DINAS ENERGI DAN SUMBER DAYA MINERAL
Provinsi Nusa Tenggara Barat

Danish Energy Agency

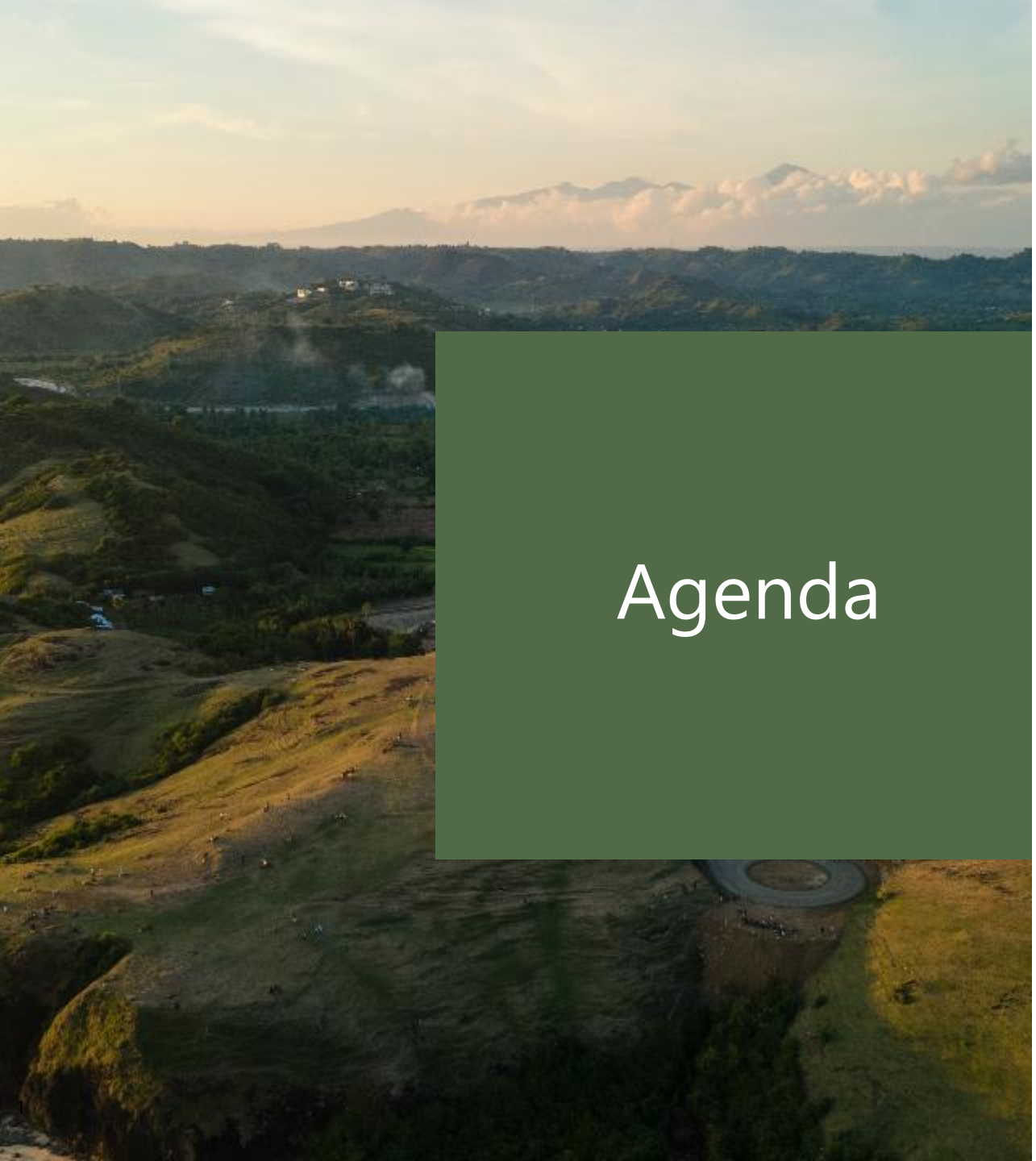
Ea Energy Analyses

EMBASSY OF DENMARK
Jakarta

NTB Energy Masterplan

Propelling West Nusa Tenggara to Lead Indonesia's Energy Transition

Report Launch – 7th December 2023



Agenda

1. Introduction
2. Current conditions
3. Modelling setup
4. Projections of energy demand
5. End-use development
6. Power sector development
7. Financial estimates on power sector
8. Conclusions and recommendations

Introduction

Navigating the Path to Net-Zero Emissions

- **Global imperative** for net-zero emissions: pivotal for social, environmental, and economic sustainability

- **NTB's ambitious goal**: achieve net-zero emissions by 2050, announced during COP26

- Net-zero emissions (NZE) in NTB would help **mitigate climate change, foster economic growth and improve overall living conditions**

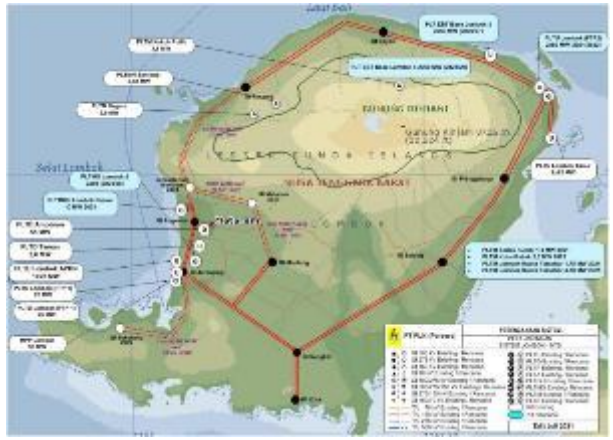
- Need for sustained **global efforts**, starting with **local initiatives**

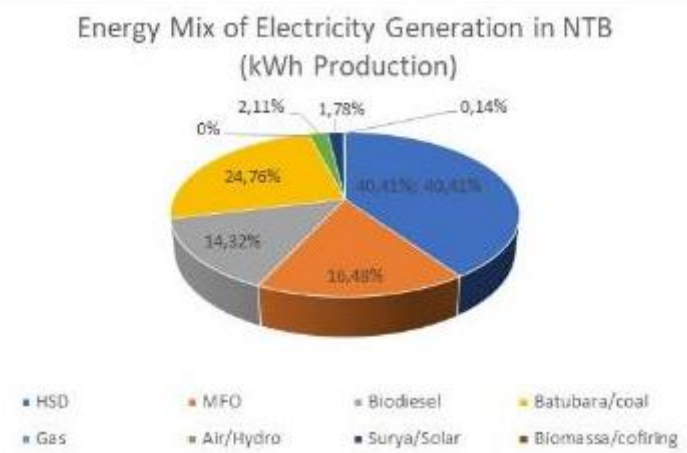
Navigating the Path to Net-Zero Emissions

- The NTB Energy Masterplan focuses on an **energy strategy until 2050**
- LEAP and Balmorel models are utilized for **demand and power sector analysis**
- **Two scenarios**:
  - Baseline representing current conditions
  - NZE with a net-zero target for NTB by 2050
- **Financial analysis** examines power system costs and feasibility of solar and wind plants
- **Comprehensive approach** balances various factors that need to be considered for energy planning

Current conditions

Current Energy Profile of NTB





Overview of Electric Power Systems

- Lombok 150 kV, Tambora 70 kV & 150 kV systems.
- Various sources: Coal, natural gas, diesel, hydro.

Energy Mix for Electricity Generation

- Dominated by diesel, transitioning to biodiesel.
- Gradual shift from coal to biomass co-firing.
- Minor contributions from solar and hydro power.

Projected Electricity Demand (2021-2030)

- Anticipated growth in household, business, public, and industrial sectors.
- Total demand growth: 7.2% to 9.2% annually.

Infrastructure Development and Renewable Energy

Capacity potentials used for the power sector analysis (MW)		
Source	**Lombok**	**Sumbawa**
Bioenergy*	297	19
Geothermal	100	75
Hydro	26	26
Municipal waste	32	0
Wind onshore	938	1,667
Solar PV	1000	9,628

**Bioenergy predominantly refers to biomass*

Development Plans (2021-2030)

- Planned projects include coal, gas, hydro, solar, biomass, and geothermal
- Emphasis on reducing coal-fired power with gas

Renewable Energy Potential

- Geothermal, hydroelectric, solar, wind, and biomass
- Exploration of wave and tidal energy

Challenges and Initiatives

- Barriers: Uncertain gas and coal supply, long commissioning process, technical challenges in integrating renewables
- Initiatives: Subsidies for electric vehicle adoption, encouraging alternative technologies like hydrogen

Sector-specific development

Residential Sector

- Shift to LPG for cooking and promotion of **electric stoves**

Commercial Sector

- **Tourism sector's growth potential** is significant
- Increases hotel occupancy rates and trade

Industrial Sector

- Emphasis on industrialization, **growth expected in formal and non-formal industries**
- Focus on downstream policies for added value

Sector-specific development

Transportation Sector

- **Highest emission contribution**
- Heavily dependent on fossil fuel with **government subsidies**
- Push for **electric vehicle** adoption, charging station initiatives

Others (Mining, Agriculture, Construction)

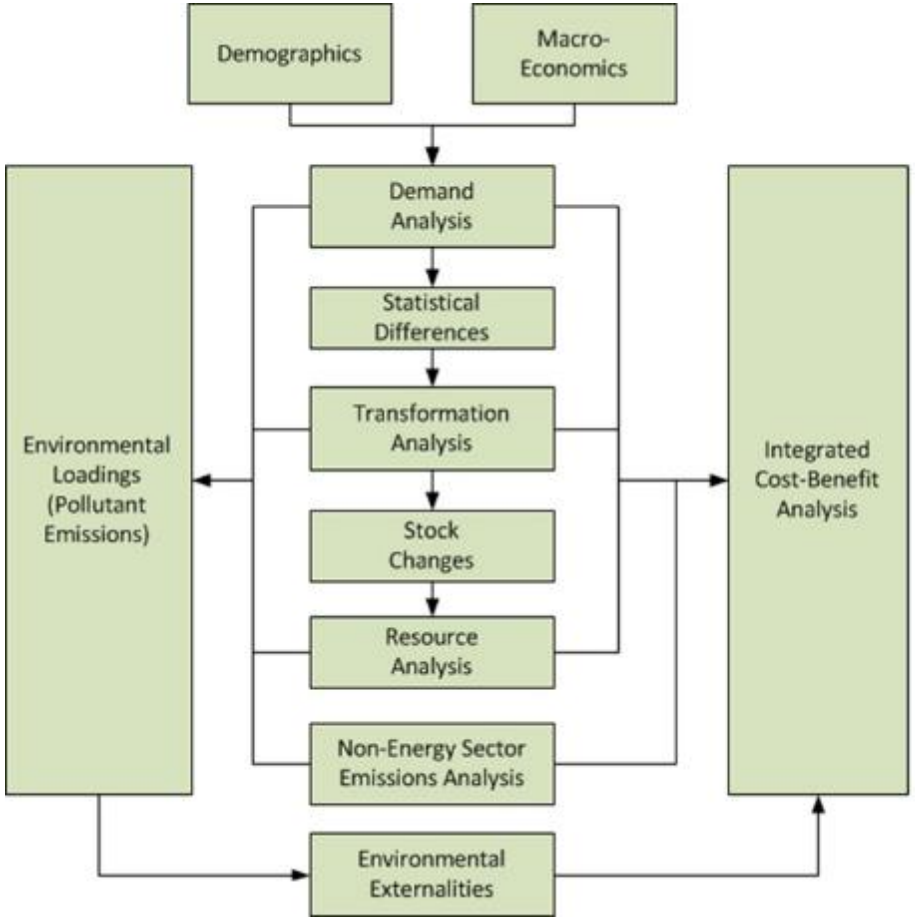
- Contribute significantly to NTB's economy
- Policies aim to increase the value of raw materials, boost economic growth, generate employment and enhance state revenues

Challenges going forward

- **Affordable** power supply
- **Uncertain** gas and coal supply
- **Long process** for commissioning
- **Technical challenges** in renewable energy integration.
- Post-COVID **economic recovery**, slow progress in projects
- **Just and inclusive** energy transition.

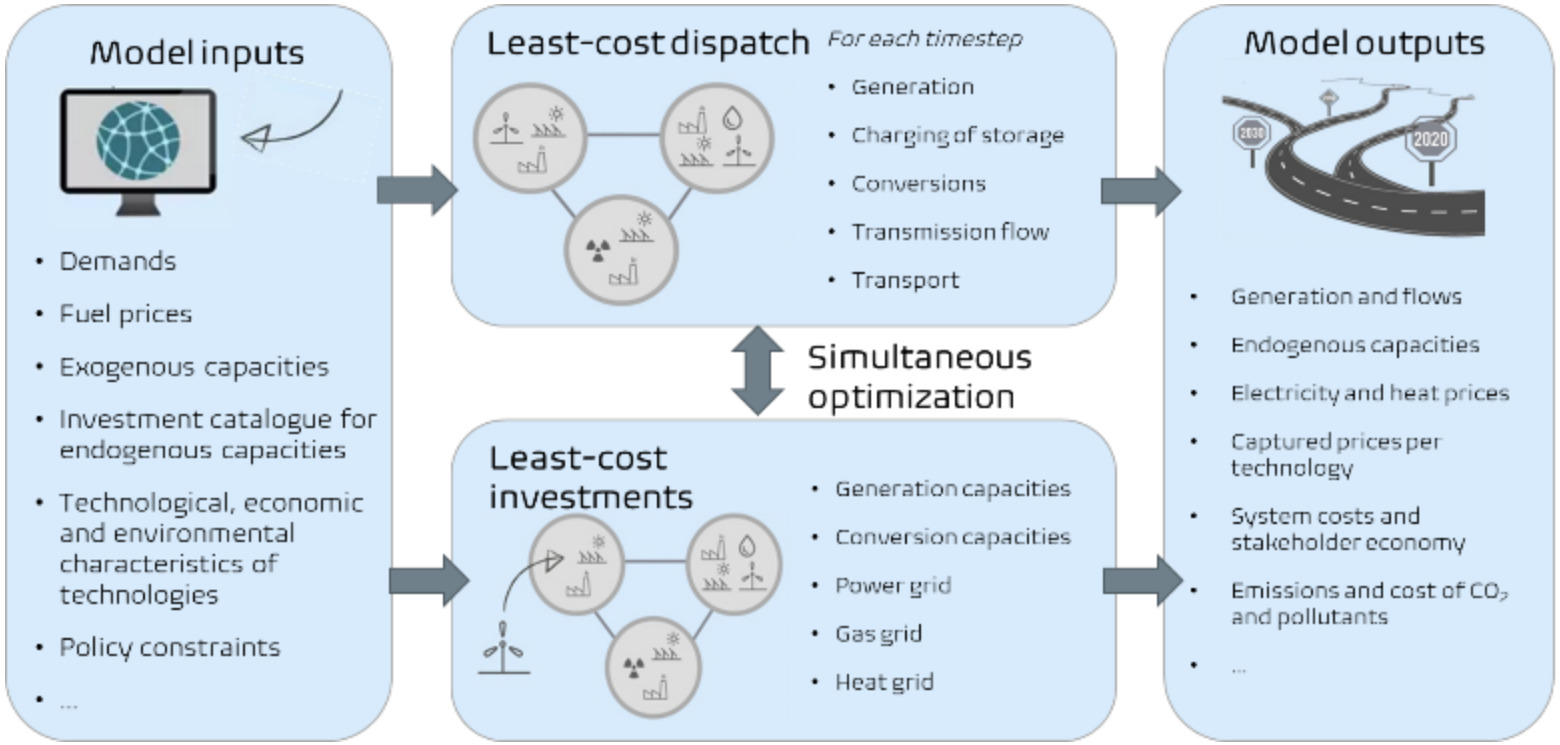
Modelling setup

Energy demand modelling using LEAP



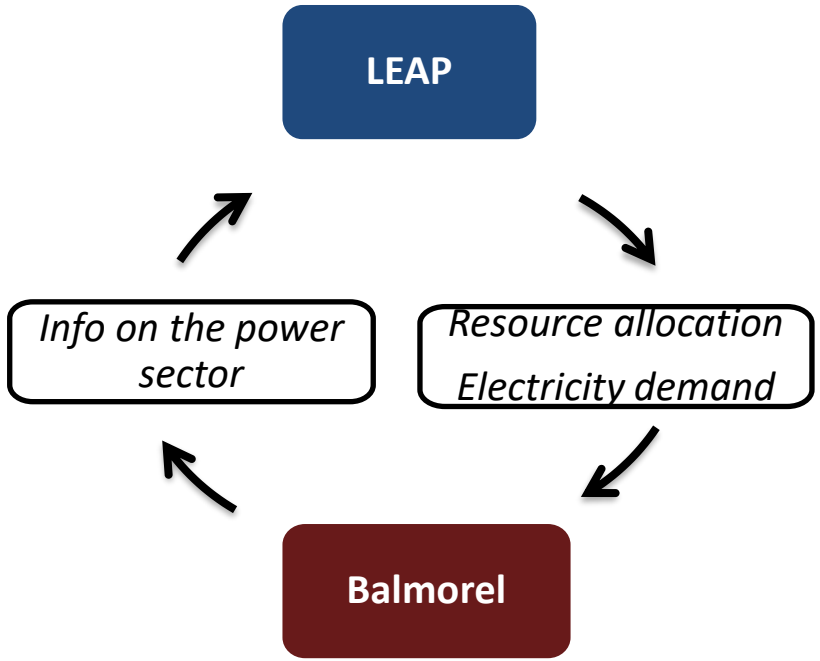
- LEAP facilitates comprehensive energy planning, tracking production, consumption, and resource extraction in all sectors.
- It enables scenario-based analyses, evaluating policy impacts, technological shifts, and changes in energy patterns.
- Used nationally in Indonesia, LEAP contributes to development plans via mapping and projecting final end-use energy consumption.

Power sector modelling using Balmorel



- Supports technical and policy analyses of power systems
- Optimises:
  - least-cost dispatch and capacity expansion
  - generation and transmission
- Good representation of RE variability

Model linking and scenarios



- Similar approach as used in the national level modelling
- Allows for a study of the whole energy sector
- Scenarios:
  - **Baseline Scenario:** Follows existing trends, aligns with national policies, and targets net zero emissions by 2060 for power sector with no specific provincial targets.
  - **NZE Scenario:** Aims for carbon neutrality in NTB's energy system by 2050, prioritizing electrification and allowing power sector decarbonization by 2048.

Projections of energy demand

Input data – Demographics and macroeconomics

NTB GDP structure in 2021

Sector	Lombok		Sumbawa	
	Billion IDR	%	Billion IDR	%
Industry	3,774	7.1	709	1.7
Commercial	25,753	48.4	12,230	28.7
Transportation	3,203	6	1,456	3.4
Mining	2,581	4.9	14,267	33.5
Agriculture	11,022	20.7	10,899	25.6
Construction	6,756	12.7	3,028	7.1
Other	128	0.2	52	0.1
Total	53,217	100	42,641	100

NTB Population, GDP and GDP per capita in 2021

Type	Units	Lombok	Sumbawa	Total
Population	1,000 people	3,809	1,581	5,390
Population Growth	%	1.34	1.26	1.31
GDP	Billion Rp	53,659	42,639	96,29
GDP per capita	Million Rp/person	14.1	27	17.8

Input data – Fuel consumption

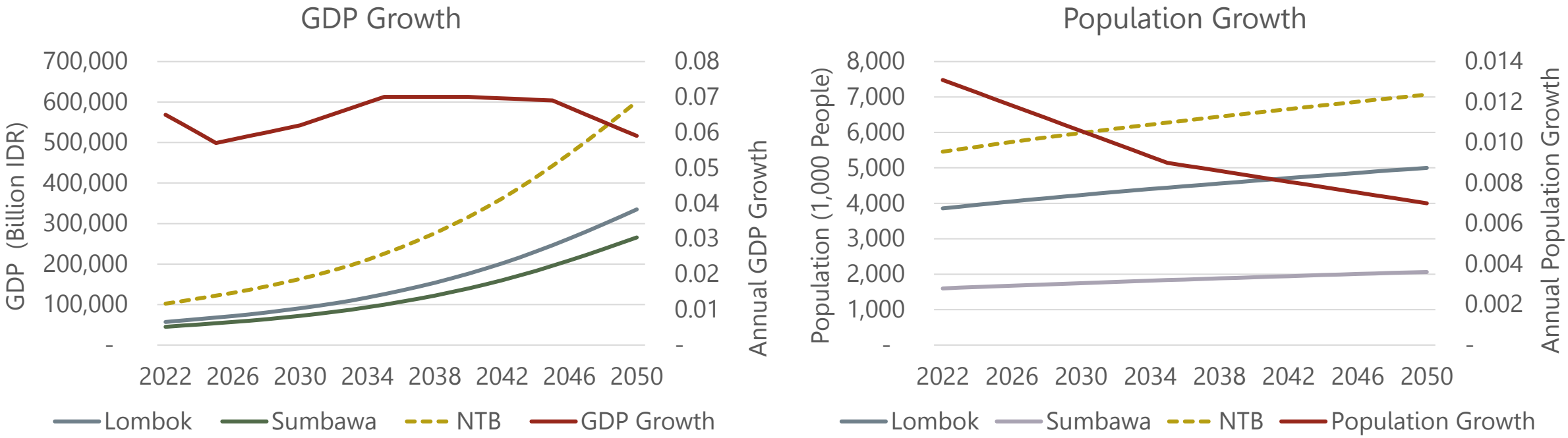
Oil Consumption (Kilo litres)			
Oil Products	Lombok	Sumbawa	Total
Avtur	7,002	778	7,780
Gasoline	282,793	148,099	430,892
Kerosene	5,666	1,688	7,354
Diesel	363,684	406,256	769,940
Fuel Oil	63,855	22,610	86,465
Total	723,000	579,431	1,302,431

LPG Consumption (Ton)			
Sector	Lombok	Sumbawa	Total
Residential	97,355	23,894	121,249
Industry	281	69	351
Commercial	523	129	651
Total	98,159	24,092	122,251

Coal Consumption (ton)			
Sector	Lombok	Sumbawa	Total
Power Generation	447,184	212,501	659,685
Mining	-	493,889	493,889
Industry	78,630	14,977	93,607
Total	525,814	721,367	1,247,181

- Oil consumption is provided by DG Oil and Gas for whole NTB (split between Lombok Sumbawa based on local feedback and assumptions)
  - **Gasoline:** Mostly road transport, shipping and industry
  - **Kerosene:** Residential and industrial sectors
  - **Diesel:** Mostly road transport but also shipping, industry, mining and power generation
  - **Fuel oil:** Power sector
- LPG consumption is calculated based on available data from DG Oil and Gas
- Coal consumption is based on DG Mineral and Coal for power generation and mining, while industrial data is based on BPS Industry Survey

Assumption on GDP and population growth



- GDP growth is based on **Bappenas data** and population growth is based on **national and local historical trends**
- Economic activity is expected to bounce back from COVID-19, **increase steadily until peak in 2035**, followed by a 5-year plateau which will eventually lead to a reducing rate until 2050
- **Population growth is currently much higher than the national average** and the growth is **expected to slow down until reaching the current national levels** of 0.7% in 2050

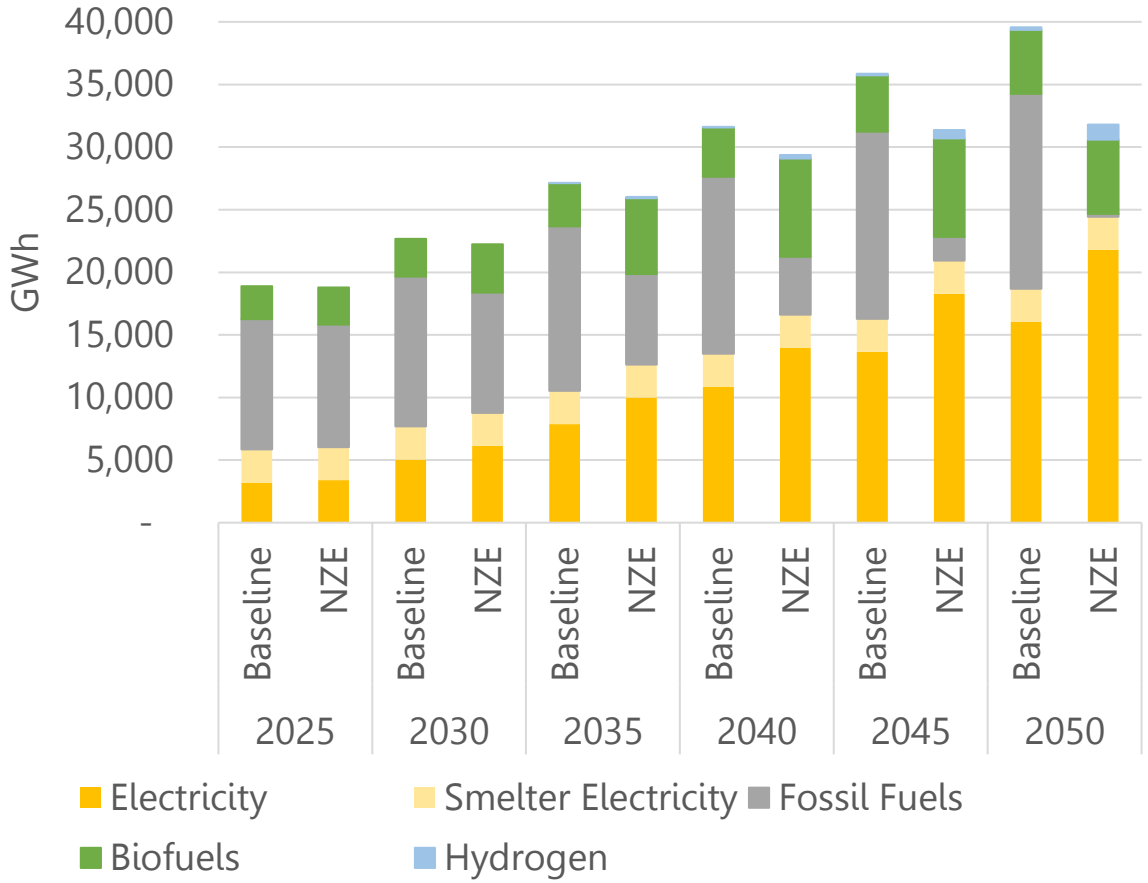
Other assumptions for end-use

- **Fuels**: Shifting toward biodiesel and biogasoline on certain annual rates
  - NZE assumes full substitution by 2050 to phase out conventional diesel and gasoline
- **Residential sector**: Gas stoves replacements with electric and biogas and efficiency improvements for electric appliances
  - Kerosene is phased out in both scenarios by 2030 and LPG consumption is eliminated in NZE by 2050
- **Commercial sector**: Substitution of diesel with electricity and biodiesel
  - Energy efficiency measures via state-of-the-art equipment, machineries and improved building energy management results in 25% reduction in energy demand by 2050
- **Industrial sector**: Substitution of diesel, coal and LPG to electricity and bioenergy and technological advancements
  - Energy intensity declines steadily to 25% by 2050 based on state-of-the-art or retrofitted machineries and boilers, heat pumps, as well as optimised process designs and circularity
- **Transport sector**: Electrification, biofuels and BEV efficiency improvements
  - NZE assumes all road transport vehicles, i.e. cars, motorbikes, trucks and busses to run solely on electricity and hydrogen by 2050

End-use development

Total final consumption

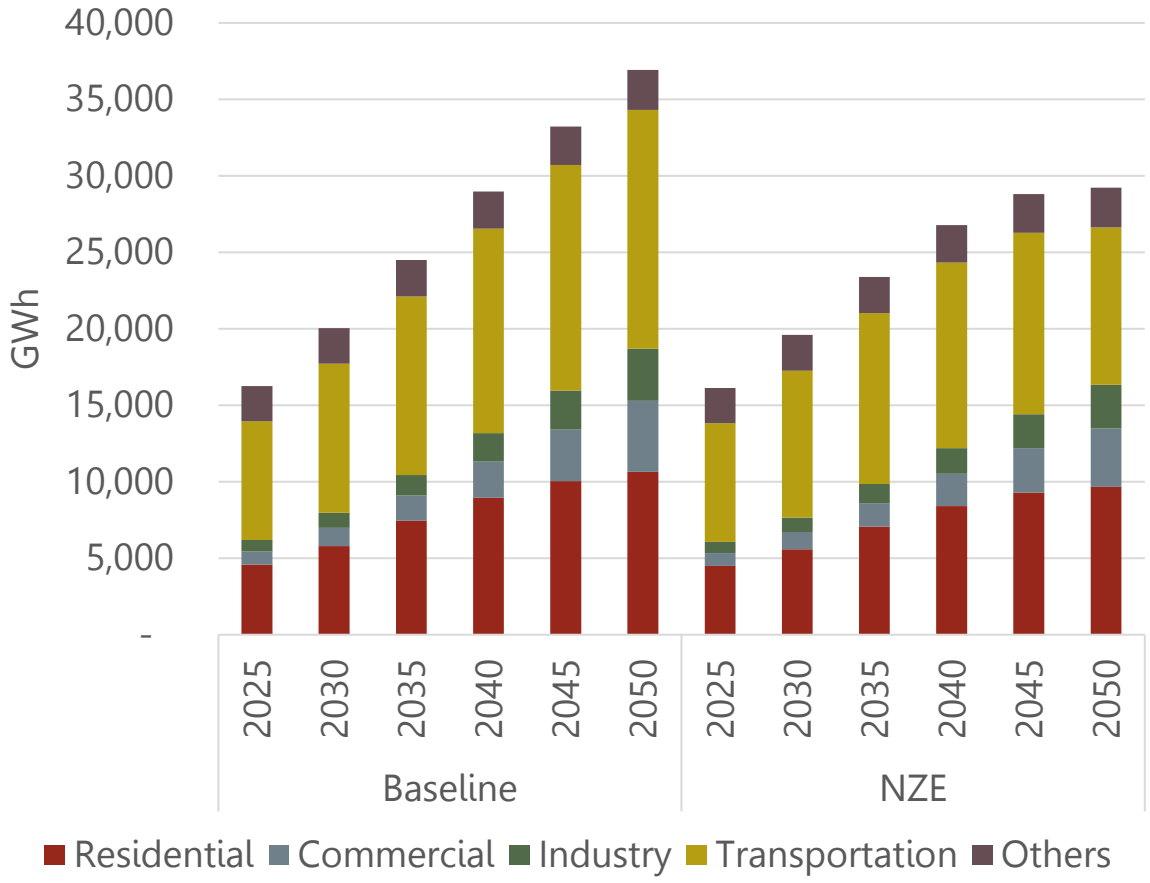
A holistic paradigm shift



- Fossil fuels: Gasoline, avtur, kerosene, diesel, LPG and coal
- Biofuels: Biogas, biogasoline, biomass, biodiesel and bioavtur
- **Constantly increasing demand** with **NZE presenting lower levels** already by 2030 **due to electrification and energy efficiency** measures
- Electricity constitutes 40% and 68% of total final consumption in 2050 for Baseline and NZE scenarios respectively

Total final consumption

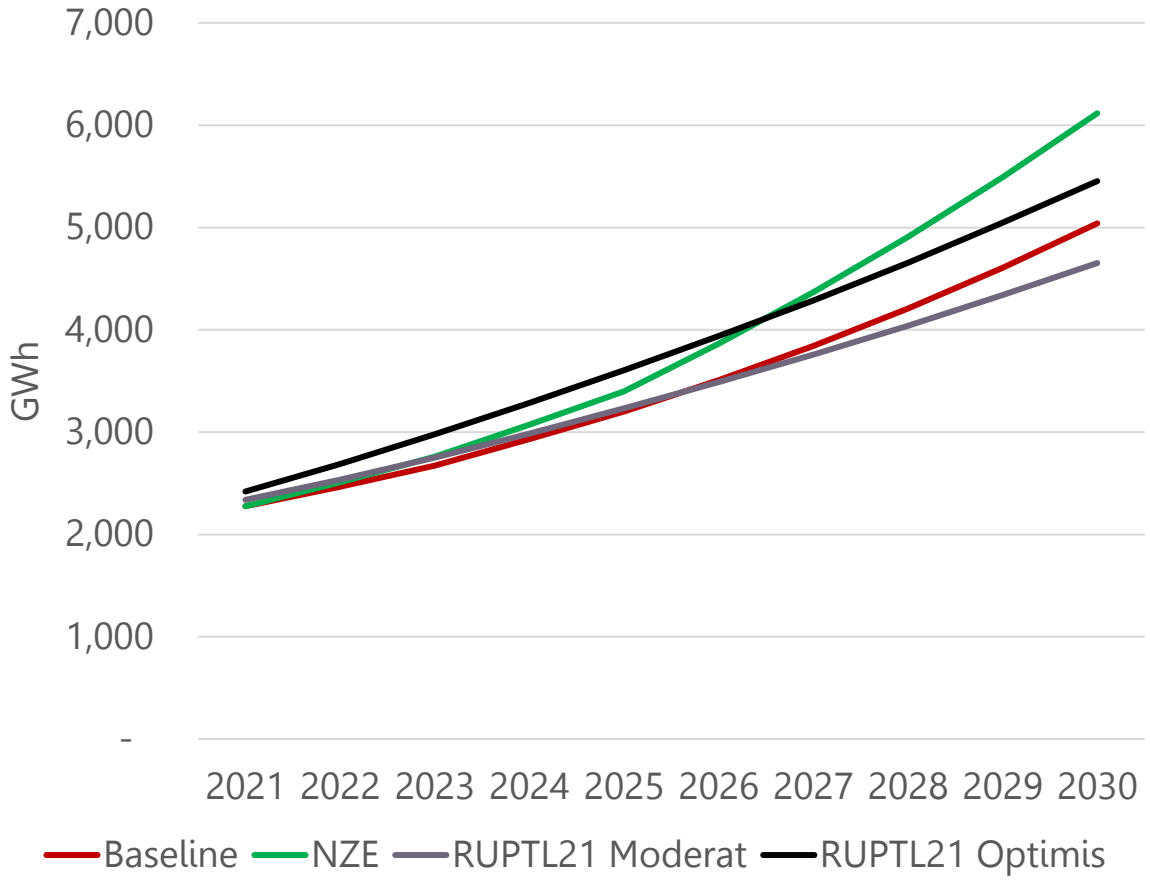
Sectoral comparison



- **Transport sector is the most energy-intensive** throughout 2050 in both scenarios, followed by the residential
- **Industrial activity showcases a share increase of 5%** between 2025 and 2050, reaching equal levels with others (agriculture, mining and construction)
- **Commercial sector rises fivefold**

Total electricity consumption – Driving the transition

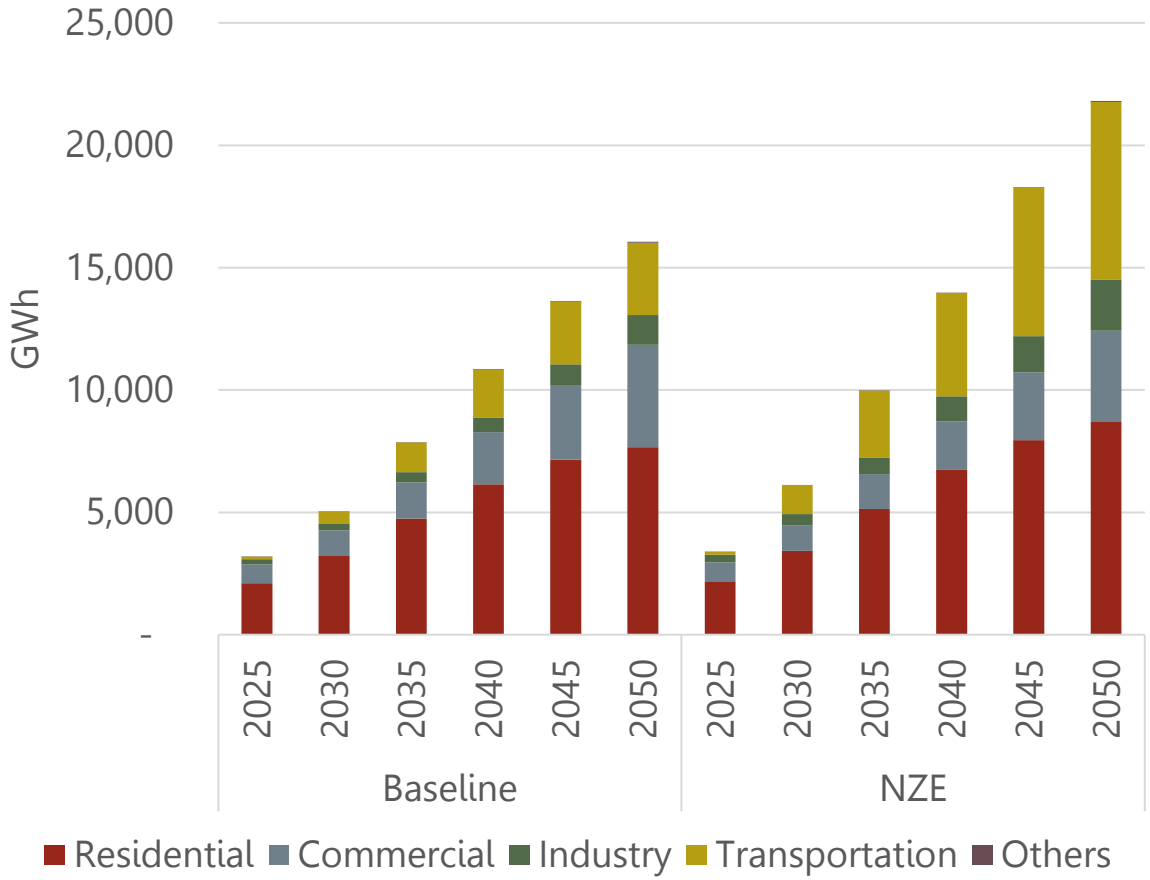
Comparison with RUPTL21 until 2030



- **RUPTL21 has been used to calibrate the electricity consumption** development of end-use sectors for Baseline scenario
- Baseline follows the moderate PLN scenario until 2025 and reaches in-between moderate and optimistic in 2030
- **NZE** surpasses all other scenarios post 2026, mainly due to **higher BEV penetration** in transport

Total electricity consumption – Driving the transition

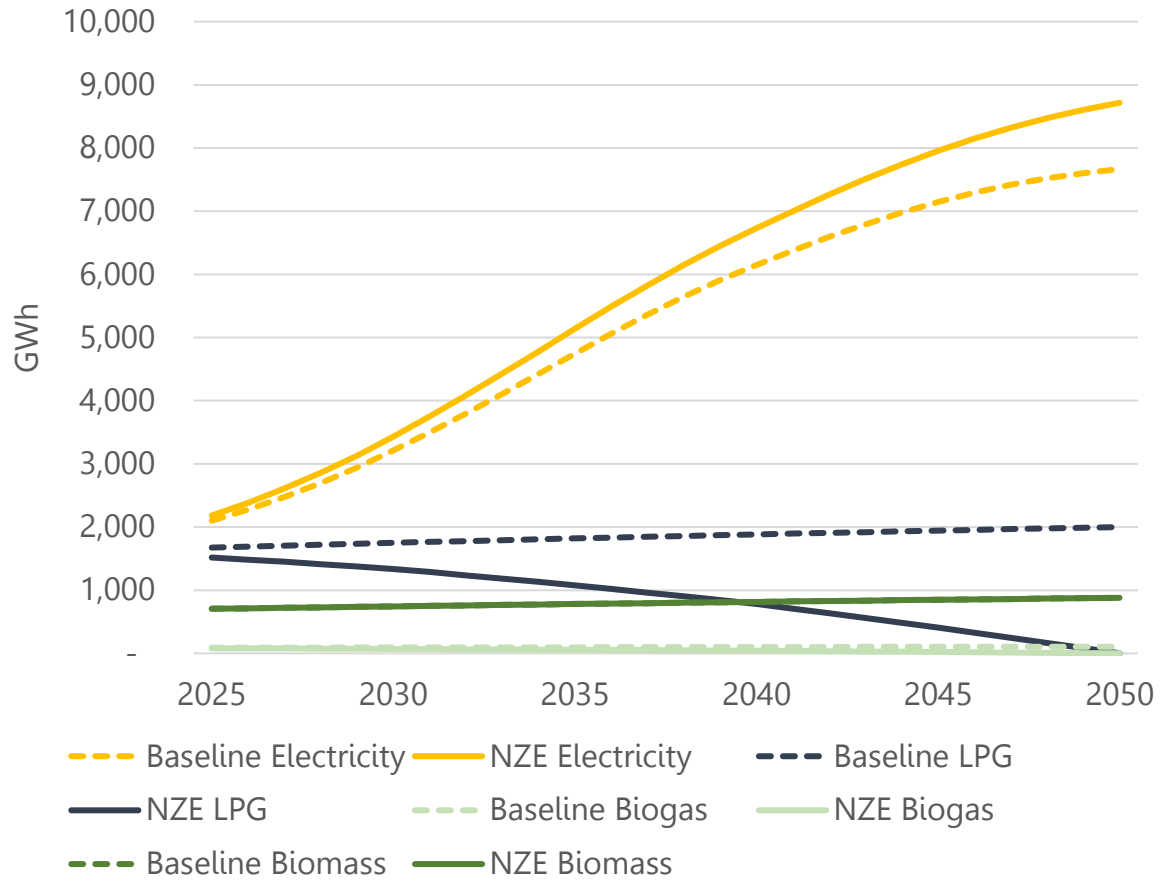
A sectoral comparison



- **Constant electricity growth** in all sectors with transportation enjoying the largest increase
- **Residential sector remains the highest consuming** in both scenarios and for all years
- NZE scenario consumes **21.8 TWh** of electricity which is 5.8 TWh higher than Baseline
- Electric appliances and machineries, electric boilers and heat pumps, as well as electrification of road transport mainly for light-duty vehicles contribute to total demand

Residential sector

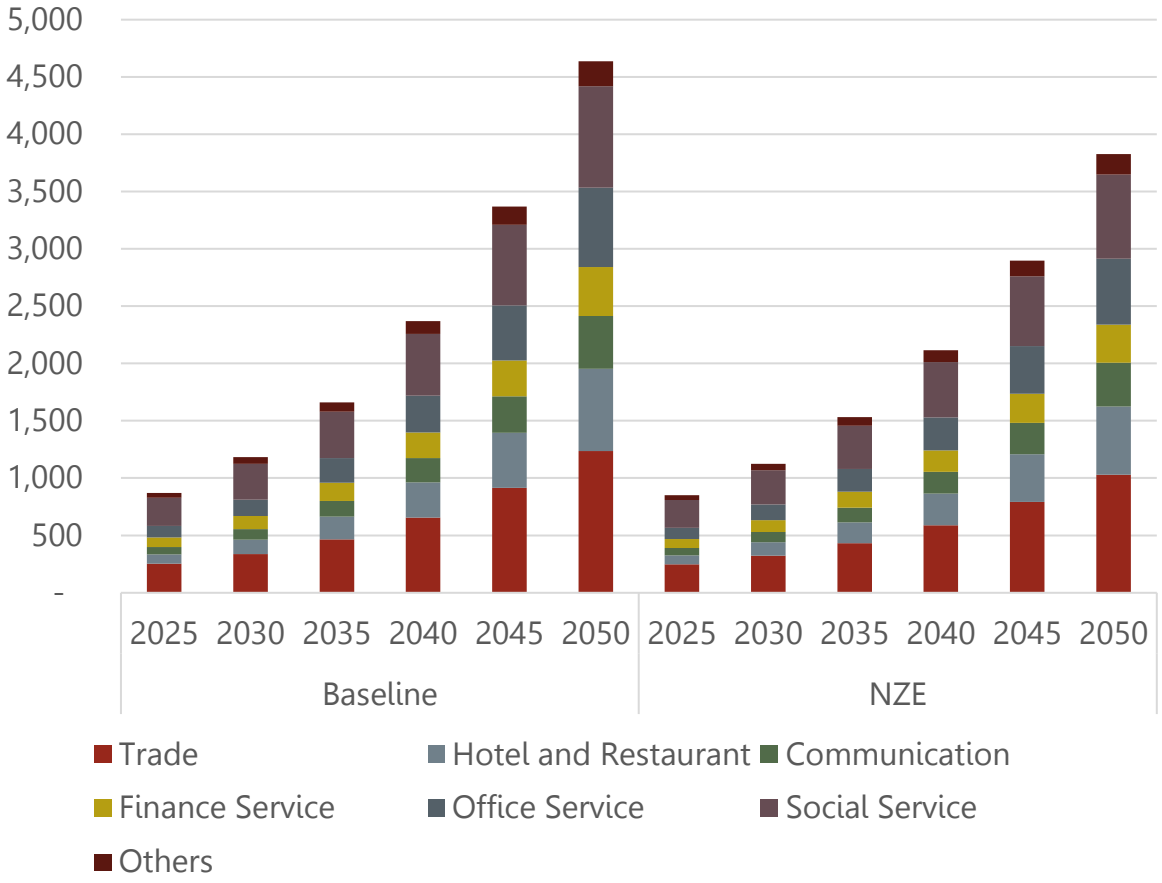
Clean cooking and energy efficiency as first fuel



- **Electricity drives the residential demand** reaching 8.6 and 7.6 TWh respectively in Baseline and NZE
- LPG which is consumed in **gas stoves for cooking is steadily phased-down, substituted mainly with electricity** but also biomass in NZE scenario
- Kerosene is currently used but at very low levels and is phased out before 2030 in both scenarios
- By 2050, **NZE assumes that all households have access to clean cooking**
- Higher energy efficiency results from **more efficient appliances and cooking equipment**

Commercial sector

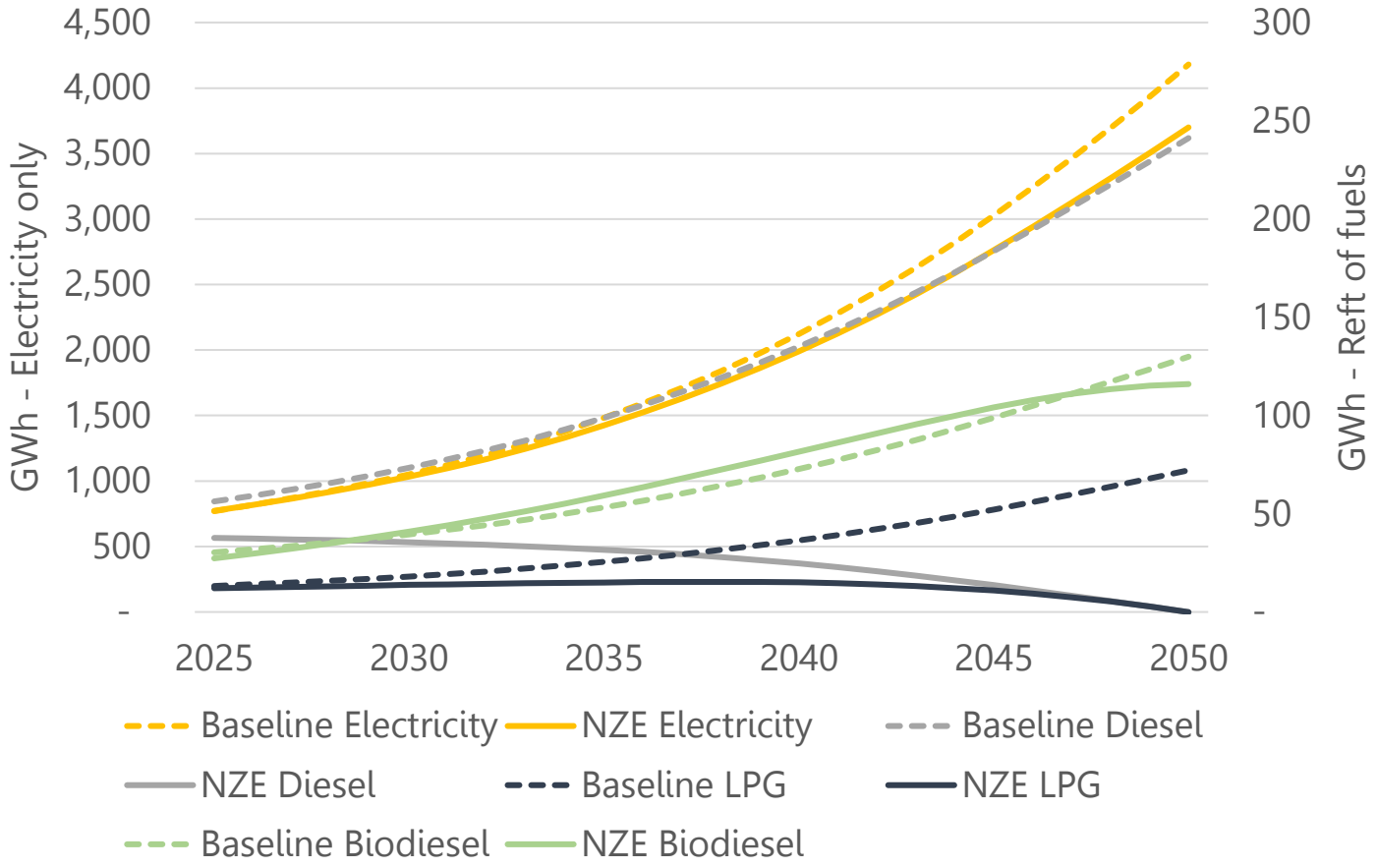
Exploring low-hanging fruits



- Commercial sector encompasses various services, trading activities and businesses
- Commercial applications are **expected to grow following the provincial economic development**
- Relative shares of total annual consumption of the different subsectors remain at similar levels between 2025 and 2050, however, **hospitality sector is anticipated to grow faster than other services**
- NZE scenario showcases a 17% decrease against Baseline in 2050 due to **more efficient appliances, materials and equipment** used, along with improved **energy management** in buildings

Commercial sector

Exploring low-hanging fruits

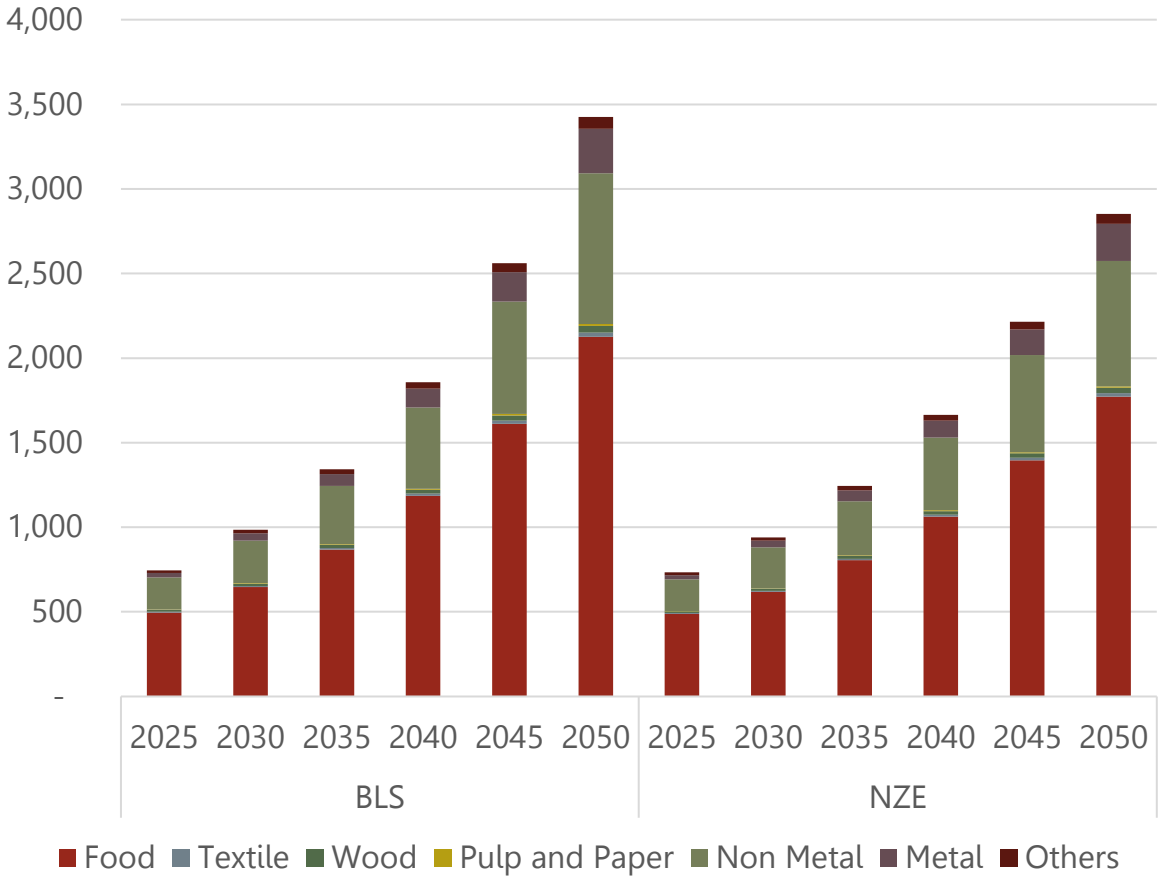


- Over **85% of the fuel mix is constituted by electricity already by 2030** in both scenarios and reaches more than **90% in 2050**

- Baseline sees a steady but slow uptake of **diesel** and **LPG** in both Lombok and Sumbawa which are gradually **phased-down in NZE via substitution with electricity and biodiesel**

Industrial sector

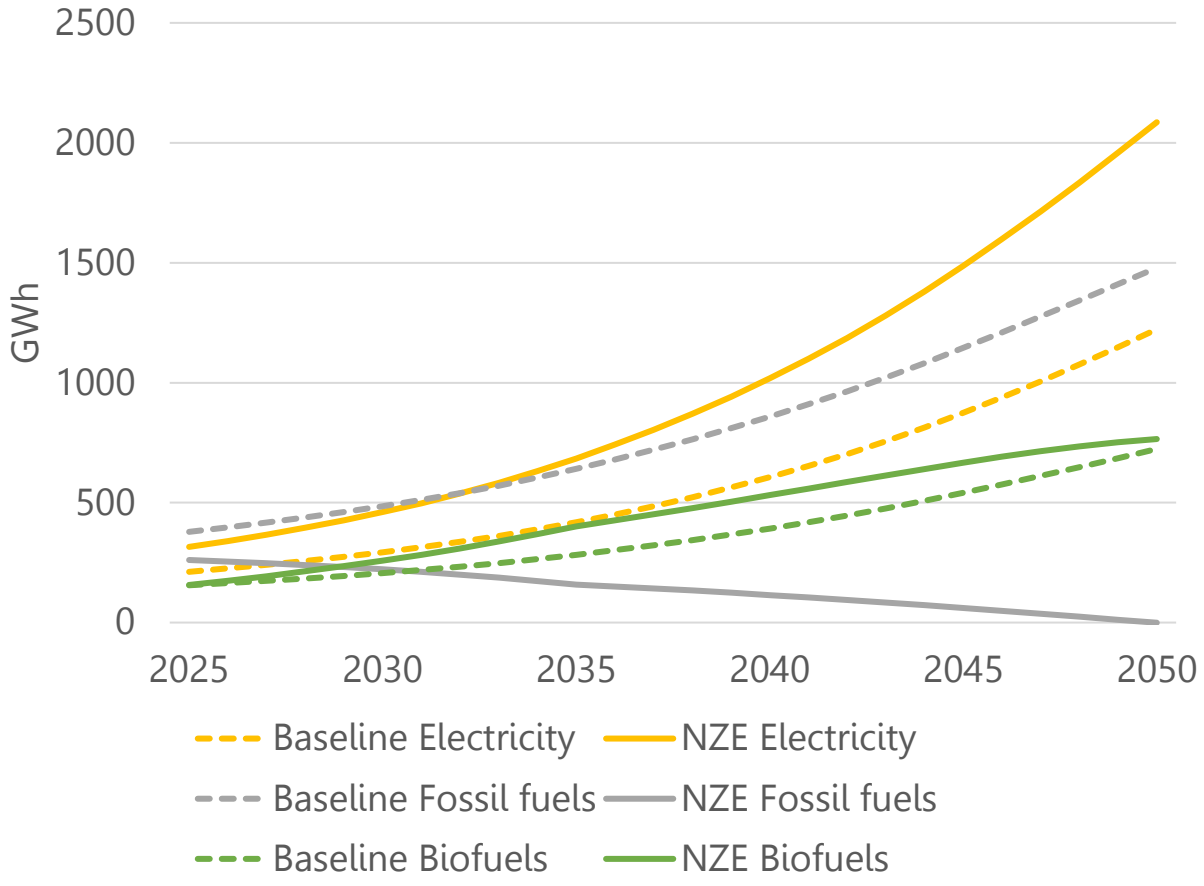
Electrification and biofuels pave the way



- Industrial activity is relatively low in NTB and constituted about **7% of total GDP for Lombok and 1.7% for Sumbawa** in 2021
- Some of the key industries are food and beverage, wood, metal and non-metal
- The **food sector consumes more than 60%** of industrial fuel consumption, followed by non-metals at roughly 25%
- **Baseline** total fuel consumption **raised more than fourfold compared to 2025 levels**, while **NZE presents a 17% decrease against Baseline in 2050** via electrification and installation of state-of-the-art equipment and machineries

Industrial sector

Electrification and biofuels pave the way

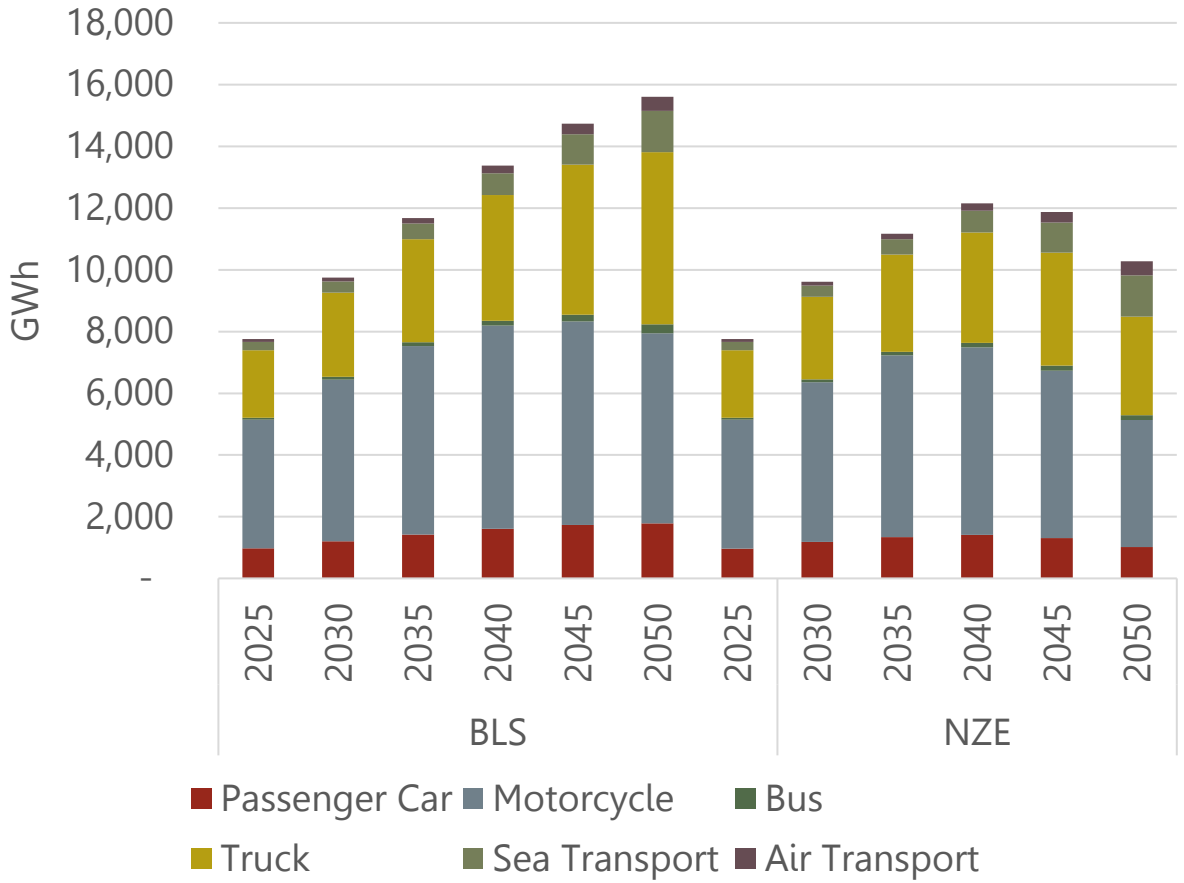


- **Baseline scenario relies heavily in fossil fuels** (i.e. diesel, LPG and coal) throughout 2050 with **diesel being the main driver** which is constantly higher than electricity consumption

- **NZE scenario presents higher electrification** of various low-temperature industrial processes, **fuel switching toward biofuels** (mainly biodiesel and biomass) and **higher energy efficiency**

Transportation sector

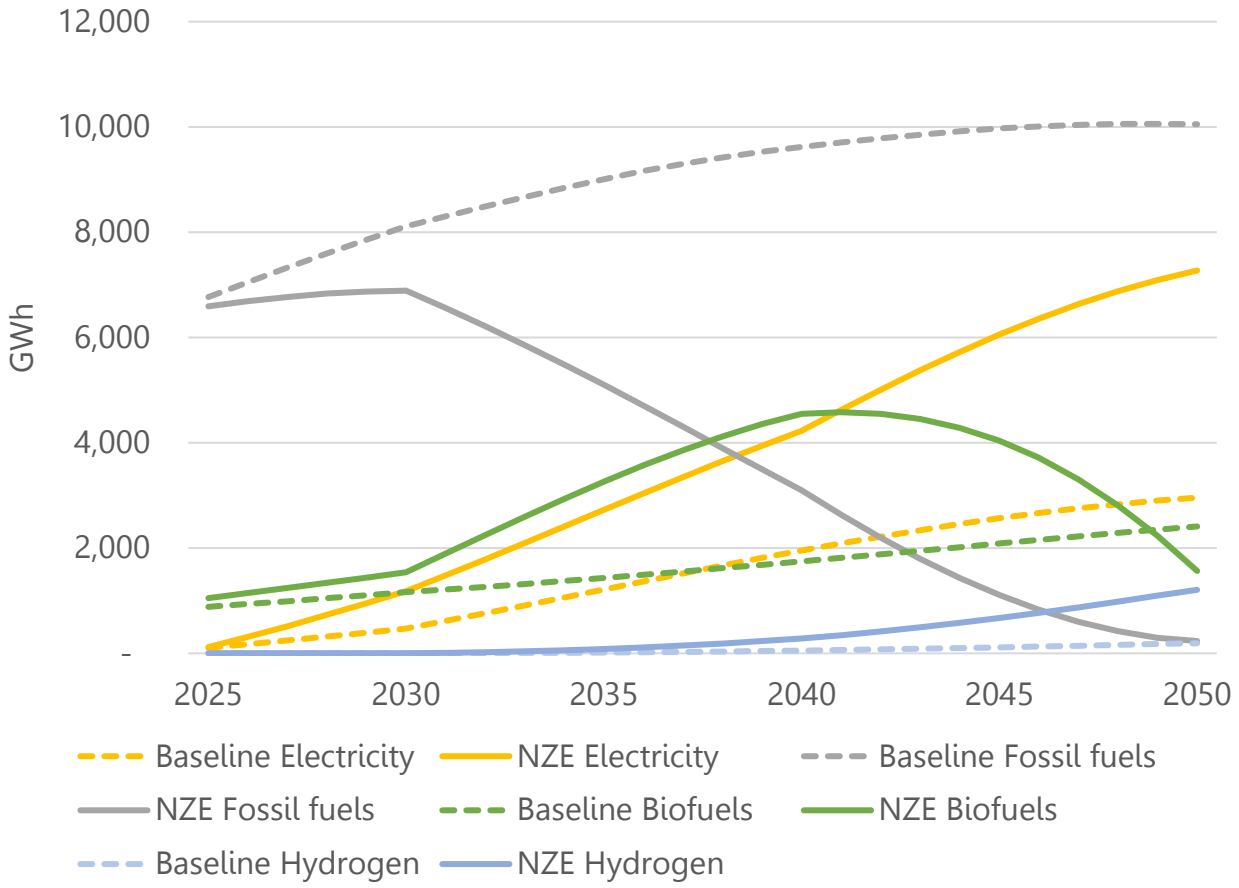
Domination of electric vehicles



- Gasoline, diesel and B30 have the highest demand today
- **Motorcycles dominate the mobility market** with more than 1.6 million listed in 2021 and thus most energy-intensive in all years
- **Electric vehicles anticipate a large growth** in the upcoming years and policies are already in place, e.g. subsidies and VAT reductions
- **NZE sees a peak in energy consumption in 2040** and declines thereafter due to higher electrification and technological advancements
- In 2050, the two scenario present a 5.3 TWh difference

Transportation sector

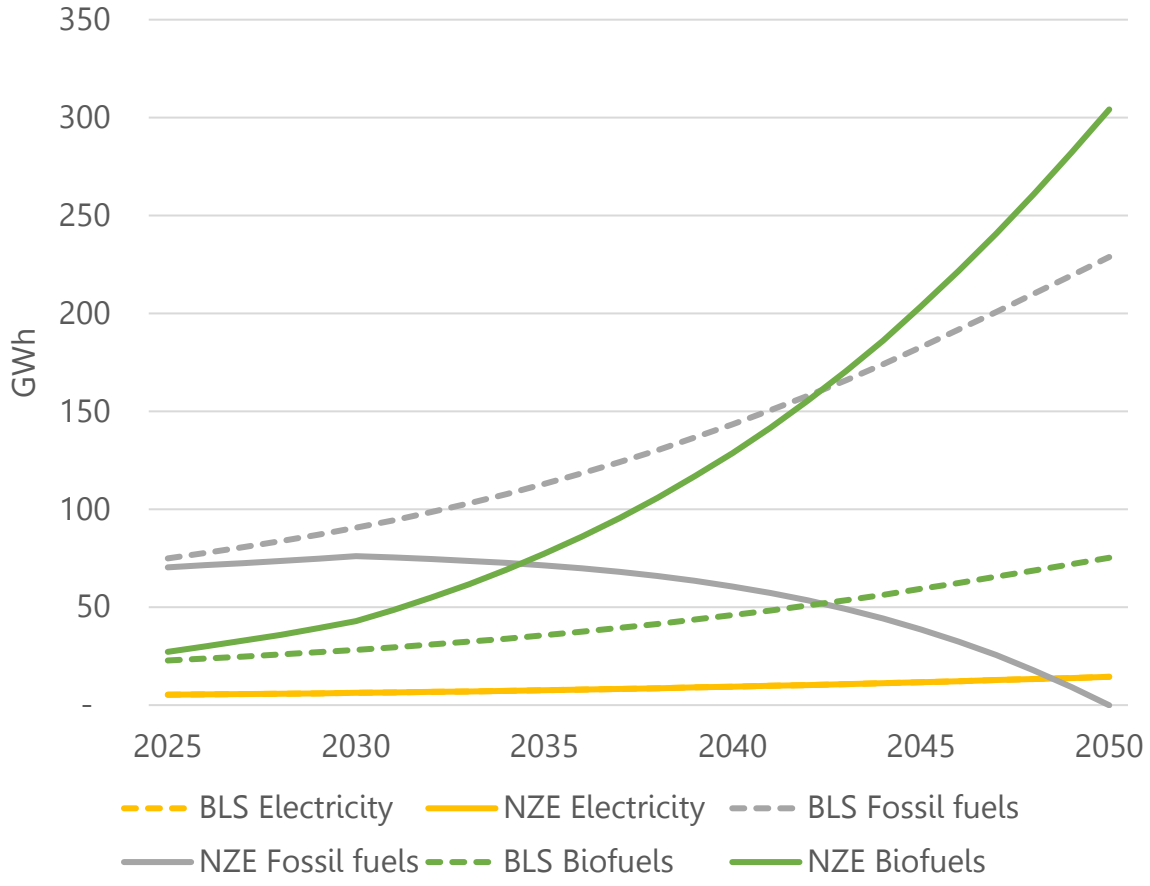
Domination of electric vehicles



- **Baseline inherits some of the measures and policies adopted in NZE**, in a less optimistic approach but in line with national ambitions
- **NZE illustrates** a much larger penetration of BEVs along with **higher hydrogen and biofuel uptake**
- **By 2050, NZE assumes road transport** (cars, motorbikes, trucks and busses) to **run solely on electricity and hydrogen**, while **aviation and shipping** shift to **biofuels** e.g. biodiesel, biogasoline and biojetfuel

Others sector

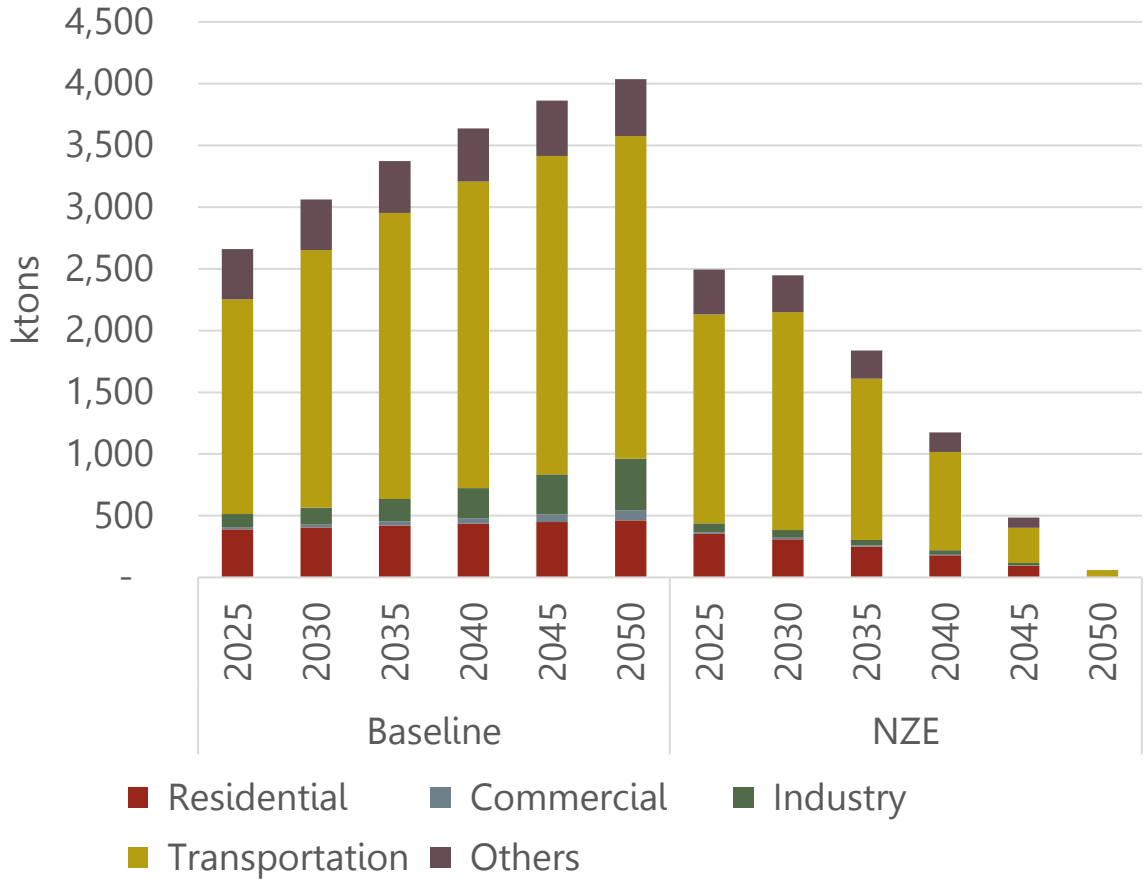
Shifting to alternative fuels – the case of Lombok



- Others include agriculture, construction and mining
- **Agriculture and mining are of very high and strategic importance** and occupy a large number of the population
- Mining sector which is most active in Sumbawa is **assumed to remain relatively stable in terms of consumption** as there is only one operating facility at the moment
- **Diesel and gasoline** are the ascendant fuels which are highly **substituted with biofuels in the NZE scenario**

End-use CO_2 emissions

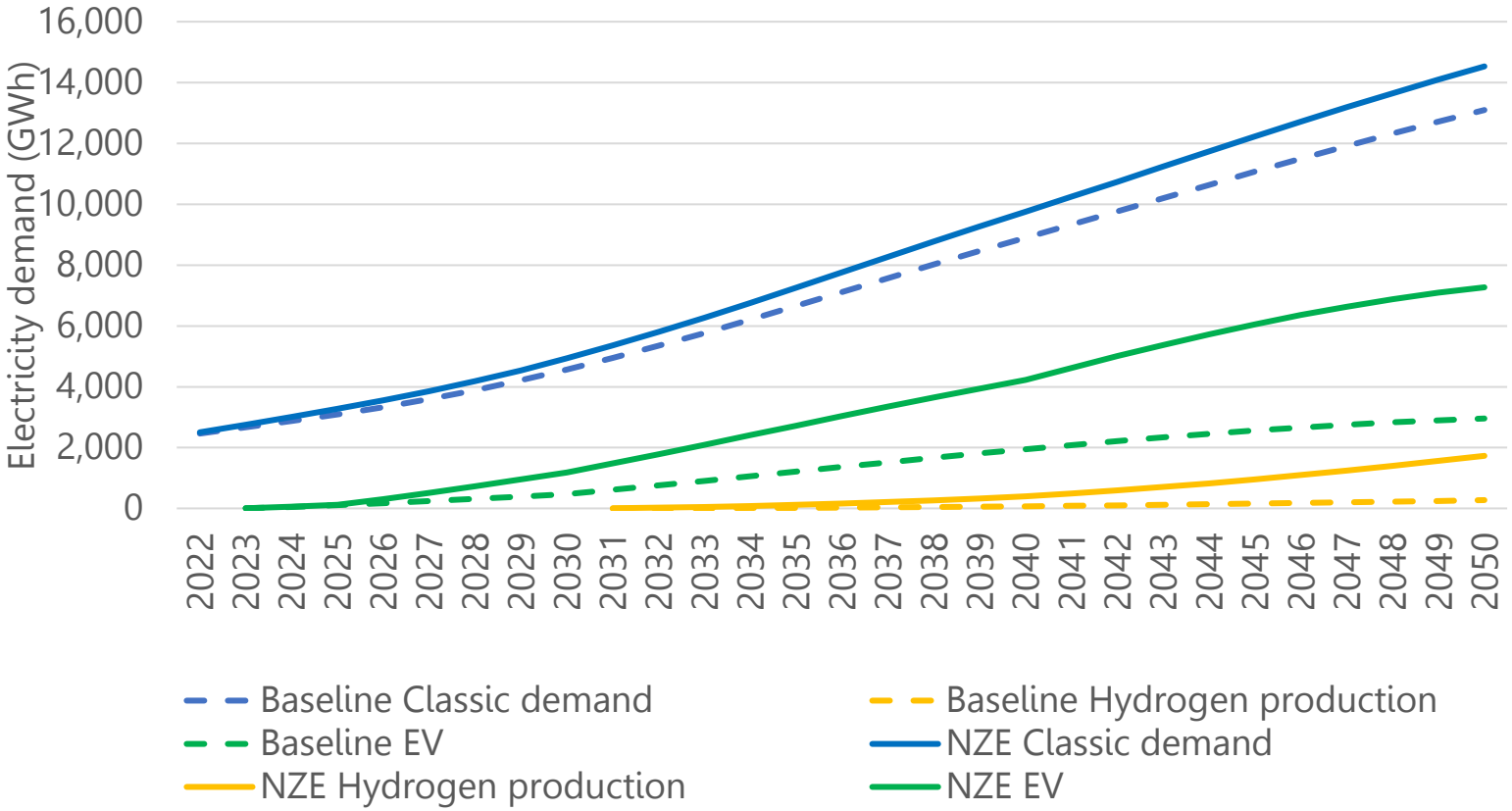
Achieving net-zero for end-use sectors are possible



- Transportation is by far **the highest emitting sector throughout 2050 in both scenarios** followed by the residential and others sector
- Already **by 2030, a 20% reduction between Baseline and NZE** is feasible, mainly driven by **BEV sales and more efficient appliances**
- **NZE sees a carbon emission peak in 2025** which is only marginally higher than 2030
- In 2050, Baseline reaches 4 Mt with transportation taking up 65%, while NZE has roughly 60 kt left linked with aviation
- **Full decarbonisation of transportation would require negative emissions** via BECCS or the introduction of e-fuels, e.g. e-jet fuel

Power sector development

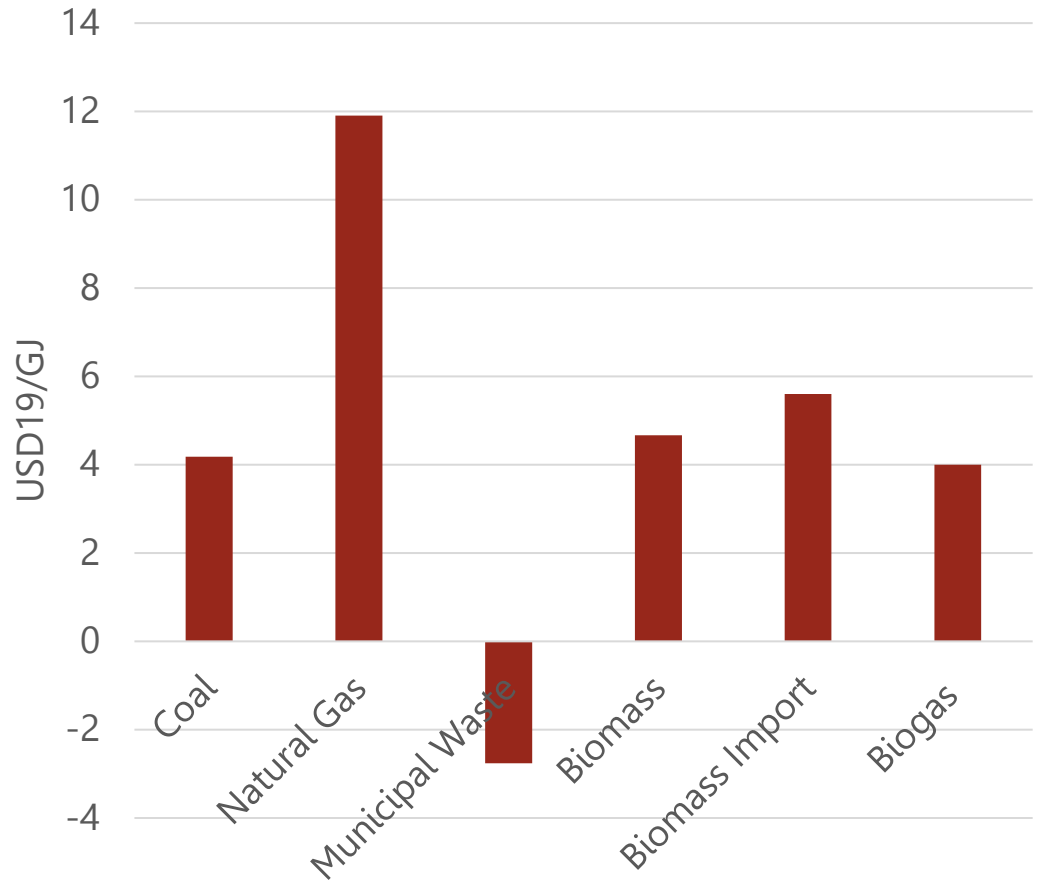
Electricity demand



Electricity Consumption (GWh)			
Sector	Lombok	Sumbawa	Total
Residential	1,037	473	1,510
Commercial	476	125	602
Industry	89	89	179
Total	1,603	688	2,290

- By 2050 the total electricity demand **increases 6-fold in baseline and 9-fold in NZE**
- **Different level of electrification of transport** contributes most to the difference between scenarios.

Financial inputs for the power sector

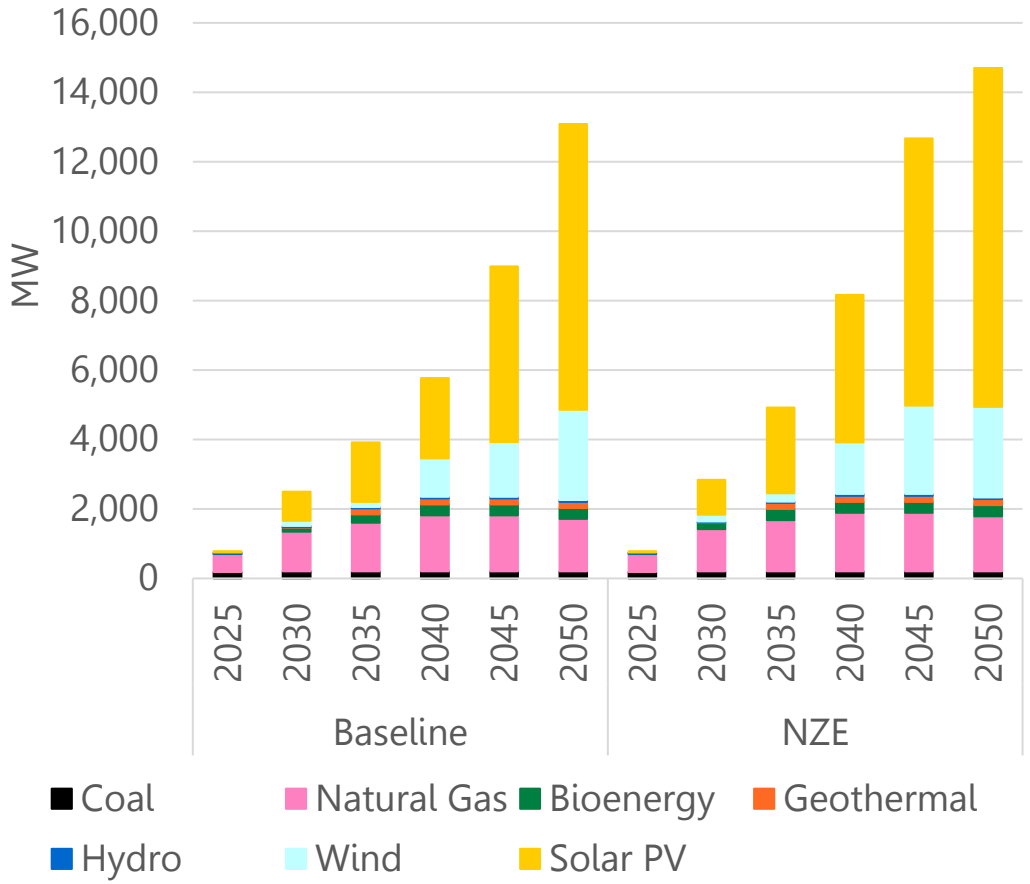


Investment costs (USD19/MW)				
Technology	**2020**	**2030**	**2040**	**2050**
Solar PV (large)	0.61	0.43	0.38	0.32
Wind Onshore	1.39	0.73	0.67	0.62
Biomass	1.85	1.69	1.59	1.48
Gas combined cycle	0.94	0.89	0.86	0.82

- Fuel prices calibrated to reflect **DMO prices**
- Investment cost for capacity expansion based on **Indonesia technology catalogue** (2021)

Capacity Expansion

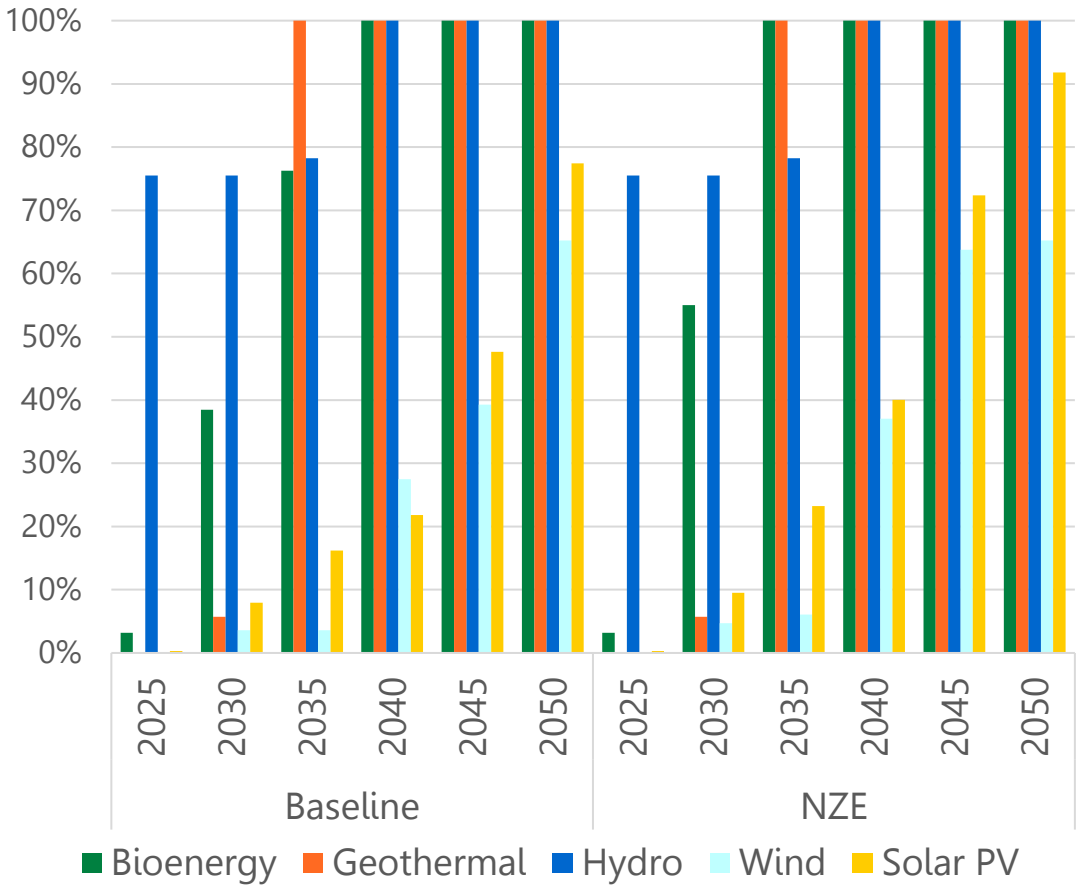
Extensive short- and long-term capacity investments, especially in solar and wind



- Capacity expansion form 2026
- By 2050, both scenarios project **solar and wind as primary sources**
- **13 GW of RE in the NZE scenario by 2050**
  - Solar PV 9 GW (90% in Sumbawa)
  - Wind 2.6 GW
- **No decommissioning** = existing coal and gas assets still a part of the fleet (can be considered for retrofitting in the future)
- **Hydropower, bioenergy, and geothermal potential fully utilized** by 2050 in both scenarios.

Capacity Expansion

Extensive short- and long-term capacity investments, especially in solar and wind



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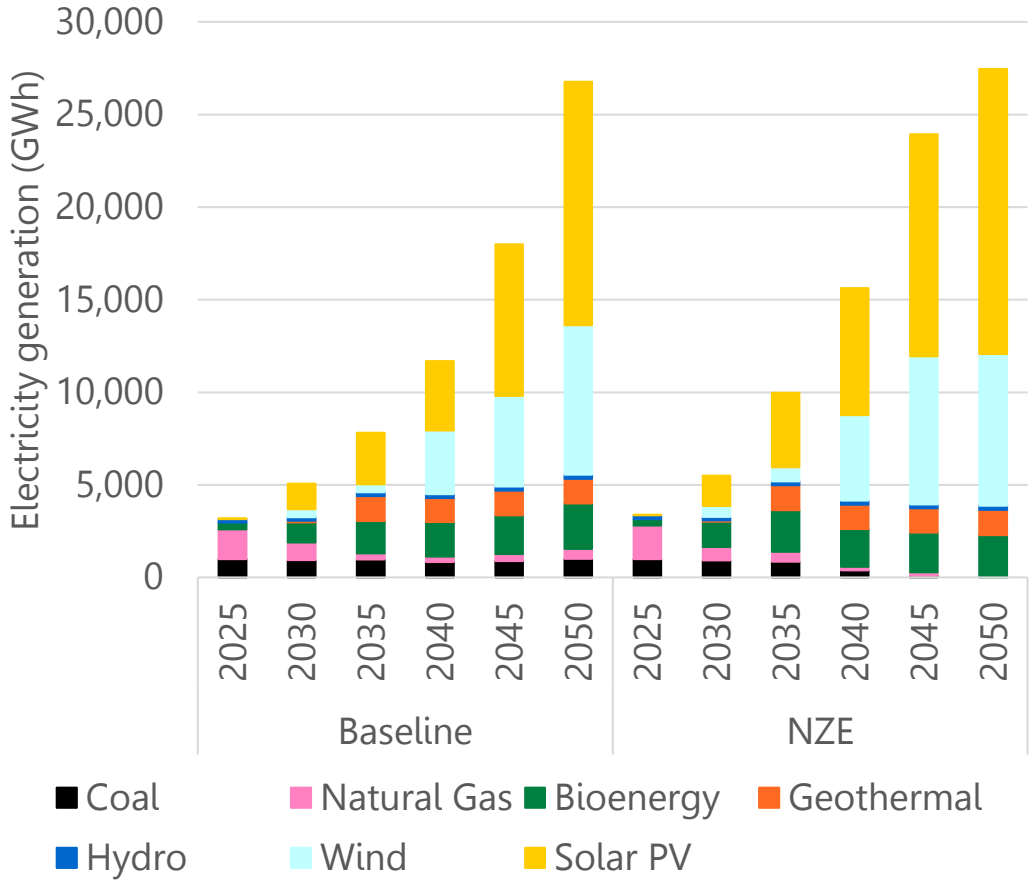
Electricity Generation

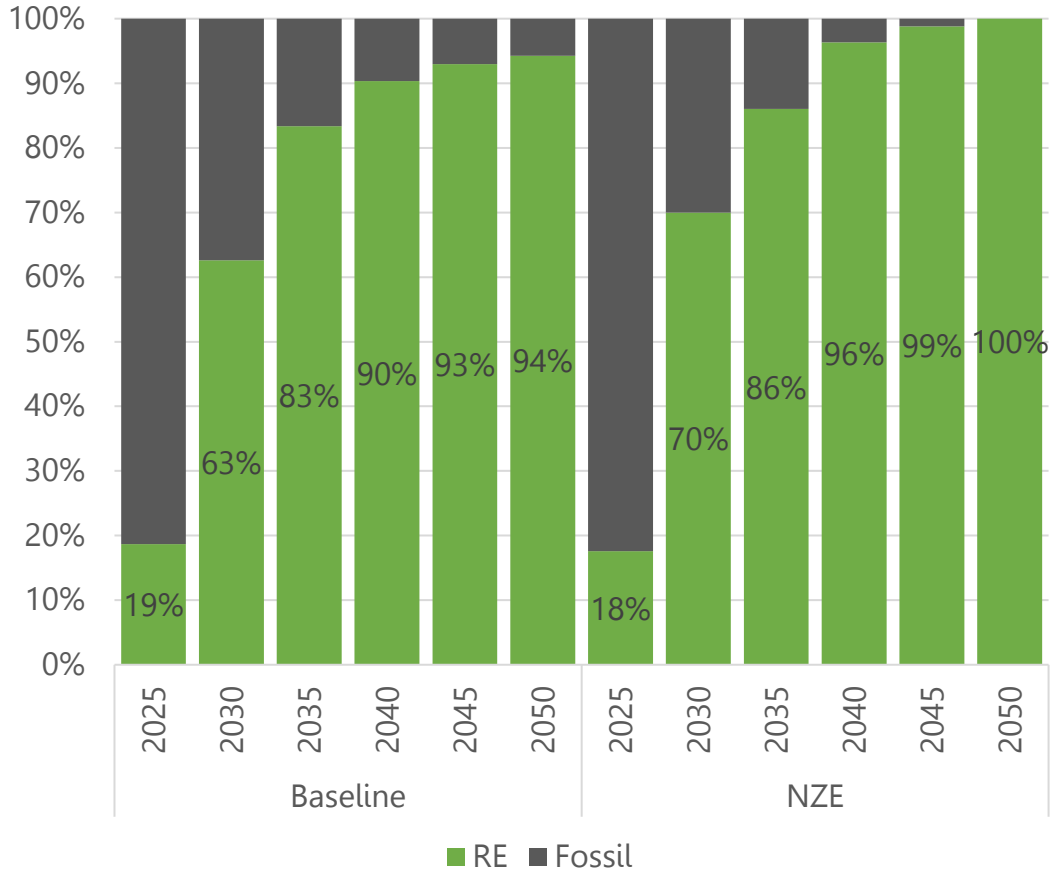
Renewable energy dominates generation



- By 2050
  - Generation grows 10-fold in both scenarios
  - **NTB is a net surplus state** (when generation is compared to NTB electricity demand)
- In line with capacity expansion, **most of this increase in generation comes from solar and wind**.
- **Share of RE is rapidly growing** in both scenarios.
- **Fossil fuel consumption goes down completely in NZE**
- **Share of renewables reach 99% in 2045 in NZE**
  - Showing that RE development is inherent to a CO_2 target and might not require separate goal.

Electricity Generation

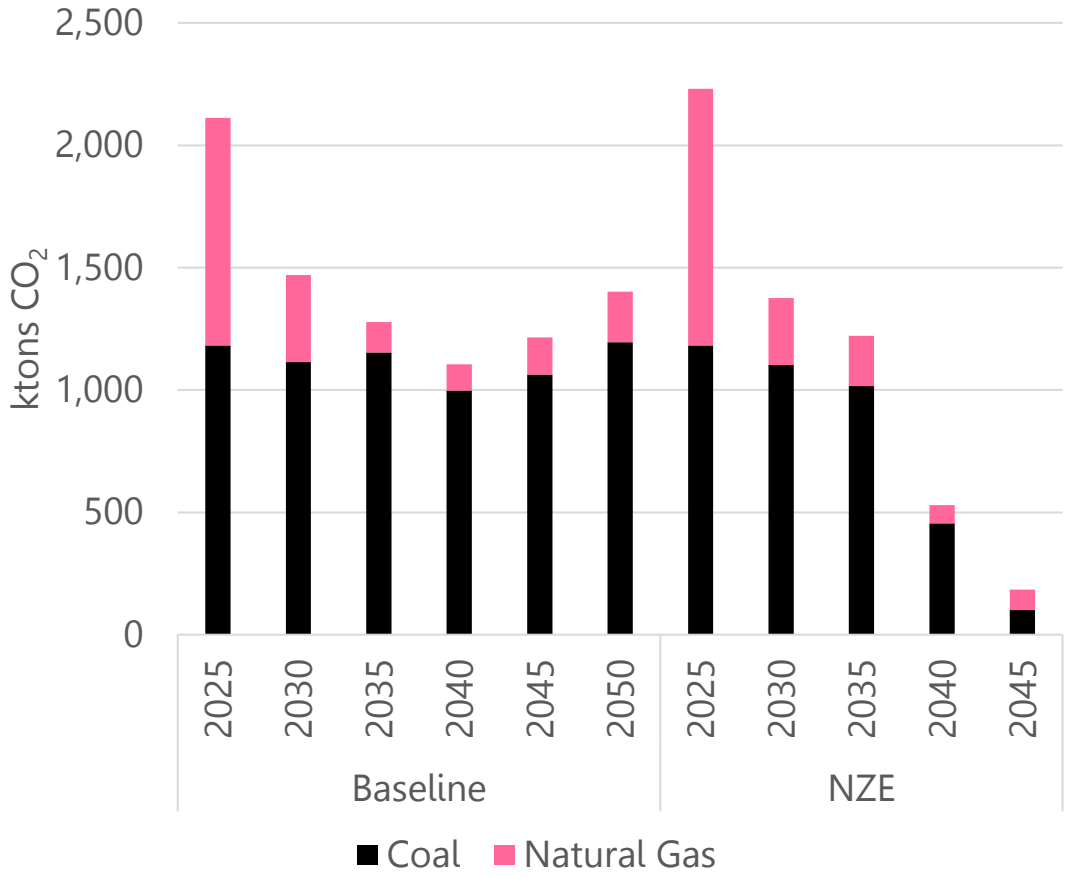
Renewable energy dominates generation



- By 2050
  - demand increases by 6 times in baseline and 9 times in NZE
  - Generation grows 10-fold in both scenarios
  - **NTB is a net surplus state**.
- In line with capacity expansion, **most of this increase in generation comes from solar and wind**.
- **Share of RE is rapidly growing** in both scenarios.
- **Fossil fuel consumption goes down completely in NZE**
- **Share of renewables reach 99% in 2045 in NZE**
  - Showing that RE development is inherent to a CO_2 target and might not require separate goal.

CO_2 emissions

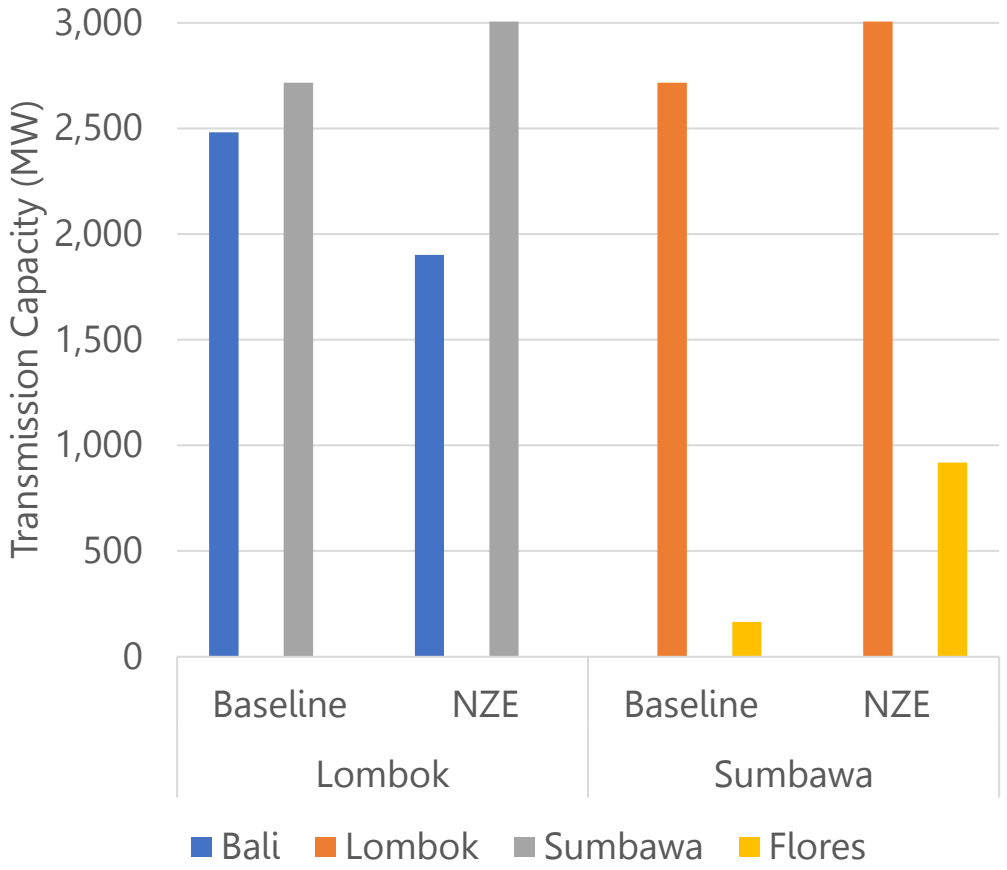
Ambitious CO_2 reduction is achievable

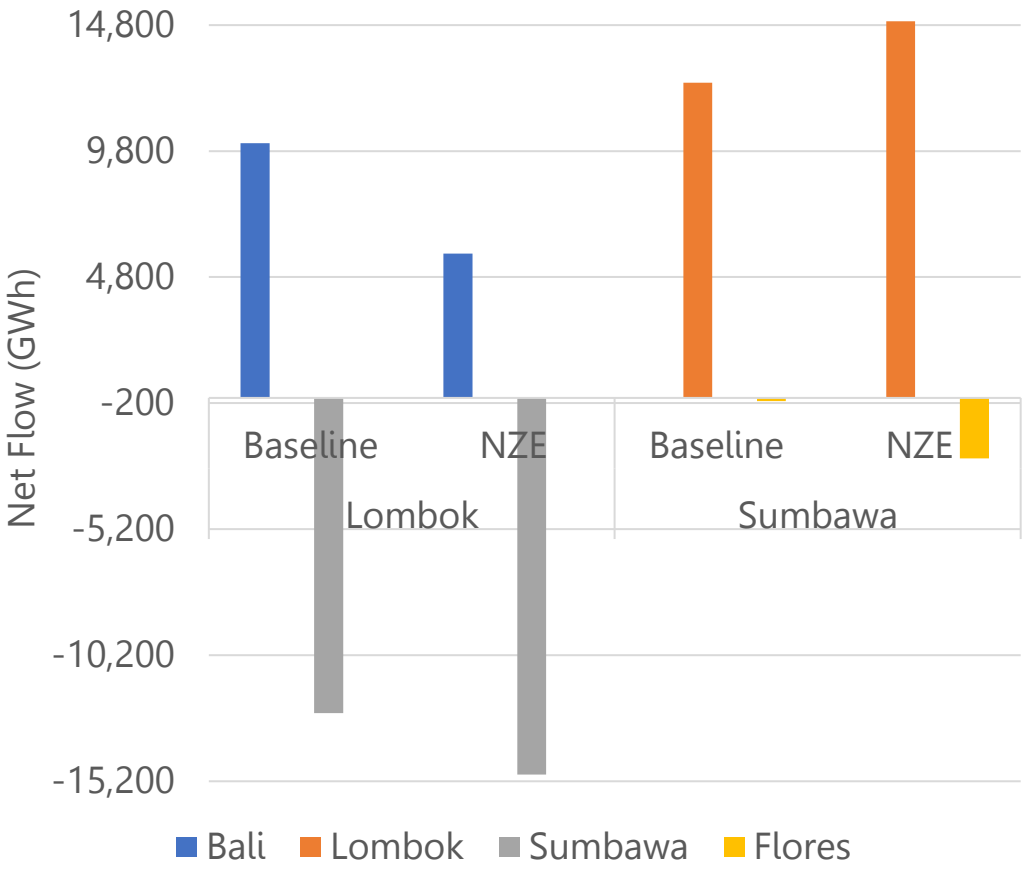


- **CO_2 emission reduction by 2050 in both scenarios**
- Emission per unit of electricity produced also goes down
- **Power sector emission down to zero by 2048 in NZE** to allow reduced decarbonization of other sectors when electrification is the solution
- **Coal main source** for emissions in power sector
- Decarbonized electricity supply in NTB also means **lower emissions for regions importing** electricity from NTB

Increased interconnections

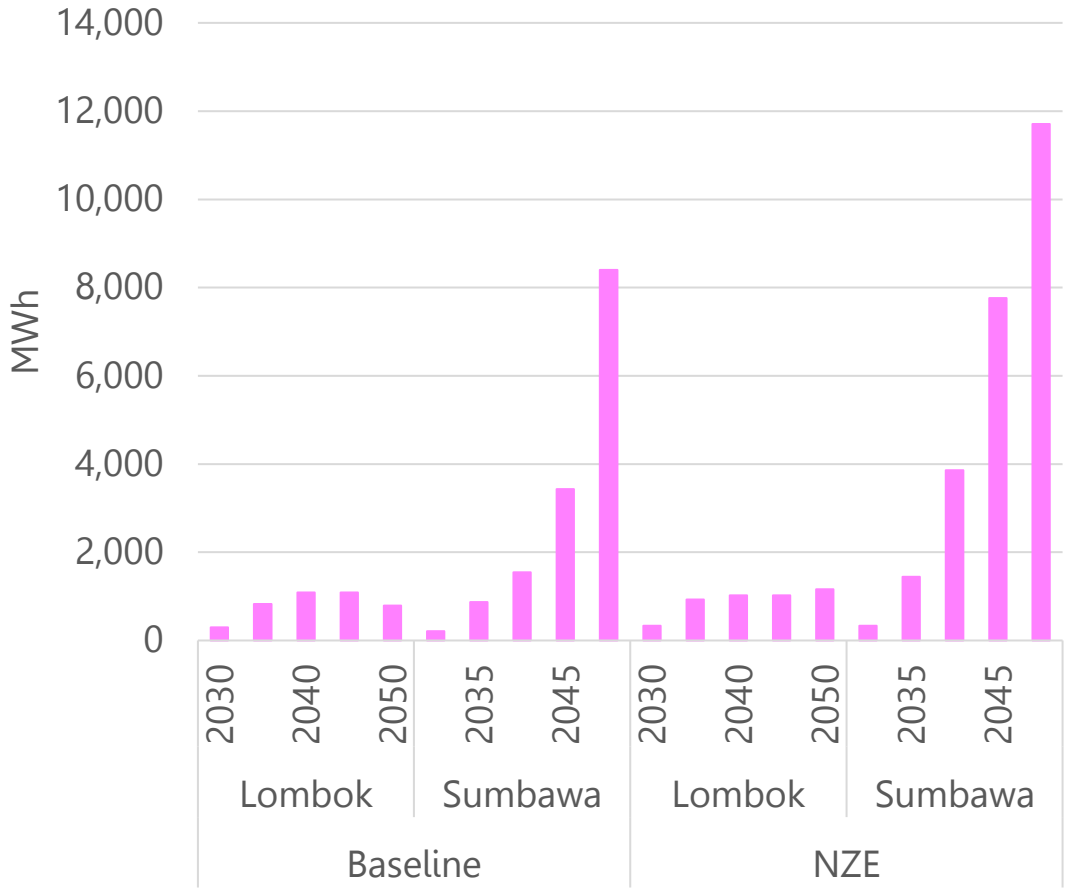
Transmission improves resource utilisation and supports national decarbonisation





Battery storage capacity

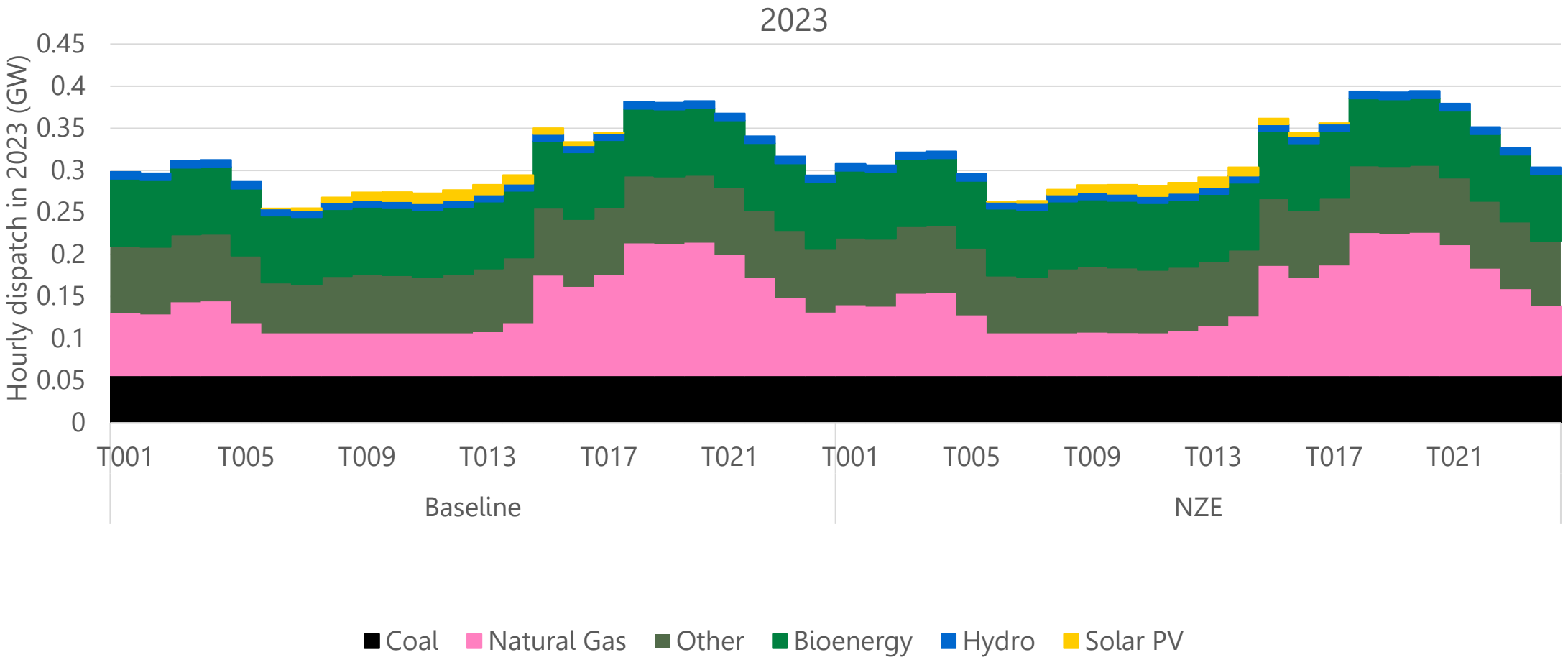
Storage required for enhanced solar utilisation and flexibility



- Increasing battery storage capacity important to **better utilize solar resource** of Sumbawa
- This can include large battery projects and hybrid solar and wind projects with storage
- Allows for shifting supply to higher load hours which helps **reducing requirement for peaker capacity** (usually thermal)

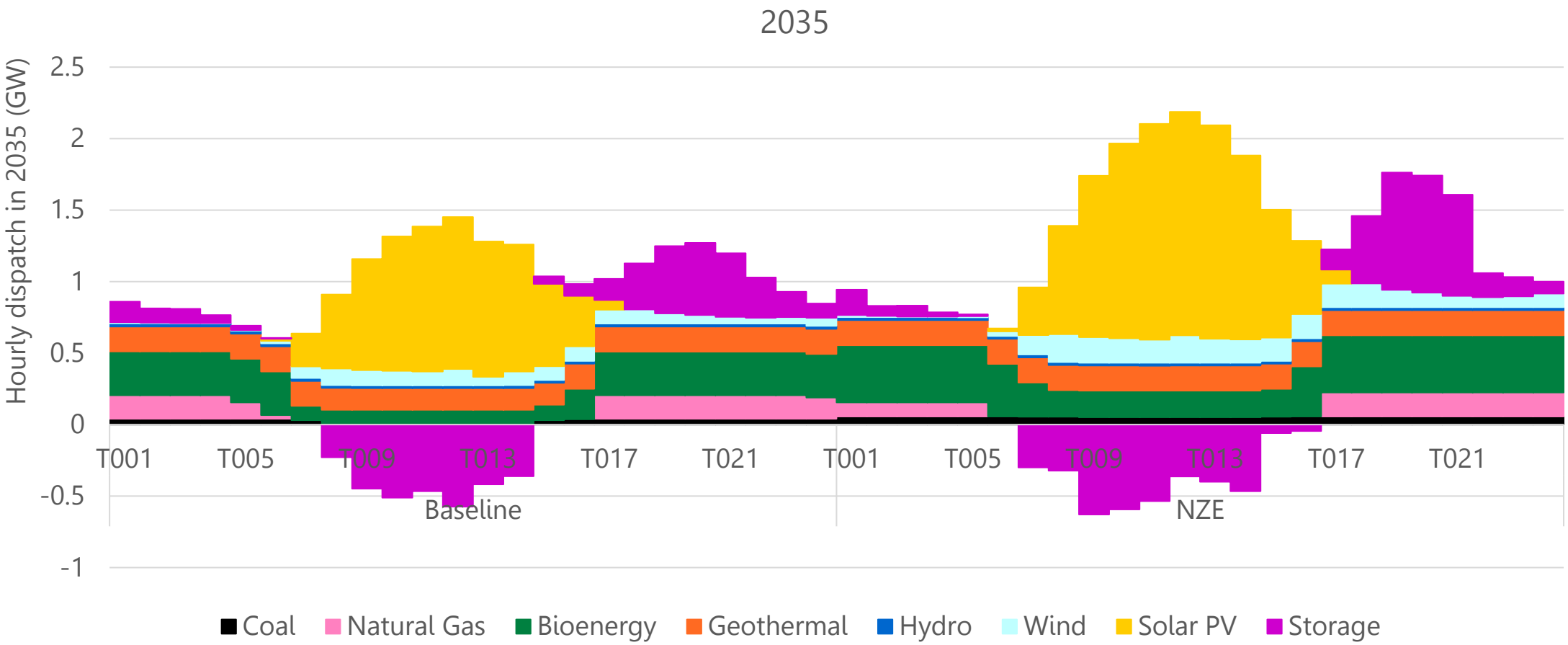
Increasing VRE and storage

A transformation of the energy dispatch and system operations



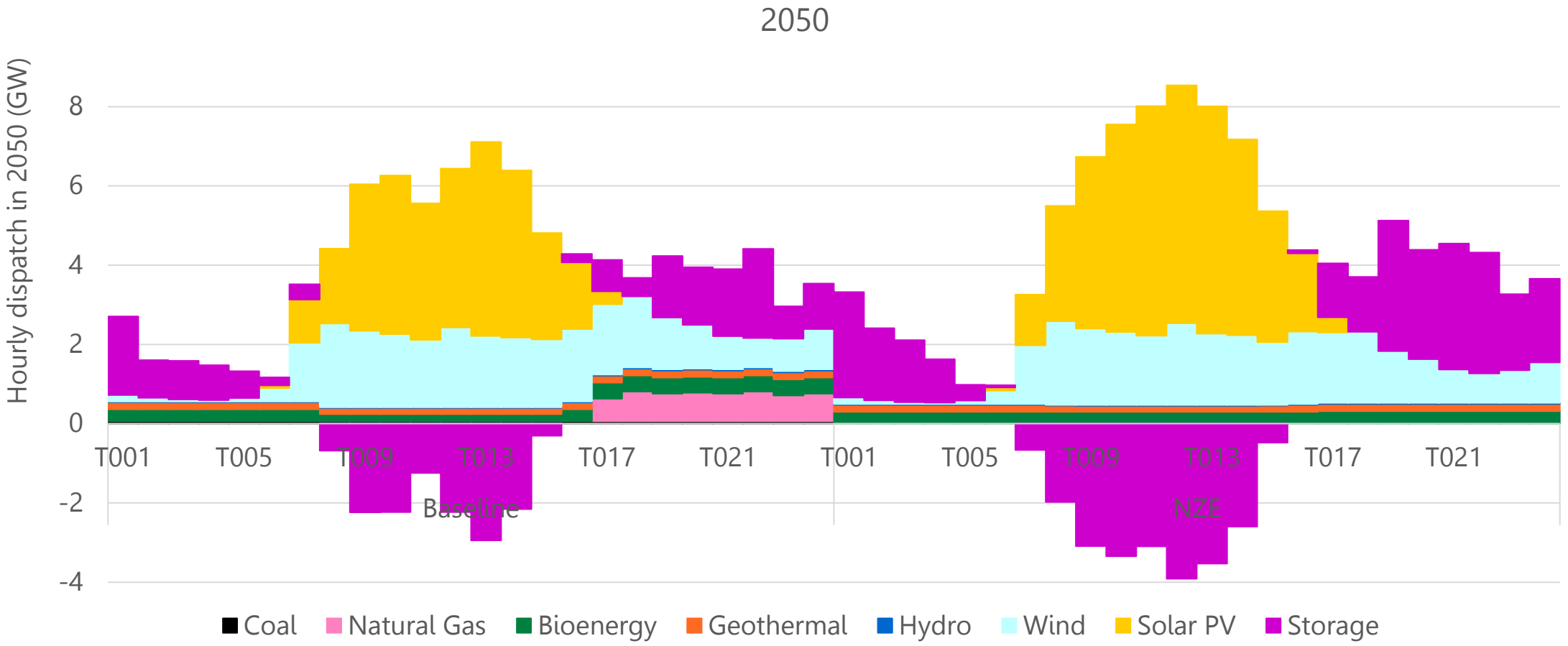
Increasing VRE and storage

A transformation of the energy dispatch and system operations



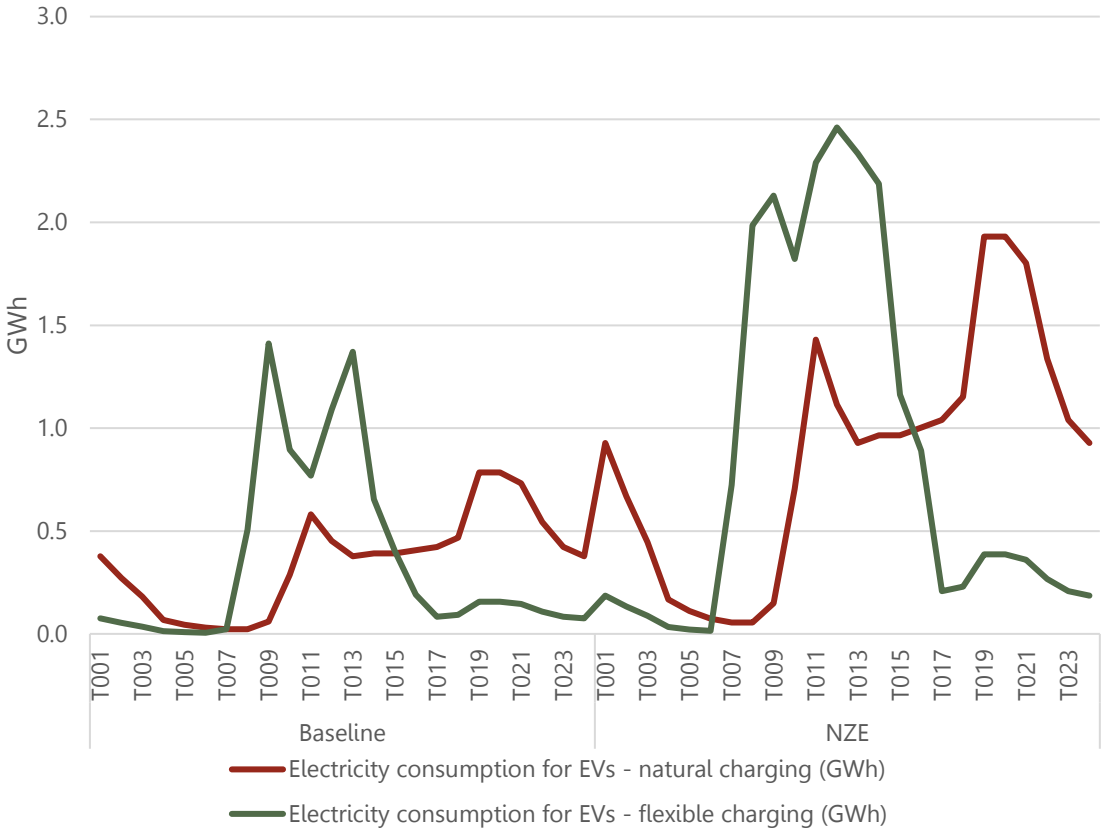
Increasing VRE and storage

A transformation of the energy dispatch and system operations



Electric vehicle charging

Smarter charging enhances system flexibility

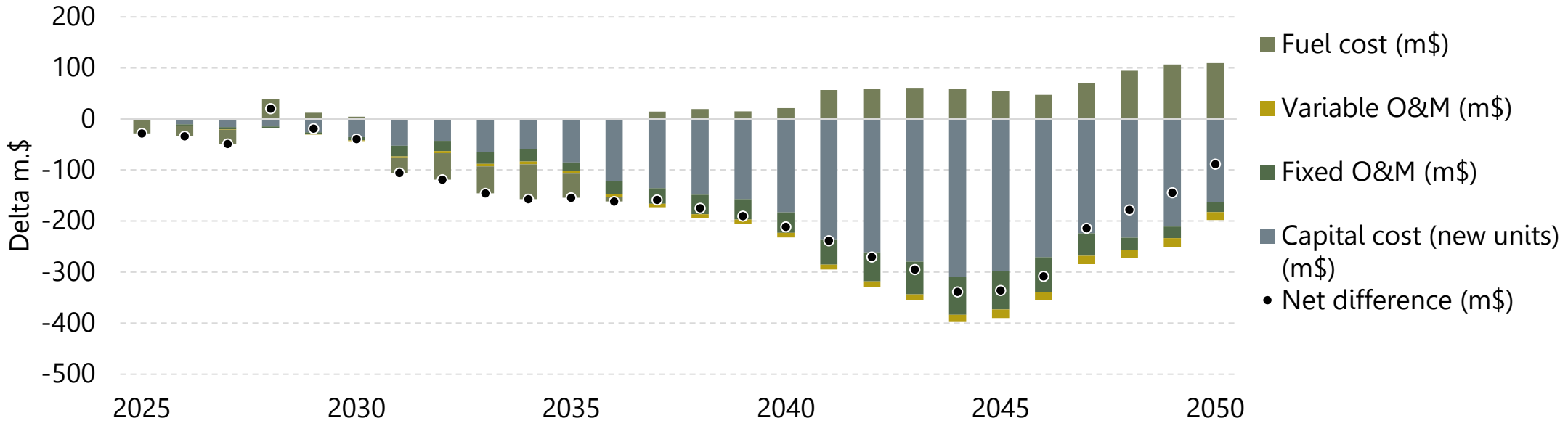


- System flexibility is important when transformed to a variable renewable energy dominant system
- **EVs storage increases flexibility** with shifting time of charging based on supply
  - more charging around peak solar hours = better resource utilization and reduced stress during evening peak.
- Important to **consider charging infrastructure planning**, development of charging technology and consumer awareness

Financial estimates

Total power generation costs

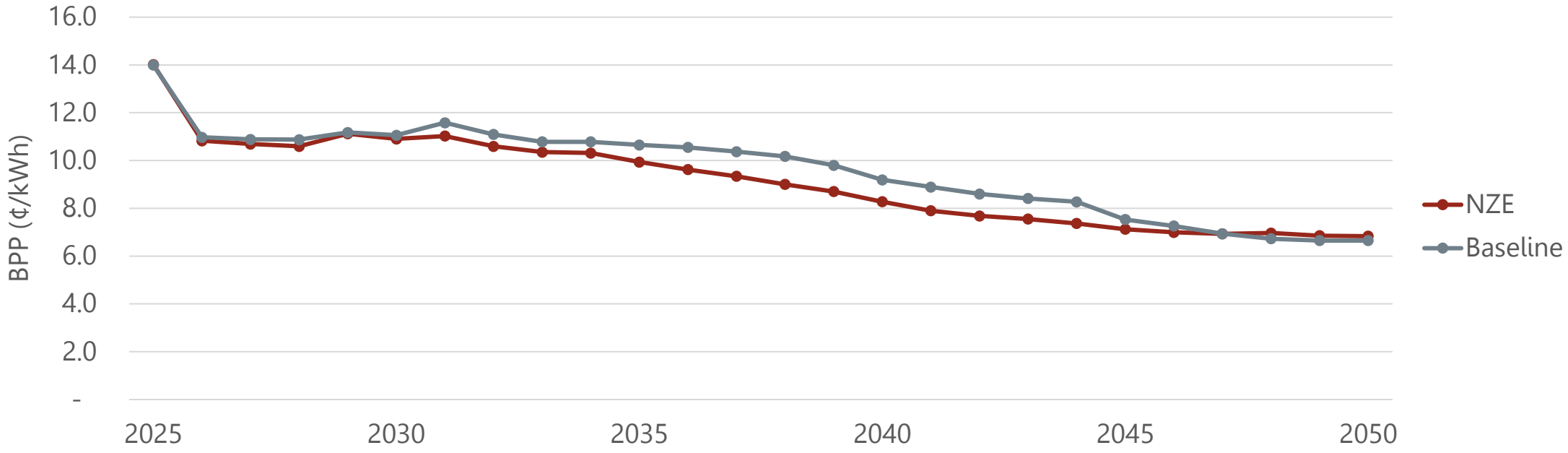
System costs set to fourfold by 2050 in both scenarios



- By 2050 annual system cost in baseline reaches 1.75 bn$ compared to 1.84 bn$ in NZE
- Four-fold increase is lower compared to demand increase (6-fold in baseline and 9-fold in NZE)
- **Fuel cost in NZE lower due to reduced coal and gas consumption, but capital cost is higher due to increased capacity**

Lower generation costs in NZE

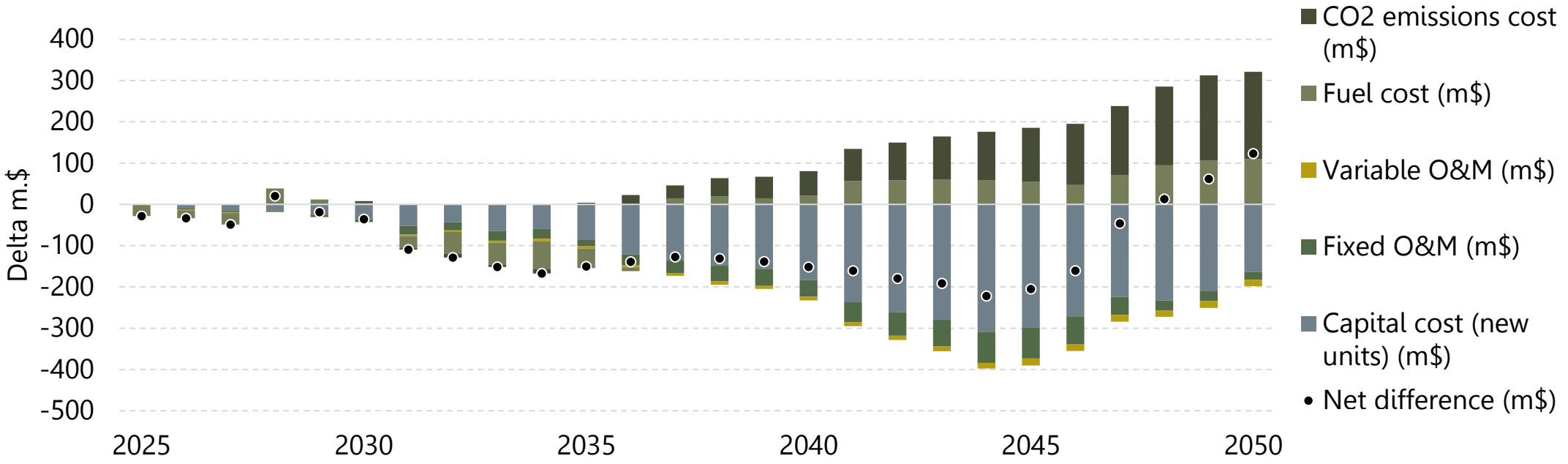
Average generation cost in the medium term is higher in baseline



- **BPP reduced significantly in both scenarios** due to the increased contribution from low cost solar and wind
- **VREs support decarbonization and reduce overall cost** of meeting the increasing demand

CO_2 costs impact system costs

System costs in NZE lower than Baseline when including CO_2 costs

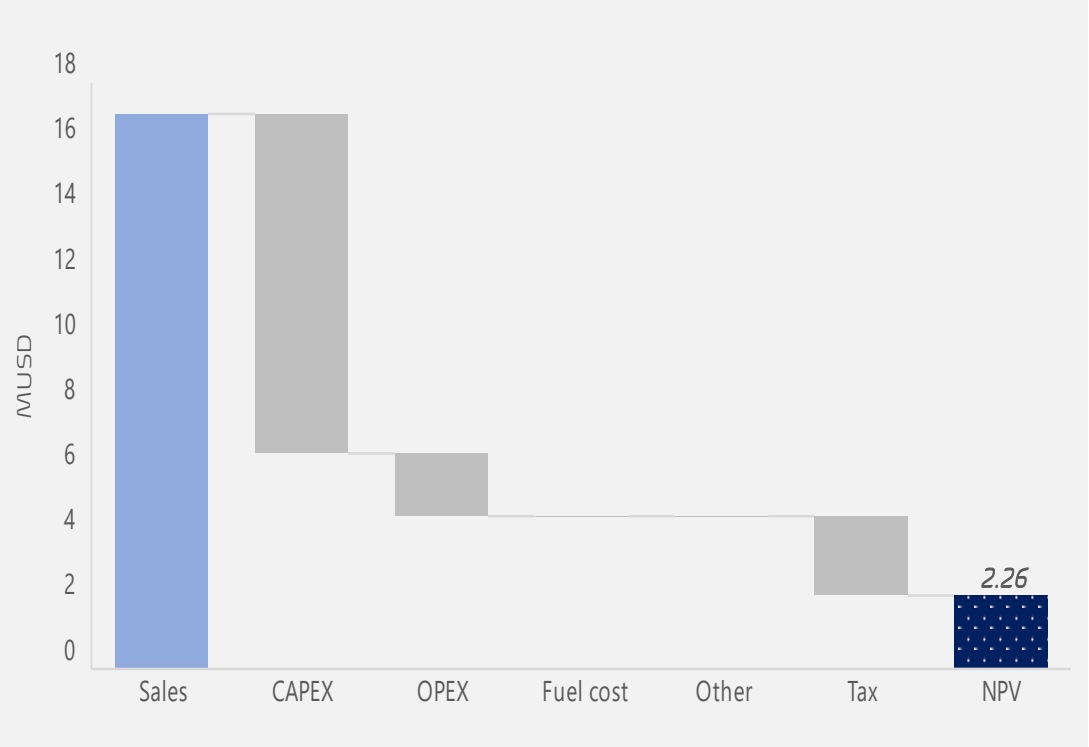


- Cost of CO2: 38 USD/t CO2 in 2030, 104 USD/t CO2 in 2040 and 151 USD/t by 2050
- **After 2045 NZE costs less than baseline** despite a much higher demand
- **CO2 cost aims to reflect the impact of emissions on society**

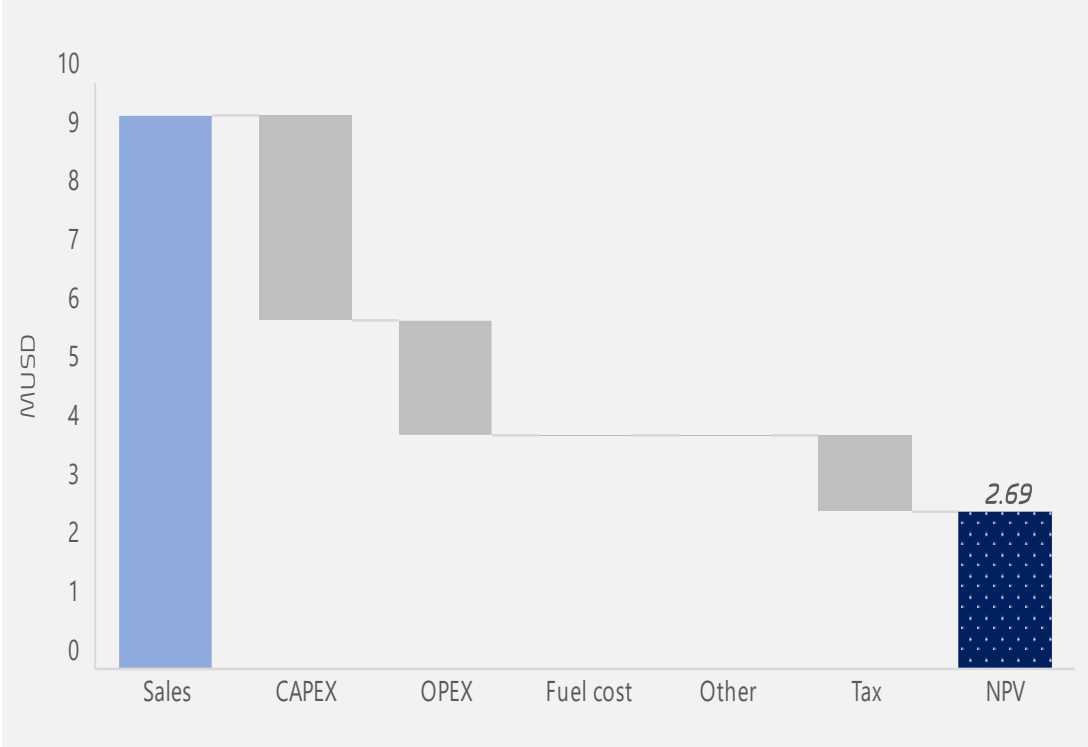
Financial feasibility of solar and wind

2030 NZE scenario

50 MW Solar in Sumbawa



10 MW Wind in Lombok



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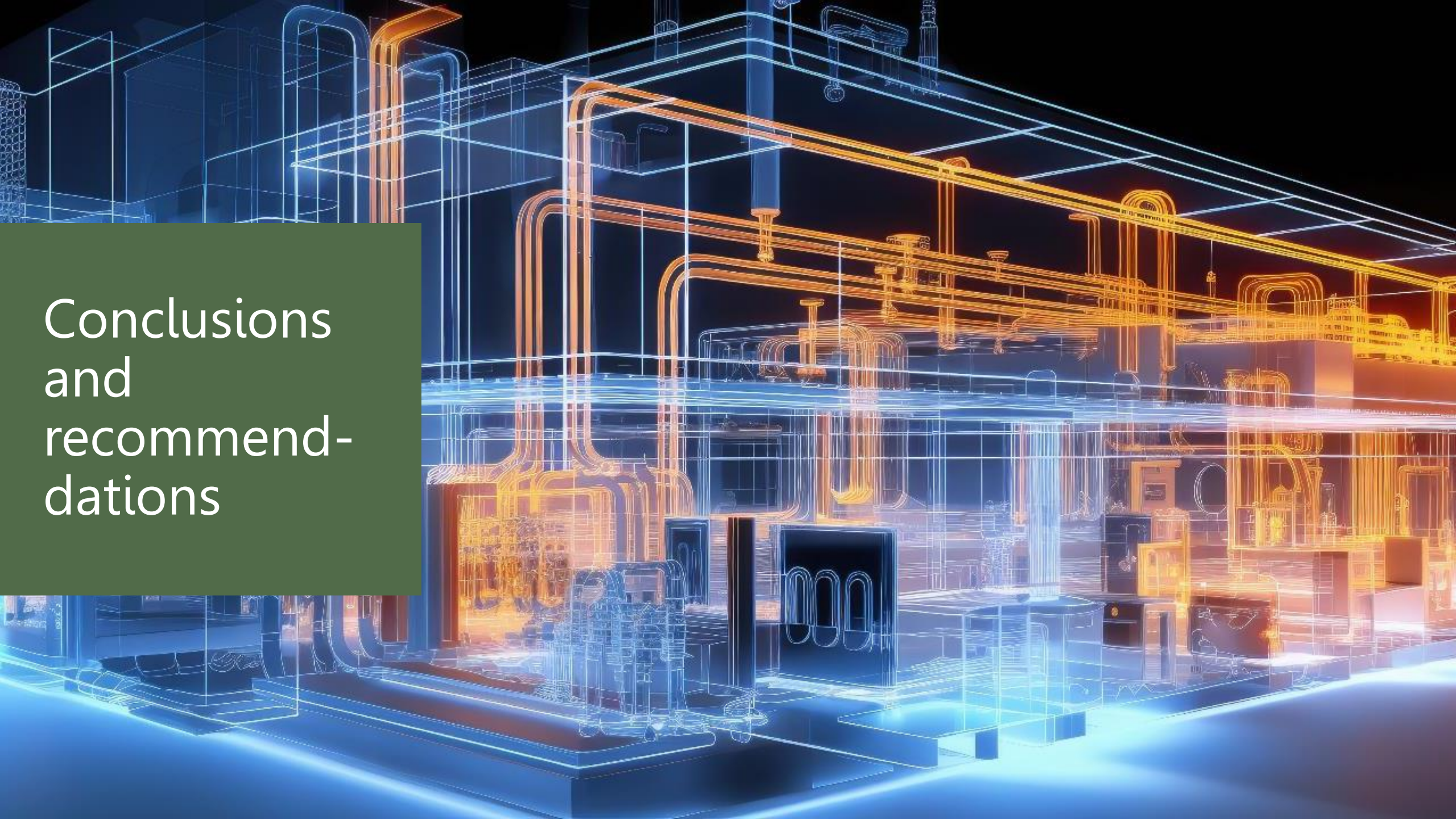
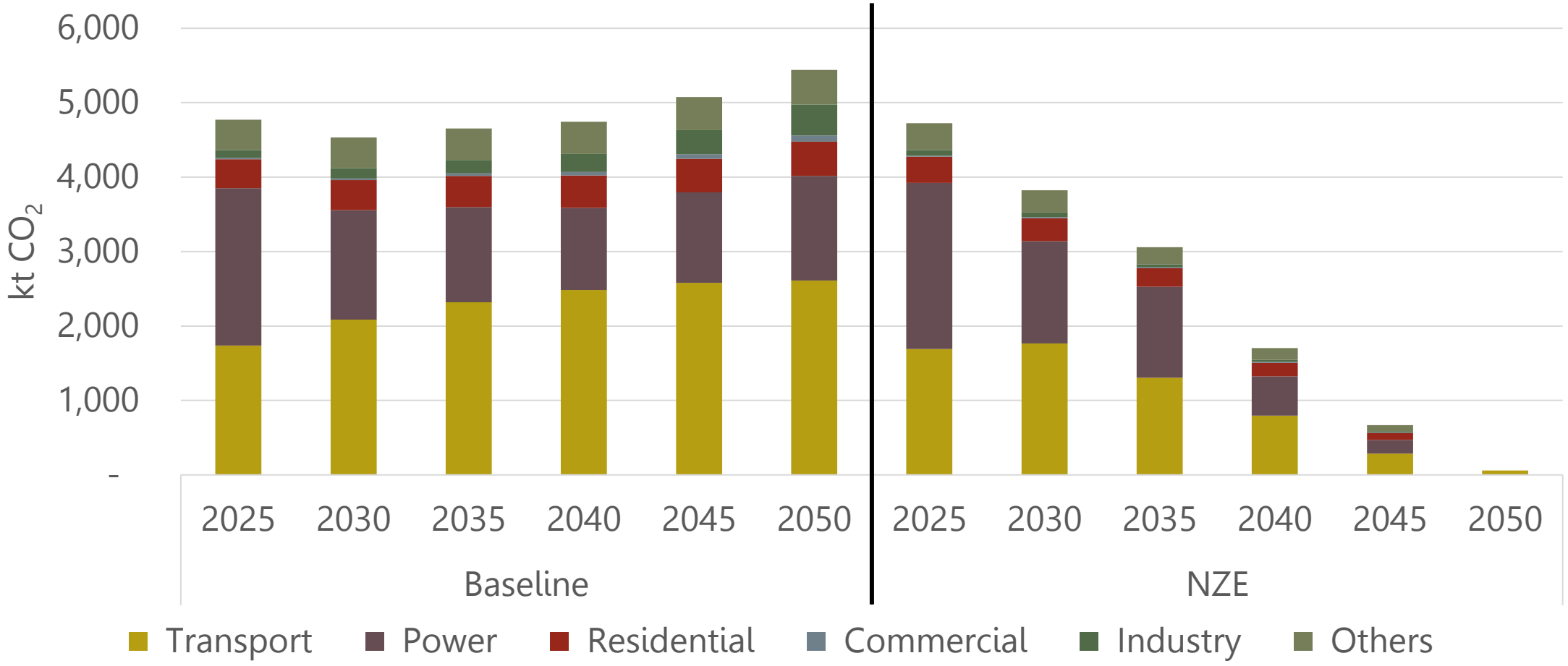


Conclusions and recommend-dations

Total CO_2 emissions from the energy sector

Achieving net-zero by 2050 for energy sector in NTB is theoretically possible



Pathway to a Net Zero Emissions Energy System
Key Steps and Investments for a Sustainable Energy Transition

For the end use demand side:	Net Zero Emissions (NZE) scenario requires **long-term targets to shape policies**
	Sector-specific policies to **enhance energy efficiency**
	High electrification of all sectors where possible starting off low-hanging fruits
	Need to ensure **sustainable use of bioenergy**
	Support businesses and industries in their transition, including energy audits and incentives for fuel switching

Pathway to a Net Zero Emissions Energy System
Key Steps and Investments for a Sustainable Energy Transition

For power sector:

- Transition requires **reliable resource assessments** and **financial incentives**
- A **clear institutional set-up** needed for development of renewable power
- Investments needed in **transmission and storage** for a **clean and flexible** system
- Future power system operations necessitates **grid reinforcement with smarter technology** to ensure **security and reliability**
- Initially **high capital investment** needed, but will result in **lower per unit cost in long-term**

Concluding remarks

Achieving a Net Zero Emissions scenario at low cost is feasible.

It is demanding, requiring technological innovation, substantial investments, and operational shifts.

The solution requires a continued holistic and collaborative approach, considering the system's various dimensions and limitations.

This study offers initial steps and directional choices, guiding the province toward an enhanced energy framework for a significant positive impact.

Hopefully, this spurs more ambitious development contributing to a sustainable future for the world.

Terima Kasih!

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