National Low-Carbon Outlook and Technology Roadmap: Cases from South Asia

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Project Introduction
Cluster Technical Assistance

Integrated High Impact Innovation in Sustainable Energy Technology (Regional Cluster Technical Assistance)

Subproject 1: Energy System Analysis, Technology Road Maps and Feasibility Studies for Pilot Testing (Technical Assistance 9690 – Delivered by PwC India)

Subproject 2: Prefeasibility Analysis for Carbon Capture, Utilization and Storage (Technical Assistance 9686)

Subproject 3: Pilot Testing of Innovative Energy Technologies and Business Models (Technical Assistance 9960)

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Background and Objectives of the Study
Sustainable innovative technologies and business models are needed by developing countries to facilitate and expedite just energy transitions, and infrastructure investment must be future-proof in terms of rapid technological evolution and climate change.

Implementation of Paris Agreement-aligned Nationally determined contributions (NDCs) and the United Nations Sustainable Development Goal-7 (SDG-7) targets are now more essential in the context of providing livelihood and sustainable development.

Many countries have been expressing the need for external financial, technical, and capacity-building assistance to support NDC implementation, a move that could also enable some to raise their contributions.

Innovative low-carbon energy technologies can be scaled up by performing practical analysis through future-looking scenarios that could identify and match country-specific energy needs with sustainable energy technology and business model solutions which could provide not only access to energy but also affordable energy while helping countries meet their climate goals.
Objectives of the Study

- Develop national energy mix outlook and technology pathways towards 2050 by analyzing energy scenarios of i) meeting universal energy access by 2030, and ii) enhanced policies for implementing NDCs under Paris Agreement.
- Undertake a thorough investigation of national energy technology priorities in meeting SDG 7 and implementing NDCs considering the low carbon energy outlook developed.
- Identifying investment-associated costs and financing requirements considering the developed low-carbon energy pathway.
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Modelling Framework and Approach
Structure of MESSAGEix Model

**LIST OF VARIABLES**
- **OBJ**: System cost
- **EXT**: Resource extraction
- **REN**: Renewable resource
- **CAP**: Total installed capacity
- **ACT**: Activity performed by each of the technologies
- **COMMODITY_USE**: Total commodity used and consumed for activities.
- **DEMAND**: Energy demand
- **EMISS**: Aggregated emissions
- **COST_NODAL**: System cost at nodal level over the time

**LIST OF PARAMETERS**
- Resource volume / Resource cost / Rate of extraction
- Peak load factor
- Capital Cost / Fixed cost / Var Cost
- Construction time
- Technical lifetime
- Capacity factor
- Emissions factor
- Reliability factor
- Flexibility factor
- RE potential per grade

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Developing a National Energy Model

**Representative Bottom-up energy model: Energy flow and levels of energy use**

- **Useful energy demand***
  - Agriculture energy demand
  - Transportation demand
  - Cooking energy demand
  - Residential Building energy demand
  - Commercial building energy demand etc.

- **Final energy demand**
  - Oil based vehicle
  - Electric Vehicles
  - Gas cooking
  - Biomass cooking
  - Electric pumps
  - Solar Thermal
  - Residential

- **Secondary energy (electricity)**
  - Subcritical PP
  - Supercritical PP
  - Nuclear PP
  - Hydro PP
  - Biomass PP
  - Gas PP
  - Wind PP
  - Solar PP
  - Geothermal PP

- **Primary energy demand (coal, RE)**
  - Domestic Resources (coal, oil, RE)
  - Imported Resources (coal, oil, RE)

- **Imports**
  - Renewable energy fuel-mix
  - Emissions
  - Costs

- **Final energy (coal, oil, gas RE)**
  - **Biomass Reserves**
  - **Coal Reserves**
  - **Oil Reserves**
  - **Gas Reserves**
  - **Solar Potential**
  - **Wind Potential**
Technology Mapping

**Demand Technology** - Information regrading demand, like passenger demand from road, passenger demand from rail, residential energy demand, commercial, etc.

**Utility Technology** - technology that utilises the demand in terms of different modes, like electric vehicles, oil-based vehicles, gas-based vehicles, etc.

**Grid Technology** – distribution supply channel between generating technology and final energy demand like electric grid.

**Generation Technology** – technology that transforms one commodity into another to meet the demand, like power plants

**Import Technology** – these are open channels that is used to meet the excess demand in the system and can be treated as channel to meet unmet requirements.

**Resource Extraction Technology** – technology that provides resources like solar, wind, coal, oil, gas, etc. to the system
Assumptions

Scenario Storylines

Business-as-Usual (BAU) scenario

Draws upon based a combination of factors to project future energy and emissions trajectory, such as the objective of least-cost, historic trends, trends in installed capacities and utilization, resource potentials, growth in end-use energy demands.

Projections are based on the current and historic utilization pattern of various energy commodities, emerging renewables and cleaner technologies such as solar, wind, and nuclear without any forced constraint.

Low Carbon (LC) Scenario

Some demand-side management and/or behavioural interventions assumed in the Low-carbon scenario are reflected at the useful energy or end-use level. The final to end-use energy conversion efficiencies reflects the process/technological efficiencies.

Takes into consideration a set of policy and technology measures at both supply and demand side for low carbon pathway. Outcomes are evaluated to analyze the potential of interventions in meeting NDC targets without any explicit application.
Useful Energy Demand Estimation

Development trends by Sector

Sectoral end-use demands are important as they provide insights into the driving levers for growth and energy needs of the sector.

Data Collection Of Historical Energy Use
Analysis of historical energy use to arrive at the growth pattern
Analysis of sectoral policies to identify future growth prospects / shift in energy use pattern
Estimating useful energy demand based on historical and future growth prospects

Based on the above approach, key sectoral demand parameters that influence energy use patterns were determined.

Useful Energy Demand by Sector

The MESSAGE model uses useful energy as the main demand input. Deriving useful energy demand helps in creating scenarios easily where switching between fuels/modes in a sector becomes easy in the context of scenario modelling.
Country-specific Assumptions

The IAM simulates future human development scenarios aligned with the Shared Socioeconomic Pathways (SSPs). The SSPs represent the most recent incarnation of consistent global population, urbanization and GDP projections used to develop global emissions pathways.

The country-level data on GDP growth rate and population has been taken from the IIASA SSP2 scenario database (IIASA, 2018). For the Bangladesh study, the Bangladesh 2050 Pathway Calculator developed by Ministry of Environment, Forest and Climate Change (Bangladesh) was also used as a guidance.

- Pakistan’s population is expected to grow from 207 mn in 2020 to 292 mn by 2050. GDP is expected to grow from USD 640 bn 2010 PPP prices in 2020 to 1988 bn 2010 PPP prices in 2050.

- Bangladesh’s population is expected to grow from 166 mn in 2020 to 196 mn by 2050. GDP is expected to grow from USD 719 bn 2010 PPP prices in 2020 to 1717 bn 2010 PPP prices in 2050.

*Source: IIASA SSP2 database, 2018*
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Modelling Outcomes for Pakistan

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Pakistan’s Climate Efforts and Commitments

- As per the first round of NDC, a target of 20% emissions reduction below ‘BAU’ emissions by 2030.
- In 2021, Pakistan updated its NDC to target 50% emissions reduction (15% unconditional and 35% conditional) by 2030.

By 2030, the country aims for at least 30% of all new vehicles sold in Pakistan in various categories to be Electric Vehicles (EVs).

Aims to produce 60% of all energy produced in the country to be generated from renewable energy resources including hydropower by 2030.

From 2020, new coal power plants are subject to a moratorium, and no generation of power through imported coal.

High Priority Climate Mitigation Actions*

*Source: Pakistan  Updated NDC 2021
Summary of Energy Outlook Results (1/2)

- **Energy and Emissions Outcomes – BAU vis-à-vis LC scenario**

  - **LC scenario Final Energy Reduction (%) over BAU scenario (2050)**
    - **50 mtoe reduction**
      - Agriculture: 1%
      - Commercial: 5%
      - Residential (Cooking): 8%
      - Electricity: 0%
      - Industry: 39%
      - Residential (Appliances): 6%
      - Transport (Freight): 0%
      - Transport (Passenger): 41%

  - **50 mtoe (12%) final energy reduction from BAU scenario (416 mtoe), largely from passenger transport (41%) and industry (39%) sectors**

  - **LC scenario GHG Emissions Reduction (%) over BAU scenario (2050)**
    - **494 MTCO2 eq reduction**
      - Agriculture: 1%
      - Commercial: 2%
      - Cooking: 4%
      - Electricity: 36%
      - Industry: 0%
      - Residential: 0%
      - Transport (Freight): 23%
      - Transport (Passenger): 1%
      - Energy Supply, Others: 33%

  - **494 MT (36%) emissions reduction from BAU scenario (1376 MT), top reductions in Industry (36%), passenger transport (34%), power (23%) sector**
Summary of Energy Outlook Results (2/2)

**Investments**

- Pakistan would need to invest **USD 594 billion** between 2020 and 2050, under BAU scenario.
- An additional investment of **USD 192 billion** (USD 6.4 bn/yr) would be required to support decarbonisation efforts under LC scenario.

**GHG Emissions**

- In LC scenario, total emissions would reach **327 MtCO2e** by 2030 and **882 MtCO2e** by 2050 – 21% and 36% lower than BAU scenario.
- About 75% of the total emissions reduction are expected in the demand-side by 2050.

**Primary Energy (PE) Supply**

- Under LC scenario, PE is projected to be 3% and 13% lower than BAU by 2030 and 2050.
- Import dependence continues but composition changes. Highest growth in natural gas imports accounting for about 40% of total imports, followed by oil (32%) and uranium (20%).

**Final Energy (FE) Demand**

- BAU FE requirements would reduce by 7% and 12% by 2030 and 2050 under LC scenario.
- By 2050, Coal share to reduce from 41% under BAU to 23% in LC scenario; electricity share to increase from 11% under BAU to 16% under LC scenario.
- Off-grid electricity demand would grow at CAGR of 15% between 2020 and 2050 against 2% in BAU.

**Installed Capacity & Generation**

- Grid-connected capacity would reach **67 GW** by 2030 and **234 GW** by 2050, under LC scenario.
- Renewables would account for around 60% and 80% capacity by 2030 and 2050.
- Generation under LC scenario would increase by about 5 times and 16% higher than BAU levels by 2050.

*In billion USD, 2022 prices*
Low Carbon Pathway for Pakistan between 2020 and 2050

2025

- Continued investment in large nuclear power projects
- Investment in coal-based power plants continues
- Gas-based power generation continues
- Phase out of diesel-based pumps in agriculture
- Gradual investment started in electrification of public and private passenger transport

2030

- Scaling up of solar, wind, and nuclear based power generation capacities
- Peaking of coal power plants
- Complete electrification of rail-based transport
- Investment of USD 157 Billion* is required between 2020 and 2030 to achieve the low carbon growth

2035

- Gas, hydro and nuclear dominate power generation mix
- Increased investment in biomass-based power generation
- Ramping up investment for electrifying passenger transport
- Sluggish growth in traditional biomass-based cookstoves

2040

- Significant capacity addition started in hydro power plants
- Decline in coal-based power generation
- Demand side transition towards cleaner fuels in industry, cooking, and transport
- Investment of USD 228 Billion* is required between 2030 and 2040

2045

- Complete phase out of gas-based power plants
- Rapid growth in investment towards electric vehicles
- Rapid growth in investment towards nuclear power plants
- Higher electrification of various end-use demands
- Demand side transition towards cleaner fuels continues

2050

- High share of non-fossil power generation leads to an emission reduction of 68% over baseline power sector emissions
- Power generation mix dominated by nuclear, hydro, and solar and wind
- Renewable and clean energy transition across the demand sectors
- Investment of USD 401 Billion* is required between 2040 and 2050

*2022 prices

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Conclusions and Recommendations for Pakistan
Conclusions and Recommendations (1/2)

Role of Energy Efficiency

- Final energy requirements are estimated to be **12% lower** by 2050 under the LC scenario vis-à-vis BAU scenario. **Energy efficiency improvement** has a critical role in reducing demand.
- **Potential energy demand reduction** measures for Pakistan include energy efficient buildings, industrial efficiency, transportation electrification, efficient lighting, appliance standards & labeling and demand side management measures.

Electrification and Power Sector transition

- Increased electrification across sectors such as transport, industry, and agriculture is crucial driver of energy efficiency improvements. This is demonstrated by the **share of electricity in final energy consumption**, which is 11% in BAU scenario, compared to 16% under LC scenario.
- To meet decarbonization targets, electrification requires a simultaneous transition to renewable energy in power sector. This necessitates effective system planning, supply and demand-side flexibility incentives, as well as short-term balancing and stability procedures.

Role of Coal in Clean energy transition

- The LC scenario envisages coal capacity to **peak in 2030** at 9.3 GW. Therefore, any further investments in coal-based power plants need to be carefully evaluated to avoid carbon lock-ins.
- It is recommended that **HELE (High-Efficiency Low Emissions) coal technologies** like USC and IGCC must be deployed if domestic Thar coal reserves are to be utilized. **Coal-derived syngas** can also be used to manufacture **hydrogen, ammonia, steel or fertilizers**.

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Conclusions and Recommendations (2/2)

Investment in power sector

- Pakistan has significant potential of non-fossil energy, particularly hydro, nuclear, solar and wind power. This transition can help reduce reliance on fossil fuels and lower carbon emissions. **Power sector emissions** reduce by 68% in 2050 under the LC scenario vis-à-vis BAU scenario.
- Between 2020 and 2050, **additional cumulative power sector investments** (over and above BAU scenario) of ~USD 30 Bn USD in nuclear, ~USD 25 Bn in solar, ~USD 33 Bn in wind and ~USD 90 Bn in hydropower would be required in the LC scenario vis-à-vis BAU.

Investments

- The study indicates that with consistent efforts towards efficiency gains across sectors, electrification of end-uses, and a shift towards low-carbon fuels, Pakistan can **reduce its emissions by almost one third by 2050 compared to a BAU scenario with the same economic growth**.
- Given Pakistan’s ongoing financial crisis, requirements of additional **USD 192 billion USD** between 2020 and 2050 seems to be a challenging task and country might require external funding support to achieve its climate goals.

Role of Institutions

- The government can promote low-carbon investments by **implementing policies** to attract **private sector funding** in this area (Government alone cannot fund this initiative) and develop an effective regulatory system to support these goals.
6 Modelling Outcomes for Bangladesh
Bangladesh’s Climate Efforts and Commitments

- In its first NDC, Bangladesh proposed 5% unconditional reduction in GHG emissions from BAU scenario by 2030 and further 10% conditional reduction (total 15% reduction from BAU by 2030) in GHG emissions taking base year of 2011.
- In 2021, Bangladesh updated NDC, in unconditional scenario, GHG emissions would be reduced by 6.73% below BAU in 2030 and in conditional scenario, GHG emissions would be reduced by additional 15.12% (total 21.85% reduction from BAU by 2030) contingent upon international funding and technological support.

By 2030, the government aims to lower energy intensity (national primary energy consumption per unit of GDP) in 2030 by 20% compared to the 2013 level.

- The Government has set a target of covering 40% of its power generation with clean energy by 2041 and to import around 9 GW under regional and sub-regional cooperation.
- National Solar Energy Roadmap; The Energy Efficiency & Conservation master Plan (EECMP)

High Priority Climate Mitigation Actions*

- Automobile Industry Development Policy 2021 targets to transform majority of passenger cars, bus, trucks and 3-wheeler auto rickshaws to EV by 2030.
- Other proposed draft Policies under review are Electric Vehicle Registration & Operation Policy -2022 and EV Charging guideline/policy(draft)

*Source: Bangladesh Updated NDC 2021; ** Energy Efficiency and Conservation Master Plan
Summary of Energy Outlook Results (1/2)

Energy and Emissions Outcomes – BAU vis-à-vis LC scenario

About 5 mtoe (4.8%) final energy reduction from BAU scenario (92 mtoe), largely from Residential cooking (76%) and industry (14%) sectors.

About 135 MT (38%) emissions reduction from BAU scenario (357 MT), top reductions - Energy supply (83%), Industry (8%) and residential cooking (7%).
Summary of Energy Outlook Results (2/2)

**Investments**
- Bangladesh would need to invest USD 223 billion* between 2020 and 2050, under BAU scenario.
- An additional investment of USD 102 billion* (3.4 Bn USD/yr) would be required to support decarbonisation efforts under LC scenario.

**GHG Emissions**
- In LC scenario, total emissions would reach 123.9 MtCO2e by 2030 and 221.7 MtCO2e by 2050 – 16% and 38% lower than BAU scenario.
- About 82.7% of the total emissions reduction are expected in supply-side in 2050.

**Primary Energy (PE) Supply**
- Under LC scenario, PE is projected to be 13% and 10% lower than BAU scenario.
- Import dependency for PES would be 38% by 2050 vis-à-vis 45% under BAU.
- Energy imports reduce by 25% by 2050; largely from gas and oil.

**Final Energy (FE) Demand**
- FE would reach 87.7 Mtoe by 2050, under LC scenario, 5% reduction over BAU scenario
- Natural gas demand would occupy 46% share, followed by electricity at 43% by 2050.
- Off-grid electricity demand would grow at a CAGR of 12% between 2030-50 against 3% under BAU scenario

*In billion USD, 2023 prices

**Installed Capacity & Generation**
- Grid connected capacity would reach 54.3 GW by 2030 and 109.7 GW by 2050, under LC scenario.
- Renewables would account for 64% and 63% of installed capacity by 2030 and 2050
- Generation would increase by over 5 times to 516 TWh by 2050 – 7% rise over BAU levels.

*In billion USD, 2023 prices
Low Carbon Pathway for Bangladesh between 2020 and 2050

2025
- Investment steps up in Solar PV-based power
- No new investments in coal-based power generation
- Continued increase in gas-based power generation
- Energy supply continues to rely on natural gas
- Investment in onshore and offshore wind, biomass-based power generation & electric vehicles begins
- Gradual reduction in traditional biomass utilization

2030
- Rapid investment towards electrification of transport & cooking
- Scale up of biomass-based power and Onshore & Offshore wind projects
- Investment of USD 85 Billion* is required between 2020 and 2030 to achieve the low carbon growth

2035
- Rapid transition in residential cooking from biomass to gas & electric
- Transition from oil to electricity and off-grid solar pumps in irrigation
- Mass-scale investment in electric vehicles
- Traditional use of biomass would be replaced by modern use of biomass

2040
- Significant capacity addition started in Off-grid power generation
- Higher decarbonisation of electricity with increasing renewable-based capacity
- Demand-side transition towards cleaner fuels in industry, cooking, and transport
- Investment requirement of USD 91 Billion* between 2030 and 2040

2045
- Rapid growth in investment towards Electric vehicles
- Overall growth in clean power generation technologies
- Increased reliance on electricity imports
- Gradually increasing electrification in various end-use demands
- Demand side transition towards cleaner fuels continues
- Overall reduction in energy imports

2050
- High share of non-fossil energy-based power generation leads to emission reduction of ~52% over the baseline in the power sector
- Increasing share of renewable energy and clean energy transition in the demand sectors are the factors driving emission mitigation
- Complete phase-out of traditional biomass-based cooking
- Investment of USD 148 Billion* is required between 2040 and 2050

*2023 prices

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Conclusions and Recommendations for Bangladesh
**Conclusions and Recommendations (1/2)**

**Renewables for power generation and power system planning**

- Renewable energy plays a crucial role in Bangladesh’s mitigation and sustainable development efforts. The LC scenario projects renewable energy share in electricity generation to increase to 26% by just 2% currently.
- As renewable energy penetration rises, efforts are needed to ensure the integration of variable renewable energy sources into the grid and enhance grid stability through smart grid technologies and energy storage solutions.

**Role of Natural Gas and minimizing energy security risks**

- Bangladesh needs careful deliberation on investments in additional gas-based capacities given price volatility of the fuel and overcapacity challenges. Under LC scenario, with increased focus on RE, natural gas PE requirements and electricity generation vis-à-vis BAU would reduce by 10% and 18% respectively.
- Bangladesh therefore should shift its focus away from gas to prevent energy security risks. The country must also invest in exploring domestic gas reserves to reduce import dependency.

**Supply and Demand Side Opportunities**

- Key demand-side interventions for Bangladesh are modal shift and electrification in transport, energy efficient buildings, industrial energy efficiency and decentralized use of renewable energy.
- Supply and demand side technologies to be promoted - CCGT, Cogeneration, or combined heat and power (CHP), EVs, electric cookstoves.
## Conclusions and Recommendations (2/2)

### Synergies

- Low carbon energy transition can unlock numerous **opportunities** contributing to prosperity of its people and economy. For example: Bangladesh has one of the **largest off-grid solar power programs** globally, with millions of SHS* installations in rural areas that saved approximately 1.4 MT of kerosene worth USD 411 mn, while creating 75,000 employment opportunities**.
- The **success story of SHS could be replicated** in urban & industrial areas and for promoting other decentralized options like biogas and electric cooking.

### Policy and Institutional Support

- **Policy Integrating** climate change considerations into national and sectoral policy and planning is pertinent. Attractive and effective policies, suitable incentives needed to nudge consumer and producer behavior towards cleaner alternatives and judicious use of resources.
- **Institutional and technical capacity building** is necessary for effectively implementing and monitoring progress towards a LC pathway.

### Investments

- Additional investment of **USD 102 Bn*** between 2020 and 2050 would be required to achieve an annual reduction of about **38% emissions** by 2050.
- **Major supply side additional investments** are expected in solar technologies (USD 65 Bn) and biomass (USD 19 Bn), hydro (USD 11 Bn) based–power technologies.
- **Majority of demand-side additional investments** of USD 6 Bn are expected in transport and industry, particularly targeting energy efficiency improvement measures.

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*Solar Home System; **https://idcol.org/home/solar; ***In billion USD, 2022 prices
Thank you

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