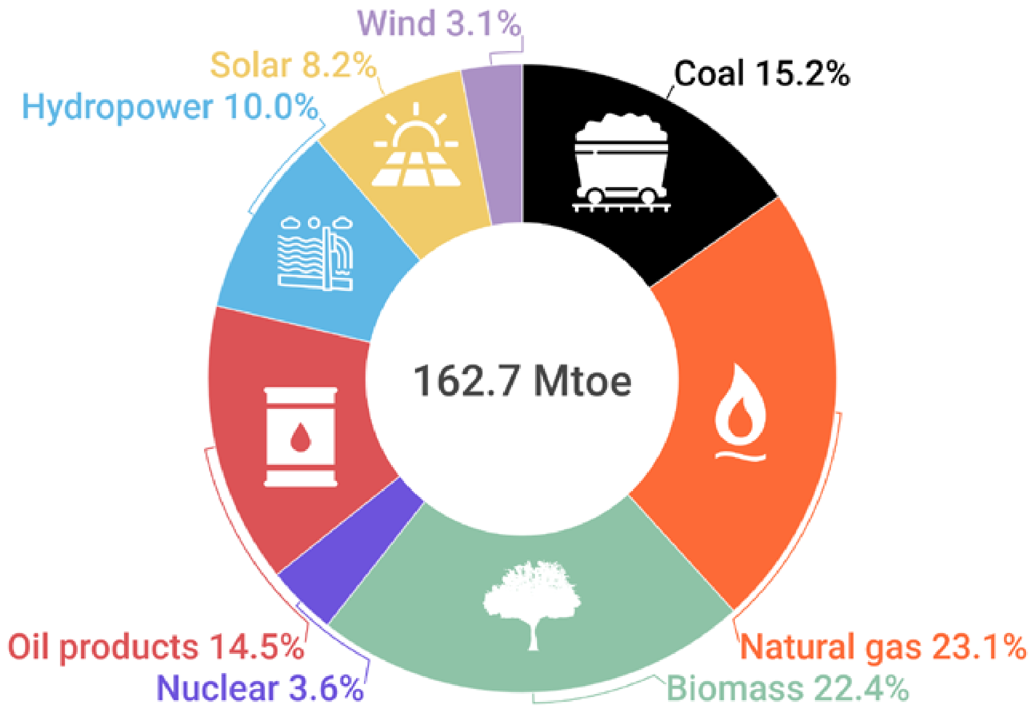
Sector	NEECA targets	2023		2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*	Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)*
Transmission and Distribution	400 ktoe reduction by 2023 through improvement in the intervention of various energy efficiency (EE) programmes, which includes transformer and LT capacitor programmes, carrying out heat rate assessments, and enforcement of mandatory energy audits in the power sector (Ministry of Energy, Power Division, 2021.	411.0	1.66	531.5	2.14
Total		**411.0**	**1.66**	**531.5**	**2.14**

* GHG emission reduction for electrical appliance is calculated using the grid emission factor 0.346 kg CO_{2-e}/kWh.

4.3. Supply

In the current policy scenario, the TPES is forecast to increase from 119.6 Mtoe in 2021 to 162.7 Mtoe in 2030. As shown in figure 8, natural gas is the dominating fuel supply, followed by biomass, coal, oil, renewables and nuclear. The fuel shares in 2030 are projected to be natural gas – 37.5 Mtoe, biomass – 36.4 Mtoe, coal – 24.7 Mtoe, crude oil and oil products – 23.5 Mtoe, renewables – 8.3 Mtoe, hydropower – 16.2 Mtoe and nuclear – 5.9 Mtoe. The primary supply of renewables and hydropower have been ramped up significantly, compared with the value in 2021, from 1.1 Mtoe and 8.5 Mtoe respectively.

Figure 8. Total primary energy supply by fuel type in 2030, CPS scenario



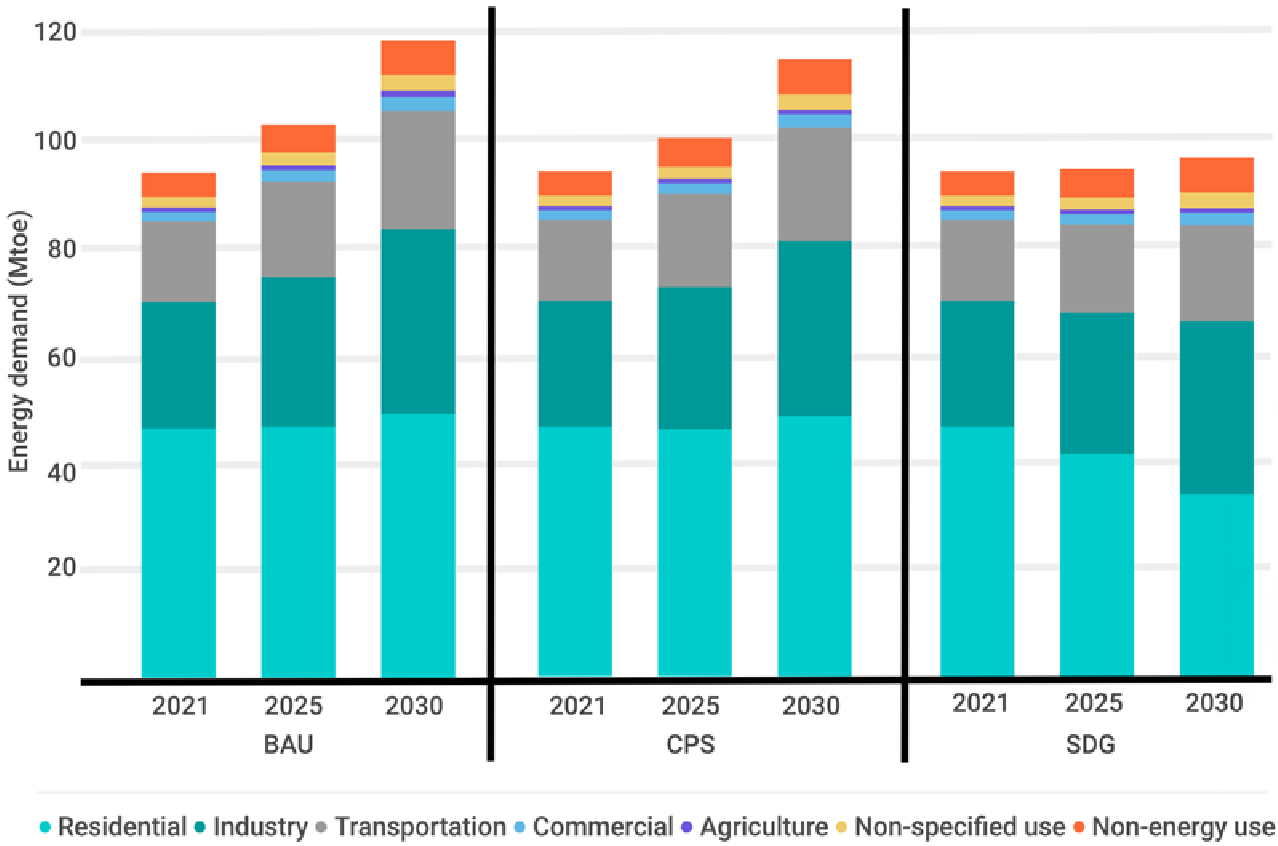
5. SDG scenario: An assessment of SDG 7 targets and indicators

In this section, first a brief overview of the energy demand and supply under the SDG scenario is provided. Later, the results are evaluated against the SDG 7 and NDC targets and other relevant indicators. Finally, Pakistan's current energy policies are evaluated based on the outputs from the NEXSTEP analysis in order to highlight any policy gap.

5.1. Energy demand and supply

In the SDG scenario, TFEC increases from 94.1 Mtoe in 2021 to 96.3 Mtoe in 2030, a reduction of 18.3 Mtoe (15.9 per cent) compared with the CP scenario (figure 9). This is due to a substantial decrease in demand from the residential sector, due to the phasing out of unclean and inefficient cooking and heating technologies. In 2030, the residential sector consumption will be, by far, still the largest at 35.2 per cent, followed by the industry sector, 33.5 per cent, transport sector, 18.2 per cent, commercial sector, 2.6 per cent and agriculture sector, 0.8 per cent.

Figure 9. Comparison of energy demand between scenarios



An additional 14.5 Mtoe energy saving in the residential sector can be attained by 2030 in the SDG scenario (table 8). A substantial decrease in demand from the residential sector occurs due to the phasing out of unclean and inefficient cooking and heating technologies.

Clean heating is not specifically mentioned in the SDG 7 targets, yet it is an important issue in Pakistan, as it contributes to indoor air pollution and associated health impacts. In 2021, around 20.5 million of Pakistan's households relied on traditional solid fuel heating stoves, particularly low-income households in the rural areas, making them susceptible to the consequences of inadequate heating and increased risks of respiratory illness (Janjua and others, 2012) from indoor air pollution. The SDG scenario looks at the usage of improved heating technologies (HELE) solid fuel stoves in rural areas for achieving the goal before cleaner options become more affordable. In addition, while the use of natural gas for heating needs to be reduced, energy efficient gas appliances must be considered to ensure its efficient use in the short term. NEXSTEP has identified a potential saving of 0.19 Mtoe from 30 per cent improvements to natural gas heater efficiency.

Furthermore, since the residential sector has a significant share of energy demand, in this scenario, more intensive energy efficiency measures are considered. The measures include a higher adoption of energy efficient equipment compared to the share presented in the CP scenario. In addition, MEPS for television is introduced in this scenario. These measures can substantially increase energy savings in the residential sector in Pakistan.

Table 8. Energy saving and GHG emission reduction in the residential sector under the SDG scenario by 2030, compared to BAU

Sector	Measure	2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)
Cooking	Replacing solid fuel stoves with electric stoves in urban areas and ICS stoves in rural areas	11,086.5	4.11
Heating	Replacing traditional heating stoves with HELE stoves in rural areas	2,426.8	1.02
Heating	Improvement of natural gas heater efficiency by 30 per cent	192.0	0.45
Lighting	Doubling the adoption of LED lights (64.4 per cent penetration of LED lights)	133.8	0.54
AC and refrigerators	Doubling the adoption of EE appliances (65.4 per cent penetration of EE AC and refrigerators)	131.5	0.53
Electric fans	Doubling the adoption of EE fans (64.4 per cent penetration of EE fans)	168.3	0.68
Water pumps	Doubling the adoption of EE water pumps (64.7 per cent penetration of EE pumps)	41.8	0.17
Televisions	Promoting the adoption of EE televisions (64.8 per cent penetration of EE televisions)	358.8	1.45
Total		**14,539.4**	**8.95**

Additional energy efficiency measures can substantially increase energy savings in the industrial sector in Pakistan through the acceleration and full implementation of zig-zag brick kiln adoption (table 9). A study mentioned that full implementation of zig-zag brick kilns might reduce energy use by 17.8 per cent (Abbas and others, 2021).

Table 9. Additional energy saving and GHG emission reduction in industrial sector under SDG scenario by 2030

Sector	Measure	2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)
Brick kilns	The acceleration and full implementation of zig-zag brick kilns by 2030	359.1	0.83

Together with electric vehicles, Pakistan can further save the energy demand by encouraging mass transit and public transport systems as well as improving fuel standards. Pakistan aims to improve mass public transport; however, there has not been a publicly announced target. NEXSTEP investigated what will happen if the Government increases the passenger-km of public transport by 10 per cent and improves the fuel economy for passenger car by 25 per cent from 12 km/l to 15 km/l. As shown in table 10, there will be an additional 3.4 Mtoe energy saving and 9.6 GHG emission reduction compared with the CP scenario.

Table 10. Additional energy saving and GHG emission reduction in transport sector under SDG scenario by 2030

Sector	Measure	2030	
		Energy demand reduction (ktoe)	GHG emission reduction ($MtCO_{2-e}$)
Mass transport	Encouraging public transport by improving services is modelled in the scenario, with the passenger-km for public transport increasing by 10 per cent by 2030 from the current state. This is expected to reduce motorcycle and private car passenger-km.	1,786.4	4.95
Fuel standard	Fuel economy standards for passenger cars to improve average fuel economy from 12 km/l to 15 km/l, based on the promotion of hybrid vehicles.	1,573.1	4.62
Total		**3,359.4**	**9.57**

Under the SDG scenario, the total primary energy supply is estimated to be 144.6 Mtoe by 2030, an 18.1 Mtoe reduction compared with the CP scenario. The phasing out of traditional biomass in cooking and heating will reduce biomass supply by 14.7 Mtoe. The remaining reduction comes from natural gas, oil products and coal due to additional energy efficiency improvements. The substantial decrease in primary energy supply not only reduces Pakistan's energy intensity, but also enhances its energy security by reducing the need for fuel imports.

5.2. SDG 7 targets

5.2.1. SDG 7.1.1, Access to electricity

The electrification rate in Pakistan was 93.6 per cent in 2021. However, only 77 per cent of the population had access to grid electricity. Therefore, there are improvement opportunities to provide better electricity services to its citizens. In all scenarios, it is projected that 100 per cent access to electricity in the urban areas can be achieved in 2022, whereas in the rural areas it can be achieved in 2027. Table 11 explains the relevant policy that is likely to accelerate the access to electricity.

Table 11. Assessment of access to electricity

Existing policy	NEXSTEP analysis – gaps and recommendations
The National Electricity Policy, 2021 (Government of Pakistan, 2021) has proposed a three-pronged goal for the power sector, i.e., access to affordable energy, energy security (uninterrupted supply), and sustainable energy.	Pakistan will achieve universal access to electricity by 2027

5.2.2. SDG 7.1.2, Access to clean fuels and technologies for cooking

Accelerated effort is required to achieve universal access to clean cooking. As of 2021, 49.3 per cent of households relied on polluting cooking technologies, specifically solid fuel stoves (assuming biomass as primary fuel). Access to clean cooking fuels and technologies will not be achieved in the current policy scenarios – it will reach only 59.2 per cent in 2030, leaving 40.8 per cent of the population relying on inefficient and hazardous cooking fuels and technologies. However, under the SDG scenario, the clean cooking access rate is set to achieve universal access (100 per cent) by 2030 (figure 10).

Figure 10. Pakistan's access to clean cooking in the BAU, CPS and SDG scenarios

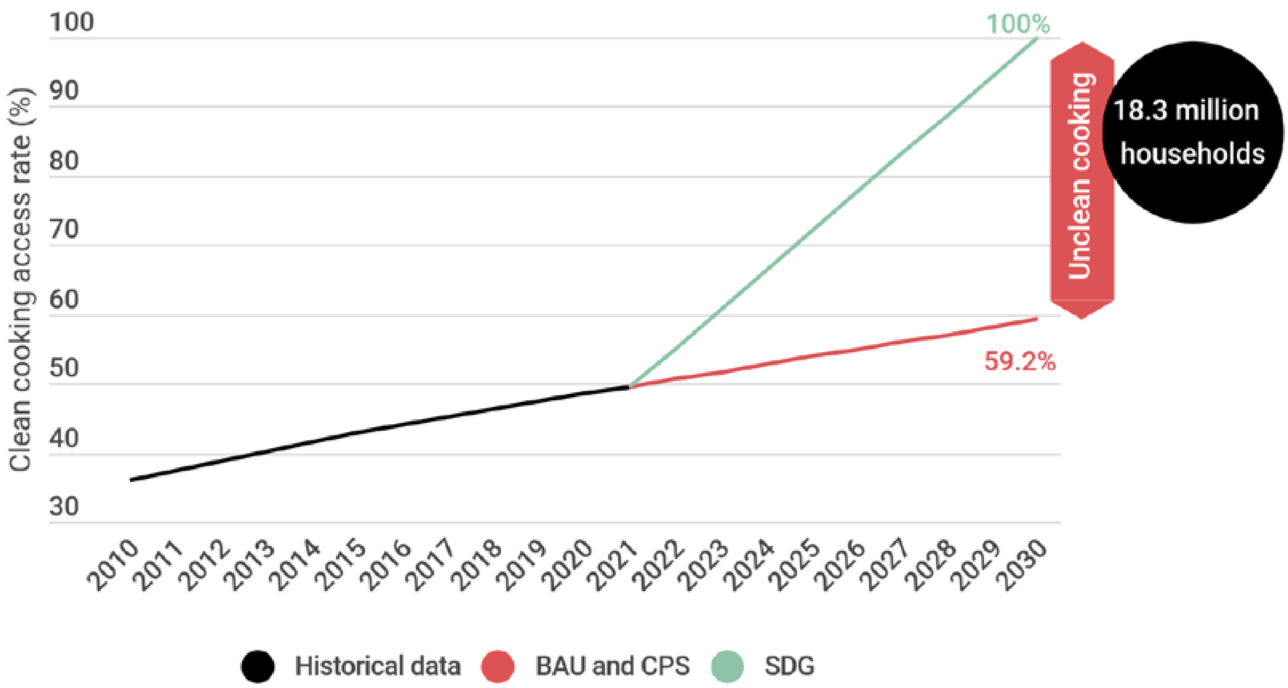


Table 12 summarises the estimated annualized cost of different cooking technologies in the context of Pakistan. Annex IV summarizes the cost and technical assumptions used in the economic analysis. The NEXSTEP analysis indicates that the use of electric cooking stoves in urban areas and improved cooking stoves as the most appropriate technology for filling in the gap.

Table 12. **Annualized cost of cooking technologies**

Technology	Annualized cost
Electric cooking stove	US$ 162
Improved cooking stove (ICS)	US$ 89
Natural gas stove	US$ 166
LPG stove	US$ 208

Electric cooking stoves provide the most appropriate solution for urban areas due to cost and environmental effectiveness. Although there is an under-investment in transmission and distribution (T&D) to comply with the increased requirements of electricity, electric stove is still a better choice compared to natural gas stove in urban areas. The availability of gas in Pakistan is becoming a constantly increasing challenge given the depleting resources and the supply of LNG to the industrial sector. The residential sector would soon face the challenge of gas shortage. Electric cooking stoves may not be suitable for households using off-grid electricity systems in rural area, as the appliance requires substantial power supply capacity. The better options would be the other modern and efficient technologies, such as improved cooking stoves in rural areas. Box 1 explains the basis for evaluation of clean cooking technologies. Table 13 summarises the gap assessment and recommendations to address the clean cooking in Pakistan.

Table 13. **Assessment of access to clean cooking**

Existing policy	NEXSTEP analysis – gaps and recommendations
Not available.	**Gap:** The NEXSTEP analysis projects that Pakistan may only reach a 59.2 per cent clean cooking access rate as per the historical improvement trend. **SDG scenario:** In consideration of comments from stakeholders, the NEXSTEP analysis suggests bridging the remaining gap with electric cooking stoves in urban areas and improved cooking stoves in rural areas as the most appropriate clean cooking solution.

Box 1. Clean cooking technology evaluated

Electric cooking stoves

Electric cooking technology is classed as Level 5 in the World Bank Multi-Tier Framework (MTF) for Indoor Air Quality Measurement. Electric cooking stoves are more efficient than other cooking stoves, including gas stoves. Electric cooking stoves can generally be divided into two types – solid plate and induction plate. While solid plate cooking stoves use a heating element to transmit radiant energy to the food and reach about 70 per cent efficiency, induction plate cooking stoves, on the other hand, use electromagnetic energy to directly heat pots and pans, and can be up to 90 per cent efficient.

Improved cooking stoves

Studies suggest that ICS programmes often have low adoption rates due to inconvenience of use, preference for traditional cooking stoves, and the need for frequent maintenance and repairs. ICS programmes initially require strong advocacy to promote adoption, after which they require ongoing follow-up, monitoring, training, maintenance and repairs in order to facilitate continuing usage. In addition, based on the World Health Organization (WHO) guidelines for emission rates for clean cooking, only certain types of ICS technology comply, particularly when considering the fact that cooking stove emissions in the field are often higher than they are in laboratory settings used for testing. Tier 3+ ICS, which meets the WHO clean cooking guidelines, has the potential to reduce GHG emissions and provide socio-economic and health benefits, when it is promoted in carefully planned programmes. It can also play an intermediary role until cleaner options become more affordable.

LPG cooking stoves

LPG is constrained due to fuel import dependency and supply chain challenges. LPG cooking stoves generate lower indoor air pollution compared to ICS. They are classified as Level 4 in the World Bank MTF[10] for cooking exposure, and reduce indoor air pollution by 90 per cent compared to traditional cooking stoves.

Natural gas stoves

Clean cooking with natural gas is not a viable solution for rural households as it would require building a gas distribution infrastructure, which is extremely difficult for remote locations. In addition, the requirement for natural gas is competing with the needs for industrial and power sectors. Since the reserve of natural gas in Pakistan has been depleted, fuel imports cannot be avoided. The current geopolitical situation has worsened the situation since the price of natural gas has also skyrocketed.

5.2.3. SDG 7.2, Renewable energy

SDG 7.2 does not have a quantitative target, but encourages a "substantial" increase of the renewable energy share in TFEC. The NEXSTEP methodology first estimates the net increase in energy demand in response to universal energy access (both electricity and clean cooking) and energy efficiency improvement. It then uses the unconditional NDC target for the energy sector to estimate the optimum renewable energy share in TFEC, if necessary. Accordingly, the share of renewable energy (excluding traditional biomass usage) in TFEC in 2030 will be 23.5 per cent in the SDG scenario compared to 6.8 per cent in CPS scenario (figure 11). The increase from 3.2 per cent in 2021 is attributable to the higher rate of increase in electricity consumption (which is dominantly RE-based) as the energy system gets more efficient as well as increase the usage of modern biomass. Table 14 further explains how the RE share will increase in the SDG scenario.

10 See http://documents.worldbank.org/curated/en/937711468320944879/pdf/88699-REVISED-LW16-Fin-Logo-OKR.pdf

Figure 11. Renewable energy in TPES and TFEC, 2030

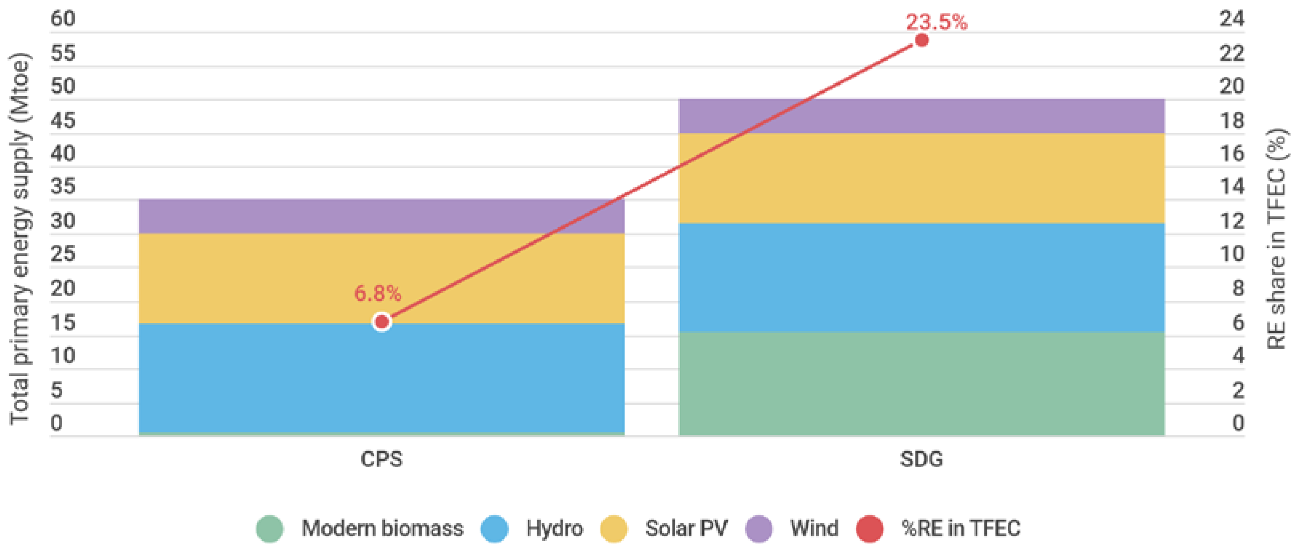


Table 14. Assessment of renewable energy share in TFEC

Existing policy	NEXSTEP analysis – gaps and recommendations
Alternative and Renewable Energy (ARE) Policy 2019 (Government of Pakistan, 2019) sets a target of at least 20 per cent on-grid RE generation by capacity by the year 2025 and at least 30 per cent by 2030. The alternative and renewable technologies covered in this policy are biogas, biomass, waste-to-energy, geothermal, hydrogen, synthetic gas, ocean/tidal/wave energy, solar, wind, hybrid and storage technology. Indicative Generation Capacity Expansion Plan (IGCEP) 2022-31 (National Transmission and Dispatch Company, 2022). The base case results show that a generation capacity of 69,372 MW is proposed, which includes the utilization of existing generation facilities, consideration of committed power plants, and optimization of candidate power plants. To meet the demand by 2031, the share from variable renewable energy (VRE) resources stands at 8,350 MW, 4,928 MW and 394 MW of solar, wind, and bagasse, respectively.	**CP scenario** The renewable share in TFEC is projected to be 6.8 per cent in the CP scenario due to the increase of planned hydropower and renewable power capacities. **SDG scenario** The inefficient traditional biomass cooking and heating stoves are phased out with improved cooking stoves and HELE for modern use of biomass. The renewable energy share in TFEC is projected to be 23.5 per cent in 2030. This increase also results from the improvement in energy efficiency.

5.2.4. SDG 7.3, Energy efficiency

The energy intensity of Pakistan declined at an average annual rate of 0.55 per cent between 1990 and 2010. A doubling of the 1990-2010 improvement rate is required to achieve the SDG 7.3 target, which corresponds to an average annual rate of 1.11 per cent between 2010 and 2030. Consequently, the energy intensity in 2030 would need to be 4.08 MJ/USD_{2017}.

Under the CP scenario, the energy efficiency improvement target will not be achieved as it will only be reduced to 4.47 MJ/USD_{2017}. The energy intensity in 2030 is expected to become lower in the SDG scenario, forecast to be 3.97 MJ/USD_{2017} (2.08 per cent EE improvement rate), meeting the energy efficiency target for SDG 7. This is primarily due to the additional measures in the SDG scenario, such as the phase-out of inefficient cooking and heating technologies. These are replaced with more efficient stoves and heaters. In addition, further energy intensity reduction can be realised through the additional proposed measures for industry and transport sectors discussed in the previous section. Figure 12 shows additional energy saving opportunities under the SDG scenario, compared with the CP scenario, and table 15 further explains each energy efficiency measure as well as identifies gaps.

Figure 12. Additional energy saving measures under the SDG scenario compared to the CP scenario

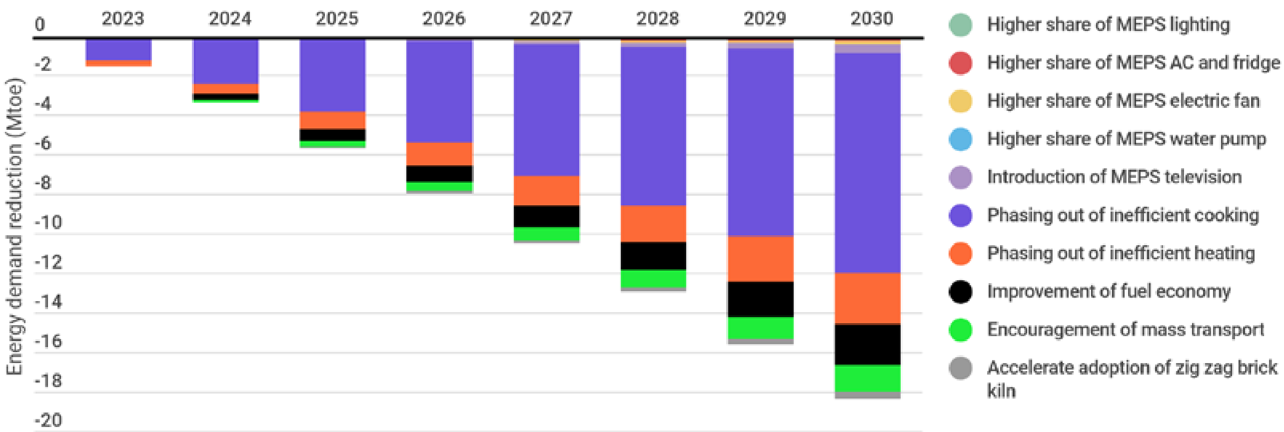


Table 15. Assessment of energy efficiency

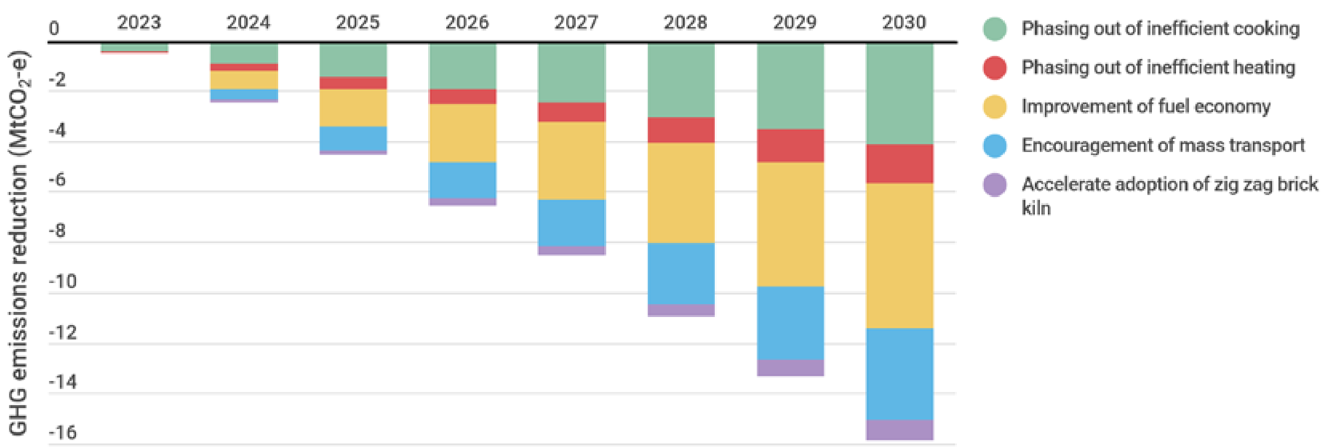
Existing policy	NEXSTEP Analysis – Gaps and recommendations
National Energy Efficiency and Conservation Authority (NEECA) Strategic Plan, 2020-2023 (Ministry of Energy, Power Division, 2020) sets the goal of 3 Mtoe energy saving by 2023.	**Gap(s):** The CP scenario will not achieve the energy efficiency improvement target of 1.11 per cent or 4.08 MJ/USD_{2017} in 2030. It is projected that the energy intensity will be 4.47 MJ/USD_{2017} in 2030. **SDG scenario:** The energy intensity is further reduced to 3.97 MJ/USD_{2017} in 2030 or 2.08 per cent EE improvement rate, which exceeds the energy efficiency target. Achievement of the target requires phasing out inefficient cooking and heating technologies, increasing MEPS adoption, encouragement of mass transport, improvement of passenger car fuel economy, and accelerating the zig-zag brick kiln implementation to realise an additional energy demand reduction of 18.3 Mtoe in 2030, compared with the CP scenarios.

5.3. Nationally Determined Contribution targets

The energy sector emissions, from the combustion of fossil fuel, are calculated based on IPCC Tier 1 emission factors assigned in the LEAP model and expressed in terms of 100-year global warming potential (GWP) values. For the combustion of biomass and biomass products, the carbon emissions are not attributed to the energy sector, but are accounted for in the agriculture, forest and land-use change (AFOLU)[11] as per the accounting system suggested by IPCC. Nevertheless, the emissions of other GHGs, such as methane and nitrous oxide, are included in the total emissions in the energy sector.

Under the CPS, total emissions are expected to grow from 194.9 $MtCO_{2-e}$ in 2021 to 236.2 $MtCO_{2-e}$ in 2030. This corresponds to a 43.7 $MtCO_{2-e}$ (5.6 per cent) reduction compared to the BAU scenario meeting the unconditional NDC target. The decrease in GHG emissions, relative to the BAU scenario, is due to the higher RE share in electricity supply. Figure 13 shows additional emissions reduction under the SDG scenario, compared with the CP scenario.

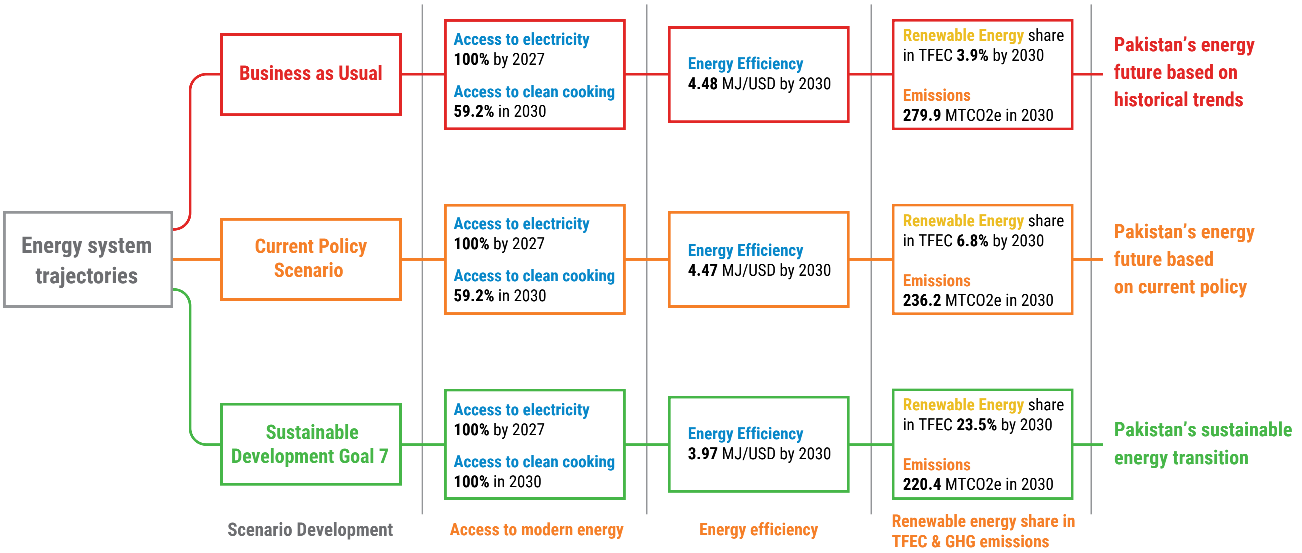
Figure 13. Additional emission reduction measures under the SDG scenario



In the SDG scenario, total emissions are expected to grow to 220.4 $MTCO_{2-e}$ by 2030. This corresponds to a 59.5 $MTCO_{2-e}$ (or a 21.3 per cent) reduction compared to the BAU scenario, which exceeds the unconditional NDC target of 8.4 per cent in the energy sector. The additional decrease in GHG emissions compared with the CP scenario is due to measures discussed in the previous section. Figure 14 summarizes the SDG 7 indicators from three different main scenarios.

11 The AFOLU sector is not within the scope of NEXSTEP.

Figure 14. Summary of SDG 7 indicators for different main scenarios



5.4. Marginal abatement cost curve for achieving SDG 7

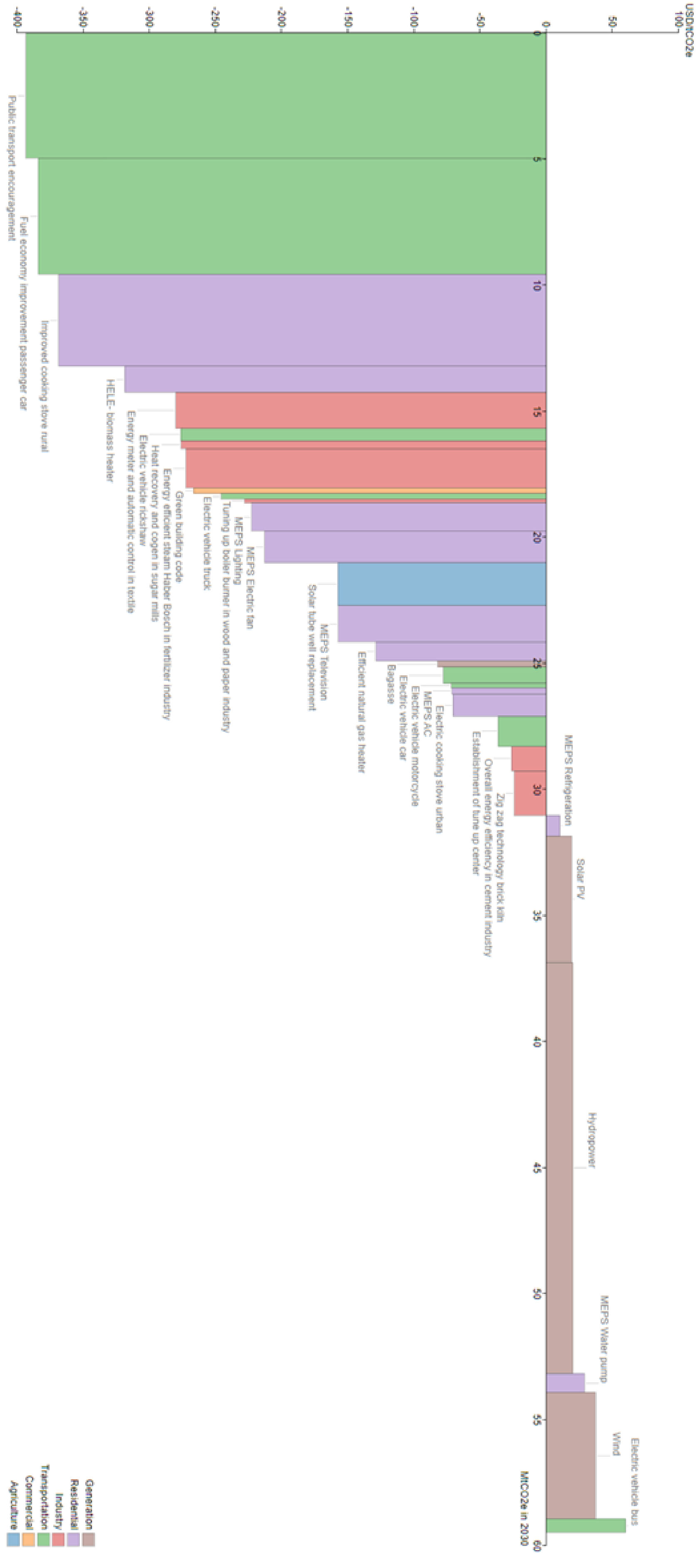
Figure 15 shows the indicative marginal abatement cost (MAC) curve for all sectors in Pakistan. The MAC curve follows the measures proposed for the SDG scenario and uses the BAU scenario as the reference baseline. In the SDG scenario, total emissions reduction is expected to be 59.5 $MtCO_{2-e}$.

It should be noted that the transport, residential and industrial sectors have a high GHG mitigation potential, which are cost-effective in the long term. For example, the encouragement of public transport and the improvement of fuel economy discussed in the previous section might provide the highest saving with high abatement potential.

Nonetheless, cost savings can be expected due to the reduced usage of expensive imported oil products. In addition, since rural areas are the largest traditional biomass consumers, replacing traditional biomass stoves and heaters with improved ones will provide significant savings.

In terms of renewable power capacity, high capital expenditure is generally required for new renewable power capacities. It is reflected in the MAC curve that all renewable generation has a positive cost. Interestingly, solar PV has lower abatement cost per tonne of CO_2 compared with wind and hydropower. The abatement costs for solar PV, hydropower and wind are US$ 19/tonne CO_{2-e}, US$ 20/tonne CO_{2-e} and US$ 38/tonne CO_{2-e}. A carbon price around US$ 60/ tonne CO_{2-e} might make the proposed measures attractive (including EV buses).

Figure 15. Marginal abatement cost curve (MACC)



6. Going beyond SDG 7

The SDG scenario, as discussed in the previous chapter, sets out various strategies for facilitating an economy-wide, energy-efficiency improvement in alignment with the 2030 Agenda for Sustainable Development and the Paris Agreement. It also identifies appropriate technology options in advancing sustainable energy transition in Pakistan. These allow GHG emission reduction sufficient to meet the unconditional NDC target and a modest increase in the renewable energy share in TFEC. However, Pakistan could consider more ambitious pathways going beyond just achieving the SDG7 targets. This chapter discusses Pakistan's potential to raise its ambition in energy transition.

The measures that have been discussed in the previous chapter, have allowed an energy demand reduction of 18.3 Mtoe and emission reduction of 15.8 $MtCO_{2-e}$, relative to the CPS. With countries and cities pledging net-zero emissions by 2050, two ambitious scenarios have been developed – the Decarbonization of the Power Sector by 2030 (DPS) scenario and the Decarbonization of Whole Economy by 2050 (DWE) scenario. While the first scenario explores how Pakistan can raise its ambitions in moving towards making its power sector carbon-free by 2030, the later scenario assesses the potential for Pakistan to achieve net zero for the entire energy sector by 2050. The longer timeframe for the net zero scenario will allow gradual decarbonization of heating and direct fuel combustion technologies in the industry and transport sectors.

The DPS scenario focuses on the opportunities in decarbonizing the electricity supply by increasing the share of RE in electricity generation. It provides a plausible decarbonization pathway that seeks commitments by the Government to phase out thermal generation. On the other hand, the DWE scenario aims to move the whole of Pakistan's energy system towards net zero, which requires cooperation from its stakeholders, by adopting cleaner, more efficient technologies (i.e., electric vehicles and high efficiency electric cooking stoves). The two ambitious scenarios are further described in the following sections.

6.1. Decarbonization of the power sector by 2030 scenario

Building on the SDG scenario, this scenario further explores how the country can decarbonize its power sector. There are no additional measures on the demand side, thus the TFEC values remain similar to those in the SDG scenario.

6.1.1. Power sector strategy in the decarbonization of the power sector scenario

Pakistan has an abundant hydropower potential. In addition to hydropower, the following are several pathways that the country may explore, in collaboration with citizens and/or private investors, to achieve a diversified renewable power supply objective:

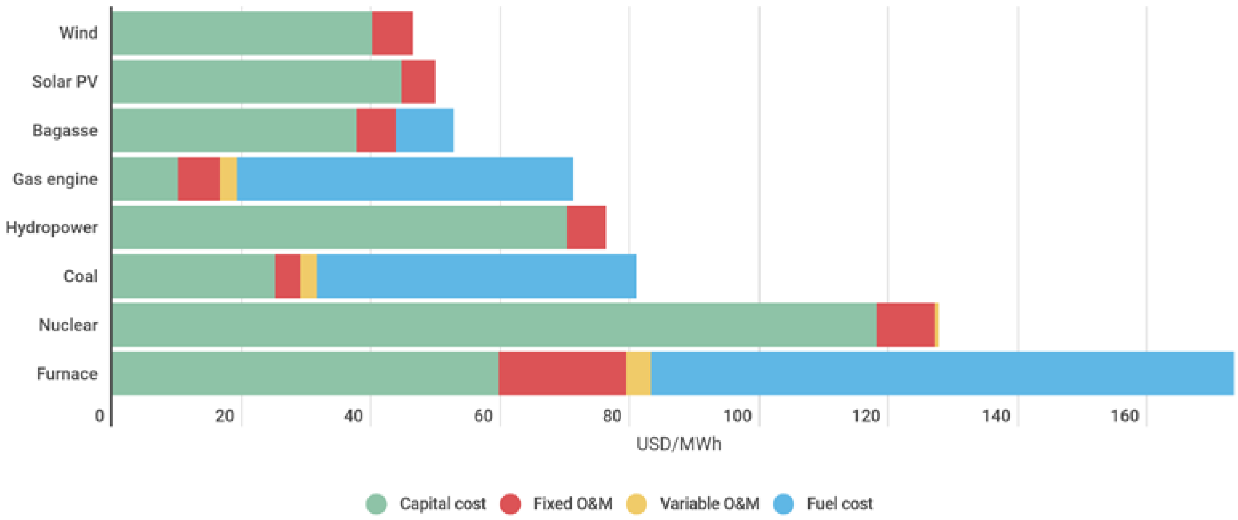
(a) Rooftop solar PV installation can be promoted both for new and existing buildings. Incentivising rooftop solar PV installation provides two benefits to the country – (i) a reduction of the financial burden on the country in establishing a utility-scale solar PV system, and (ii) a reduction of land use requirement for ground-mounted PV systems. The national Government may consider offering incentives to increase the uptake of solar PV rooftop systems;

(b) Decentralized solar PV and wind systems installation can be promoted in rural areas. It is predicted that the electricity demand in the rural areas may increase because of the promotion of electric stoves. Solar PV and wind systems installation would help to improve the electricity access in rural areas while simultaneously reducing emissions;

(c) Retrofitting fossil-fuel based thermal generation with biomass technologies. The existing fossil fuel-based power generation can be retrofitted with the biomass system.

This retrofitting would help the country to solve its rising electricity demand. The agriculture sector accounts for around one-fifth of Pakistan's GDP and generates a significant amount of crop residue. The waste material from the agriculture sector can be processed into pellets that can be the energy source for biomass power plants. The co-benefit of this solution will be sustainable agricultural waste management. Figure 16 shows the average levelized cost of electricity (LCOE) in Pakistan. Renewable energy technologies have the lowest LCOE compared with the thermal generation ones.

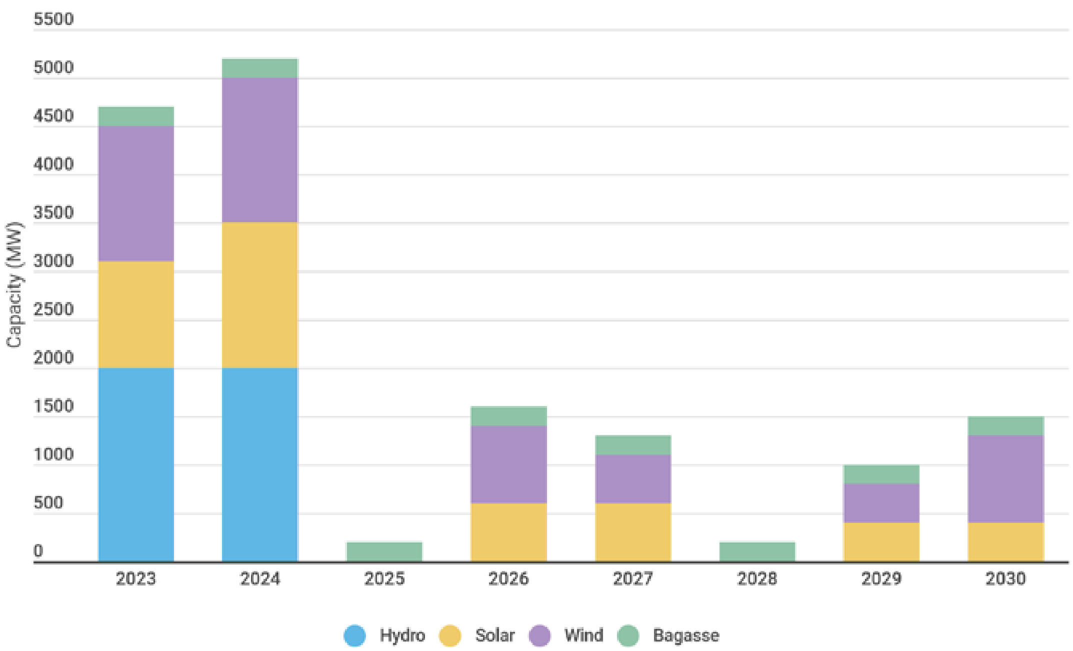
Figure 16. Average levelized cost of electricity, component analysis, power plant technology



6.1.2. Power generation outlook

To decarbonize the power sector by 2030, around 19.7 GW of fossil-fuel generation in Pakistan must be retired. Consequently, a total of 15.7 GW hydro, solar, wind and biomass power plants must be installed in addition to the hydro and renewable expansion plan mentioned in the IGCEP. It requires an investment of US$ 13.5 billion in addition to that contained in the current IGCEP's expansion plan. Figure 17 shows the mix of different renewable energy technologies needed in addition to the capacity mentioned in the CP scenario.

Figure 17. Hydro and alternative renewable energy required for decarbonizing power sector in addition to capacity mentioned in IGCEP



6.1.3. Challenges and opportunities to decarbonize the power sector

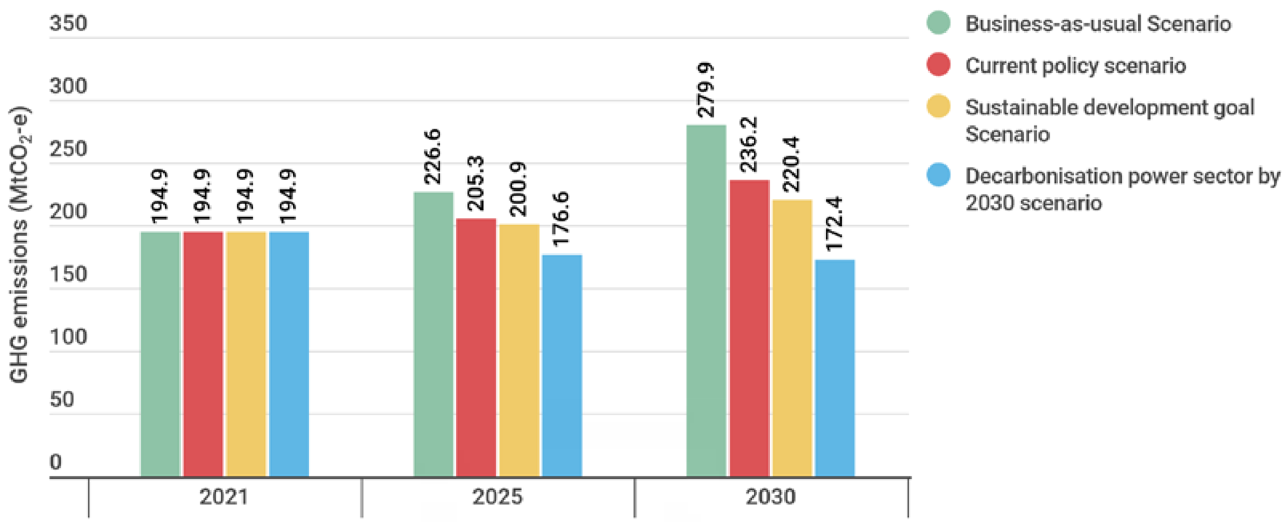
To achieve full decarbonization by 2030 (including solar-based systems, mini grids, and grid expansion), a significant amount of funding (US$ 13.5 billion) is required. The stakeholder consultation confirms that funding could be possible if there are concrete plans of what is needed, backed by credible data and information, including feasibility or pre-feasibility studies where needed. This Road Map presents directions for Pakistan's energy transition backed by an in-depth analytical study using reliable data collected from national sources and validated by the Ministry of Energy. It also serves as an important basis for undertaking feasibility studies for specific projects in alignment with the results and findings stipulated in this Road Map.

In addition, wind and solar projects involve more than 90 per cent of foreign currency components. Stakeholders indicate that in order to make renewables sustainable, at least 70 per cent of local value addition (LVA) is required. Such an LVA for wind is possible if locally manufactured concrete towers for wind turbines are used together with local civil works and electrical balance of plants. For PV solar, local manufacturing of solar cells will be required to achieve that level of LVA. Initially Pakistan can have solar cell supply agreements with some countries together with the transfer of technology agreements. The Government of Pakistan should set up a local power component industry instead of importing one.

Another challenge is that the distribution companies (DISCOs) of Pakistan lack the knowledge and technical support needed to switch the system from central to distributed generation. Government departments and agencies relevant to the energy sector (e.g., PPIB, AEDB, DISCOs, NTDC, CPPA and NEECA) need extensive training and capacity-building programmes for transitioning.

Despite the challenges, decarbonizing the power sector would be beneficial to the country since it would significantly reduce GHG emissions in 2030 (compared to the SDG scenario) by 48 $MtCO_{2\text{-}e}$ (figure 18). Therefore, a total emission reduction (including the demand sector) will be around 38.4 per cent. Moreover, transitioning to fully renewable energy-based power system would be more cost-effective in the long run than to relying on fossil fuel-based power generation.

Figure 18. GHG emission comparison in Pakistan in the BAU, CPS, SDG and DPS scenarios



6.2. Decarbonization of the whole economy by 2050 scenario

Around three-quarters of current greenhouse gas emissions globally come from the energy sector. Although this sector might have a critical role in avertin the worst impact of climate change, a significant challenge cannot be avoided. Limiting the temperature rise to 1.5^{0}C requires climate mitigation effort on an unprecedented scale and speed to reduce GHG emissions by about 45 per cent from 2010 levels by 2030, reaching net zero around 2050 (IPCC, 2018). Failing to act on the most pressing issue of this generation may lead to a catastrophic impact on human livelihoods. Pakistan is highly vulnerable to the impacts of climate change, with the greatest impacts likely to come from flooding events.

In addition, COP 26 in Glasgow has created momentum and called for transitioning towards net zero. This scenario examines the potential for Pakistan to achieve net zero by 2050. The rationale for the choice of a longer timeframe for this scenario is to allow the non-electric energy consumers, e.g., heating and direct fuel combustion in the industry and transport sectors, gradually transition to a fully electric system. As this scenario builds upon the previously discussed SDG scenario, electricity in Pakistan is assumed to become carbon-free by 2030.

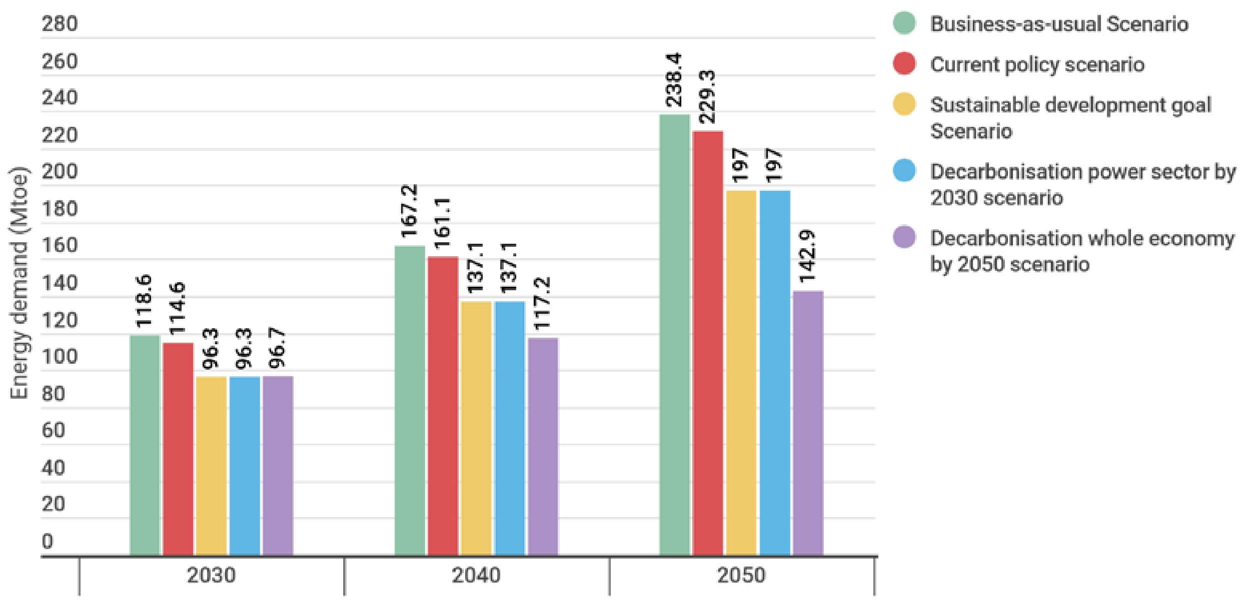
6.2.1. Demand sector strategy

The energy system of Pakistan is well-positioned for an accelerated de-carbonization effort as the required net-zero technologies in decarbonizing its energy system are readily available, i.e., electric vehicles, electric cooking stoves and renewable power technologies. As discussed earlier in this Road Map, decarbonizing its electricity supply is key to deep decarbonization. A decarbonized electricity supply is also required to complement the hastened adoption of electricity-based technologies, such as electric vehicles and electric cooking stoves, in order to realise the greatest potential of electrification.

The measures in this scenario are implemented beyond 2030 after the implementation of the SDG scenario. NEXSTEP suggests the utilization of 100 per cent electric cooking stoves and electric heaters by 2050 in order to achieve net zero in the residential sector. The adoption of 100 per cent e-mobility is also critical to decarbonize the transport sector. In the industrial sector, fuel switching has a significant role, particularly the switching from fossil fuel to biomass and electricity. Fuel switching can also be implemented in the agriculture sector.

While this scenario requires an additional 44 Mtoe (512 TWh) of electricity, compared to the BAU scenario, it requires the least amount of energy among all scenarios by 2050, as shown in figure 19. Energy demand in this scenario in 2050 is 95.5 Mtoe less than the BAU scenario, 86.4 Mtoe less than the CPS, and 54.1 Mtoe less than both the SDG and DPS scenarios. Further implementation of energy efficiency would help to reduce this electricity demand.

Figure 19. Energy demand comparison among all scenarios

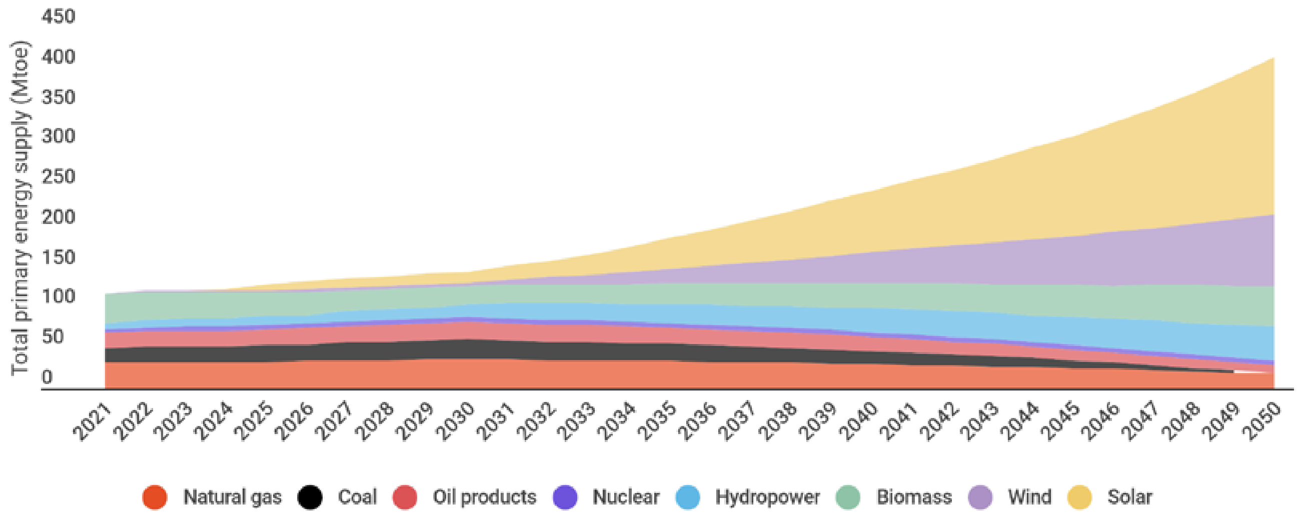


6.2.2. Power sector and energy supply outlook

To fulfil the increasing electricity demand due to electrification, a mix of different sources of renewable energy is required. Using the optimization feature in LEAP modelling, NEXSTEP investigates the fact that the power generation capacity must be 49.1 GW hydropower, 193.4 GW solar PV, 124.6 GW wind power and 4.4 GW bagasse in 2050. The capacity of solar generation is expected to be the largest since it has the largest potential in Pakistan. It is followed by wind generation and hydropower generation in second and third place, respectively.

In terms of power supply, the decarbonization of the whole economy will reduce the demand for fossil fuel. On the other hand, there will be a significant increase of renewable energy into Pakistan's energy system (figure 20), since the proposed power generation under this scenario will be 100 per cent renewable energy, coming mainly from solar generation. This situation will improve the energy security of the country through indigenous generation by 2050.

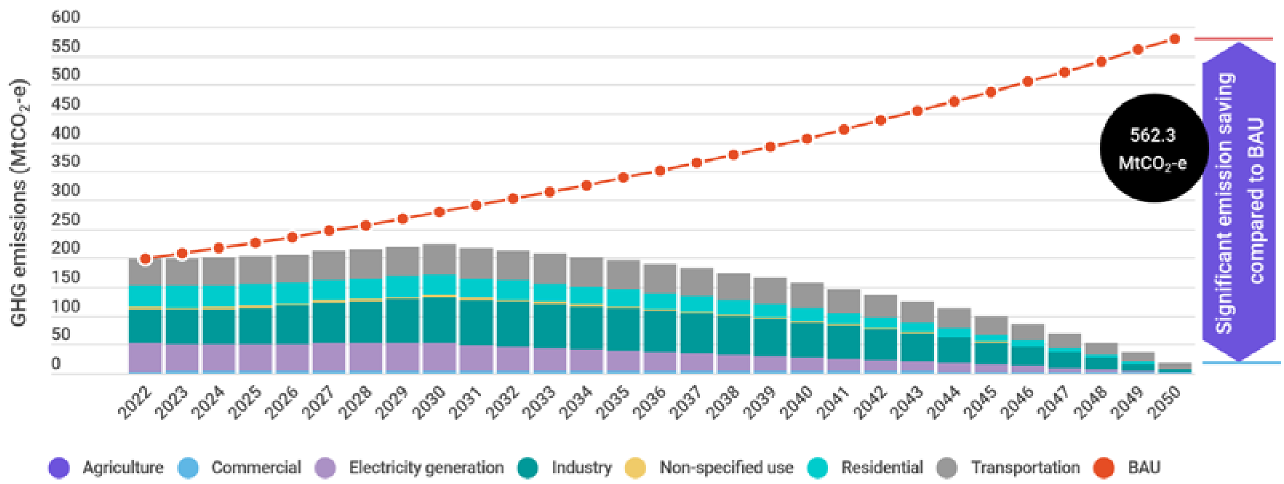
Figure 20. Total primary energy supply in Pakistan, 2022-2050, by sector in the DWE scenario



6.2.3. GHG emission outlook

Figure 21 illustrates the GHG emissions in the demand sector under the BAU and DWE scenario by 2050. It appears that the emissions will increase by almost three times to 580.2 $MtCO_{2-e}$ in 2050 under the BAU scenario if no significant measures are implemented during this period. However, under the DWE scenario, the emissions will almost reach zero in 2050. A very small amount of residual emission is due to certain limitations in fully decarbonizing the industry as well as rail and aviation sectors. Therefore, carbon sinks, such as reforestation or forest management, or other carbon capture technologies should be considered for absorbing the remaining carbon emissions.

Figure 21. GHG emission in Pakistan, 2022-2050, by sector in the DWE scenario



7. Policy recommendations

7.1. Scenario evaluation

The current policy, SDG and the ambitious scenarios have been evaluated and ranked, using the Multi-Criteria Decision Analysis (MCDA) tool, with a set of 12 criteria and weights assigned to each criterion (table 16). While the criteria and weights have been selected based on expert judgement, ideally the process should use a stakeholder consultation. If deemed necessary, this step can be repeated, using the NEXSTEP tool in consultation with stakeholders where the participants may want to change weights of each criterion. The following factors have been considered to assume comparative weights across the set of criteria, where the total weight needs to be 100 per cent:

(a) Universal access to electricity to be achieved;

(b) Universal access to clean cooking fuel to be achieved;

(c) Renewable energy share in the total final energy consumption to increase;

(d) Energy efficiency improvement should be doubled, and where there is an economic benefit, it should be further enhanced;

(e) The unconditional NDC target should be achieved. Where possible, the conditional target should be achieved if it is economically viable;

(f) Total investment should be kept low, but the net benefit should be high. This was done by assigning both indicators the same weight to ensure that a scenario is chosen on the value-for-money basis; and

(g) Carbon pricing should be introduced to encourage investments in clean energy.

Table 16. Criteria with assigned weights for MCDA

Criterion	Weight
Access to clean cooking fuel	10%
Energy efficiency	10%
Share of renewable energy	11%
Emissions targets in 2030	10%
Alignment with Paris Agreement	10%
Fossil fuel subsidy phased out	5%
Price on carbon	5%
Fossil fuel phase-out	5%
Cost of access to electricity	7%
Cost of access to clean cooking fuel	7%
Investment cost	10%
Net benefit from the power sector	10%
Total	**100%**

Table 17 shows the summary of results obtained through this evaluation process. The scenario recommendation suggests that the ambitious scenario, "decarbonization whole economy by 2050" scenario, is the highest-ranked energy transition pathway for Pakistan.

Table 17. Scenario ranking based on MCDA

Scenarios	Weighted scores	Rank
Decarbonization whole economy 2050	58.4	1
SDG scenario	54.0	2
Decarbonization power sector 2030	51.0	3
Current policy scenario	25.1	4
Business-as-usual scenario	18.1	5

Based on the above analysis, this Road Map recommends that Pakistan consider the adoption of the scenario "decarbonization of the whole economy by 2050". Since this scenario is further implemented after the SDG 7 scenario, Pakistan can also implement the suggestions given in the SDG 7 scenario.

7.2. Policy actions for achieving SDG 7

7.2.1. Electric cooking stoves and improved cooking stoves provide a sustainable long-term solution with multifold benefits

The NEXSTEP analysis suggests the remaining clean cooking gap in urban areas should be closed with the promotion of electric cooking stoves. Electric cooking stoves are a prime solution to closing the remaining clean cooking gap, capitalising on carbon-free electricity. They serve as a long-term solution with no added burden on fuel imports. Electric cooking stoves appear viable compared to gas stoves since natural gas supply in Pakistan is facing challenges. Electric cooking stoves are also more efficient than other cooking stoves, including gas stoves. Electric cooking stoves, however, might not be a viable solution for some rural households as it would require an extension of transmission and distribution infrastructure to remote locations. Therefore, adoption of improved cooking stoves is proposed as the most appropriate solution for closing the gap in rural areas within the short time frame. This builds on the traditional practice of using biomass as cooking fuel, which is abundant and cheap. As shown in table 12 and discussed in subsection 5.2.2, ICS has the cheapest annualised cost, which will be more affordable for rural households.

7.2.2. Adoption of sustainable and clean heating in the residential sector to reduce air pollution-related health impacts

Due to Pakistan's location and geography, heating is a necessity in the country's cold winter seasons. However, a substantial proportion of the country's households do not have access to clean and efficient heating technologies. A total of 11 per cent of urban households and 91 per cent of rural households rely on solid fuel stoves (biomass as fuel sources) for heating purposes. Many urban and rural households that are relying on biomass heating utilize low efficiency, high emission traditional heating stoves.

HELE heaters are the appropriate heating technology to be promoted for rural households. These heaters reduce fuel consumption by 40 per cent due to their higher efficiency, while also keeping larger areas of homes warm. Indoor air pollution is reduced significantly, which ultimately reduces negative impacts on health. For example, a World Bank study has seen the mean $PM_{2.5}$ exposure decrease 65 per cent from 92.3 μg/m^3 to 32.4 μg/m^3 (World Bank, 2019). This meets the WHO interim target, IT-1 of 35 μg/m^3, for an annual mean concentration of $PM_{2.5}$ (World Health Organization, 2014). The results also show that the CO_2 exposure dropped below the WHO air quality guidelines.

More can be done to raise community awareness of the benefits of HELE heating technology. Similar to promoting clean cooking technologies, a participatory approach with key stakeholders, together with frequent monitoring, evaluation and feedback, should be pursued to ensure a successful implementation of programmes. In addition, the sustainable heating issues should garner more attention and have a place in national policies and plans. In the long term, progressing towards electric heating should be considered as the affordability of households increases.

7.2.3. Raising the efficiency standards of household appliances to save running costs

In Pakistan, MEPS was first rolled out in 2016 (NEECA, 2022). These include household appliances such as air conditioners, refrigerators, motors and electric fans. In addition to these appliances, NEXSTEP suggests that the Government should roll-out MEPS for television since televisions consume a significant amount of electricity in the residential sector. It is critical for the Government to accelerate such ambitions since the implementation for NEECA target will be in 2023. To further achieve the SDG 7 target, the Government must double the adoption of efficient appliances in the domestic sector.

Complementing the roll out of MEPS, stakeholder consultation ton confirms that the Government of Pakistan may consider having appliance replacement programmes, such as providing subsidies to promote early retirement of existing inefficient appliances. This will allow a more rapid adoption of efficient appliances. There is also a need to create awareness among the population about the socio-economic advantages of energy savings. These measures might help to accelerate the adoption of MEPS in the long term.

7.3. Policy recommendations to raise ambitions beyond SDG 7

7.3.1. Transport electrification is a major step towards net zero 2050

Pakistan seeks to capture 30 per cent of all passenger vehicle and heavy-duty truck sales by 2030, and 90 per cent by 2040 to be electric vehicles, with 50 per cent of electric vehicles sales to be two-wheelers and three-wheelers, and buses by 2030. With Pakistan's ambition to achieve 60 per cent of hydropower and renewable power share, electric vehicles can help to substantially reduce overall GHG emissions. Other positive impacts include reducing local pollutant emissions due to their zero-tailpipe emissions and reduced reliance on imported petroleum fuels. However, the uptake of electric vehicles needs to be promoted with government initiatives, i.e., financial incentives and an awareness programme.

It is also critical for the Government to reduce the demand in the transport sector. Mass transportation must be promoted to reduce the passenger-km by private vehicles. Simultaneously, the improvement of fuel efficiency standards using hybrid models can be affordable pathways during the transition period before moving towards 100 per cent e-mobility. Box 2 discusses the global progress of electric vehicles.

Box 2. Electric vehicle gains global interest

Electric vehicles have garnered great interest globally, growing exponentially during the past decade. Electric car sales passed two million globally in 2019, with a projected compound annual growth rate of 29 per cent through to 2030 (Deloitte, 2020). Various government policies have been introduced that directly or indirectly promote the adoption of electric vehicles as a means to achieve environmental and climate objectives. For example, 17 countries have stated their ambition to phase out internal combustion engines before 2050, while the European Union's stringent CO_2 emissions standard has accelerated the adoption of electric vehicles (IEA, 2022a).

Despite supply chain bottlenecks and the ongoing COVID-19 pandemic, electric car sales hit a new high in 2021. Sales nearly doubled to 6.6 million, representing a world sales share of approximately 9 per cent, compared to 2020, increasing the total number of electric vehicles on the road to 16.5 million. In 2021, the sales share of electric vehicles rose by 4 percentage points. China had the most sales in 2021, tripling those of 2020 with 3.3 million, followed by Europe with 2.3 million sales, an increase from 1.4 million in 2020. In 2021, 630 000 electric vehicles were sold in the United States, doubling their market share to 4.5 per cent. Electric car sales increased more than twice as much in emerging nations, although they are still relatively small (IEA, 2022a).

7.3.2. Incentivize industrial energy efficiency measures for a more competitive industry sector

Pakistan's industry sector is the second largest energy-consuming sector, which accounted for around 25.1 per cent of total energy consumption in 2021. Strengthening energy efficiency in this sector will lead to significant energy savings. Energy audits should be promoted for all industries to identify and realise the energy savings potential. In addition, various policy measures can be considered for accelerating the green transformation through a range of policy measures. Since cement and brick kiln industries are energy-intensive, further energy efficiency improvements such as the implementation of vertical shaft brick kilns should be considered.

For industrial decarbonization, it is understood that to mitigate the impact of climate change, all products for export in future must get an ecofriendly, climate compliance certificate for the methods and mechanics of production. Transition will require strategic planning and timelines that remain consistent with a change of government. These could include market instruments (i.e., subsidies or taxes), emissions caps and trade systems (e.g., the European Union Emission Trading Scheme) or regulatory instruments. The *Practitioner's Guide to Strategic Green Industrial Policy* by the Partnership for Action on Green Economy (PAGE)[12] provides industrial policymakers with tools and information for developing a strategic green industry policy (SGIP).

Fuel switching is also critical to decarbonize the industrial sector in Pakistan. There is should be consideration given to implementing hydrogen and synthetic fuels in the industry sectors. This might be an option in the future once the technology becomes technologically and commerciality mature. However, it must also be considered that there will be an increase in electricity demand for electrolysis process should the use of hydrogen fuel be accelerated.

7.3.3. Decarbonization of the power sector to meet national energy demand

Pakistan is endowed with substantial hydropower potential, which supplied almost 30 per cent of its electricity requirements in 2021. As of 2021, there was 9.9 GW of hydropower capacity, generating a total of 39.4 TWh of electricity. The Government of Pakistan plans to add 22.6 GW of large hydropower plants during 2022-2031. The Government has also considered increasing the capacity of variable renewable energy (VRE) in the power system. The total capacity from VRE resources is planned to be 8.4 GW, 4.9 GW and 0.4 GW of solar, wind and bagasse, respectively, in 2031.

A decarbonized electricity supply is, however, required to complement the hastened adoption of electricity-based technologies, such as electric vehicles and electric cooking stoves, in order to realise the greatest potential of electrification in a net-zero society. Thus, it is recommended increasing the existing capacities to reach 49.1 GW of hydropower, 193.4 GW of solar PV, 124.6 GW of wind power and 4.4 GW of bagasse by 2050.

7.3.4. Green financing

Sustainable green transition in the energy sector often offers financial benefits in the long term. This could entail financial incentives to promote efficient vehicles or efficient household appliances. It should be noted that the transport, residential, and industrial sectors have a high GHG mitigation potential, which in most scenarios are cost-effective in the long term. For example, the encouragement of public transport usage and the improvement of fuel economy might provide the highest saving with high abatement potential. Nonetheless, cost savings can be expected due to the reduced usage of expensive imported oil products.

Increasing renewable power capacity, particularly for power trade, provides additional revenue to the country, while also contributing towards global climate mitigation efforts. However, high capital expenditure is generally required for new renewable power capacities. It is reflected by the MAC curve that most renewable generation has positive cost. Interestingly, solar PV has a lower abatement cost per tonne of CO_2 compared with wind and hydropower. A carbon price of around US$ 60/ tonne $CO_{2\text{-}e}$ might make the proposed measures attractive in the SDG scenario (including electric buses).

Accelerating green financing is critical to achieving the proposed sustainable energy transition. Policymakers need to work with central banks, regulatory authorities and investors to examine the possibility of developing a green finance policy and establishing a green finance bank or fund to help close the investment gap. Another option is green bonds to mobilize resources from domestic and international capital markets to finance climate solutions. Renewable energy technologies have relatively high financing costs in developing countries, which reflects their unattractive risk/return profile. This is because of their long-term horizon, high initial capital costs (including high infrastructure cost), unfavourable policy for grid access, illiquid equipment and project risks.

Policymakers can reduce high financing costs by using two methods – de-risking and direct incentives. De-risking has two basic forms –

12 See https://www.unido.org/sites/default/files/2016-11/practitioners_guide_to_green_industrial_policy_1__0.pdf

policy de-risking instruments that reduce risk, and financial de-risking instruments that transfer risk. Direct incentives are direct finance transfers or subsidies to low carbon investments. The United Nations Development Programme's (2021) *De-risking Renewable Energy Investment* is an important guide for policymakers in developing strategies to reduce risks in renewable energy investment. An example of a funding mechanism in Thailand to promote energy efficiency and renewable energy is discussed in box 3.

Box 3. Case study – Energy Efficiency Revolving Fund in Thailand

In 2003, the Government of Thailand launched the Thai Energy Efficiency Revolving Fund (EERF) as part of its Energy Conservation Programme. The EERF works to overcome barriers within the Thai financial sector to stimulating adequate financing for energy efficiency and reducing the country's greenhouse gas emissions. It was aimed at strengthening the capacity of commercial banks to finance energy efficient (EE) projects, developed the ESCO revolving fund to enable smaller companies to access EE financing, and works with the Bureau of Investment to provide tax/duty exemptions for EE products. The establishment and implementation of EERF has been successful in supporting initial investments in energy efficiency and creating a self-sustained market by encouraging the involvement of commercial banks in this area. This fund was initiated in 2003 to attract investments in energy efficiency, create confidence of entrepreneurs and promote ESCOs as a vehicle to improve energy efficiency.

The fund was made available by DEDE with financial support from the Department of Energy. The total budget for five phases of the fund was US$ 245,100,000. Phase 5 of the fund operated from June 2010 to May 2013. During the first phase (2003-2006), the fund was made available to commercial banks without interest; however, an interest rate of 0.5% was introduced from Phase 2 and was continued at the same rate through to phase 5. Facility owners, ESCOs and project developers were eligible to borrow from this fund for a maximum of seven years for EE and RE projects. Single loan size was capped at about US$ 1.56 million with an interest rate of 4 per cent. Until 2013, 295 project proposals were received (EE projects, 60 per cent and RE projects, 40 per cent) for a total investment of US$ 498.7 million, of which US$ 226 million was contributed by this fund and the remainder by financial institutions (Achavangkool, 2014)

8. Building back better from COVID-19

Energy will play a key role in rebuilding better in the recovery from the COVID-19 pandemic. Energy services are essential to supporting health-care facilities, supplying clean water for essential hygiene, enabling communication and IT, and off-grid renewables refrigeration for vaccine storage. Economic challenges resulting from the pandemic have the potential to force countries in the Asia-Pacific region to focus on short-term fixes to revive GDP growth, potentially undermining long-term sustainable development. In the energy sector, this can result in the decline of investment in clean energy development – slowing progress on renewable energy and energy efficiency, and eventually, impeding national economic growth.

The COVID-19 pandemic has caused social and economic devastation globally, including in Pakistan. While grappling with the devastation caused by the pandemic, Pakistan should not lose sight of its progress and ambitions towards achieving the SDGs and NDC targets. Pakistan should build back better from this crisis, to become more resilient to face future challenges such as climate change.

Thus, it has never been more important to design a well-planned energy transition pathway that enables the country's energy sector to shield itself from the likely impacts of the COVID-19 pandemic, and which helps to build back better in the recovery. The SDG 7 Road Map has identified several key areas that will assist policymakers in strengthening policy measures to help recover from the COVID-19 impact, while maintaining the momentum to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement.

8.1. Accelerating access to clean and modern energy services

Access to clean and modern energy services is essential in helping rural populations to combat challenges related to COVID-19. Relying on traditional and hazardous technologies for cooking increases their susceptibility to the effects of the virus. It is important to consider how these seismic shifts in the energy sector from COVID-19 affect the most vulnerable people.

Around 50.7 per cent of Pakistan's population lacked access to clean cooking fuels in 2021. In addition, a substantial number of the population is relying on polluting heating solutions. One medium-term impact of COVID-19 could be decreased investment in energy access, as national budgets come under strain and priorities shift. In addition, access to clean cooking and heating technologies is a major development challenge that is often forgotten. WHO has warned about the severity of health impacts arising from the exposure to traditional use of biomass for cooking and heating and is encouraging policymakers to adopt measures to address this challenge.

The SDG 7 Road Map has analysed and identified technical options for connecting the remaining population to cleaner fuels for cooking and heating. The benefits resulting from this measure, in the form of reduced mortality and health impact, will exceed the needed investment to advance the clean cooking rate and clean heating rate to 100 per cent.

8.2. Savings from the energy sector will help to build other sectors

The NEXSTEP analysis shows that there are ample opportunities for Pakistan to save energy by improving energy efficiency beyond the current practices. Several of these measures also provide cost savings and strengthen the country's energy security, making it less susceptible to fuel supply and price shocks. Savings from this improvement can help investment in other sectors, such as health, social protection and stimulus, which are critical in responding to, and recovering from the COVID-19 pandemic.

The electrification of the transport sector provides multiple additional related benefits (in addition to energy saving), including the reduction of expenditure on importing petroleum products and the reduction of local air pollution. Such measures are very important to solidifying the pathway to recovery from COVID-19 and building back better.

8.3. Long-term recovery planning to build back better while ensuring sustainable growth

The COVID-19 pandemic has caused unprecedented socio-economic impacts around the world. On the brighter side, many countries have taken this opportunity to "reset" their economies. For example, the World Economic Forum has launched the Great Reset initiative, to encourage economic transformation and the building of a better society as the world recovers from the global health-care crisis (World Economic Forum, 2020), and the European Commission has placed the European Green Deal at the heart of their long-term sustainable recovery from the pandemic (European Commission, 2020). The global crisis has caused Pakistan's economy to plunge. Nonetheless, this may be an opportunity for Pakistan to re-examine its economic structure and leverage the potential of climate-smart sectors.

9. Conclusion and the way forward

The 2030 Agenda for Sustainable Development and Paris Agreement provide a common goal for all countries to achieve sustainability and climate objectives. Achieving the SDG 7 and NDC targets is not an easy feat, but it will help to create a more sustainable and resilient society. This Road Map has presented a number of different scenarios together with their technical feasibility, investments, benefits, challenges and opportunities to inform policymakers of different pathways to energy transition. NEXSTEP has also looked beyond just achieving SDG 7 targets and has explored the full potential of the country in relation to decarbonizing the country's power sector and assessing the potential to advance towards net zero by 2050.

It is projected that Pakistan will achieve universal access to electricity by 2027. On the other hand, much needs to be done if Pakistan is to achieve universal access to clean cooking by 2030. Similarly, Pakistan lags in terms of clean heating. A coordinated approach is therefore much desired from the private and public sectors in advancing the clean cooking and heating gaps in order to provide clean technologies to the population. These are, for example, electric cooking stoves, improved cooking stoves and High Efficiency Low Emissions (HELE) heating technology, which build on current commonly used practices, while reducing fuel consumption and household indoor pollution.

The major concern of the energy sector of Pakistan is the heavy reliance on imported fossil fuel, particularly oil products. Ample opportunities exist in the residential, industrial, transport, commercial, and agriculture sectors to save a substantial amount of energy through the implementation of energy efficiency measures. The residential sector provides the biggest energy saving potential and should be the main focus, as this sector has the largest share of Pakistan's energy consumption, particularly via the adoption of clean cooking and heating technologies. Pakistan has the potential to increase its ambition beyond what is needed for the SDG 7 energy efficiency target and to further reduce energy consumption in all sectors. For example, the introduction of MEPS for household appliances, green building codes, and increasing the energy efficiency are key policy areas to be considered. whereas in the transport sector the encouragement of mass transport and improvement of fuel economy (in addition to the adoption of electric vehicles) will result in substantial energy savings. These measures will eventually reduce the energy sector's reliance on imported petroleum fuel.

Modern renewable energy delivered still accounts for a very small share, only 3.2 per cent of TFEC in 2021. Improvement of energy efficiency and increasing modern renewable energy share might increase the renewable energy share in TFEC to 23.5 per cent. The promotion of electric cooking stoves and electric vehicles will require a substantial amount of electricity in the future. Diversification of generation sources using solar PV, wind, and biomass might help the country to fulfil the increasing demand as well as improve energy security. The scenario analysis using the MCDA tool suggests that the Government should consider the decarbonization of whole economy by 2050 scenario for transitioning the energy sector. In addition to achieving the SDG 7 targets, this scenario will also enable Pakistan to exploit its full potential for emission reduction in the long term.

Finally, the energy transition pathway presented in this SDG 7 Road Map will support building back better after the COVID-19 pandemic. The proposed energy transition presents opportunities to reduce economic risks, both for public and private investment, and identifies areas for financial savings in the energy sector that can support the recovery of other critical sectors, such as the health sector.

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Annexes

I. National Expert SDG 7 tool for energy planning methodology

The analysis presented in this national Road Map is based on the results from the National Expert SDG 7 Tool for Energy Planning (NEXSTEP) project. NEXSTEP is an integrated tool for assisting policymakers in making informed policy decisions that will help in achieving SDG 7 and NDC targets by 2030. The SDG 7 and NDC targets are integrated in the LEAP energy model and back-casted from 2030, since the targets for 2030 are already defined.

Annex table 1. Targets and indicators for SDG 7

Target	Indicators	2021	2030
7.1. By 2030, ensure universal access to affordable, reliable, and modern energy services.	7.1.1. Proportion of population with access to electricity.	93.6%	100%
	7.1.2. Proportion of population with primary reliance on clean fuels and technology for cooking.	49.3%	100%
7.2. By 2030, increase substantially the share of renewable energy in the global energy mix.	7.2.1. Renewable energy share in total final energy consumption.	3.2% (excluding traditional biomass)	23.3%
7.3. By 2030, double the global rate of improvement in energy efficiency.	7.3.1. Energy intensity measured as a ratio of primary energy supply to gross domestic product.	4.80 MJ/US$ (2017) PPP	4.08 MJ/US$ (2017) PPP

SDG 7.3. Energy Efficiency. "By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production, plus net imports minus international marine and aviation bunkers and plus stock changes. For comparison purposes, GDP is measured in constant terms at 2017 PPP.

$$Primary\ energy\ intensity = \frac{Total\ Primary\ Energy\ Supply\ (MJ)}{GDP\ (USD\ 2017\ PPP)}$$

$$CAGR = \left(\frac{EI_{t2}}{EI_{t1}}\right)^{\frac{1}{(t2-t1)}} - 1$$

where EI_{t1} is energy intensity in year t1 and EI_{t2} is energy intensity in year t2.

Base period improvement rate for Pakistan (1990-2010): 0.55 per cent.

SDG 7.3. improvement rate for Pakistan (suggested doubling improvement rate): 1.11 per cent.

SDG 7.2. Renewable Energy.

Methodology: Share of renewable energy in total final energy consumption, where TFEC is total final energy consumption, ELEC is gross electricity production and HEAT is gross heat production.

$$\%TFEC_{RES} = \frac{TFEC_{RES} + \left(TFEC_{ELEC} \times \frac{ELEC_{RES}}{ELEC_{TOTAL}}\right) + \left(TFEC_{HEAT} \times \frac{HEAT_{RES}}{HEAT_{TOTAL}}\right)}{TFEC_{TOTAL}}$$

II. Key assumptions for NEXSTEP energy modelling

(a) General parameters

Annex table 2. GDP, PPP and growth rate

Parameter	Value
GDP (2021)	346.3 billion
PPP (2021, constant 2017 US dollar)[13]	1043.7 billion
Growth rate	4.3%

Annex table 3. Population, population growth rate and household size

Parameter	Value
Population (2021)	225.22 million
Population growth rate	2%
Number of households (2021)	37.53 million
Household size (constant throughout the analysis period)	6

(b) Demand-side assumptions

(i) Industry

- The industry sector is further differentiated into 17 subcategories. The fuel consumption by industry subcategories is as detailed in annex table 4.
- The industrial GDP is assumed to grow at an annual rate of 4.3 per cent, similar to the national GDP growth rate. The energy intensity is assumed constant throughout the analysis period in the absence of energy efficiency interventions

13 2021 is extrapolated based on 2000 - 2020 data provided at https://worldeconomics.com/GrossDomesticProduct/Real-GDP-PPP/Pakistan.aspx (accessed 1 July 2022)

Annex table 4. Fuel consumption by industry subcategories in 2021

Industry	Fuel consumption (ktoe)					
	Coal	Natural gas	Oil products	Electricity	Biomass	Total
Food, beverages and tobacco	-	517.9	96.8	268.3	180.8	**1,063.8**
Textile and wearing apparel	-	2,744.1	389.1	1025.1	832.2	**4,990.6**
Leather and related products	-	14.3	12.8	18.9	2.05	**48.0**
Wood, paper and printing products	-	145.3	17.0	102	51.0	**315.3**
Coke and refined petroleum products	-	0.9	0.5	87.6	1.4	**90.3**
Chemical and chemical products	-	461.5	32.7	166.1	18.7	**679.0**
Fertilizer	-	680.4	0.1	117.2	0.1	**797.6**
Pharmaceutical products	-	44.5	15.5	50.3	2.2	**112.5**
Rubber and plastic products	-	512.2	14.1	48.6	10.3	**585.1**
Other non-metallic products	-	37.7	9.8	71.6	2.87	**121.9**
Cement	6,099.6	6.5	352.8	396.0	-	**6,854.9**
Brick kiln	4,054.4	28.9	73.6	26.0	2,870.9	**7,053.9**
Basic metals and fabricated metal products	-	252.3	25.2	206.2	147.0	**630.6**
Computer, electronic, optical product and electric equipment	-	17.2	18.4	37.7	1.9	**64.3**
Machinery, motor vehicles and other transport equipment	-	55.4	2.9	39.3	35.7	**148.9**
Furniture	-	1.2	6.2	12.0	0.1	**16.1**
Other manufacturing	-	14.9	2.6	10.1	1.6	**33.0**
Total	**10,154**	**5,535**	**1,075**	**2,683**	**4,159**	**23,606**

(ii) Transportation

- Land transport sector consumption is estimated using the vehicle statistics, load factor, annual travel mileage and estimated fuel economy as shown in annex table 5. The factors are based on vehicle statistics compiled by the local consultant and assumptions made by ESCAP and the local consultant, as local specific data is scarce.
- Transport activities in 2021 are estimated to have been 1,907 billion passenger-kilometres (1,201 billion-km when considering only public transport) and 223 billion tonne-kilometres. The growth in both passenger transport and freight transport activities is assumed as growing at the same rate as the population, i.e., 2 per cent per annum.

Annex table 5. Transport sector floorspace baseline assumptions

Passenger transport	No. of vehicles	Annual mileage (km)	Load factor (pass-km/veh-km)	Fuel consumption	% share of passenger-km
Passenger car	2,351,856 (gasoline) 521,828 (diesel) 133 (electric) 1,140,243 (CNG)	10,950	2.5	12.00 km/l 5 km/kWh	5.8%
Motorcycle	24,777,230 (gasoline) 498 (electric)	5,541	1.6	36.00 km/l 6.67 km/kWh	11.5%
Taxi	113,638 (gasoline) 58,000 (CNG)	54,750	2.6	14 km/l 17 km/l	1.3%
Rickshaw	113,638 (gasoline) 58,000 (CNG)	32,000	2.5	13 km/l	4.1%
Bus	256,829 (diesel)	72,000	65	8.3 km/l	63%
Tractor	666,000 (diesel)	1,000	1.8	6 km/l	0.06%
Mini-bus	75 (CNG)	60,000	12	8 km/l	0.003%
Other	1,890,051 (gasoline)	8,000	18	8.5 km/l	14.3%
Freight transport	No. of vehicles	Annual mileage (km)	Load factor (tonne-km/veh-km)	Fuel consumption	% share of tonne-km
Freight truck	295,485 (diesel)	43,800	11	8.3 km/l	63.6%
Freight van	309,000 (diesel)	22,000	12	12 km/l	36.4%

(iii) Commercial sector

- The total annual energy consumption in the commercial sector was 1,741 ktoe in 2021. It is projected to grow at an annual rate of 4.3 per cent, similar to the national GDP growth rate in the BAU scenario. Energy savings are, however, expected in the current policy scenario through the obligatory building standards.
- The commercial sector is further differentiated into four categories and the energy consumption by categories are as shown in annex table 6.

Annex table 6. Commercial sector fuel consumption in 2021

Category	Floor space (million m^2)	Fuel consumption (ktoe)				
		Kerosene	Natural gas	LPG	Electricity	Total
Private office and government building	231	-	320.8	250.2	297.9	868.9
Shopping mall, food vendors and hotels	11	12.8	15.3	45.8	9.7	83.6
Medical buildings	16	-	18.1	45.3	29.4	92.8
Educational institutions	295	-	245.8	151.6	298.4	695.8
Total	**553**	**12.8**	**600.0**	**492.9**	**635.4**	**1741.2**

(iv) Residential:

- The residential sector is further divided into urban and rural households. Urban households have achieved a 99.7 per cent electricity access rate, while rural households have achieved an 89.9 per cent electricity access rate, and the overall clean cooking rate was 49.3 per cent in 2021. The breakdown is shown in annex table 7.

Annex table 7. Cooking distribution in urban and rural households[14]

Stove type	Energy intensity (GJ/household)	Urban	Rural
LPG stove	17	2.0%	0.9%
City gas stove	17	81.8%	25.7%
Electric stove	9.5	3.0%	-
Biomass stove	54	13.2%	72.4%
Kerosene stove	0.7	-	0.9%

* *This is assumed as unclean fuel/technology*

- A total of 20.9 per cent of residential demand can be attributed to residential heating. The energy intensity and heating technology breakdown is shown in annex table 8.

Annex table 8. Heating distribution in urban and rural households

Heater type	Urban		Rural	
	Distribution	Energy intensity (GJ/household)	Distribution	Energy intensity (GJ/household)
Natural gas heating	59.8%	4.2	-	-
Electric heating	9.0%	0.7	0.9%	0.7
LPG heating	19.9%	2.0	8.1%	2.0
Biomass heating	11.3%	12.5	91.0%	10.4

- The residential appliance ownership data and energy use intensity in the baseline year were provided by the local consultant. The appliance ownership is projected to grow a rate similar to the growth in GDP per capita. The average electrical demand per owning household for the different appliances are assumed to be constant throughout the analysis period, unless further energy efficiency measures are implemented.

14 The clean cooking access rate is indicated as 49.3 per cent (with uncertainty range from 33.6 per cent to 65.1 per cent) in (World Health Organization, 2022). The energy intensity is based on assumptions provided by the local consultant.

Annex table 9. Residential appliance baseline assumptions

Appliance	Electricity intensity (kWh/HH/year)	Ownership – urban	Electricity intensity (kWh/HH/year)	Ownership – rural
Lighting	243.09	100%	140.16	100%
Air conditioner	1728.00	17%	432.00	5%
Refrigerator	237.25	76%	346.75	88%
Television	776.72	84%	444.57	110%
Electric fan	594.00	100%	324.00	77%
Washing machine	7.8	82%	7.80	38%
Water pump	292.00	69%	255.50	13%
Iron	93.60	96%	26.00	227%
Others	36.50	100%	36.50	100%

(v) Other sectors

- The remaining demand sectors are (a) non-specified use, (b) agriculture and (c) non-energy use. The energy consumption in 2021 is detailed in annex table 10. The consumption growth is projected to grow at an annual rate of 4.3 per cent, the same as the national GDP growth rate.

Annex table 10. Consumption by other sectors in 2021

Category	Fuel consumption (ktoe)					
	Coal	Natural gas	Oil products	Electricity	Biomass	Total
Agriculture	-	-	112	785	-	897
Non-specified use	-	614	551	805	-	1,970
Non-energy use	-	4,208	251	-	-	4,459

III. Power technologies cost and key assumptions

The cost parameters considered for the power technologies are shown in annex table 11.

Annex table 11. Power technologies key assumptions

Technologies	Efficiency	Maximum availability	Investment cost (US$/kW)	Fixed O&M (US$/kW-year)	Variable O&M (US$/MWh)
Hydro	-	45.3%	2,348	26.6	-
Solar	-	15.3%	505	7.7	-
Wind	-	30.6%	908	18.8	-
Bagasse	20%	32.0%	891	18.8	-
Furnace	46.1%	11.8%	520	22.5	4.39
Gas engine	42%	53.9%	520	33.4	2.91
RLNG	64%	36.5%	407	18.9	3.71
Coal	40%	72.1%	1,344	26.3	2.93
Nuclear	36%	48.5%	4,227	93.9	0

IV. Economic analysis data for clean cooking technologies

The NEXSTEP economic model utilizes the technological and cost parameters to estimate the. annualised cost of clean cooking technologies (annex table 12). The calculation assumes an annual cooking thermal energy requirement of 3,840 MJ per household (Putti and others, 2015). In addition, a discount rate of 5.37 per cent is assumed.

Annex table 12. Technology and cost data for clean cooking technologies

Technologies	Efficiency[15] (%)	Lifetime[16] (years)	Stove cost (US$)	Variable O&M[17] (US$/year)	Fuel cost (US$)
ICS	30	4	35	10	0.10 per kg
LPG stove	47	7	30	10	1.03 per kg
Electric stove	84	15	37	10	0.11 per kWh
City gas stove	47	20	44	10	0.67 per m^3

15 Sources: ICS – own estimation, LPG stove efficiency ranges – (World Bank, 2014), electric cookstove (induction stove) – (IEA, 2012).

16 Sources: ICS – own estimation, LPG stove – (Clean Cooking Alliance, 2021), electric stove – (IEA, 2012).

17 Variable O&M is based on own assumptions.

V. Summary results for the scenarios

	BAU scenario	CPS scenario	SDG scenario	DPS Scenario
Universal access to electricity in 2030	100%	100%	100%	100%
Universal access to clean cooking in 2030	59.2%	59.2%	100%, via electric cooking stoves	100%, via electric cooking stoves
Energy efficiency in 2030	4.48 MJ/US$	4.47 MJ/US$	3.97 MJ/US$	3.97 MJ/US$
Renewable energy share in TFEC in 2030	3.9%	6.8%	23.5%	27.5%
GHG emissions in 2030	279.9 $MTCO_{2-e}$	236.2 $MTCO_{2-e}$	220.4 $MTCO_{2-e}$	172.4 $MTCO_{2-e}$
Power sector optimization	Percent share	IGCEP 2022-2031	IGCEP 2022-2031	LEAP's Least Cost Optimisation
Renewable energy share in power generation in 2030	33%	60%	60%	94%
Net benefits from	US$ 169.2 billion	US$ 150.1 billion	US$ 150.1 billion	US$ 134.5 billion