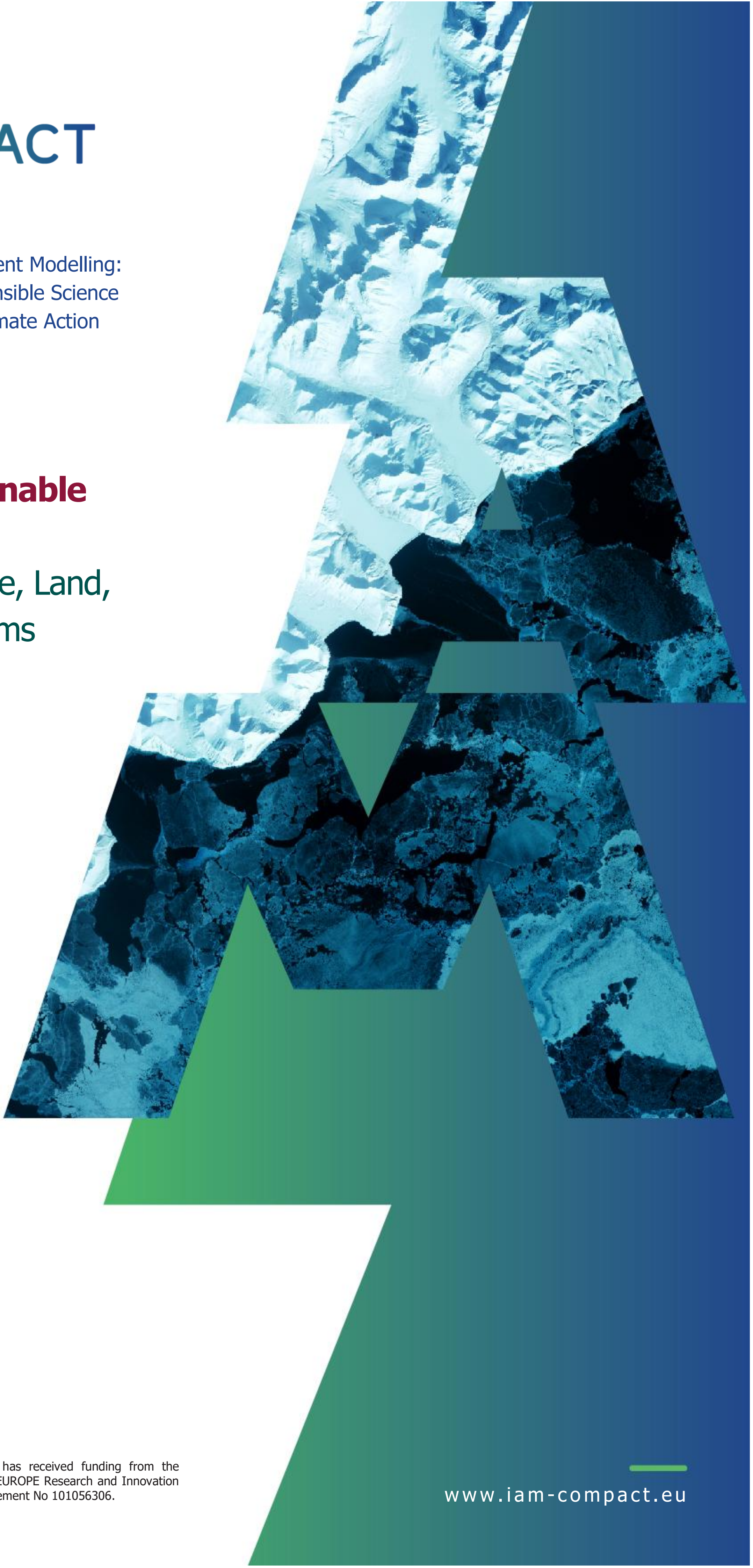
IAM COMPACT

Expanding Integrated Assessment Modelling:
Comprehensive and Comprehensible Science
for Sustainable, Co-Created Climate Action

Sri Lanka's Sustainable Energy Future:

Insights from Climate, Land, Energy, Water systems (CLEWs) Modelling

24/08/2025



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1 Motivation

Sri Lanka is a lower-middle-income island nation home to 22 million people that is under considerable pressure from severe issues including the lingering effects of COVID-19, an economic crisis, and increased exposure to climate change-related impacts. Services and industry make up the largest proportion of its economy, with agriculture being also significant. In order to meet Sri Lanka's relatively ambitious national target of carbon neutrality by 2050, it is accepted that the energy sector provides the opportunities for the most significant changes.

The energy mix for Sri Lanka is predominately comprised of imported petroleum products, which raises risks around vulnerabilities, when physical supply chain disruptions and spikes in global prices are encountered. This has been demonstrated in Sri Lanka's responses to the various impacts due to its recent economic crisis. Additionally, Sri Lanka is highly vulnerable to climate change impacts, as reflected in increased frequency and intensity of extreme weather events such as recent devastating floods and landslides that affected several districts, droughts impacting agricultural productivity and livelihoods, and rainfall changes posing challenges to water resource management, altogether further straining the nation's economy.

To counter climate change and foster economic recovery, the Sri Lankan government is acting to invest resourcefully now in renewable energy, sustainable agriculture, and disaster risk reduction. The energy sector (including transportation) approximately contributes to 59% from total greenhouse gas (GHG) emissions in Sri Lanka. In addition, Sri Lanka ratified the Paris Agreement and maintained and updated its Nationally Determined Contributions (NDCs) in 2021[1]. During the 2021-2030 time-frame, Sri Lanka committed to reduce GHGs across the power, transport, industry, waste, forestry, and agriculture sectors by 14.5% and has advanced the carbon neutrality targets from 2060 to 2050. One important commitment was to grow forest cover from 29% to 32% by 2030.

Despite ramping up its climate ambition, there remains a clear gap between the successful implementation of the country's NDC by 2030 and its net-zero target by 2050[2]. Efforts so far have remained isolated within sectoral boundaries. For islanded nations like Sri Lanka there are potential conflicting uses of the constrained land and water resources across energy, agriculture and forestry sectors. This means that choices made in an isolated sector could have significant and often unintended outcomes in other sectors. Thus, the evidence base for effective policy-making in Sri Lanka will benefit from an analytical approach such as the Climate, Land-use, Energy and Water systems (CLEWs) model.

[1] Ministry of Environment, 2021. *Sri Lanka Updated Nationally Determined Contributions*. https://unfccc.int/sites/default/files/NDC/2022-06/Amendmend%20to%20the%20Updated%20Nationally%20Determined%20Contributions%20of%20Sri%20Lanka.pdf

[2] Ministry of Environmen, 2023. *Carbon Net Zero Roadmap and Strategic Plan Synthesis Report*. https://env.gov.lk/web/images/pdf/divisions/climate_change_division/publications/2023/Synthesis_Report_for_Carbon_Net_Zero_2050__Roadmap_and_Strategic_Plan.pdf

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2 Scenario Design

The CLEWs framework has been widely used to evaluate the connections and complex relationships among Climate, Land, Energy, and Water systems in similar contexts around the world. Within the IAM COMPACT project, the **CLEWs-Sri Lanka** model has been redeveloped from scratch using the Modelling User Interface for OSeMOSYS (MUIO) v5.1. Three scenarios were defined and assessed using CLEWs-Sri Lanka. The three scenarios represent distinct future pathways for Sri Lanka, ranging from minimal intervention to aggressive decarbonization efforts, each with unique assumptions, and technological adoption rates.

- **BAU (Business As Usual):**
    - Sri Lanka continues its current energy policies and established development patterns.
    - There are no significant interventions in clean energy development, energy efficiency, forest conservation, agriculture modernization, or transport decarbonization.
    - Uptake of renewable energy, specifically solar and wind, is slowest as published for the Baseline Scenario of the Long-Term Generation Expansion Plan published in 2022 (CEB, 2023).
    - Land-allocation frameworks prioritize agriculture focusing on limiting crop imports (specially rice paddy) and other infrastructure (such as roads) over renewable energy zones.
    - Limited interventions to facilitate transport electrification and urban energy efficiency. Electric vehicle (EV) penetration remains limited, nudging the electricity demand share only up to just 2.5% by 2050 (Ministry of Environment, 2023a).
    - The country expects to recover crop export earnings from coconut, tea and rubber to the pre-COVID19 levels and maintain that level going forward. In addition, Sri Lanka expects to expand the industrial sector to support GDP growth, thus economic recovery.

- **NDC (Nationally Determined Contribution):**
    - This pathway builds on BAU, but the national policies are now aligned with Sri Lanka's updated NDCs — signalling an effective mobilization of resources and political will.
    - Renewable capacity is moderately scaled up. Natural gas power stations are taken into the electricity mix as a key resource sustaining fuel diversity and increasing security of supply.
    - Fossil fuel reliance decreases progressively, where residential cooking, industrial and commercial activities shift to electricity as the grid electricity dominates renewable energy.
    - By 2030, the scenario aims to achieve 70% of electricity generated from renewables (solar, wind, hydro, biomass). To meet this target, renewable energy capacity (onshore wind and solar PV) expansion is increased by two times the business-as-usual (BAU) rate during the 2025-2030 period, which gradually settles down to 1.5 times the BAU rate from 2030 up to 2050 (CEB, 2023; Ministry of Environment, 2023a).
    - Moderate electrification of transport is facilitated by NDC-aligned policies promoting EV adoption and public transport reforms. This is intended to increase the transport sector's share of electricity demand to 10% by 2050 (Ministry of Environment, 2023a).
    - Grid capacity and efficiency upgraded to accommodate variable renewables.
    - Land use reforms support renewable energy but safeguard food/agricultural security and forest conservation. The NDC target of increasing the forest cover to 32% of land-area by 2030 is met.

- **Ambitious RE (Ambitious Renewable Energy):**
    - Builds upon NDC scenario, with aggressive renewable energy (onshore wind and solar PV) deployment during 2025-2030 period with 3 times higher capacity addition facilitated compared to BAU, and 2.5 times higher beyond 2030 going upto 2050.
    - The other assumptions from the NDC scenario remains the same.

3 Model Results

3.1 Primary Energy Supply and Electricity Demand

- NDC and Ambitious-RE scenarios show limited growth in primary energy supply, reflecting energy efficiency measures and demand reductions.
- Solar and wind become dominant primary energy sources beyond 2030 in the NDC and Ambitious-RE scenarios.
- All scenarios show a continuous increase in electricity demand, with a shift from fossil fuels to electricity leading to more than a threefold increase in demand by 2050 compared to 2020.

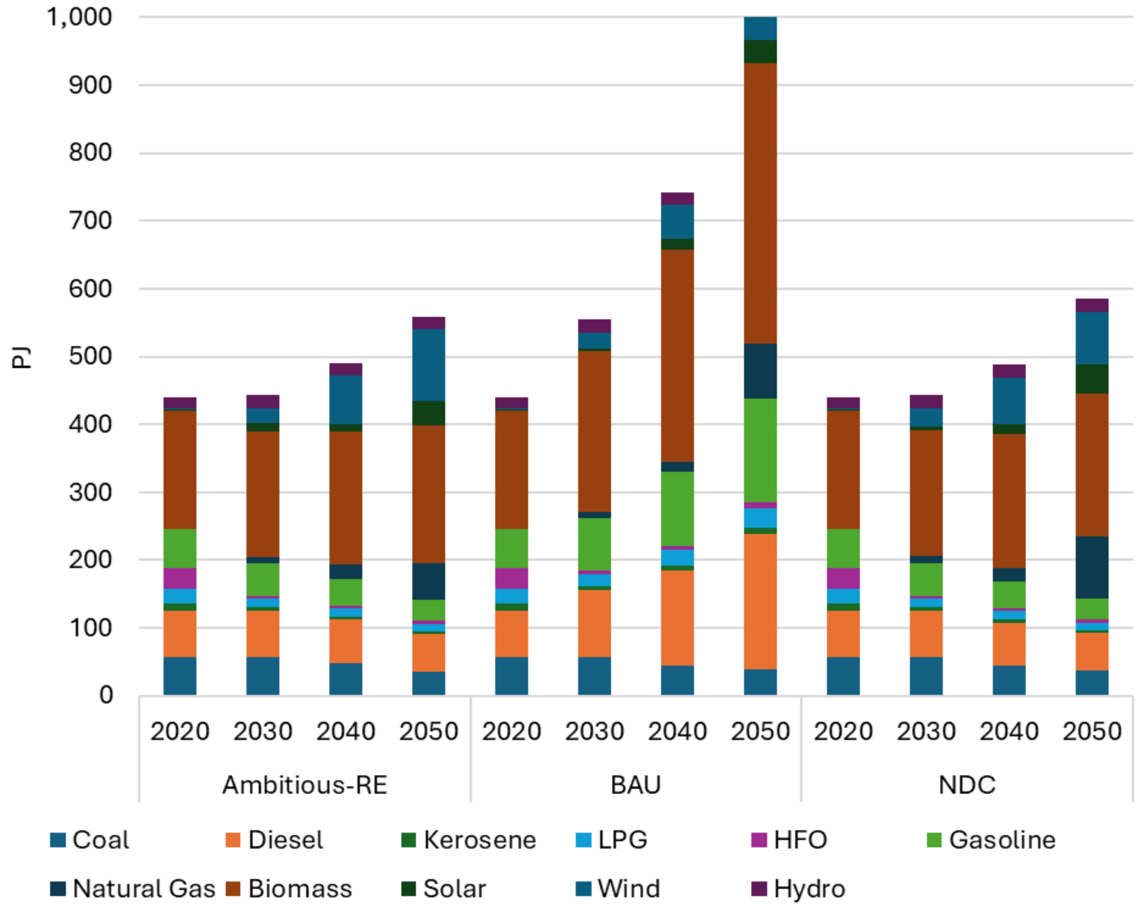

Figure 1: Primary energy supply for the three scenarios in selected years; 2020, 2030, 2040 and 2050.

3.2 Power Generation Capacity and Mix

- New generation capacity across all scenarios is primarily from solar PV, onshore wind, and natural gas, with no new coal, diesel, or HFO capacities favoured.
- The Ambitious-RE scenario shows almost fivefold capacity growth by 2050, driven by the need for larger installed GW base to produce required energy from variable renewable sources.
- By 2030, BAU has 64.8%, NDC has 66.5%, and Ambitious-RE has 67.1% share of electricity from renewable sources. The NDC target of 70% renewable electricity by 2030 requires more ambitious solar

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and wind uptake than existing plans.

- The Ambitious-RE scenario reaches 82% renewable electricity share by 2050, compared to 73.3% in NDC and 67.6% in BAU.
- During night peak hours in the dry season, all scenarios show significant fossil fuel use due to low renewable capacity factors. NDC and Ambitious-RE shift towards hydro, biomass, and wind, with natural gas playing a flexible role.
- During day peak hours, especially in high-wind season, wind, ground-mounted solar PV, and rooftop PV dominate, leading to over 90% renewable electricity generation across all scenarios by 2030.

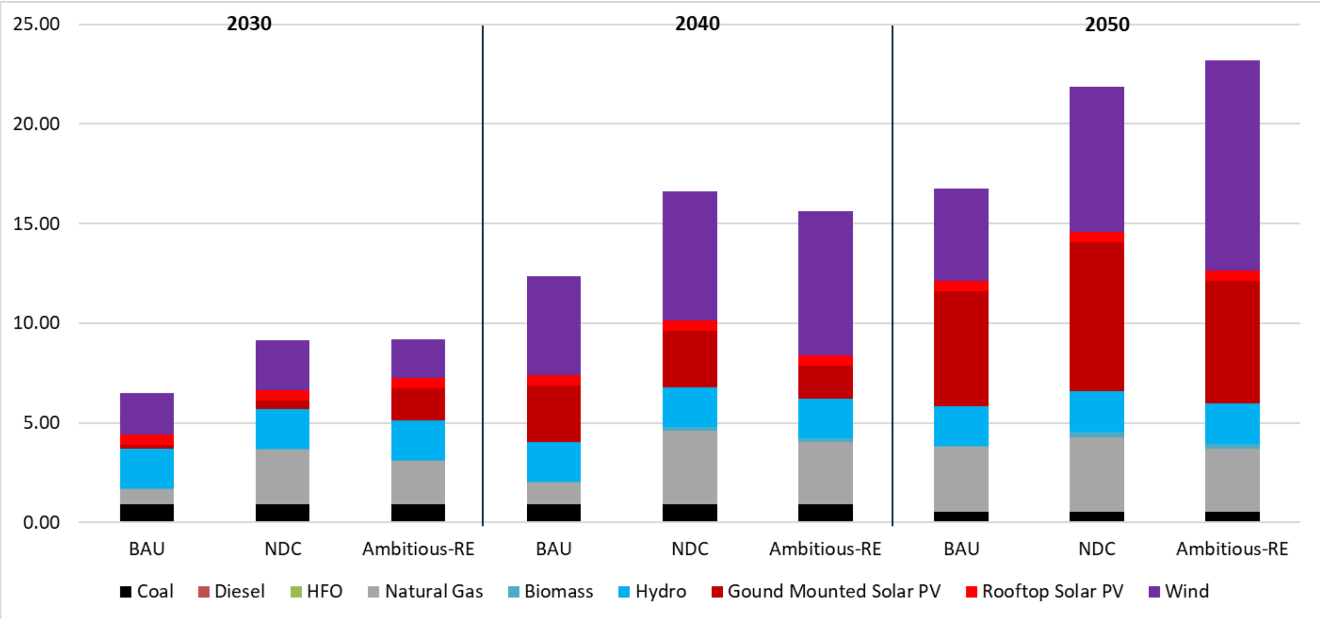

Figure 2: *Total installed power generation capacity (GW) in 2030, 2040 and 2050 across the scenarios.*

3.3 Land-use Implications

- The NDC scenario successfully meets the target of increasing forest cover to 32% of total land area by 2030, a significant difference from the BAU scenario's 29%. This increase is sustained until 2050, similar to the Ambitious-RE scenario.
- The increased forest cover in NDC and Ambitious-RE is compensated by a decrease in agriculture land, suggesting a greater reliance on agricultural intensification to meet food security needs.
- Built-up land increases in all scenarios, but the NDC and Ambitious-RE scenarios show faster growth after 2030, primarily driven by land demand for wind farms in the Ambitious-RE scenario after 2040.
- Agricultural land intensification occurs through strategic internal land reallocation and improvements in crop yields, especially for rice-paddy and coconut, by shifting from lower-yielding, rainfed cultivation to higher-productivity farming.

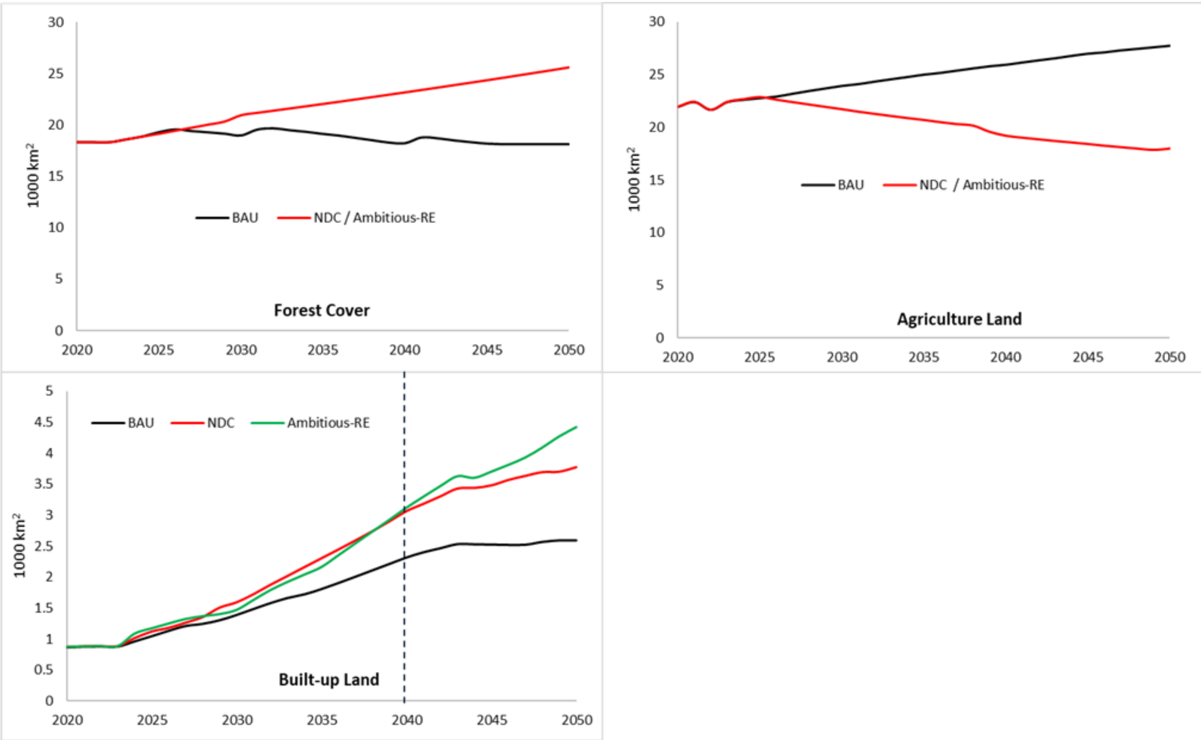

Figure 3: Changes in Land-use, particularly Forest Cover, Agriculture Land and Buit-up Land in Sri Lanka for the three scenarios.

3.4 Water Use

- Overall water demand increases steadily from 1.8 BCM in 2020 to around 2.6 BCM by 2050, with irrigation being the largest component, followed by public water supply and cooling for thermal power stations.
- The Ambitious-RE scenario shows the lowest overall cooling water demand due to its aggressive fossil fuel phase-out.
- The NDC scenario, despite its decarbonization goals, shows increased cooling water demand due to a larger share of natural gas power stations and their operational characteristics.

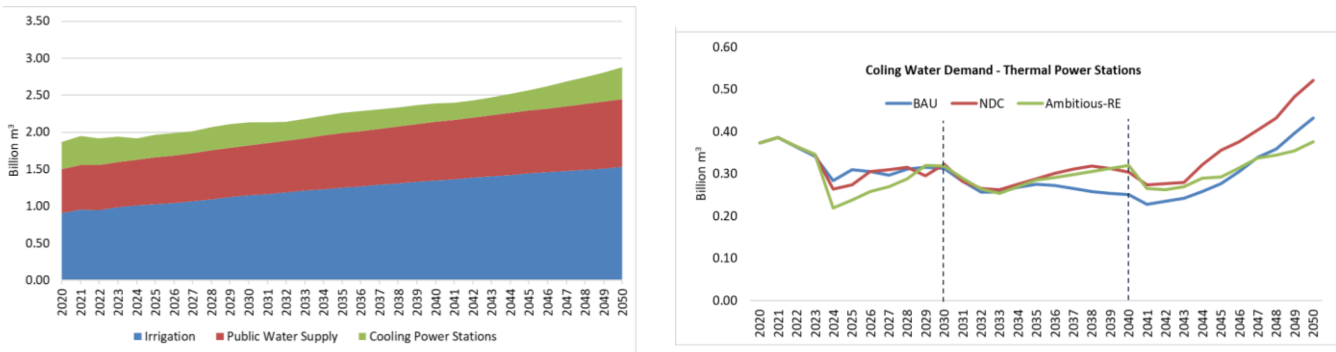

Figure 4: (Left) Water Supply in BAU and (Right) changes in cooling water demand for thermal power stations across the three scenarios.

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3.5 Emissions

- In the BAU scenario, total GHG emissions continuously increase twofold from 2020 to 2050, primarily driven by the transport, industrial, and power sectors.
- Both NDC and Ambitious-RE scenarios achieve substantial emission reductions relative to BAU.
- The Ambitious-RE scenario sees overall GHG emissions decline to 14-15 MtCO2e by 2050, largely due to aggressive renewable energy deployment, fossil fuel phase-out, and significant reductions in transport and industrial emissions through electrification and efficiency.
- The continued use of natural gas power stations for fuel diversification in the NDC scenario sustains emissions from the power sector, potentially impacting overall decarbonization efforts and achieving net-zero by 2050.

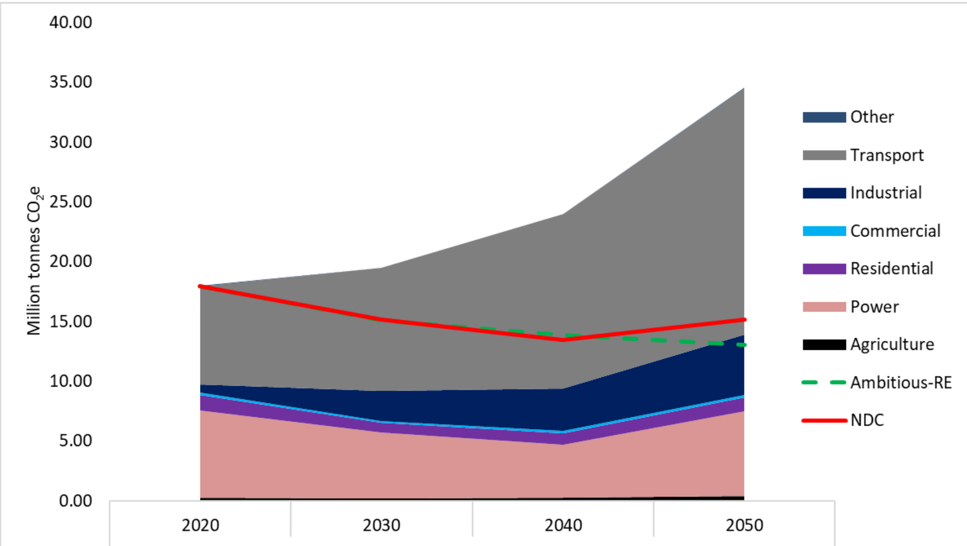

Figure 5: Annual GHG emissions by sector for the BAU scenario in comparison with the overall GHG emissions from NDC and Ambitious-RE scenario (line-charts)

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4 Policy Implications

The CLEWs-Sri Lanka modelling highlights several critical areas for policy intervention to guide Sri Lanka towards a sustainable energy future:

- To meet and surpass the NDC target of 70% renewable electricity by 2030 and achieve deeper decarbonization, an aggressive uptake of solar and wind capacity is essential, as demonstrated by the Ambitious-RE scenario. Policies should facilitate rapid investment and deployment of these technologies.
- While natural gas can offer fuel diversity and grid balancing in the short to medium term, particularly for night peak demand, its long-term role needs careful consideration in ambitious decarbonization pathways due to its impact on emissions and cooling water demand.
- The study shows that energy efficiency measures and demand reductions contribute to limiting primary energy supply growth in ambitious scenarios. Policies promoting energy efficiency across all sectors, along with smart grid technologies and flexible electricity demands, can optimize energy use and reduce overall system costs.
- The trade-offs between renewable energy infrastructure, forest conservation, and agricultural land necessitate integrated land-use planning. Policies should encourage agricultural intensification (higher yields) to free up land for vital forest expansion and renewable energy infrastructure, while also considering the land footprint of large-scale onshore wind farms.
- As electricity demand and thermal power generation evolve, cooling water demand will increase. Policies should prioritize renewable energy sources that have lower water requirements and explore water-efficient cooling technologies for any remaining thermal power plants.
- The transport sector remains a significant emitter in the BAU scenario. Ambitious electrification and efficiency measures in transport are crucial for deep decarbonization and should be a policy priority.
- To accommodate higher shares of variable renewable energy, continuous upgrades to grid capacity and efficiency are necessary. Policies should incentivize investments in smart grid technologies, distributed generation, and other infrastructure that support a reliable and flexible renewable energy system.

By strategically implementing these policy recommendations, Sri Lanka can effectively navigate its energy transition, achieve its climate goals while ensure energy security, economic growth, and environmental sustainability.

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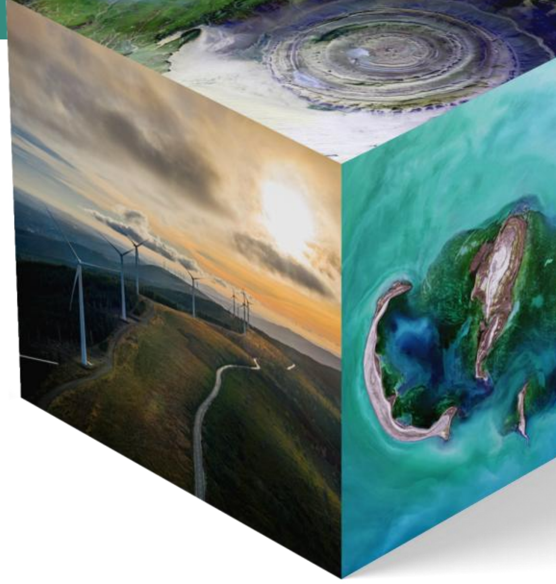

Policy Brief

Sri Lanka's Sustainable Energy Future: Insights from Climate, Land, Energy, Water systems (CLEWs) Modelling

In a nutshell

IAM COMPACT supports the assessment of global climate goals, progress, and feasibility space, and the design of the next round of Nationally Determined Contributions (NDCs) and policy planning beyond 2030 for major emitters and non-high-income countries. It uses a diverse ensemble of models, tools, and insights from social and political sciences and operations research, integrating bodies of knowledge to co-create the research process and enhance transparency, robustness, and policy relevance. It explores the role of structural changes in major emitting sectors and of political, behaviour, and social aspects in mitigation, quantifies factors promoting or hindering climate neutrality, and accounts for extreme scenarios, to deliver a range of global and national pathways that are environmentally effective, viable, feasible, and desirable. In doing so, it aligns climate action with broader sustainability goals, while developing technical capacity and promoting ownership in non-high-income countries.

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