ENERGY TRANSITION PARTNERSHIP

Powering Prosperity and Enabling Sustainability in South East Asia

REPORT

Accelerating Clean Energy Scenario in the Philippines

Deliverable 4: Report on BAU and Clean Energy Scenarios

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Australian Government Department of Climate Change, Energy, the Environment and Water
Children's Investment Fund Foundation
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Executive Summary

Background

Power system planning increasingly requires an integrated approach that considers both generation and transmission development. Decarbonisation efforts increasingly rely on leveraging renewable energy resources, which are often located at a distance from existing grid infrastructure. This creates a need for substantial transmission investment, and the associated costs can materially affect the relative merits of different generation types and locations. As a result, generation and transmission planning cannot be undertaken in isolation. A coordinated view ensures that investment decisions are efficient, timely, and capable of supporting long-term reliability and affordability objectives.

The development of the Philippines' power sector is central to the broader national energy strategy and ongoing economic growth. The direction of this development should be guided by the country's ARC objectives, ensuring that future investments are aligned with economic, social, and environmental priorities. These three priorities are commonly referred to as the energy trilemma. Addressing the trilemma (Figure 1) requires acknowledging that there is no single optimal solution, but rather a series of trade-offs that reflect national preferences and policy settings. To navigate these trade-offs effectively, robust power system modelling is essential.

The Philippines is pursuing clean energy development pathways targeting 50% share of renewables in the power generation mix by 2040. The project focus is on understanding how renewable generation under the clean energy scenarios will displace fossil-based plants, and to analyse the impact on energy supply, tariffs, and grid reliability through strategic integrated power generation and transmission planning.

Figure 1 **Philippines ARC Objectives**

Clean Energy Scenario Modelling Objectives

Much of the important groundwork for power system development has already been established through the Philippines Energy Plan framework and associated modelling. This project builds on that foundation, further developing the modelling to explore additional details and aspects of power system planning that become increasingly relevant under more ambitious decarbonisation objectives. It aims to support policymakers in understanding the impacts of the coal moratorium policy, alternative clean energy scenarios, and the displacement of fossil fuels on energy supply and system costs. The project also seeks to enhance evidence-based policy and decision-making by strengthening policymakers' capability in PLEXOS and PSSE modelling and simulations for low-carbon power sector planning, including transmission planning.

The primary focus of scenario modelling in the context of power system planning is to serve as a capacity-building exercise. The intention is to guide key power sector agencies through an end-to-end process, using the modelling of an updated equivalent Power Development Plan as a practical example. While the modelling outputs should not be regarded as definitive, the key learnings and insights on planning dynamics under high renewable energy penetration are likely to remain relevant.

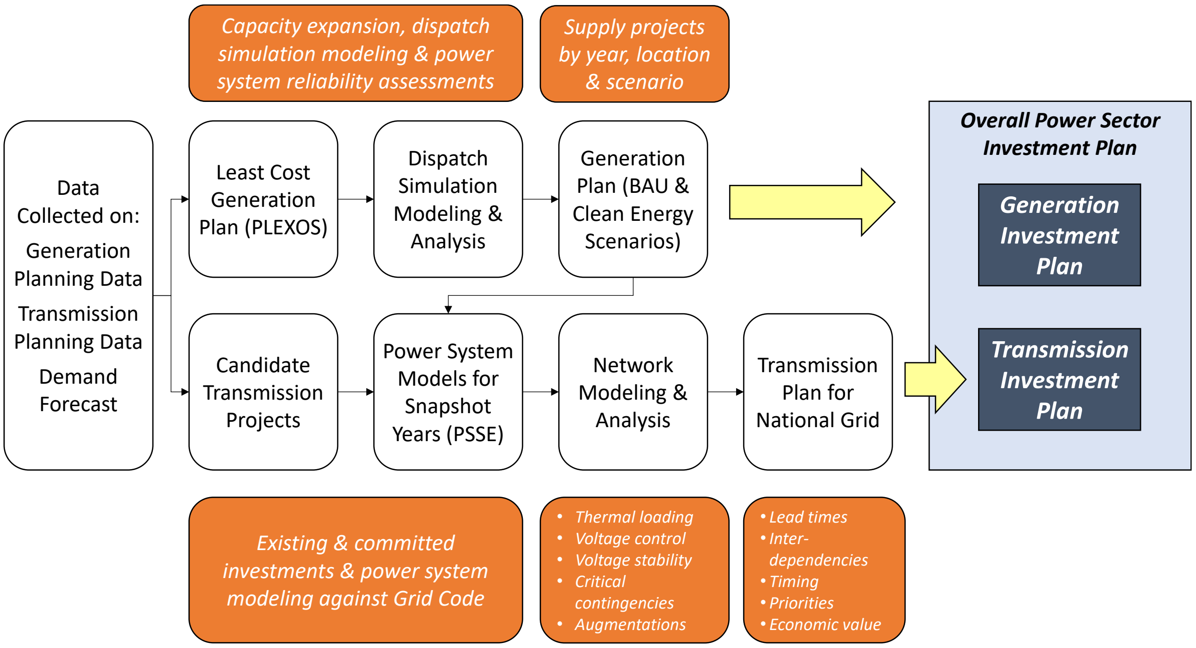
Approach

Power system planning involves numerous details and complexities that must be explicitly accounted for over a long planning horizon. In the case of the Philippine Power Development Plan and the scope of this project, the analysis extends out to 2050, requiring a comprehensive assessment of future system needs, investment pathways, and operational dynamics that must be considered. The approach to this long-term horizon and technical detail cannot be solved in a single process or model, i.e., complementary modelling approaches are required.

Techno-economic modelling using PLEXOS provides insights into least-cost generation expansion, system reliability, and the broader economic implications of policy and investment decisions. In parallel, detailed network modelling with PSS®E enables assessment of the transmission grid's capability to securely accommodate new generation and demand, ensuring technical feasibility and system stability. Together, these tools provide a robust foundation for long-term power sector planning, balancing economic, policy, sustainability and engineering considerations (Figure 2).

Jointly the two models form the basis of investments in generation and transmission over time, and collectively this becomes the investment plan (and other outcomes) for a given scenario. The investment plans for numerous scenarios can then be compared so that the pros / cons and implications of one scenario over another can be properly assessed and fed into policy decisions.

Figure 2 Interaction of PLEXOS and PSSE Modelling & Formation of Investment Plan



Scenarios

The energy development outlook explored in the Philippine Energy Plan is anchored on two scenarios: the Reference Scenario and the Clean Energy Scenario. The Reference Scenario assumes the continuation of current energy policies, while the Clean Energy Scenario reflects more ambitious renewable energy targets within the planning horizon. Although the development objectives extend across the entire energy sector, the power sector is recognised as critical in decarbonising the broader economy. The way these scenarios translate into power sector development pathways is summarised in Table 1below. Key features of these scenarios are outlined below:

- Single demand projection common to all scenarios. Forecast scheduled (or grid) demand will increase by more than threefold by 2050. This is a significant expansion of the Philippine power system.
- All scenarios focus on grid-supply developments. Small-scale generation and demand-side management measures were not explicitly modelled in the present analysis. Nevertheless, it should be noted that the Philippines already has an established policy and regulatory framework promoting energy efficiency and conservation, particularly under Republic Act No. 11285 or the Energy Efficiency and Conservation Act, its Implementing Rules and Regulations, and the National Energy Efficiency and Conservation Plan and Roadmap.[1]
- Key assumptions relating to fuel costs, generator and transmission build costs are also held constant across all scenarios.

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[1] It may also be recognized that effective DSM and load management strategies can contribute to reducing transmission congestion and may potentially defer or optimize transmission and/or generation investments.

Table 1 Scenario Definitions

Scenario	REF	CES 1	CES 2
Description	Existing policies remain in place to meet the threefold increase in electricity demand by 2050[2]	Supply-side policies targeting nuclear and offshore wind deployments, with an added 60% emissions reduction target.	More ambitious OSW targets and a higher carbon emissions reduction of 80%.
Demand	PEP annual energy and peak demand forecast (same across all scenarios). DER and demand-side policies not modelled		
Technology Development	Deployment of clean energy technologies remain consistent with the current policies	REF case with minimum addition of 19 GW off-shore wind and nuclear capacity of 1200 MW by 2032, 2400 MW by 2035, and 4800 MW by 2050.	REF case with minimum addition of 50 GW off-shore wind and nuclear capacity of 1200 MW by 2032, 2400 MW by 2035, and 4800 MW by 2050.
Policy Frameworks	Existing Policies (primarily towards meeting renewable energy targets)	REF case with emissions reduction policies and coal retirement framework to facilitate orderly retirements (as required). Small-scale generation and demand-side policies not modelled	
Infrastructure and Grid Modernisation	Transmission network and CREZ transmission investment and to accommodate higher levels of utility-scale renewable energy		
Emission Reduction Targets	None, other than what is implied through renewable energy targets	60% reduction in emissions against the Reference Case by 2050	80% emissions reduction against the Reference Case by 2050
Curtailment	Allow for up to 15% curtailment across all solar, onshore and offshore wind projects.[3]		

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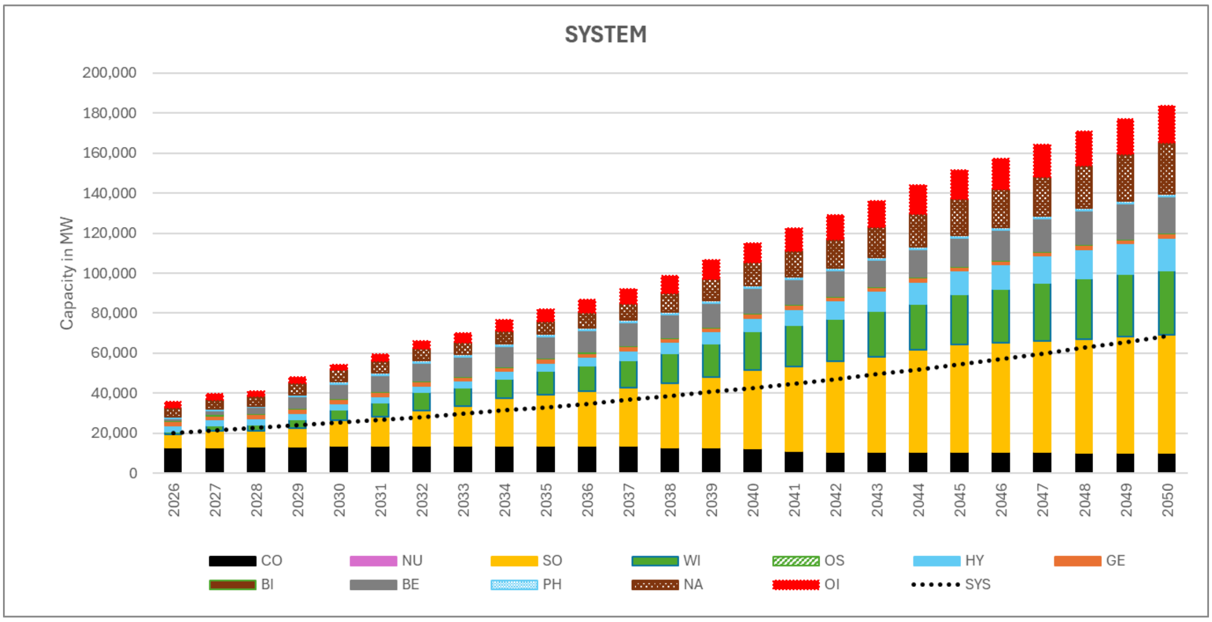
[2] An exception is the change to the current 'priority dispatch' arrangements aimed at minimising curtailment for certain generator types.

[3] Assumes priority dispatch is retained for all other eligible generation types.

Planning Outcomes – Capacity and Generation Mix

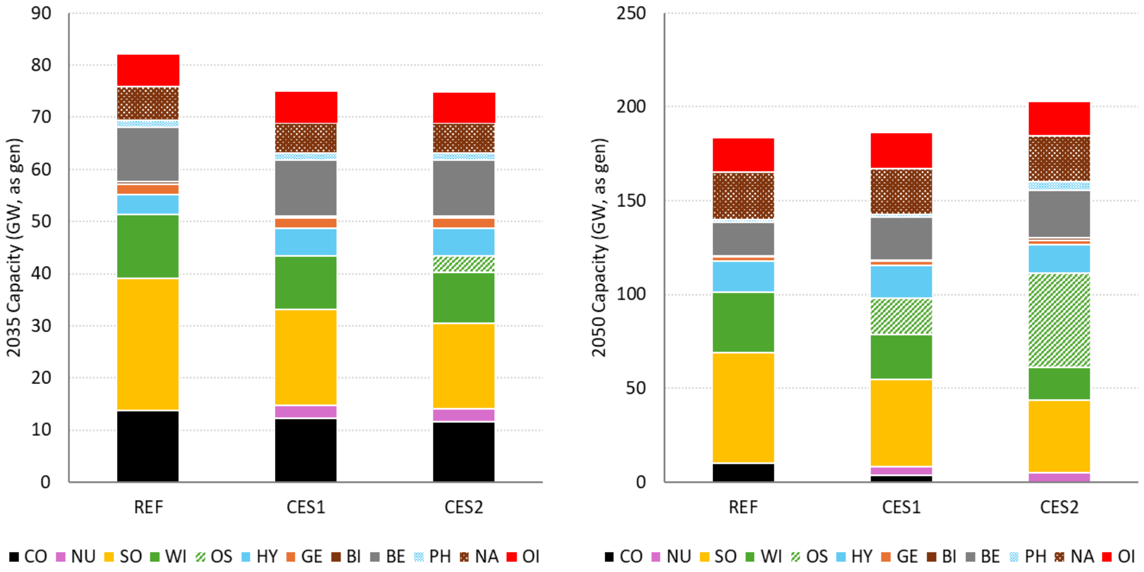
In the Reference Case, achieving the renewable generation targets relies on substantial development of solar and onshore wind capacity through to 2035, with continued growth out to 2050 (Figure 3). These developments underscore the need to prioritise CREZ from as early as 2030. Alongside solar and wind, capacity in the form of battery storage, as well as gas- and oil-fired generation, is required for firming support. With the coal moratorium in place, no additional coal projects are developed beyond those already committed, resulting in a decline in coal's share of installed capacity from 36% in 2026 to just 6% by 2050. No early coal retirements are required under the Reference Case. As coal, traditionally operating as baseload generation, declines in share, natural gas takes on a greater role in firming variable renewable generation. By 2050, nearly half of total system capacity is expected to be renewable, with solar contributing 32% and wind 17%.

Figure 3 Capacity Development (REF, System)



The Clean Energy Scenarios are presented for comparison against the Reference Case. The primary modelling differences in these scenarios are the inclusion of 4.8 GW of nuclear capacity by 2050 and the implementation of explicit offshore wind policy targets, set at 19 GW and 50 GW by 2050 for CES1 and CES2, respectively. As shown in Figure 4, the inclusion of nuclear and the substantial build-out of offshore wind under CES1 and CES2 displace much of the solar and onshore wind capacity that would otherwise be developed under the Reference Case. The solar PV and onshore wind development trajectories diverge from the Reference Case around 2032 with the commissioning of the first nuclear units, and from 2036 and 2041 respectively as offshore wind capacity expands.

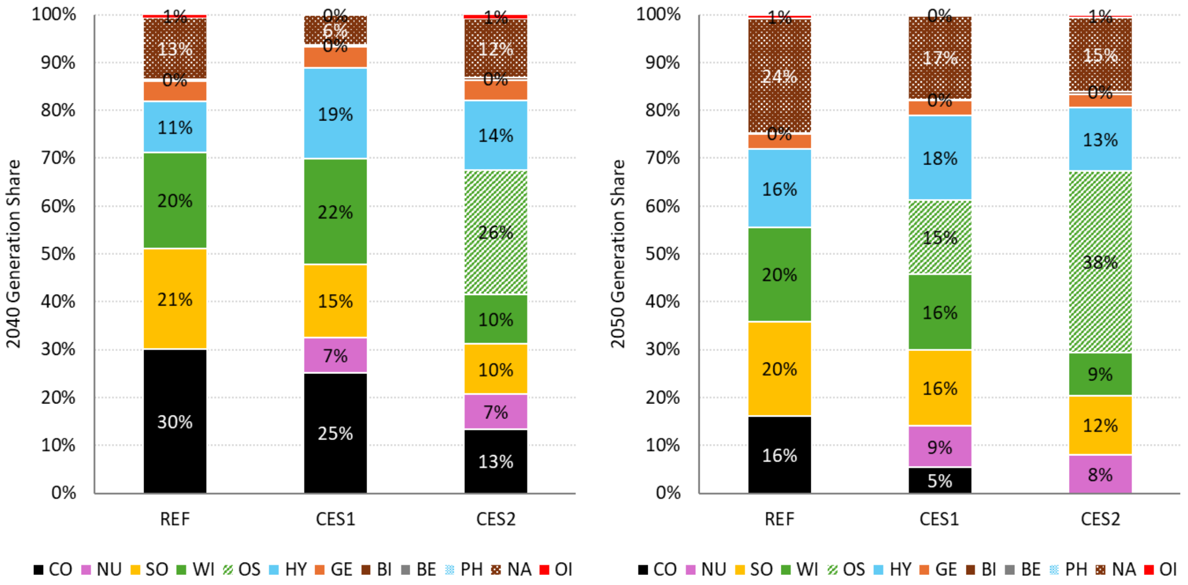
Figure 4 Capacity Development Comparison



Generation mix snapshots across the scenarios are presented in Figure 5. By 2040, the Reference Case shows demand being primarily met by coal, solar, wind, hydro, and gas generation. In contrast, CES1 incorporates nuclear generation, which displaces part of the coal output, alongside higher hydro generation shares. Offshore wind plays a much more prominent role in CES2, accounting for around 26% of total generation, while coal's share declines to approximately 13%.

By 2050, the divergence between the scenarios becomes more pronounced. Offshore wind contributes 15% and 38% of total generation in CES1 and CES2, respectively, accompanied by further reductions in coal generation. The significant introduction of offshore wind and nuclear capacity also reduces the need for solar and onshore wind development, leading to lower generation shares from these technologies in the clean energy scenarios relative to the Reference Case.

Figure 5 Generation Mix Comparison



Planning Outcomes – Importance of CREZ Development

The importance of CREZ investments is illustrated in Figure 6 through their contribution to total system generation. Under the Reference Case, CREZ developments supply up to 45% of total system demand. This contribution increases substantially under the clean energy scenarios, reaching approximately 57% in CES1 and 65% in CES2, reflecting the greater reliance on renewable generation located within CREZ to achieve higher renewable energy targets.

Figure 6 CREZ System Generation Share Comparison

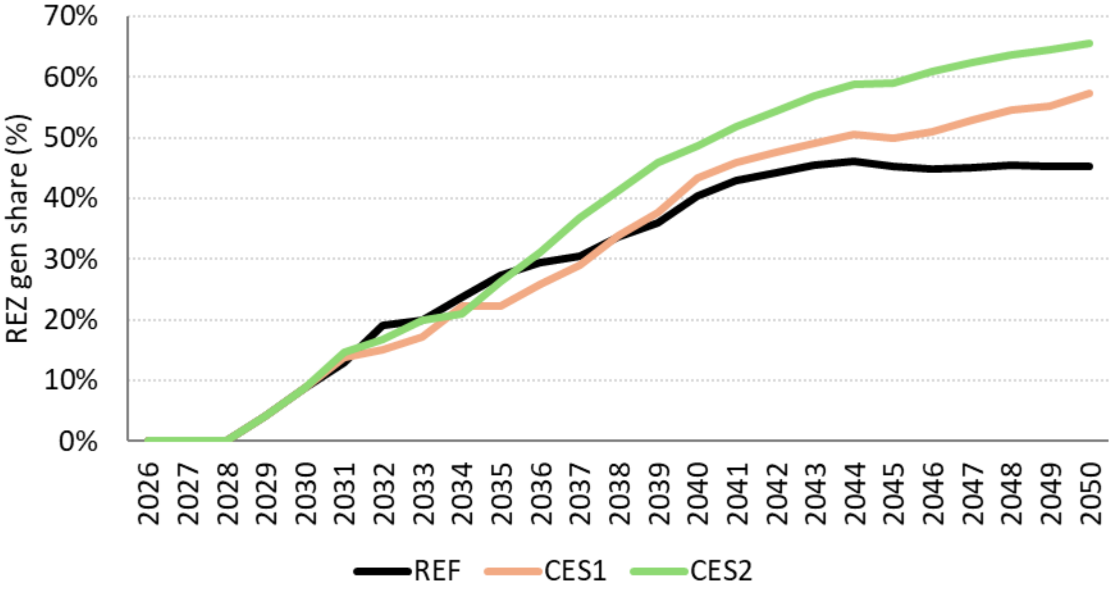
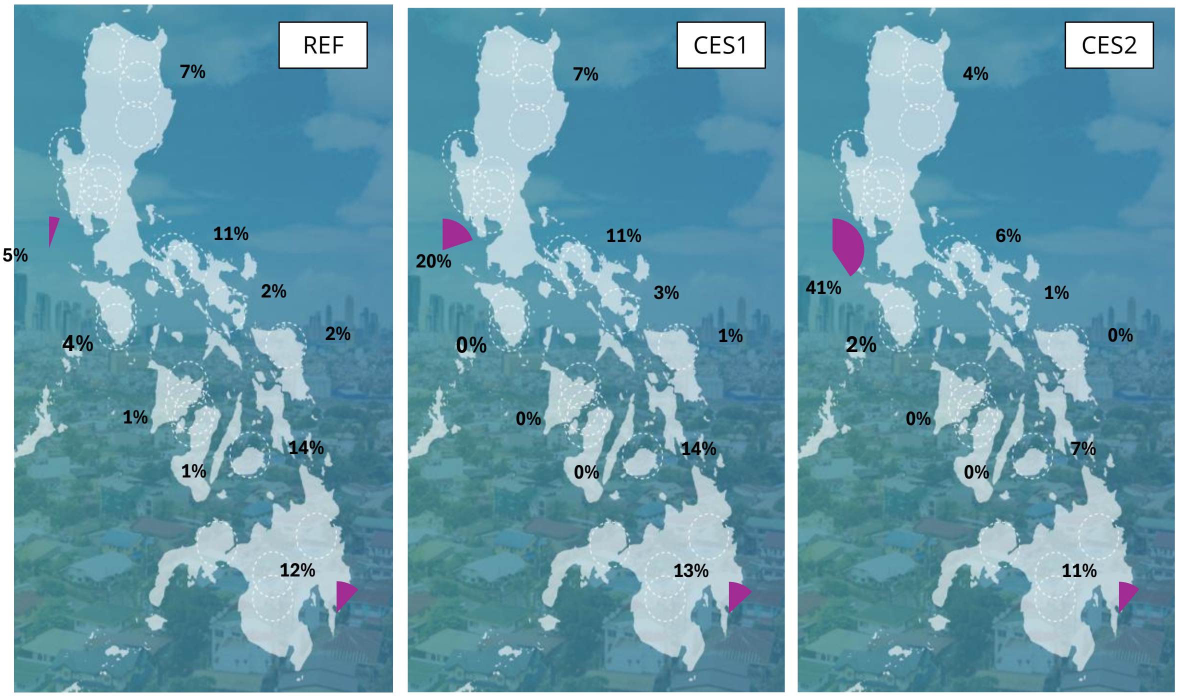


Figure 7 presents the relative locations of the CREZ and their corresponding generation shares across the scenarios. The main point of differentiation between the scenarios is the contribution from the west coast of Luzon, which hosts the offshore wind resources. In CES1 and CES2, these locations account for 20% and 41% of total generation respectively. Such a high concentration of generation within a single area introduces potential reliability risks, particularly in the event of common transmission outages or extended periods of low wind output. Moreover, the significant offshore generation must be transferred to other nodes and regions, adding further pressure on transmission requirements. The CES1 and CES2 scenarios also show minimal generation contribution from the Visayas CREZ compared to the Reference Case.

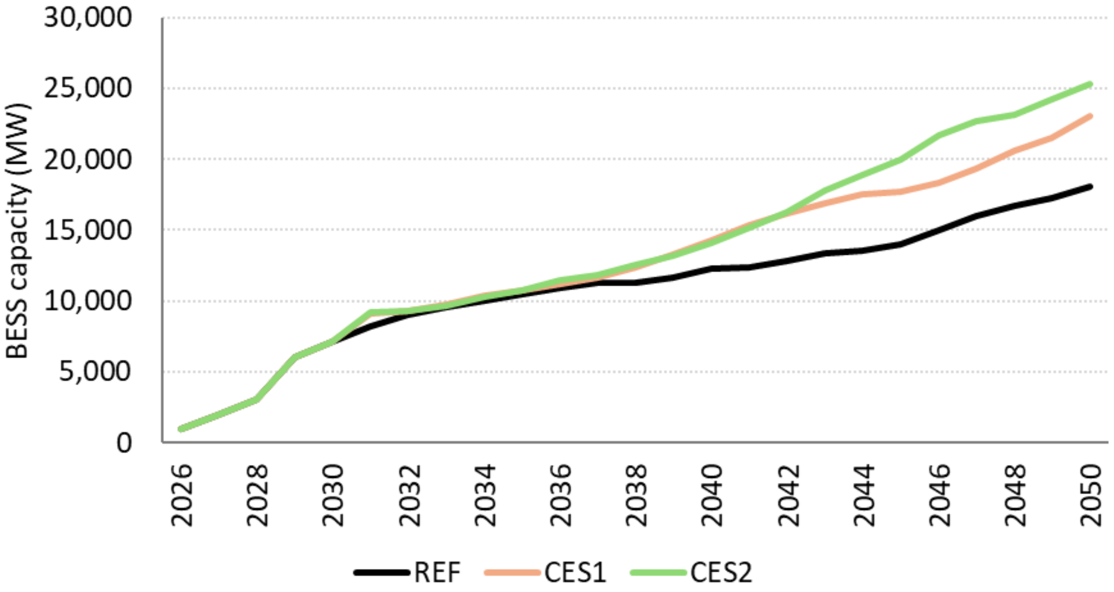
Figure 7 CREZ Total System Generation Share Comparison (2050)



Planning Outcomes – Storage and Transmission

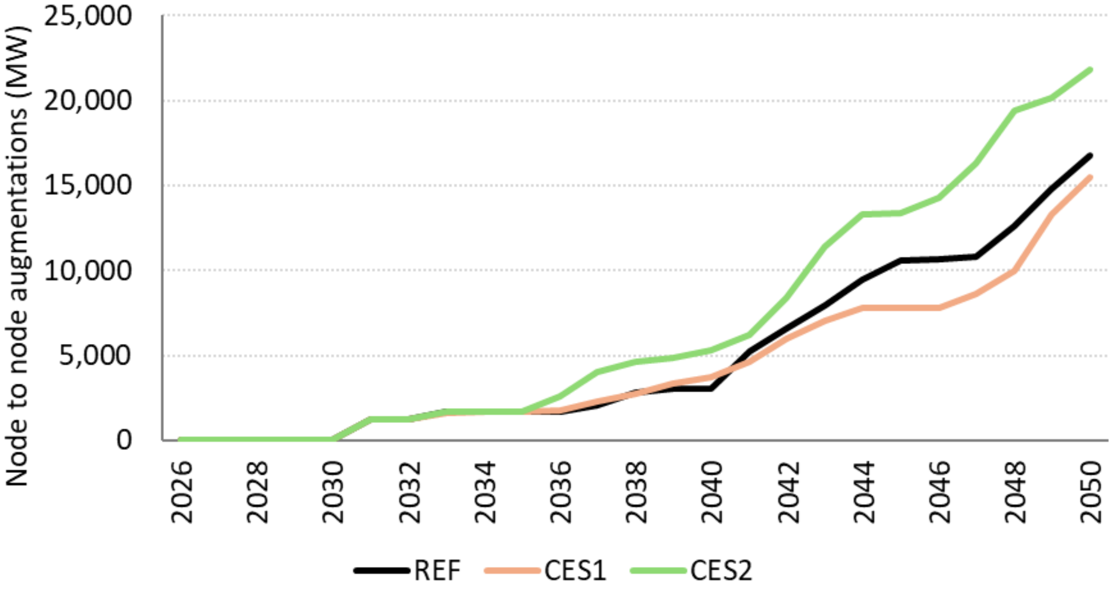
The amount of storage developed increases significantly in the clean energy scenarios relative to the Reference Case (Figure 8). As indicated in the Reference Case, storage requirements initially rise in the late 2020s due to reserve shortfalls in Visayas, with similar trajectories across all scenarios until around 2037. Beyond this point, the clean energy scenarios diverge, driven by higher VRE generation shares and the need for greater load shifting to address supply and demand mismatches and reduce curtailment. By 2050, total storage capacity is higher by approximately 5 GW and 7 GW in the CES1 and CES2 scenarios, respectively. In CES2, batteries on average also have longer duration reflecting the larger energy volumes requiring storage, and by the late 2040s, higher cost pumped hydro projects are developed. Most of the battery developments are sited in at the CREZ locations.

Figure 8 **Battery Capacity Development Comparison**



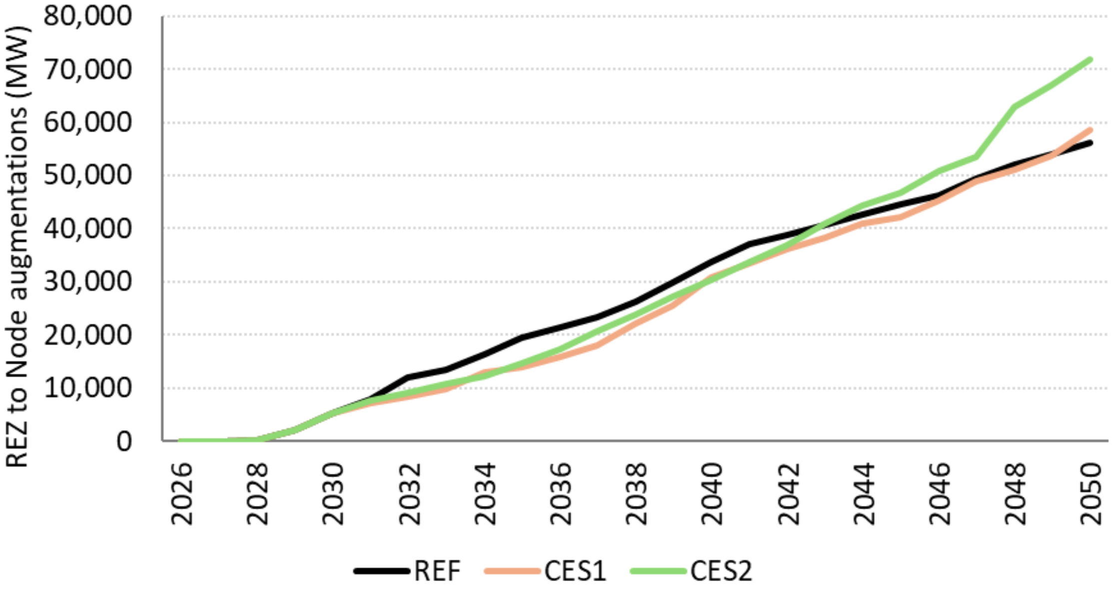
Similar to the battery development outcomes, additional transmission is required to facilitate growing energy transfers between regions (Figure 9) driven by VRE developments across multiple CREZ locations and the increased need to import and export energy during periods of surplus and deficit generation. This is most evident in CES2, which requires over 20 GW of total transfer capability across all node-to-node links (including committed augmentations). The Reference Case requires more transmission augmentation than CES1 due to the greater reliance on solar and onshore wind generation compared to the more baseload-like nuclear and offshore wind profiles in CES1. Although CES2 also includes significant offshore wind generation, the large scale of this capacity necessitates substantially greater node-to-node transmission capability to accommodate higher regional power transfers.

Figure 9 **Node-to-node Transfer Capacity Comparison**



The transmission required to support CREZ developments is directly linked to the total CREZ capacity and the mix of generation types. At a high level, CES2 requires the largest amount of transmission augmentation, while the Reference Case and CES1 show broadly similar requirements (Figure 10). However, the Reference Case requires more REZ-to-node augmentations between 2030 and 2040 due to the higher levels of solar and onshore wind development relative to the CES1 and CES2 scenarios.

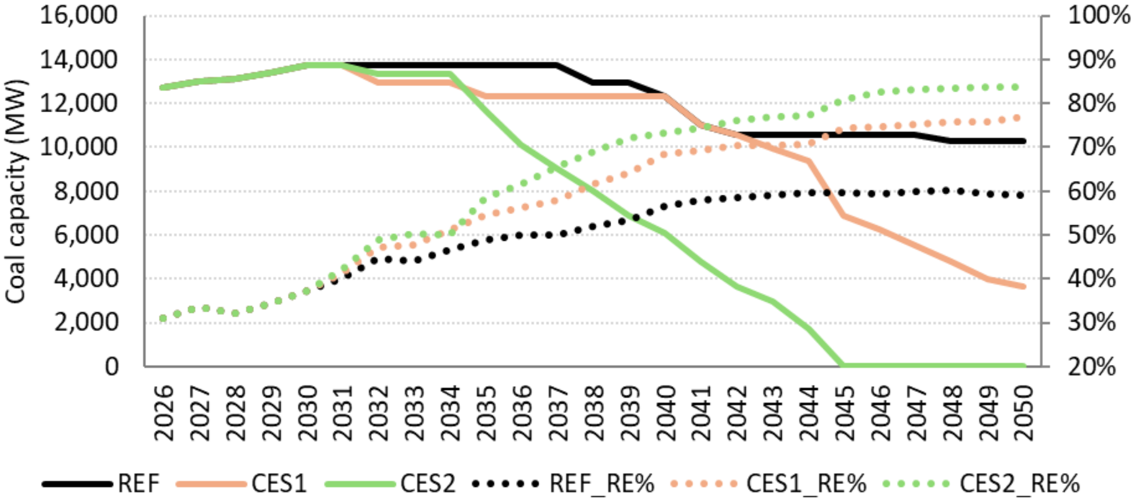
Figure 10 **CREZ Transfer Capacity Comparison**



Planning Outcomes – Early Coal Retirements

Coal capacity outcomes across the scenarios are shown in Figure 11. Under the Reference Case, there are no early coal retirements, and the decline from 14 GW to 10 GW reflects units reaching the end of their technical life. As renewable generation increases beyond the Reference Case, higher levels of renewables progressively displace coal generation, reducing utilisation levels below 60%. Coal plants are then retired based on age, allowing the remaining fleet to operate at more efficient capacity factors above 60%. This dynamic results in significant early coal retirements, particularly under CES2, which requires the full retirement of the coal fleet by 2045, compared to 4 GW of remaining capacity under CES1. Notably, the first retirements are projected to occur as early as 2032, coinciding with the commissioning of the first nuclear unit.

Figure 11 Coal Capacity Comparison (System)

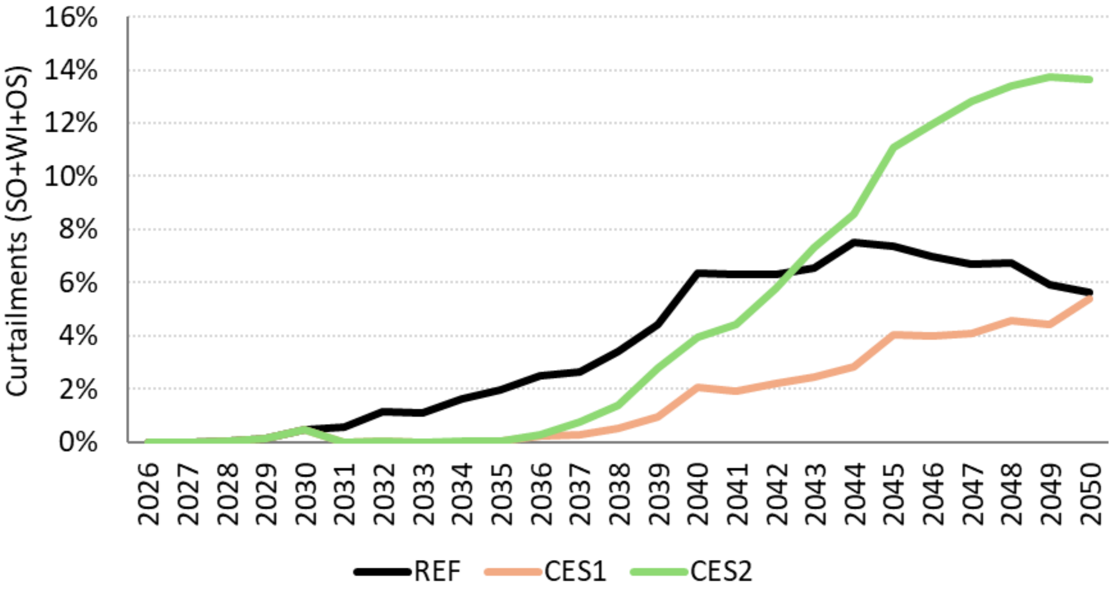


Planning Outcomes – Curtailments

Under the Reference Case, curtailment remains low in the early years but begins to rise above 1% from 2032 onwards as additional solar and wind capacity is developed within the REZ (Figure 12). In comparison, curtailment levels in the clean energy scenarios remain close to zero up to around 2035. This is primarily due to the commissioning of nuclear generation, which operates outside the CREZ and provides a steady output profile compared to variable solar and wind. From 2035 onwards, however, curtailment in the clean energy scenarios, particularly CES2, begins to rise as offshore wind comes online.

By 2050, CES2 curtailment even with higher investment in storage and transmission reaches approximately 14%, driven by the large addition of offshore wind capacity and the associated variability. The Reference Case peaks at around 8% before declining to 6% by 2050 as VRE development slows.

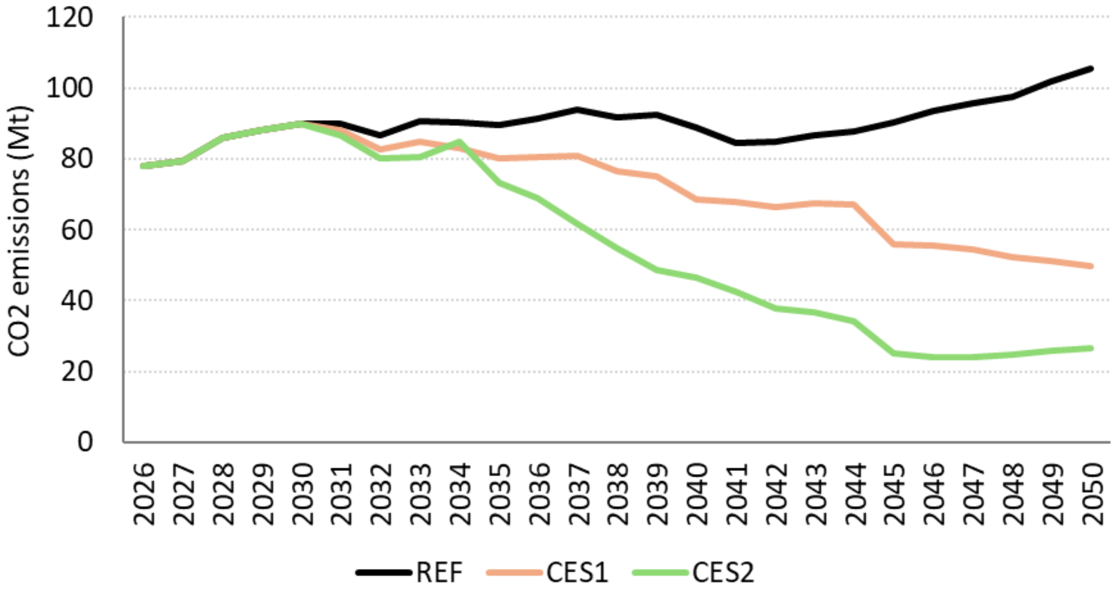
Figure 12 Curtailment Percentage Comparison



Planning Outcomes – Carbon Emissions

Total carbon emissions under CES2 decrease by approximately 75% relative to the Reference Case by 2050, while CES1 achieves a reduction of around 53% (Figure 13). These reductions are slightly lower than intended in the scenario formulation, primarily due to curtailment effects. Emission levels between the scenarios begin to diverge from 2032, coinciding with the commissioning of the first nuclear units and the commencement of offshore wind developments in CES2 from 2036. The rate of emissions reduction slows in the final five years across the clean energy scenarios, while in the Reference Case, emissions rise relative to 2026 levels due to the tripling of demand by 2050. On a grid intensity basis, all scenarios show a rapid drop in carbon emissions per unit of energy generated.

Figure 13 Total System Emissions Comparison



Planning Outcomes – Levelised Cost of Energy

Levelised cost of energy provides a fairer comparison given the high fuel and other variable costs associated with traditional thermal generation in the Reference Case. In contrast, the Clean Energy Scenarios rely heavily on renewable investments, which are largely upfront capital costs. The calculated LCOE, shown in Figure 14, mirrors the investment cost trends and highlights the divergence between the Reference Case and Clean Energy Scenarios. By 2040, the difference ranges from 8–12%, increasing to 15–40% by 2050.

The reasons for the differences can be seen in the net present value of total system costs, presented in Figure 15. The main contributors are: (a) significantly higher coal generation costs from maintaining the coal fleet to the end of its technical life, (b) $10 billion in nuclear costs associated with the 4.8 GW nuclear target, (c) up to $24 billion in offshore wind costs, and (d) higher transmission and battery investment costs.

Ultimately, the results highlight the cost trade-off between sustainability and cost, assuming reliability and security are maintained. The implied carbon abatement cost under CES1 and CES2 relative to the Reference Case is $146/t-CO2 and $186/t-CO2, respectively.

Figure 14 **Levelised Cost of Energy Comparison**

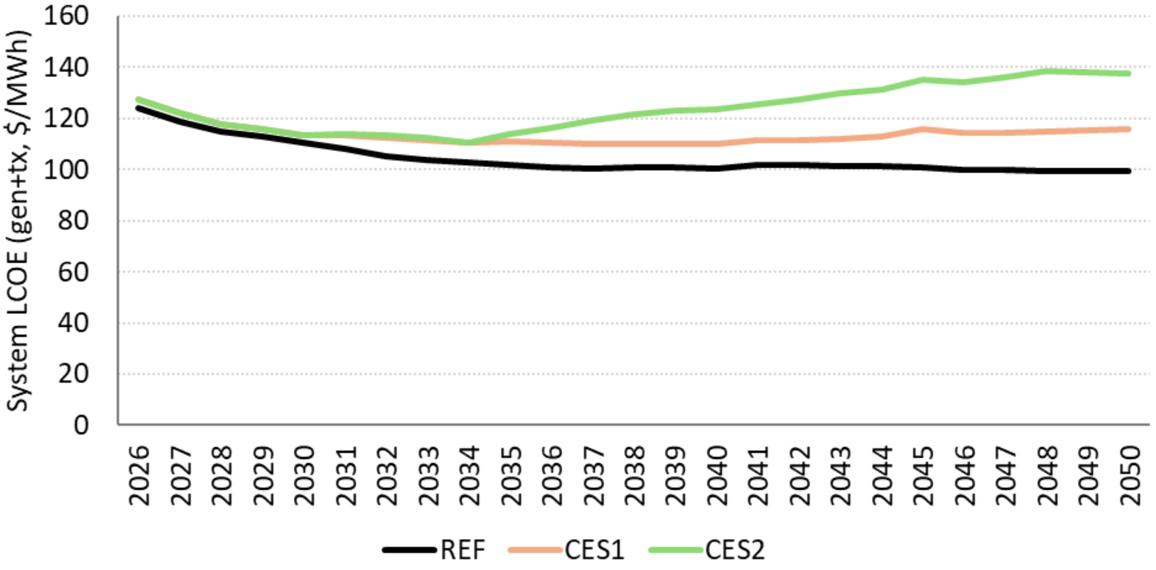
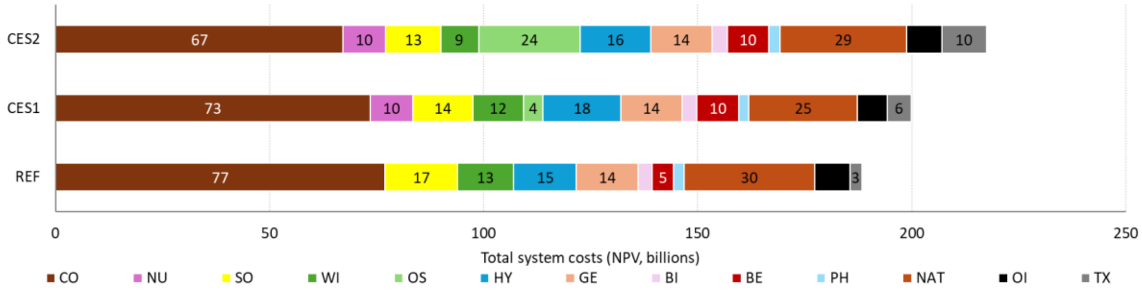


Figure 15 **System Cost Comparison (Net Present Value)**



Conclusion and Key Findings

The planning scenarios illustrate how different policy directions influence the future development of the power system. The Reference Case represents a continuation of current policies and least-cost generation expansion, reflecting a balanced mix of conventional and renewable technologies aligned with existing trends. In contrast, the Clean Energy Scenarios (CES1 and CES2) explore more ambitious decarbonisation pathways that prioritise emissions reduction and sustainability objectives, supported by policy-led investment in nuclear and offshore wind capacity.

These scenarios provide insight into the trade-offs between cost, sustainability, and system complexity. While the Clean Energy Scenarios achieve substantial emissions reductions, they do so at considerably higher investment costs. The integration of high levels of VRE, offshore wind, and nuclear generation also drives greater reliance on transmission expansion, storage development, and coordinated grid operation to maintain reliability and minimise curtailment.

The scenarios also test the implications of accelerated coal retirements, higher renewable penetration, and emerging technologies on overall system operation. As VRE becomes dominant, system flexibility, inter-regional transmission, and long-duration storage become critical enablers of efficient dispatch and security of supply. These dynamics reflect the increasing importance of planning for coordinated CREZ development and the timing of infrastructure investments across the regions.

The CES2 scenario, while associated with higher costs, highlights several important findings:

- The Philippines possess sufficient natural resources to significantly decarbonise its power system by reducing reliance on coal and, to a lesser extent, imported gas.
- Although early coal retirements require careful consideration, the CES2 scenario promotes locally supplied power and enhances energy security through reduced exposure to global supply and price volatility.
- More ambitious decarbonisation targets are achievable but will require significant coordination and planning across generation and transmission activities, alongside proactive policy and market development.

Overall, the planning outcomes highlight that there is no single “right” pathway. Each involves trade-offs between economic efficiency, environmental outcomes, and long-term energy security. The Clean Energy Scenarios represent a deliberate shift towards sustainability, achieved through higher upfront investment and increased system complexity.

Table 2 Comparison of Key Findings

Area	Reference Case	Clean Energy Scenarios
RE generation policy target and emissions levels	The RE generation targets are achieved through significant investment in solar and onshore wind capacity. The 2040 target of 50% is likely to be met even in the absence of a formal target, reflecting the competitiveness of renewables and the existing system’s inherent flexibility to accommodate such levels. However, achieving RE generation levels approaching 60% would not have occurred without an explicit policy target, as further increases beyond this point are no longer least-cost and require deliberate policy intervention. Emissions in the Reference Case increase from 78 Mt-CO2 to above 100 Mt-CO2, due to the tripling in size of the power system and continued reliance on coal and gas	Although the Clean Energy Scenarios do not include explicit higher RE generation targets, the ambitious emissions reduction goals of 60% and 80%, combined with policy-driven nuclear and offshore wind build targets that account for a large portion of future demand growth, drive substantial renewable investment. This allows CES1 and CES2 to achieve RE generation shares of 77% and 84%, respectively. Emissions fall by 53% and 75% relative to the Reference Case by 2050. The development of offshore wind and nuclear, which were not included in the Reference Case, clearly represents a trade-off between sustainability and costs.

Area	Reference Case	Clean Energy Scenarios
	generation in providing baseload and intermediate generation.	
Prioritisation of CREZ development	Prioritisation of CREZ development is critical to achieving the desired RE generation targets. The significant increase in demand, combined with limited non-CREZ RE capacity, points to the need for coordinated transmission and generation planning to unlock CREZ developments as early as 2029/2030, particularly in Luzon and Mindanao. In contrast, development of Visayas CREZ can be deferred to later years. While individual CREZs contribute only modestly to total system generation, their collective development is essential to meeting overall RE targets and diversity in renewable supply.	Prioritisation of CREZ development is crucial for achieving higher RE generation and policy targets. The timing of initial CREZ development is broadly aligned with the Reference Case, reflecting resource quality and proximity to load growth in Luzon. Under CES1 and CES2, CREZ development is largely focused on offshore wind sites off the west coast of Luzon and near Mindoro Island, displacing many of the other CREZ developments required in the Reference Case, primarily in Visayas. These offshore wind sites are projected to account for 20% and 43% of total system generation by 2050. Development of Mindanao's hydro resource remains equally important in CES1 and CES2, contributing on average 12% of total system demand, with its CREZ needed from 2030. Although the focus of CREZ in the Clean Energy Scenarios shifts to offshore wind, the collective development of all CREZ over time is vital to the Philippine energy transition.
Early coal retirements	No early coal retirements are required in the reference case, which achieves a 60% RE generation share by 2050. This outcome is partly due to the significant increase in electricity demand over the period. Coal capacity factors only slightly decline but remain above 60% through to 2050, indicating that existing coal units continue to operate at relatively high utilisation levels despite the growing penetration of renewables.	Early coal retirements are required under CES1 and CES2 due to the rapid transition to VRE and nuclear generation. The pace of offshore wind deployment is a key driver of these early retirements, which are primarily concentrated in Luzon. In the Reference Case, most coal retirements occur between 2036 and 2040 as plants reach the end of their technical life. In CES1, up to 2 GW of coal is retired by 2040, rising to 6.5 GW in CES2. By 2050, CES1 and CES2 require the early retirement of 6 GW and 10 GW, respectively, with the

Area	Reference Case	Clean Energy Scenarios
		tight emissions reduction targets requiring the entire coal fleet retired by 2045 in CES2.
Storage and transmission	The 90 GW of RE capacity development needs to be supported by complementary investments in flexible gas generation, 17 GW of battery storage, 16 GW of node-to-node augmentations, and 56 GW of transmission connecting the CREZ. The CREZ and node-to-node transmission expansions are essential to enable power transfer and meet real-time demand, while storage provides the necessary flexibility to manage the temporal mismatch between VRE supply and underlying demand.	The need for storage and transmission is higher under the Clean Energy Scenarios, mainly due to larger mismatches between VRE generation and demand, and the need to minimise curtailment. CES1 and CES2 require an additional 5 GW and 7 GW of longer duration battery energy storage investment, respectively. In CES2, the storage mix includes an extra 3 GW of pumped hydro capacity, providing longer-duration storage to manage daily energy shifts. Transmission coordination is critical. The Clean Energy Scenarios require increased interconnector capacity across regions to manage generation surplus across the VRE locations. CES1 requires a similar level of interconnection as the Reference Case, whereas CES2 needs an additional 5 GW of non-to-node transmission to handle generation surplus from 50 GW of offshore wind in Luzon. While REZ-to-node augmentations are higher in the Reference Case through to 2040, CES2 requires an additional 15 GW to support the growing RE penetration.
Curtailment	Curtailment is expected to increase over time unless significant amounts of transmission and battery storage are developed. Although there was a modelled curtailment cap of 15%, solar and wind curtailment levels only rise to around 7% by 2050, which represents the indicative economic level of curtailment. Curtailment within each node will vary	In CES2, with higher emissions reduction targets and high VRE generation, curtailment levels would exceed 15% without constraints to minimise curtailment. These constraints drive additional transmission and storage investment, as noted above, to manage curtailment. However, the overall trend of increasing curtailment across all scenarios

Area	Reference Case	Clean Energy Scenarios
	depending on nodal characteristics; however, in absolute terms, it will be concentrated in Luzon due to the scale of RE potential developed both at the node and within the connecting CREZ.	suggests that there is the notion of economic curtailment where minimising curtailment above this level becomes prohibitively expensive. Long-term policy should consider revising existing priority dispatch arrangements, given the high costs of reducing curtailment to zero in a system transitioning to higher renewable generation.
Transmission Planning (2050)	The transmission network generally operates within acceptable limits but experiences overloading along key 230 kV and 500 kV corridors in Southern Luzon and Metro Manila under contingency conditions. Luzon imports around 4.7 GW from Visayas, stressing the 230 kV lines in the southeast. In Visayas, congestion is concentrated in Cebu, Negros, and Panay, with several inter-island links operating beyond capacity. Mindanao also shows recurring overloads along major north–south 138 kV and 230 kV corridors, particularly near Davao and Zamboanga.	CES1: overloading becomes more widespread, particularly across North and Central Luzon and key transformers. Imports from Visayas reduce to about 1.9 GW, which alleviates southern congestion but increases loading elsewhere due to shifting power flows. In both Visayas and Mindanao, higher RE penetration intensifies pressure on inter-island and internal corridors, highlighting the need for local reinforcements. CES2: presents the most constrained network, with widespread overloading along Luzon's 230 kV and 500 kV corridors due to high offshore wind integration. Imports from Visayas increase to around 9.2 GW, heavily loading southern Luzon lines. Under high VRE dispatch, major congestion occurs across Northern Luzon, the Mindoro–Batangas link, and Eastern Luzon corridors. Similar congestion persists across Visayas interconnections and Mindanao transmission paths. Overall, renewable expansion under CES1 and CES2 significantly increases network congestion compared to the Reference Case, requiring substantial reinforcement of 230 kV and 500 kV corridors, inter-

Area	Reference Case	Clean Energy Scenarios
		island links, and substations, particularly under CES2.
Total investment cost and LCOE	Total investment is projected to reach $29 billion by 2035 and $140 billion by 2050, with 95% of the total relating to generation capacity investment. The corresponding LCOE declines gradually from $123/MWh to $99/MWh, driven by the continued growth in renewable generation. The most significant reduction occurs in the first 10 years, after which the decline slows as higher VRE penetration necessitates additional storage and transmission investments.	Total investment costs under the Clean Energy Scenarios are significantly higher, reaching $230 billion and $323 billion by 2050, representing increases of 64% and 131% over the Reference Case. The sharp rise is primarily driven by the high capital costs of nuclear and offshore wind developments. The LCOE outlook aligns with the investment trends, reflecting the high annualised capex associated with these technologies. CES1 and CES2 begin to diverge from the mid-2030s, reaching $114/MWh and $138/MWh by 2050, or 15% and 40% higher than the Reference Case, respectively. Ultimately, the Clean Energy Scenarios highlight the cost and sustainability trade-off, with implied carbon abatement costs of $146/t-CO2 and $186/t-CO2, respectively.