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Achieving Net Zero Carbon Emissions in Nepal: Role of Green Hydrogen and other Clean Energy Options

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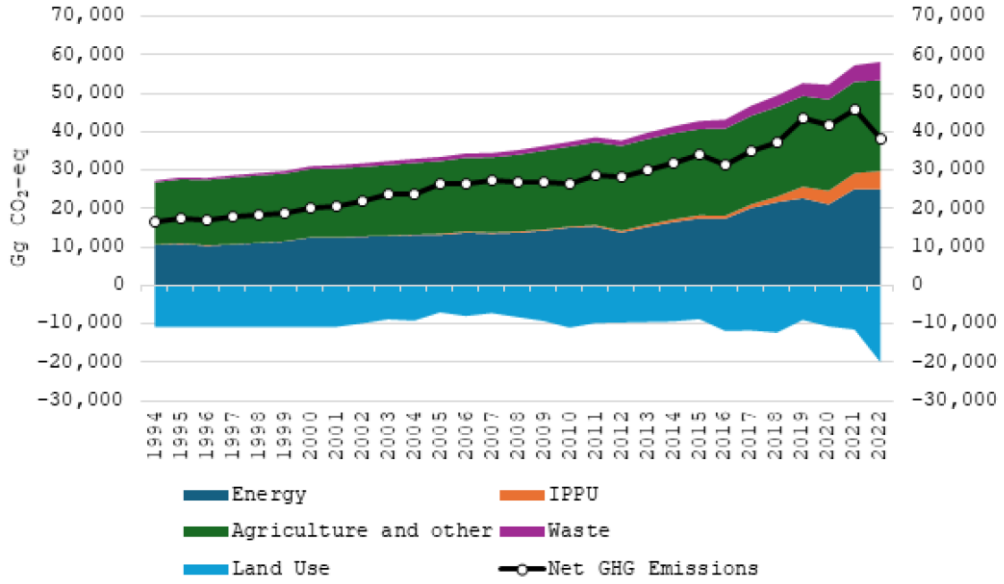
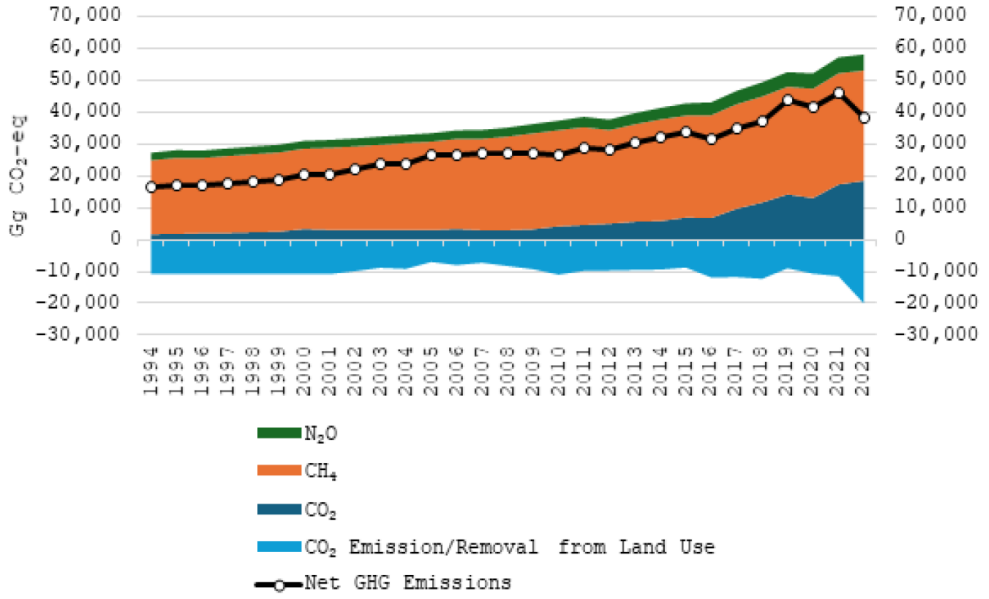
GHG Emissions Trend by Sectors in Nepal 1994-2022



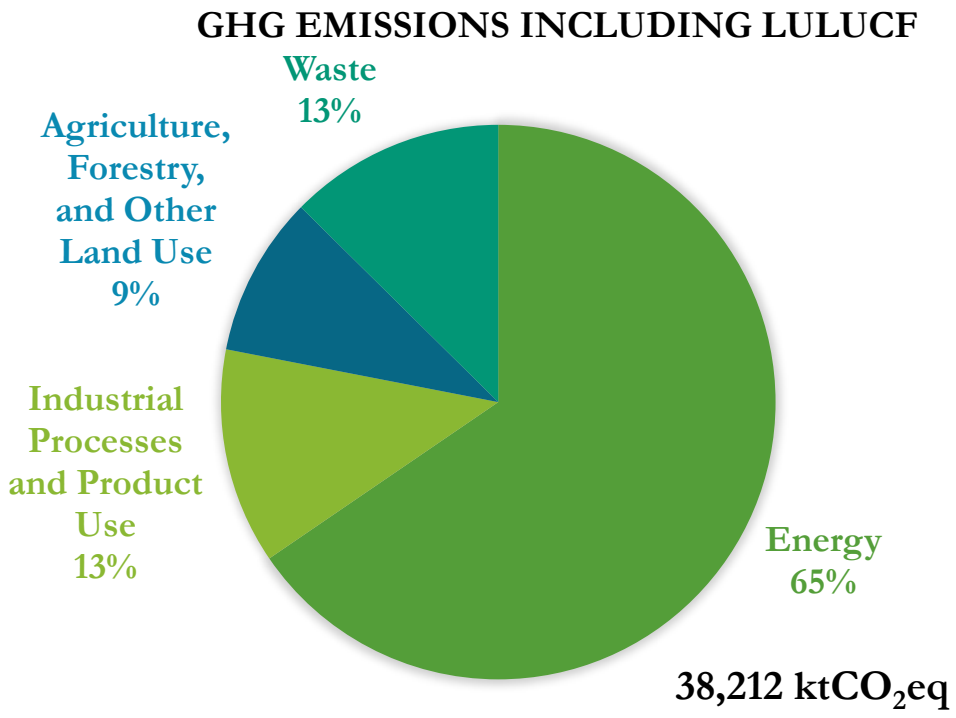


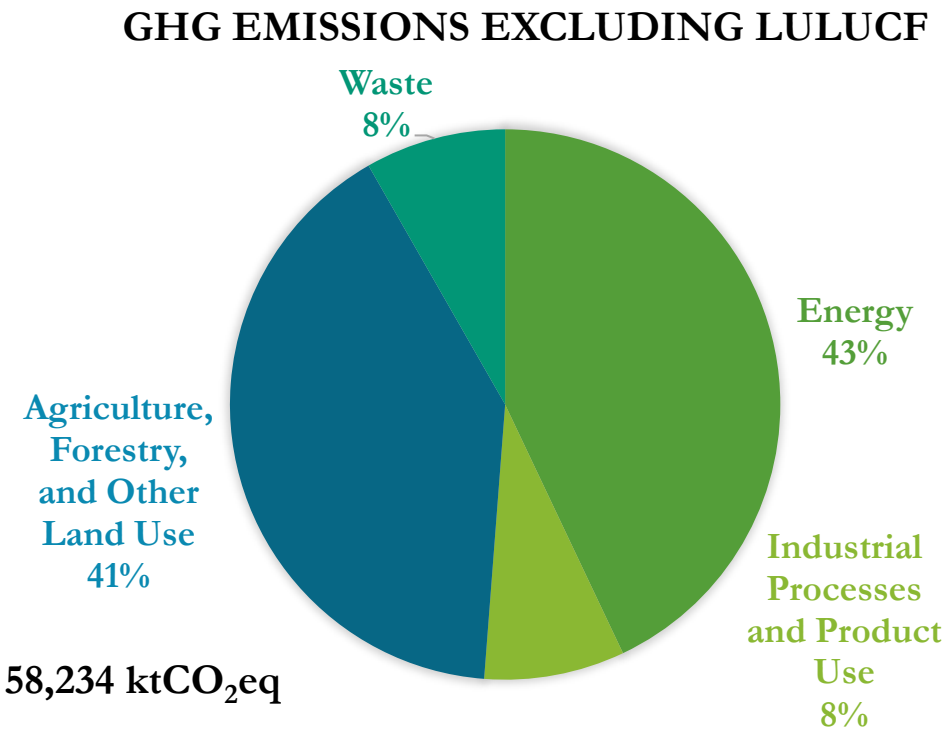
- Nepal has experienced a steady growth in GHG emissions, with an average annual increase of 4.2% since 2011.
- Energy sector remains the largest contributor.
- IPPU sector has seen the fastest growth, attributed to the expansion of industrial activities.

- **CH_4 emissions remain the largest contributor to total GHG emissions**, largely due to agricultural activities & biomass combustion.
- CO_2 emissions, primarily from the energy & industrial sectors have steadily increased.
- N_2O emissions have shown a moderate increase over time, driven by fertilizer use in agriculture.

Source: Nepal First Biennial Transparency Report, 2025, Ministry of Forest and Environment, Government of Nepal, https://unfccc.int/documents/647371

Status of GHG Emissions in 2022





Source: Nepal First Biennial Transparency Report, 2025, Ministry of Forest and Environment, Government of Nepal, https://unfccc.int/documents/647371

Major GHG Mitigation Policies & Strategies in Nepal

2016

First NDC

Achieve 80% electrification through renewable energy sources by 2050.
Reduce its dependency on fossil fuels by 50%.
Increase share of EV up to 20% from 2010 level.

2020

Second NDC

Expand clean energy generations.
Increase sales of EVs.
Increase electric & clean cooking in residential.

2021

Long-term Strategy

Achieve net-zero CO_2 emissions by 2045.
New interventions such as fuel cells & biofuels in transportation, green hydrogen for thermal purposes in industry.
Carbon capture, utilization & storage in cement industry.
Potential of clean energy trade.

2025

NDC3.0

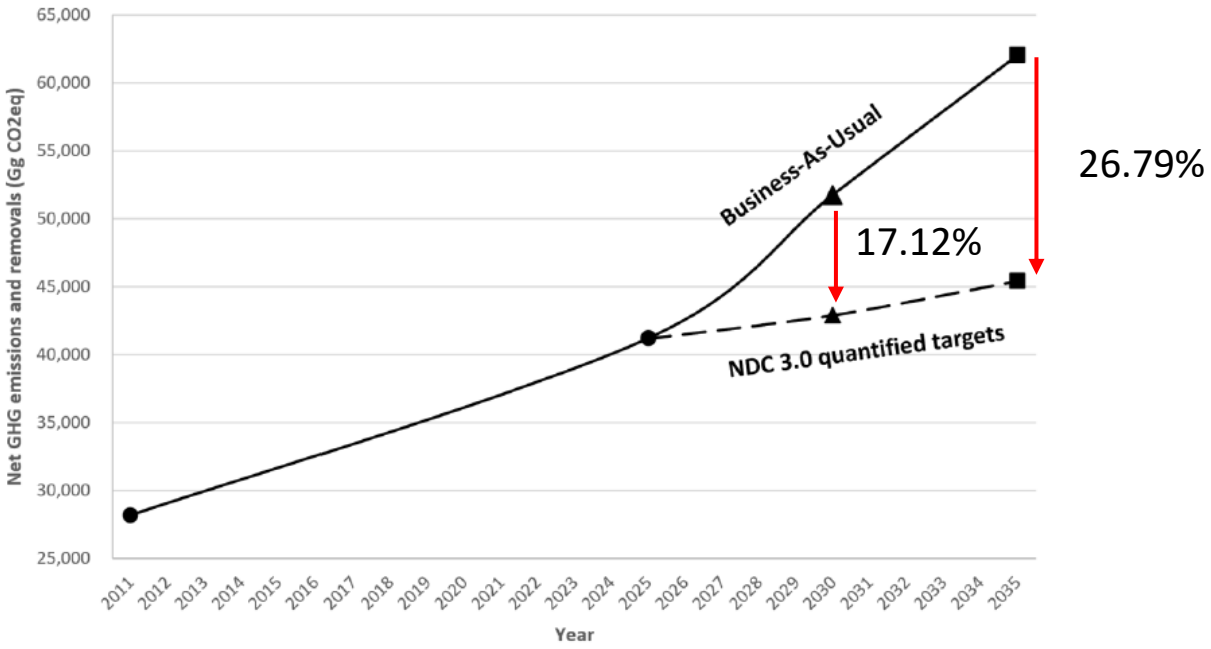
Expand renewable electricity generation capacity.
Expand the use of electric and improved cookstoves.
Increase sales of BEVs.
Increase electrification in industries.

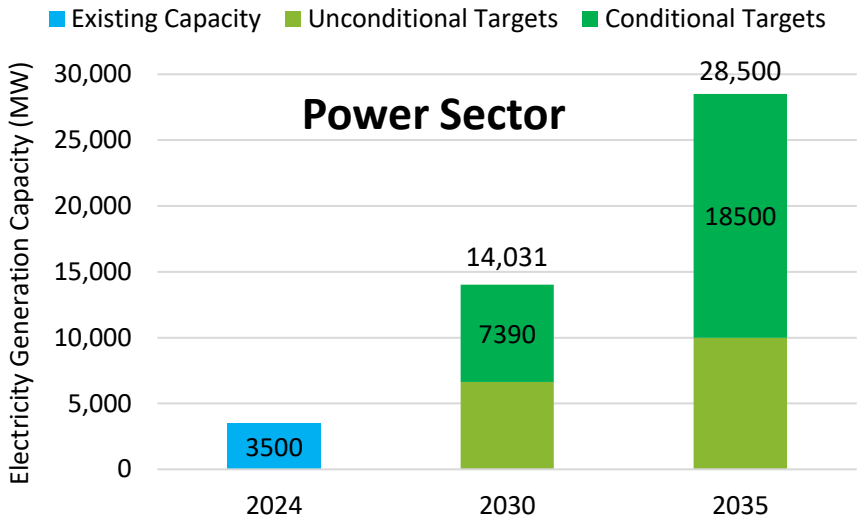
2025

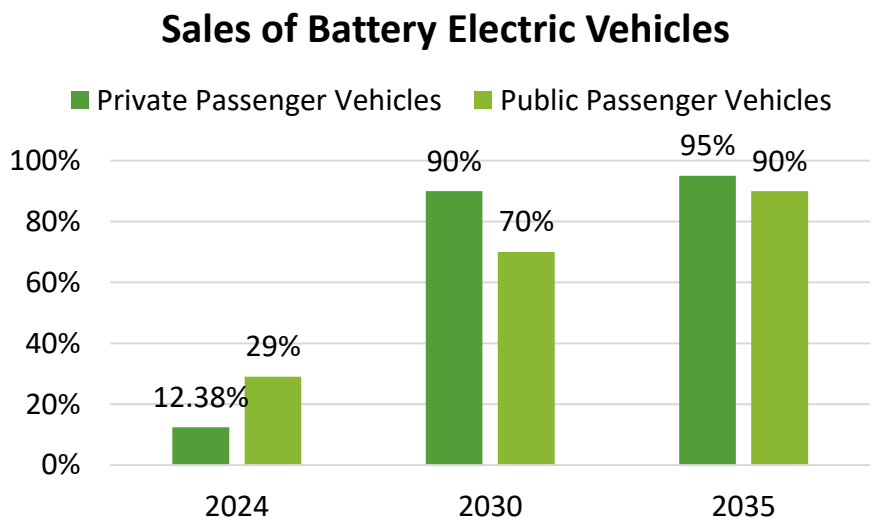
First BTR

Status of GHG emissions providing inventory for 2022.
GHG emissions trend analysis up to 2050.
Progress towards NDC targets

Nepal's NDC3.0 Targets







- Around 96% by 2030 & 97% by 2035 of total targeted emission reductions are conditional upon international climate finance & support.

Source: Nationally Determined Contribution (NDC) 3.0, 2025, Government of Nepal, https://unfccc.int/sites/default/files/2025-05/Nepal%20NDC3.pdf

Green Hydrogen Fuel

- Nepal's Green Hydrogen Policy 2024: promote the use of green hydrogen in sectors like **transportation, industrial processes & even fertilizer production**
- Nepal's potential in green hydrogen is substantial, with an estimated of 83,000 MW of hydropower potential with approximately 22,000 MW currently under development.
- Nepal Hydrogen Hub (NHH) → Aims to utilize surplus hydropower to produce green hydrogen. Nepal's Koshi basin has been identified as a prime site for Nepal's first hydrogen hub.
- Incubation of Nepal Hydrogen Initiative Program (Green Hydrogen KU Lab) → 2 electrolyzers with the total production capacity of around 1192 liters/hr at normal temperature and pressure (99.6 grams/hr).

Source:
Green Hydrogen Policy 2080, Ministry of Energy, Water Resources and Irrigation, Government of Nepal, https://moewri.gov.np/storage/listies/January2024/green-hydrogen-policy-2080.pdf
Energy Sector Synopsis Report 2024, Water and Energy Commission Secretariat, Government of Nepal, http://wecs.gov.np/source/ESR_2024.pdf

Analysis using AIM/Enduse Model

GDP Growth Assumptions

	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
Low	4%	4.5%	4.5%	5%	5%
Medium	7%	7%	7%	7%	7%
High	7.5-8.5%	9%	10%	10%	9%

Source: Nepal LTS, 16th Five Year Plan

Why consider 3 GDP Growth scenarios?

- **Medium GDP growth rates were considered by all NDCs (NDC 1.0, NDC 2.0 and NDC 3.0) ever since 2016. However, the average annual GDP growth of Nepal during the last 10 years has been only 4.37% (2014-2023), which is significantly less than 7%. Thus, it may not be prudent to consider only the medium growth scenario as the government has been doing for setting NZE & NDC targets.**

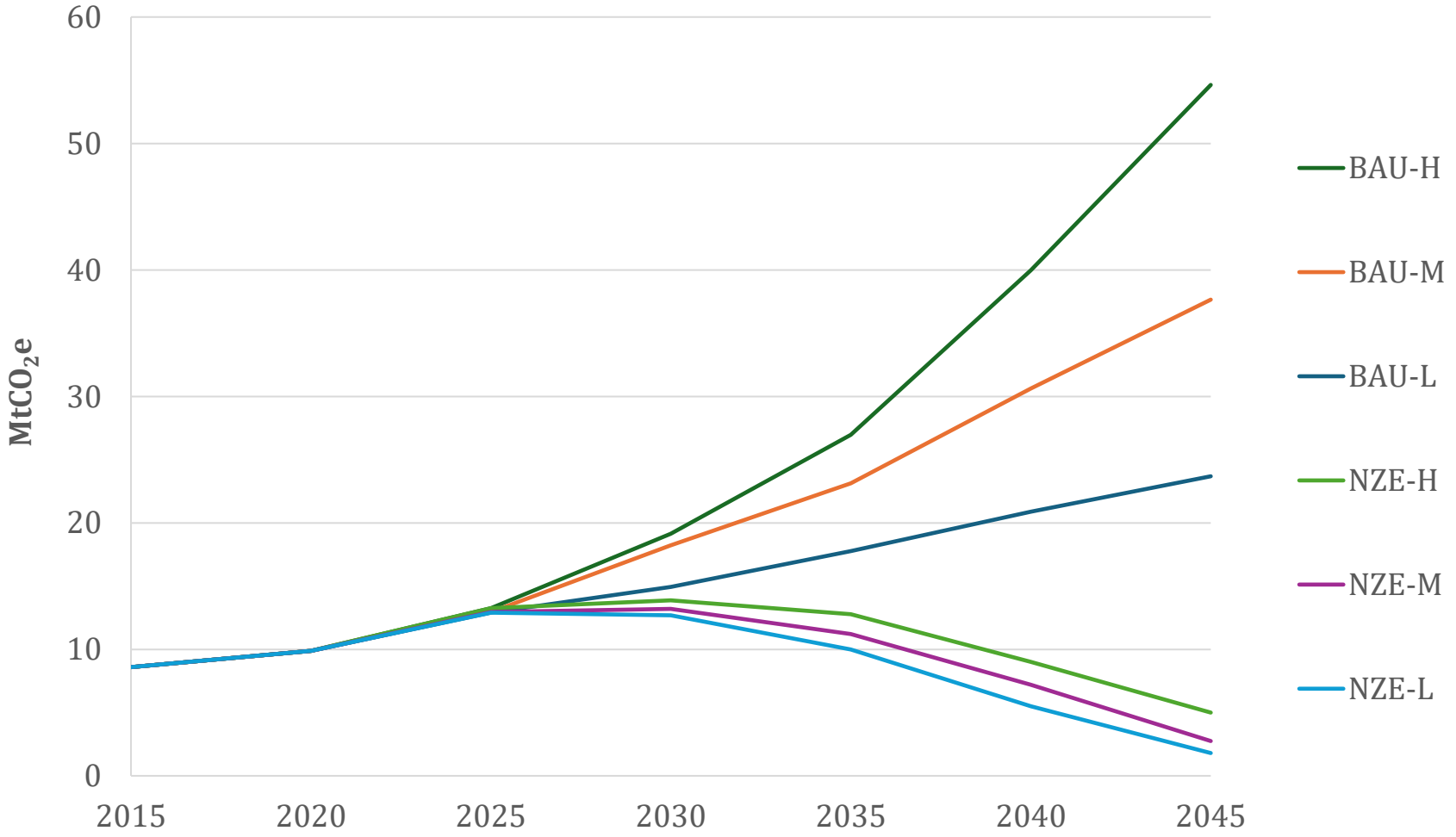
Scenario Descriptions

Scenario	Description
BAU-M (Ref)	• This is the reference scenario and assumes medium GDP growth rate. • Technological & energy use pattern follows the historical trend. • Assumes passenger EVs to grow significantly.
BAU-L	• Assumes low GDP growth rate. • Other conditions remain same as for BAU-M.
BAU-H	• Assumes high GDP growth rate. • Higher growth of railways in transport demand. • Other conditions remain same as for BAU-M.
NZE-L	• Assumes low GDP growth rate. • Emissions from energy sector in 2045 will reach maximum reduction technically feasible. • Green hydrogen fuel will be used from 2030 onwards in transport & hard-to-abate sectors.
NZE-M	• Assumes medium GDP growth rate. • Other conditions remain same as for NZE-L.
NZE-H	• Assumes high GDP growth rate. • Other conditions remain same as for NZE-L.

Scenario Assumptions: Electric & Hydrogen Options

		Business-as-usual	NZE Scenarios
Electric-transport	LDVs	Partial	Full
	HDVs	Partial	Partial
	Railways	Partial	Partial
Hydrogen-based fuel & technologies in transport	LDVs	-	Full
	HDVs	-	Full
	Aviation	-	Partial
Electrification in industry	Cement	-	-
	Brick	Partial	Full
	Process heat	Partial	Full
	Iron and Steel	Partial	Full
Hydrogen-based fuel & technologies in industry	Cement	-	Partial
	Iron and Steel	-	Partial
Electrification in residential & commercial	All heating applications	Partial	Full

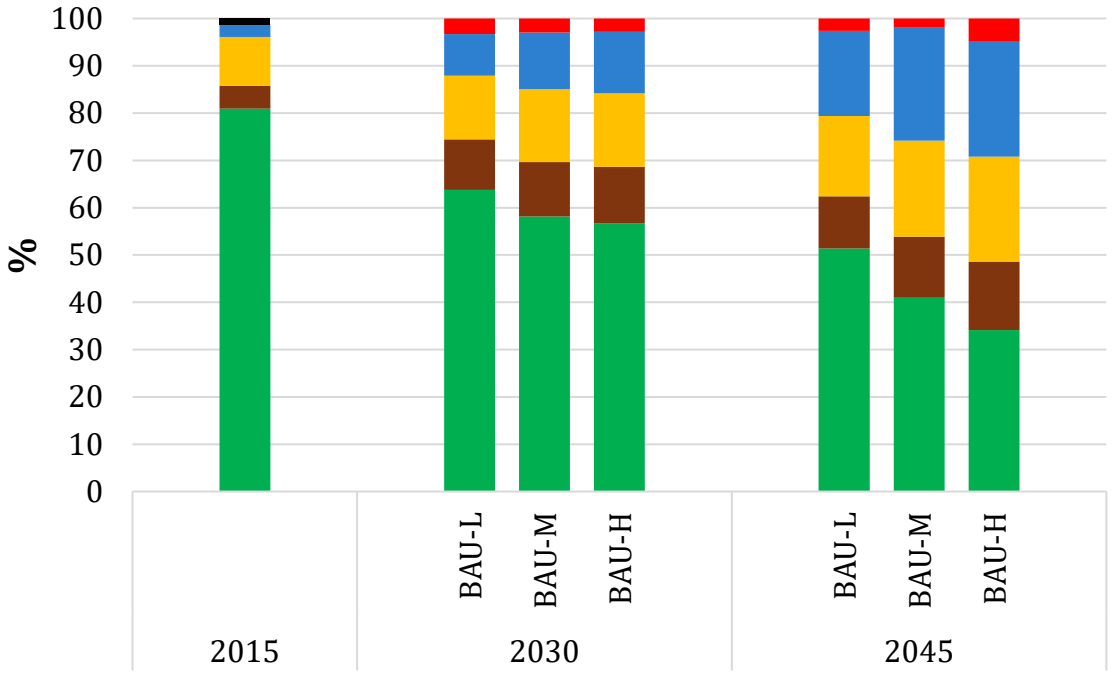
Economic Growth & Energy-related GHG Emissions in BAU & NZE Scenarios



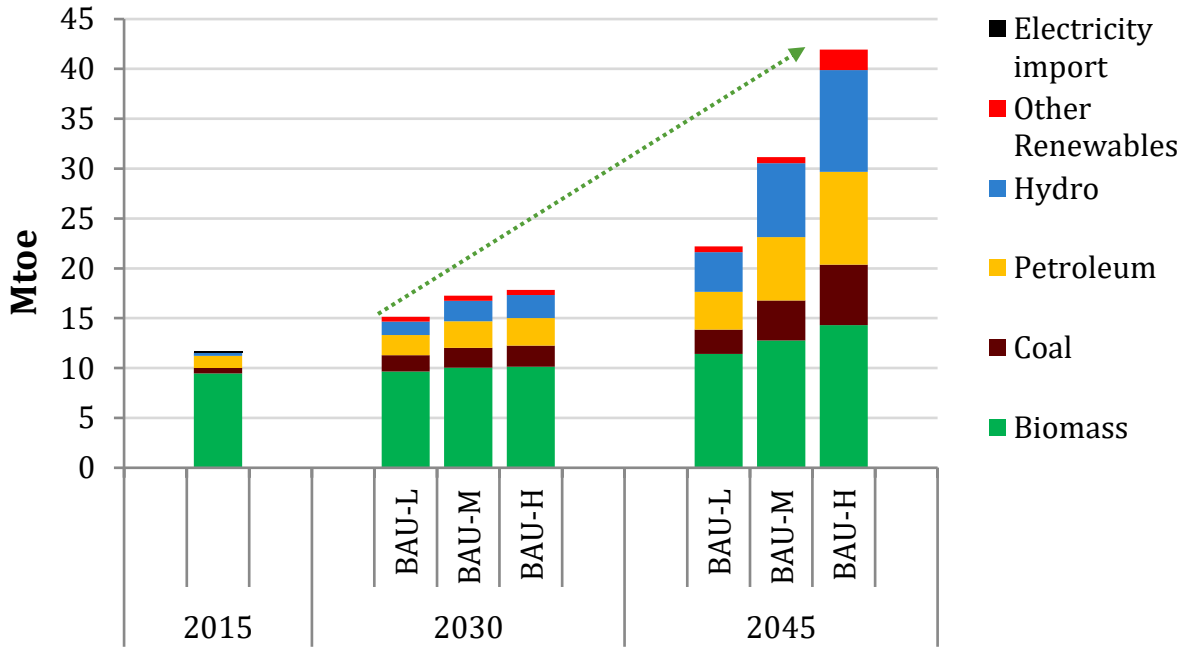
- The upward trajectories of **BAU scenarios** clearly indicates that without intervention, GHG emissions are set to rise considerably over the next two decades.
- This emphasizes a crucial point: **stronger economic growth, while desirable in many aspects, presents a significant challenge for emission reduction targets if left unchecked.**

Business-as-Usual Energy Consumption:
Low, Medium, and High Economic Growth Scenarios

Energy Mix

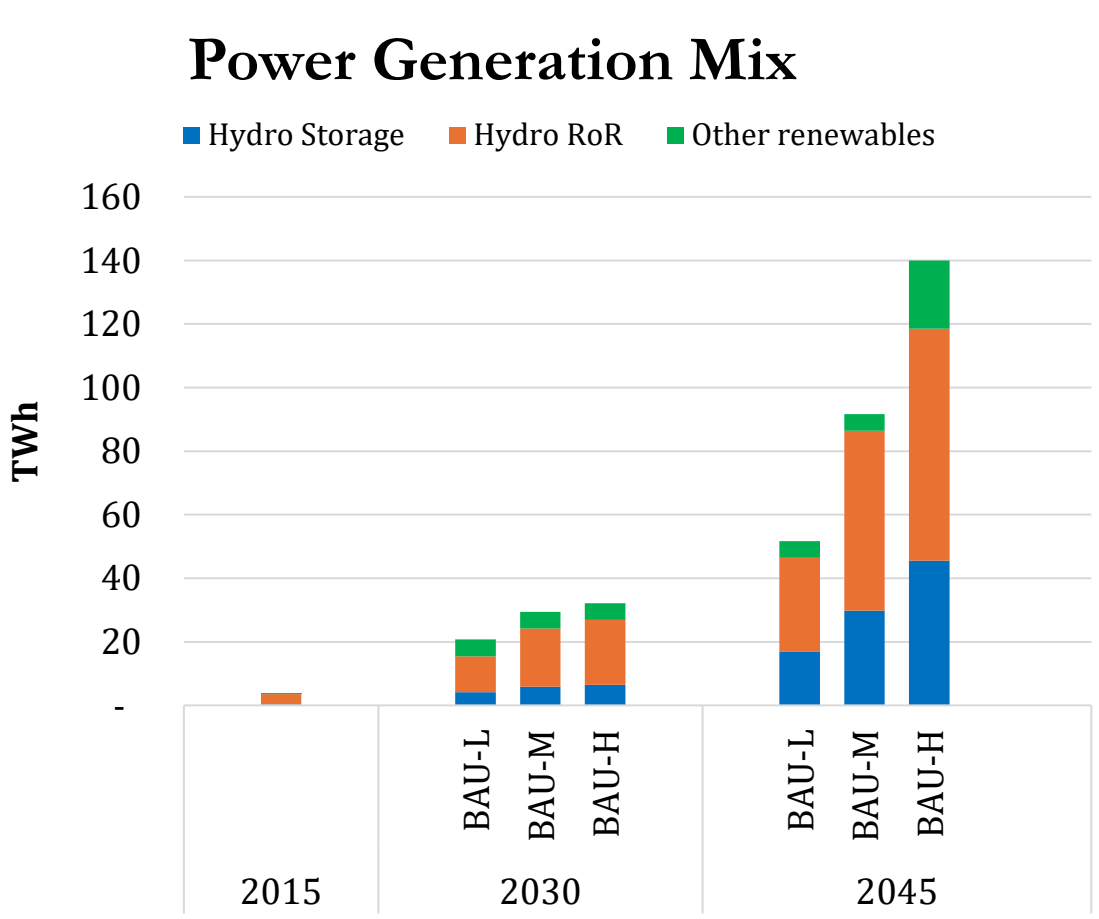


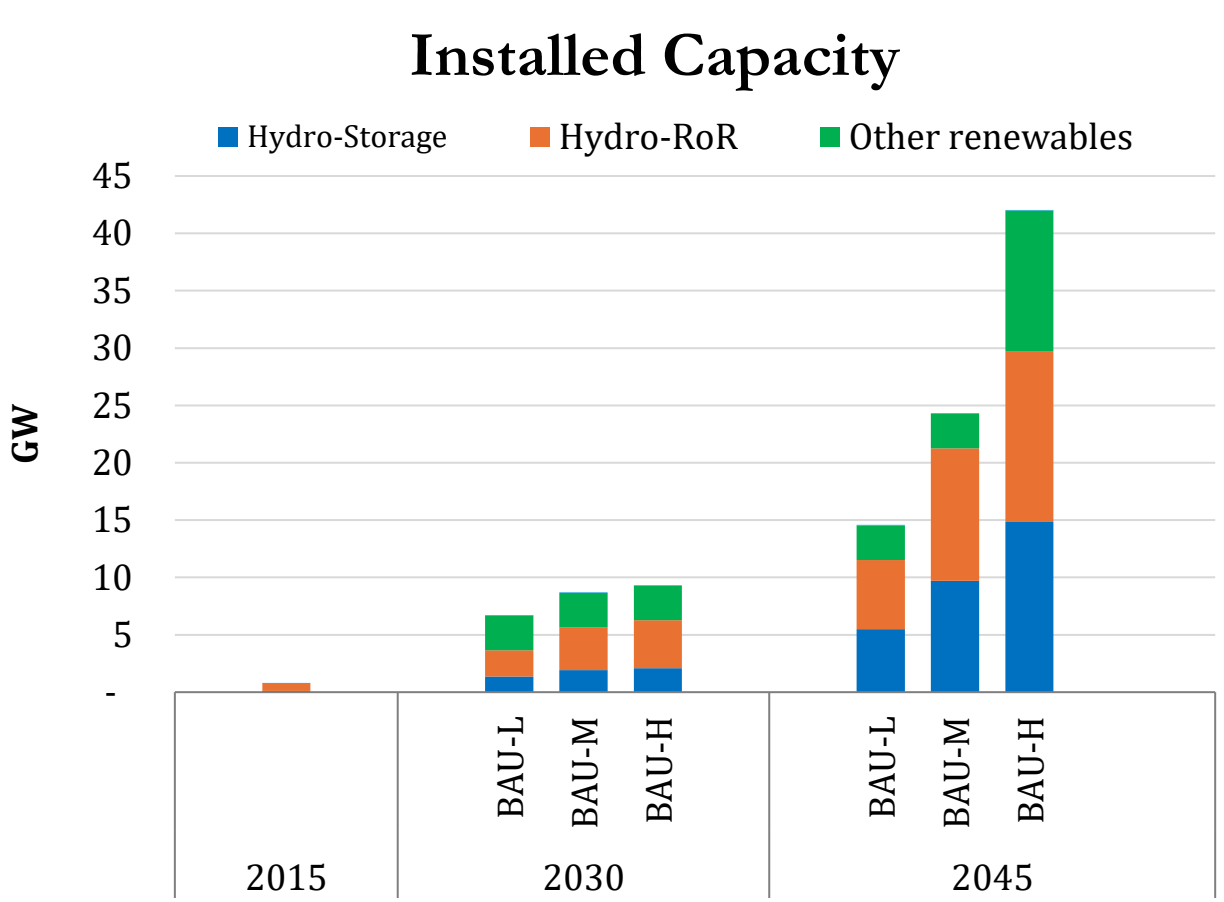
Primary Energy Supply



- Significant shift to hydro & other renewables in energy mix by 2045.
- Total primary energy supply escalates with economic growth.
- **Petroleum & Electricity Imports are increasing in higher growth scenarios, indicating growing reliance on these sources to meet rising demand.**

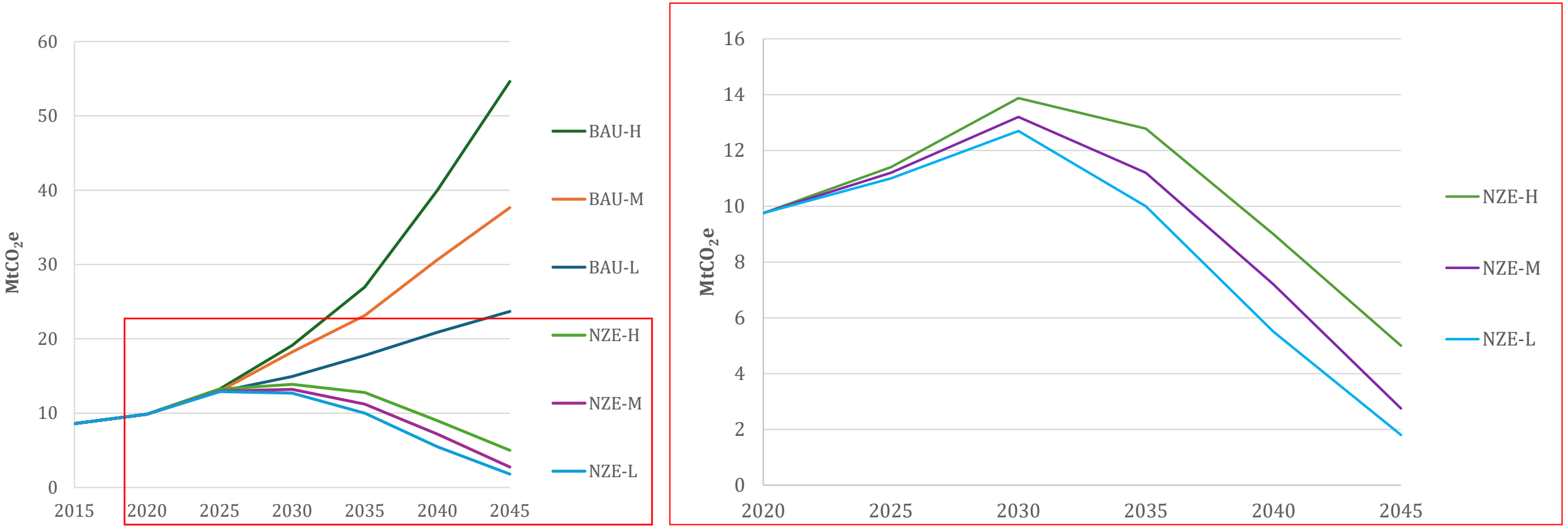
Business-as-Usual Electricity Generation: Low, Medium, and High Economic Growth Scenarios





- Installed capacity in the low & medium growth in 2045 would be 14.6 GW & 24.3 GW.
- **High growth scenario forecasts 17.7 GW higher installed capacity than medium growth.**

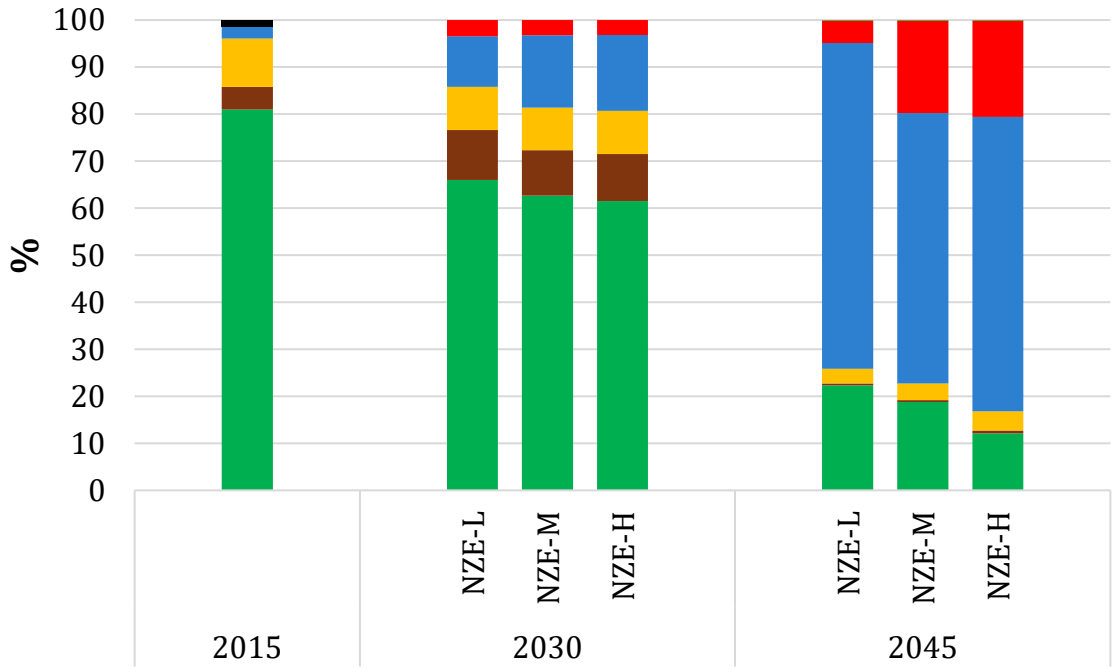
Energy-related GHG Emissions in BAU & NZE at Various Economic Growth



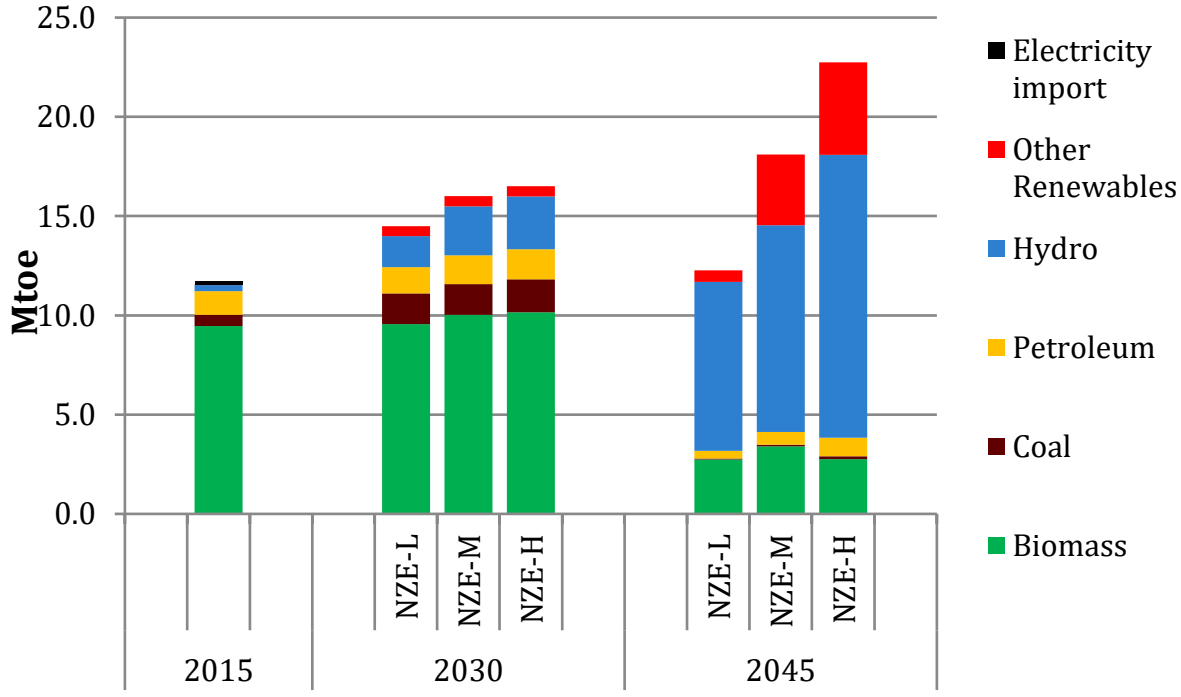
- Energy sector emissions in 2045: 1.8 $MtCO_2e$ (1.3 $MtCO_2$) in NZE-L, 2.8 $MtCO_2e$ (2.1 $MtCO_2$) in NZE-M & 5 $MtCO_2e$ (3.4 $MtCO_2$) in NZE-H.
- Net zero carbon dioxide emission goal would require forestry to offsets minimum energy emission in 2045 (that increases with economic growth) in addition to other IPCC sectors (agriculture, IPPU and Waste) emissions.

Net-Zero Emissions Energy Consumption:
Low, Medium, and High Economic Growth Scenarios

Energy Mix

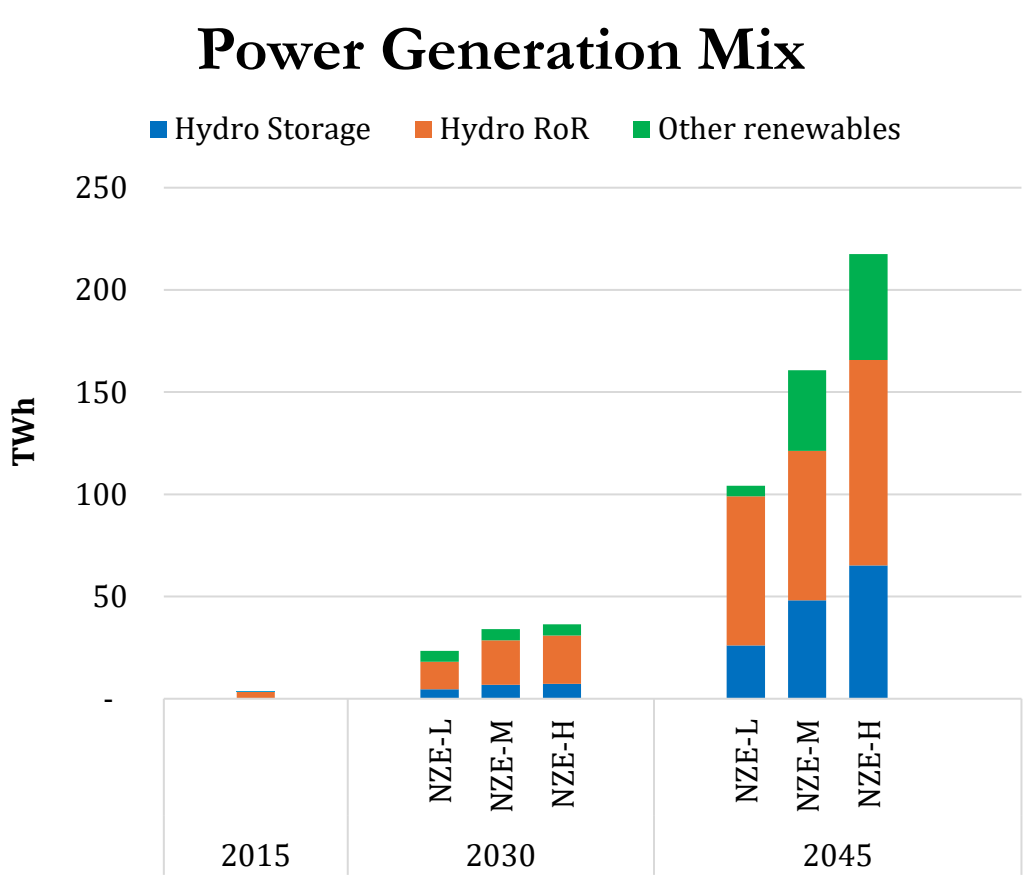


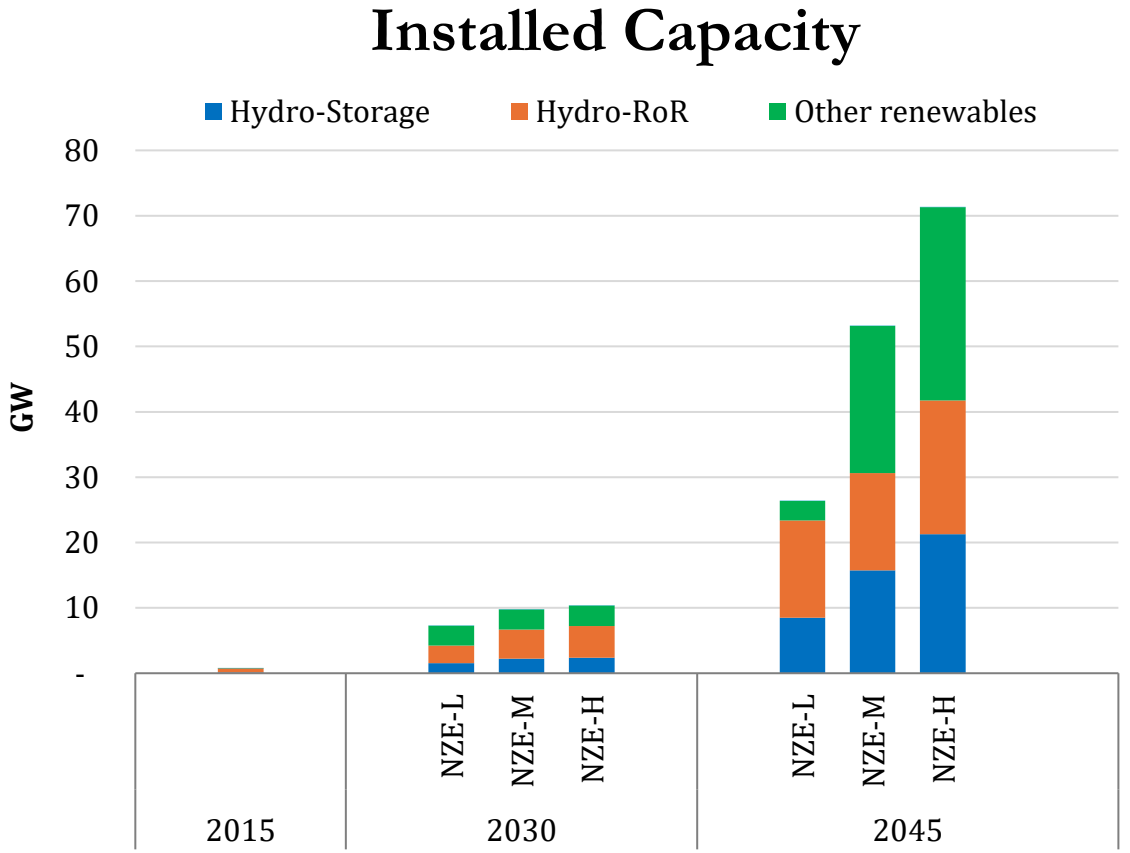
Primary Energy Supply



- **Increased role of hydropower & other renewables in power generation:**
  - Combined shares of 74% in NZE-L, 77% in NZE-M and 83% in NZE-H
- **Petroleum & coal consumption is primarily used in hard-to-abate sectors** like cement production & aviation sectors, where electrification or alternative fuels are more challenging.
- Biomass will account for more than one-tenth of primary energy mix in NZE-H scenario.

Net-Zero Emissions Electricity Generation:
Low, Medium, and High Economic Growth Scenarios

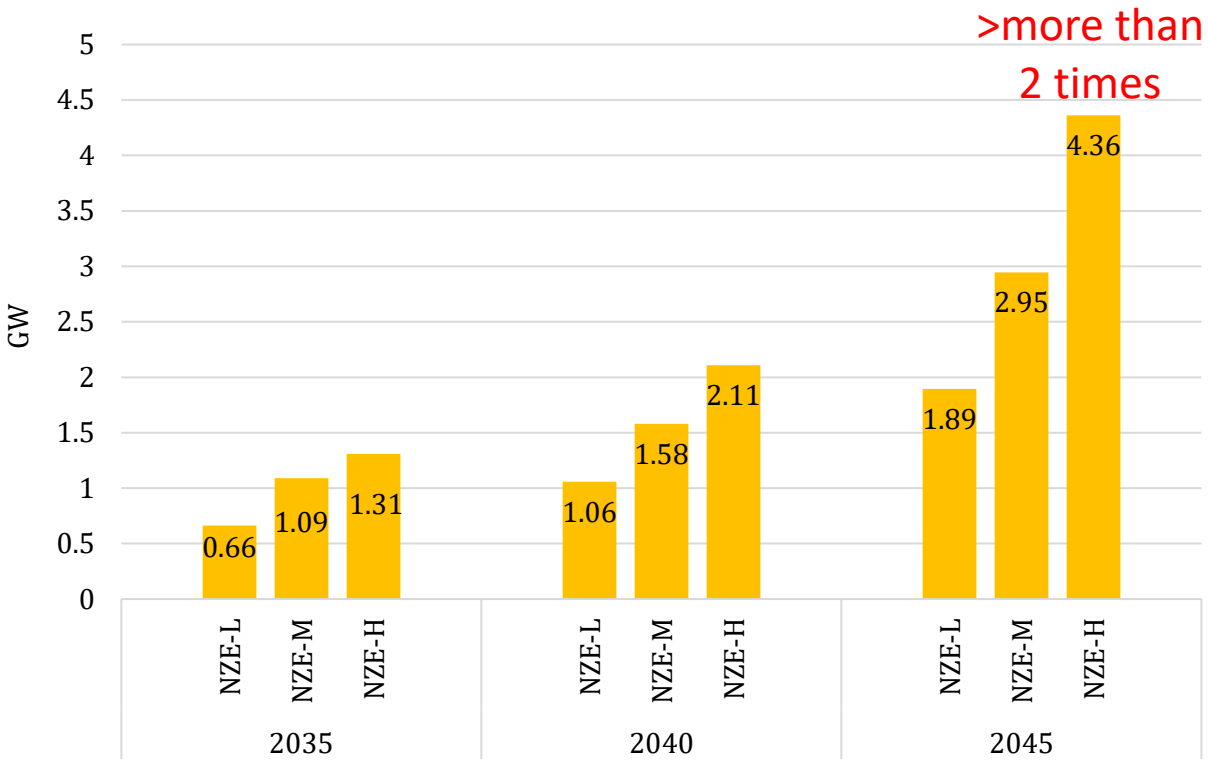




- Installed capacity in the low & medium growth in 2045 would be 26.4 GW & 53.2 GW.
- High growth scenario demands 72 GW (hydro & solar) installed capacity in 2045.
- **NZE-H will have 30 GW higher power demand than the BAU-H scenario.**

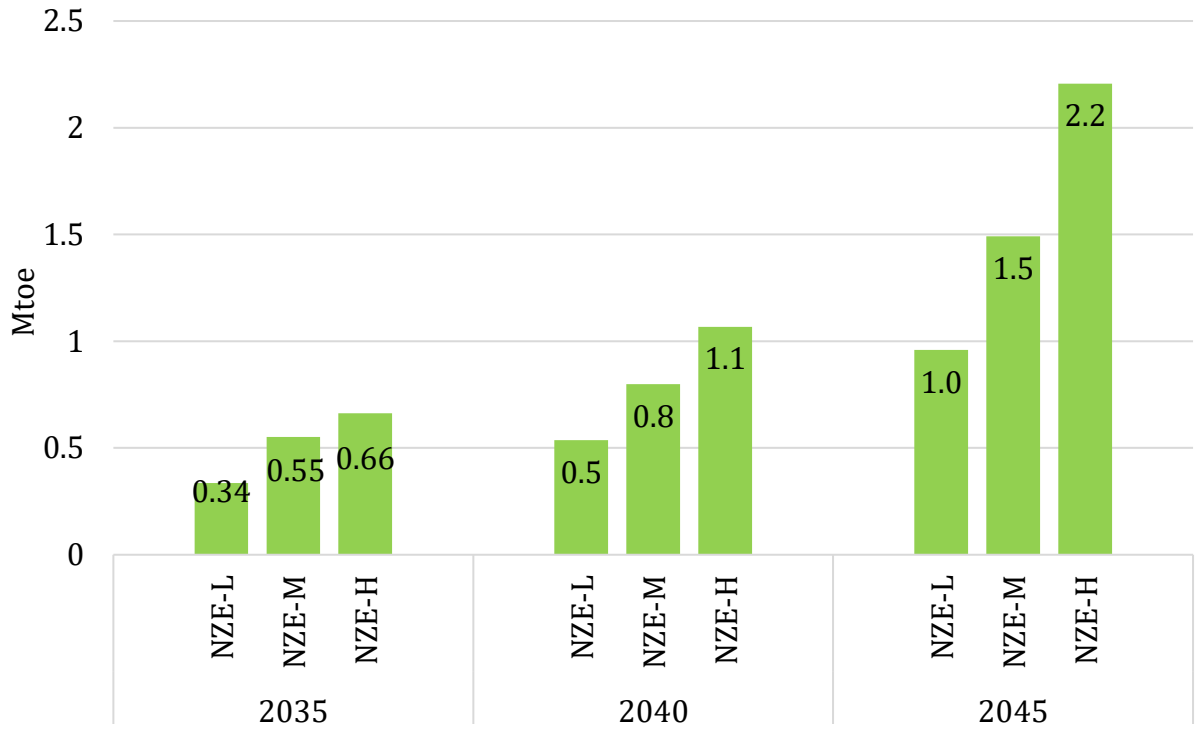
Green Hydrogen Demand

Electrolyzer capacity



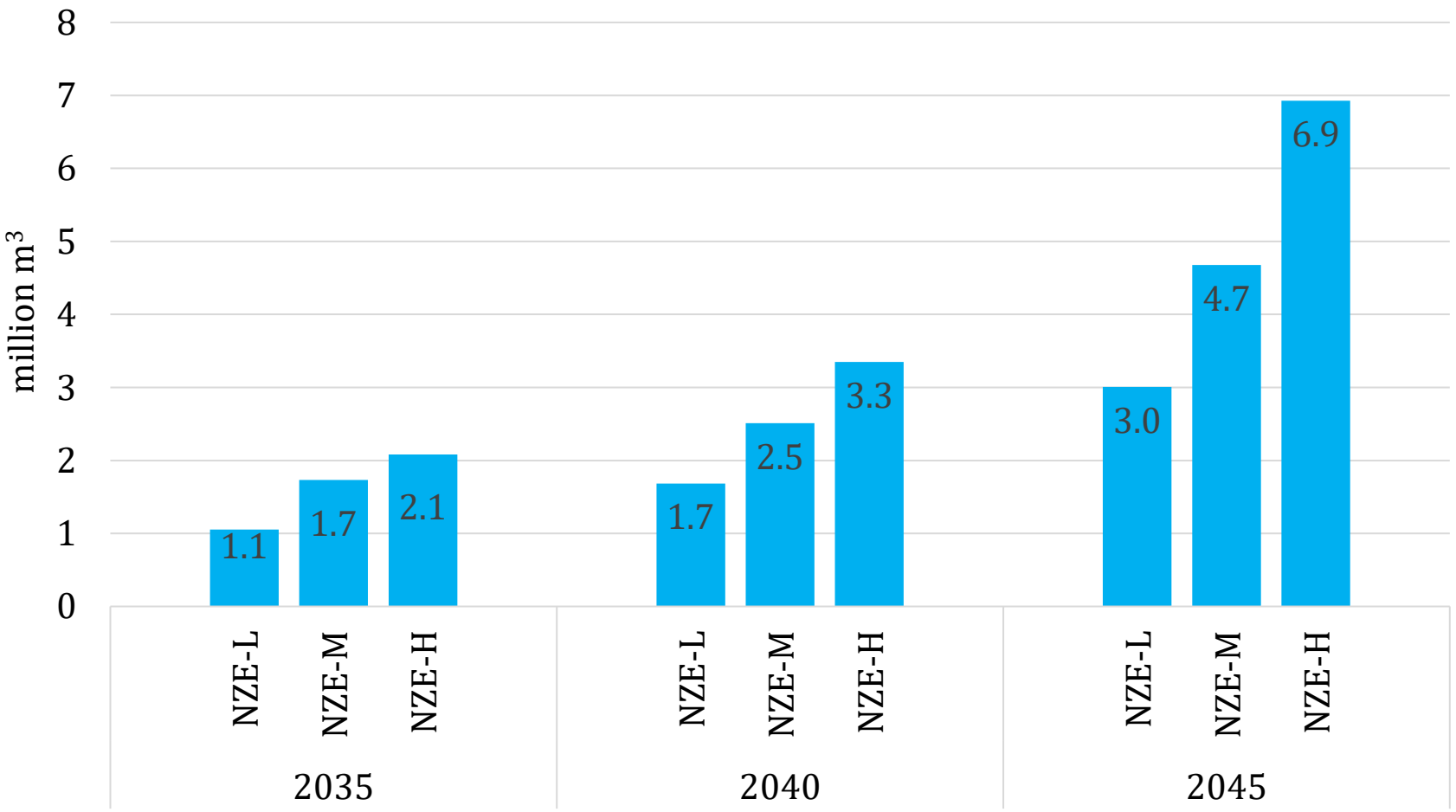
- By 2045, the NZE-M & NZE-H scenarios require 2.95 GW & 4.36 GW of electrolyzer capacity.

Hydrogen demand



- By 2045, the NZE-M & NZE-H scenarios would use 1.5 Mtoe & 2.2 Mtoe of Hydrogen.
- **Hydrogen share in FEC is 9% in all NZE scenarios in 2045.**

Fresh Water Demand

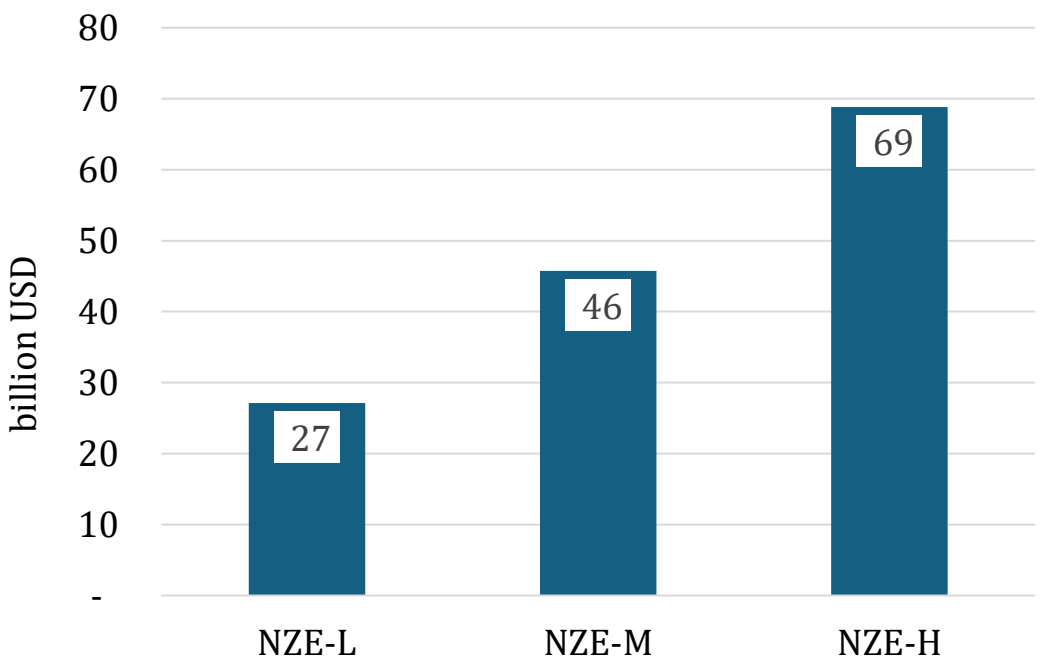


- By 2045, water demand would be 3.0 million m³ in NZE-L, 4.7 million m³ in NZE-M & 6.9 million m³ in NZE-H.

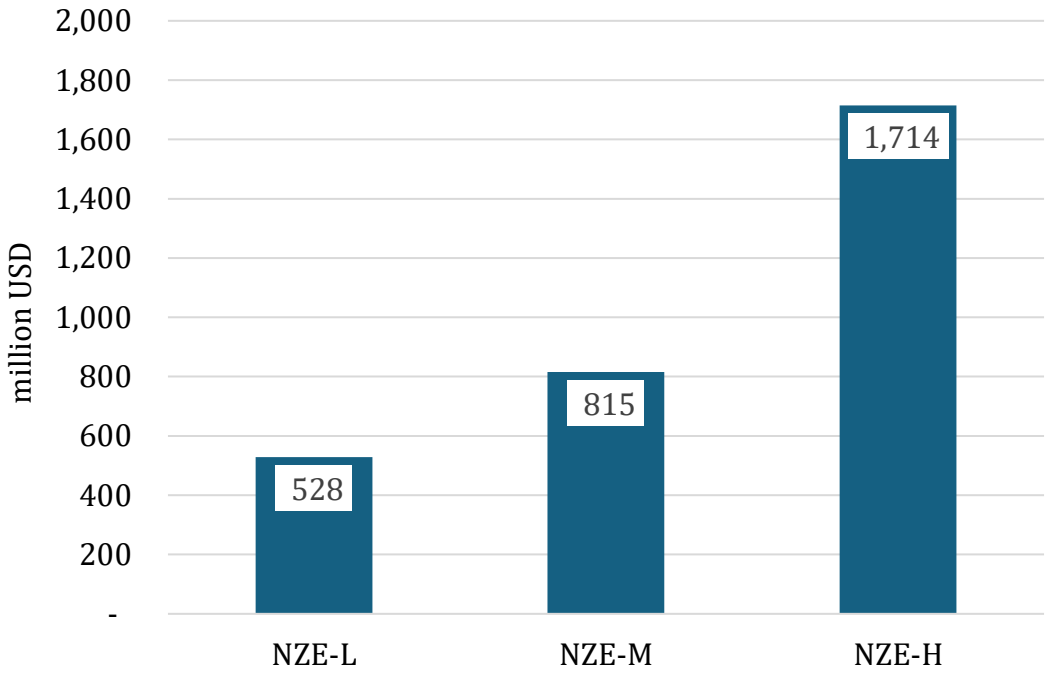
- Fresh water demand is only a tiny fraction of total annual run-off → **suggests that water availability, at a national level, is not a limiting factor for our net-zero ambitions.**

Investment Requirements

Hydropower & Solar Power Plant



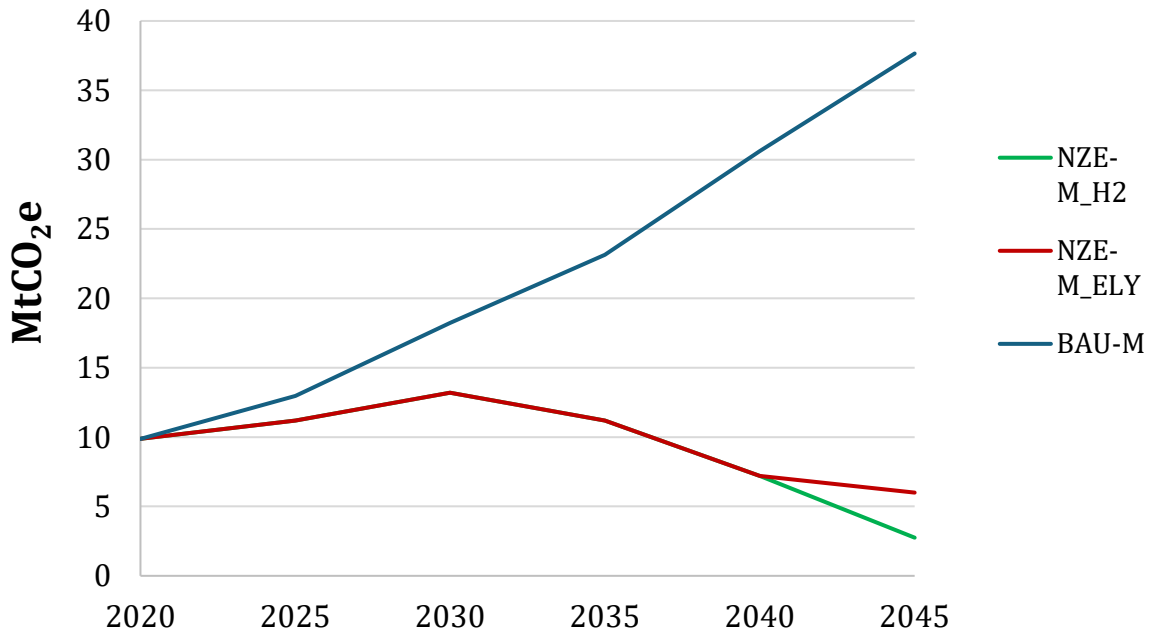
Electrolyzers



- Hydropower & solar require substantial investment during 2030-2045: $27 billion (NZE-L) to $69 billion (NZE-H).
- In NZE-M, cumulative investment in power sector would be 97% higher during 2030-2045 than in BAU-M scenario.
- Electrolyzer investments scale up significantly: from $528 million (NZE-L) to $1,714 million (NZE-H).
- **Total Investment in the energy sector during 2025-2045 in medium growth would be 30% higher in NZE than in BAU.**

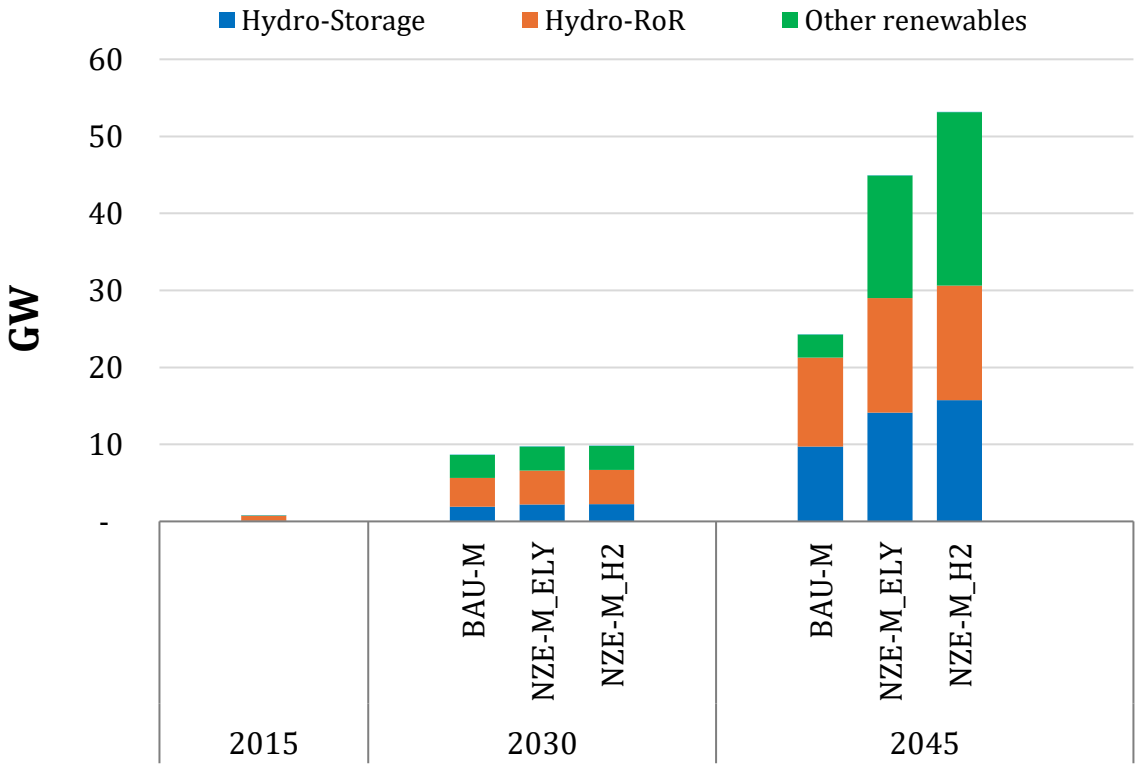
Green Hydrogen: Bridging the Net-Zero Gap

GHG Emissions



- Emission reduction under NZE-M in 2045:
  - 31.7 $MtCO_2e$ from electrification & 3.3 $MtCO_2e$ from hydrogen
- Unavoidable emissions in NZE-M_ELY: 6 $MtCO_2e$ in 2045 (with maximum feasible reduction).
- With green hydrogen, unavoidable emissions in 2045: 2.8 $MtCO_2e$

Installed Capacity



- In NZE-M with electrification option only, additional installed capacity needed would be 20 GW.
- With green hydrogen, further addition of 8.2 GW needed.

Final Remarks

- NZE scenarios reveal that higher economic growth intensifies GHG reduction challenges.
- Investment & electricity capacity needs for NZE pathways are directly tied to national economic growth.
- The development of hydrogen-based technologies (electrolyzers, FCEVs, turbines, boilers) is crucial for decarbonizing hard-to-abate sectors.
- Long-term NZE sustainability depends significantly on carbon sequestration from LULUCF.
- **A critical question remains: Can Nepal afford the substantial infrastructure investment & associated costs to meet the 2045 NZE target?**

Thank You