DEVELOPED WITH SUPPORT FROM SUSTAINABLE ENERGY FOR ALL

BARBADOS

ENERGY TRANSITION AND INVESTMENT PLAN

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FOREWORD

The Barbados Energy Transition and Investment Plan (ETIP) represents a pivotal milestone in our nation's development trajectory. This comprehensive plan charts our course toward energy independence and climate resilience while establishing Barbados as a leader in sustainable development among Small Island Developing States.

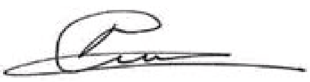
Our vision for 2035 is both ambitious and necessary: to achieve net-zero emissions while ensuring universal access to reliable, affordable electricity. For Barbados, this transition transcends mere changes in energy sources - it fundamentally reshapes our economy and society. The implementation of renewable energy and energy efficiency across our power, transport, industry, and building sectors positions us to meet both our development goals and climate commitments.

The economic case for this transition is compelling. While the required investment of BBD 19 billion through 2040 is substantial, it represents a strategic redirection of resources from fossil fuel imports toward building lasting, resilient infrastructure. This investment will generate approximately 1,500 new jobs above business-as-usual by 2035, creating opportunities particularly for our women and youth in emerging clean energy sectors.

Through strategic deployment of solar, wind, energy storage, and alternative mobility solutions, we are not only addressing climate change but building a more competitive and equitable economy while materially improving the quality of life for all Barbadians. The modernization of our transport system and power grid infrastructure will enhance our economic resilience, energy security and reduce our carbon footprint

The successful implementation of this plan requires robust partnerships and coordinated action. I call upon our development partners, private sector stakeholders, and the international community to join us in realizing this vision. Together, we can demonstrate how small island nations can lead the transition to a sustainable energy future.

This plan provides the framework for transforming Barbados into a climate-resilient, energy-independent nation. Its implementation will secure a prosperous and sustainable future for generations to come.



Sen. Hon. Lisa R. Cummins
Minister of Energy and Business

ACKNOWLEDGEMENT

The Barbados Energy Transition and Investment Plan (ETIP) is a testament to the collaborative effort and shared vision of numerous stakeholders committed to our nation's sustainable energy future. This plan was developed under the visionary leadership of Prime Minister Mia Amor Mottley and represents a comprehensive approach to transforming our energy sector.

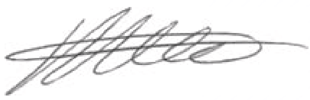
This endeavor was made possible through the dedicated work of the Ministry of Energy and Business (MEB) in close partnership with Sustainable Energy for All (SEforALL), under the leadership of CEO and Special Representative of the UN Secretary-General on Sustainable Energy, Ms. Damilola Ogunbiyi.

The analytical foundation of this plan was established by SEforALL's Energy Transition Planning team, led by Mr. Alvin Jose and co-led by Dr. Ioannis Pappis and Ms. Naomi Tan Yee Chyng. We extend our gratitude to the broader SEforALL team, including Mr. Anant Wadhwa, Mr. Akil Callender, Ms. Iqlima Fuqoha, Mr. Tamojit Chatterjee, Ms. Rosa Garcia, and Ms. Alice Uwamaliya, for their invaluable contributions.

Special recognition goes to our key stakeholders within the government: Mr. Alton Best, Mr. Bryan Haynes, Mr. Mark Millar and Mrs. Claire Best from the Ministry of Energy and Business, and Mr. Mark Durant from the Ministry of Transport, Works, and Water Resources (MTWW). Their expertise and insights were crucial in shaping this plan.

We are grateful for the active participation and valuable input from various organizations including the Barbados Light and Power Company (BLPC), Transport Board, Barbados Renewable Energy Association (BREA), Inter-American Development Bank, International Finance Corporation, and the universities of Bridgetown.

This plan represents more than just a technical roadmap; it embodies our collective commitment to a sustainable future. Its success will depend on continued collaboration between government agencies, private sector partners, and the international community. We look forward to working together to implement this transformative vision for Barbados.



Kevin Hunte
Permanent Secretary in the Ministry of Energy and Business

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Context

Barbados is a Small Island Developing State (SIDS) and therefore particularly vulnerable to the climate crisis. Despite its negligible emissions, the nation has an ambitious vision for climate action. Through its climate leadership, Barbados has demonstrated to the world that every action contributes significantly toward realising a net-zero future. Transitioning to a net-zero emissions (NZE) trajectory requires additional investments for climate-friendly technologies, particularly in the energy sector. However, when aligned with the global clean energy and climate finance framework, these trajectories serve as catalysts for moving away from expensive fossil fuel imports and mobilising local and international clean energy investment and finance. Thus, the climate crisis also presents an opportunity for Barbados to develop an energy transition pathway aimed at fostering energy security, climate resilience and socio-economic growth. By accelerating this transition, Barbados can mitigate the risks associated with inaction and take control of its sustainable development.

Implementing an NZE future presents Barbados with a range of opportunities including:

Secure investment capital. A net-zero transition will attract clean energy investors as fossil assets become increasingly difficult to finance. A net-zero 2035 target will allow Barbados to secure investment capital and donor support that are now largely directed at low-carbon assets.

New growth sectors. A net-zero transition will create new economic opportunities for Barbados in global energy and technology markets, sending signals to global investors in the region. It will also ensure that Barbados does not get left behind in the clean energy era.

Energy independence. A net-zero transition will reduce Barbados' energy dependence on expensive imported fossil fuels, improve its climate resilience and reduce domestic oil demand, maximising the value of domestic biofuel as well as its solar and wind potential.

Aims and Objectives

The Barbados Energy Transition and Investment Plan (ETIP) analyses the transition of Barbados' energy sector to NZE scenarios by 2030 and 2035, comparing them to a business-as-usual (BAU) scenario through a country-level energy systems modelling analysis that covers all sectors, namely power, building, transport, industries, and agriculture. The objective is to assess the total energy systems costs of the least-cost optimised energy transition pathway[1] for the whole economy for the two NZE scenarios compared to the BAU to achieve NZE from energy supply and use. The ETIP highlights the technology pathways associated with an accelerated net-zero transition and the investment needs and cost-benefits of the same throughout the period 2020 to 2040. Based on a multicriteria analysis the most feasible NZE scenario is identified to form the basis of the ETIP. Further, based on the analysis and evidence, the ETIP provides a policy roadmap to increase Barbados' economic development while addressing climate change goals with energy transition.

Key findings

Net Zero 2035 in Barbados is the most feasible timeline based on the multicriteria analysis of the evaluated scenarios. It allows for an accelerated Paris-aligned NZE pathway in the power, transport, buildings, industries, and agriculture sectors.

Net Zero 2035 will be driven by renewables, electric vehicles (EVs), hydrogen, batteries, and energy efficiency. To achieve NZE by 2035, a rapid reduction of 67 percent in emissions between 2025 and 2030 is imperative. Both the power and the transport sectors will play a significant role in contributing to emissions reductions. NZE will primarily rely on renewable energy, energy efficiency and the widespread adoption of EVs.

Net Zero 2035 will bring substantial fuel cost savings of BBD 15.6 billion, 37 percent less than BAU, from the penetration of energy efficiency and the transition to renewable energy as a fuel source. Additionally, focusing on energy-efficiency measures could reduce energy demand by 30 percent.

Net Zero 2035 would require a total capital investment of BBD 19 billion. However, overall, most of the capital investment required is for the transport sector, with a total of almost BBD 17.3 billion from 2020 to 2040.

Net Zero 2035 will require 57 percent more investments cumulatively, but 15 percent less spending on total system costs compared to BAU, i.e., roughly BBD 8.2 billion less additional financing needs. Although the operation and maintenance (O&M) costs in NZE 2035 are roughly 20 percent more than those associated with BAU, the fuel cost savings in NZE 2035 greatly outweigh this.

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1 Developed through SEforALL Energy Systems Model. More details in Annex.

Net Zero 2035 will add about 1,500 jobs above BAU, which is a 55 percent increase in the number of direct and indirect jobs by 2035, due to higher penetration of renewables and EVs. To achieve this, Barbados needs to expand its cross-cutting foundational knowledge surrounding renewable energy sources, energy efficiency and low carbon technologies targeting women and youth.

Barbados must take swift policy action towards Net Zero 2035 to unlock immediate investment opportunities of about BBD 3 billion. The nation can avoid the risks of a slower transition and achieve socio-economic growth by developing a low-carbon energy transition pathway aiming to be energy secure and resilient to climate change.

A range of actions can drive implementation and secure investments under a net-zero policy framework. These include creating investment enabling schemes, incentives and regulations that promote renewable energy with storage focused on battery energy storage systems (BESS), utility solar PV and onshore wind and distributed solar/rooftop solar. Similarly, energy-efficiency policies and measures will need to be promoted in areas such as minimum energy performance standards (MEPS) for appliances, building energy codes and electric cooking in buildings, while industry boilers and motor standards for higher efficiency will need to be mandated with opportunities to leapfrog to heat pumps. The adoption of EVs will be crucial and ensuring a smart charging profile will decrease the curtailment of renewable energy as well as the need for expensive storage. Spending on EV charging infrastructure will be crucial for passenger and freight road transportation. Along with the electrification of road transportation, it will be important to move towards incentivising modal shifts to public transport and addressing the fuel economy standards of new and used vehicles. Investments in research and development in a SIDS context on key low-carbon technologies such as biofuels and green hydrogen will be crucial to sustaining and ensuring net-zero energy systems. Additionally, SIDS-focused solutions on carbon removal and sink technologies such as carbon capture and storage (CCS) and bioenergy carbon capture and storage (BECCS) need to be found urgently.

The investments needed for these technologies are to be mobilised from a broad set of public and private stakeholders. The role of international climate finance and multilateral development banks will be crucial to support Barbados' net-zero ambitions. Investment grade policies and de-risking of financing are essential to attract international investors with large-scale programmes financed through local currency. Public funding should be focused on leveraging private capital by providing innovative financing facilities and de-risking instruments. Additionally, carbon finance needs to be channelled through carbon markets and/or carbon pricing.

The need for an agency or unit that ensures cross-ministerial coordination with an implementation mandate cannot be overstated. A robust system for monitoring and reporting emissions data is also crucial in tracking progress towards Net Zero 2035 and can assist in making necessary adjustments to strategies to ensure the nation's target is reached. To tie all these actions together, investing in human capital such as education for new skills, reskilling and upskilling is needed to keep up with the clean energy era. Continuous stakeholder engagement as well as public awareness and education campaigns are also necessary to encourage individuals and businesses to adopt more sustainable practices that will ensure a just energy transition.

CHAPTER ONE

INTRODUCTION

1.1 Context

The Paris Agreement adopted in December 2015 at COP21 set the ambition to limit global warming to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase even further to 1.5°C (UNFCCC, 2015). A key lever for achieving the Paris Agreement is the transition from fossil-based energy systems to 'clean' energy solutions from renewable resources while reducing emissions from the demand sectors (i.e., power, buildings, transport, industries, and agriculture) through accelerated energy-efficiency improvements, electrification, and use of low- to zero-emission fuels (such as biofuels, green hydrogen, etc.). All these policy decisions need to be aligned with achieving the Sustainable Development Goals (SDGs), in particular SDG7 – access to affordable, reliable, sustainable, and modern energy for all – and SDG13 – [take] urgent action to combat climate change and its impacts.

Barbados is a Small Island Developing State (SIDS) with a diversified economy built on tourism and commercial services that has one of the Caribbean's highest GDPs per capita (USD 17,225). In 2022, fossil fuels accounted for 80 percent of its primary energy supply, mainly due to oil power plants (0.24 GW) and oil consumption in the transport sector (49 percent of the total final energy consumption). Barbados has no onshore reserves of oil and gas and relies on fossil fuel imports. This makes it vulnerable to price increases that can significantly affect the country's energy security as was seen during the COVID-19 pandemic (Barbados Government Ministry of Energy and Business, 2023). In 2022, Barbados derived 91 percent of its electricity from fossil fuels, with the remaining 9 percent generated by solar energy. The installed electrical capacity of Barbados was 360 MW in 2022 (The Barbados Light & Power Company Limited, 2023). The country is fully electrified and has full access to clean cooking services that are mainly fuelled by expensive fossil fuel commodities such as LPG and natural gas. Barbados is greatly affected by many aspects of climate change, including rises in sea levels and increasingly powerful storms/typhoons.

Accordingly, the move towards renewable energy is an attempt for the island to mitigate some of the effects of climate change, become climate resilient and energy secured and for it to achieve environmental sustainability.

Barbados aims to become the first country using 100 percent renewable energy as it moves away from a petroleum-based economy via the Barbados National Energy Policy (BNEP) 2019-2030 . To do so, it plans to introduce solar PV, wind, biofuels, and biogas to make up the renewable energy mix and fully electrify the transport sector.

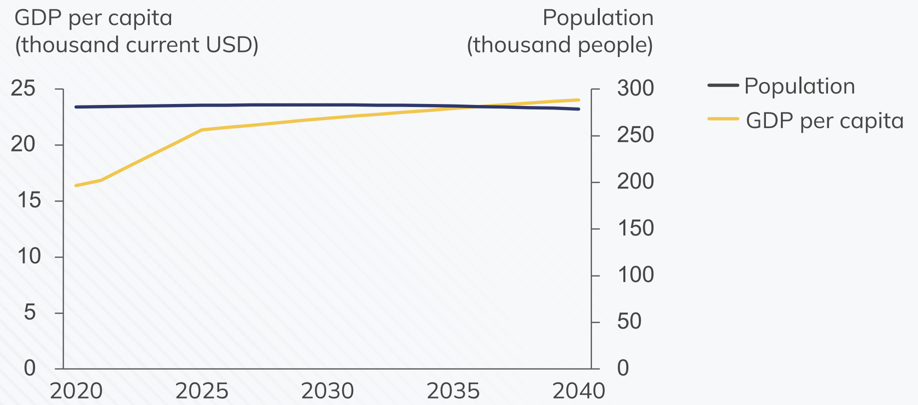
To achieve net-zero emissions (NZE), Barbados will need to evaluate sectoral investment needs and trade-offs (i.e., socio-economic) and lay out a high-level implementation plan that covers all the major sectors. Its Energy Transition and Investment Plan (ETIP) will build on the Barbados National Energy Plan 2020–2035, align long-term energy planning with its nationally determined contribution (NDC), and identify an orderly transition for energy systems across all the major sectors.

1.2 Background

Population and GDP

Barbados' population was 281,000 in 2020 and is expected to reach 283,000 in 2030. The population is then expected to plateau and decrease slightly to 279,000 by 2040. Barbados boasts a high-income economy, where GDP per capita is expected to grow significantly from USD 16,000 in 2020 to USD 21,000 by 2030. This economic growth is projected to reach approximately USD 24,000 per capita by 2040 (Figure 1). As a result of this growth, the energy demand is expected to increase significantly, resulting in additional emissions, and requiring investments on the supply side.

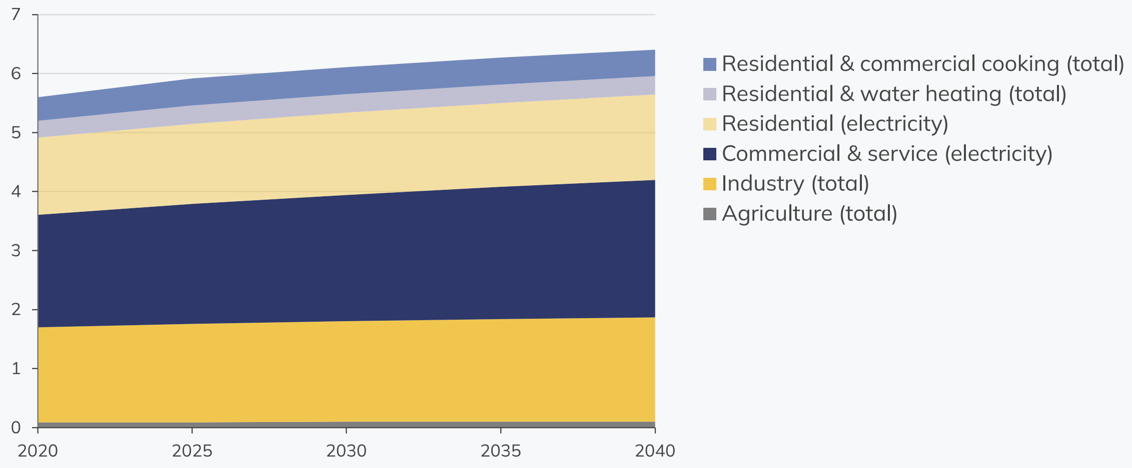
Figure 1: Projected population and GDP per-capita growth



Energy, Electricity and Transport Demands

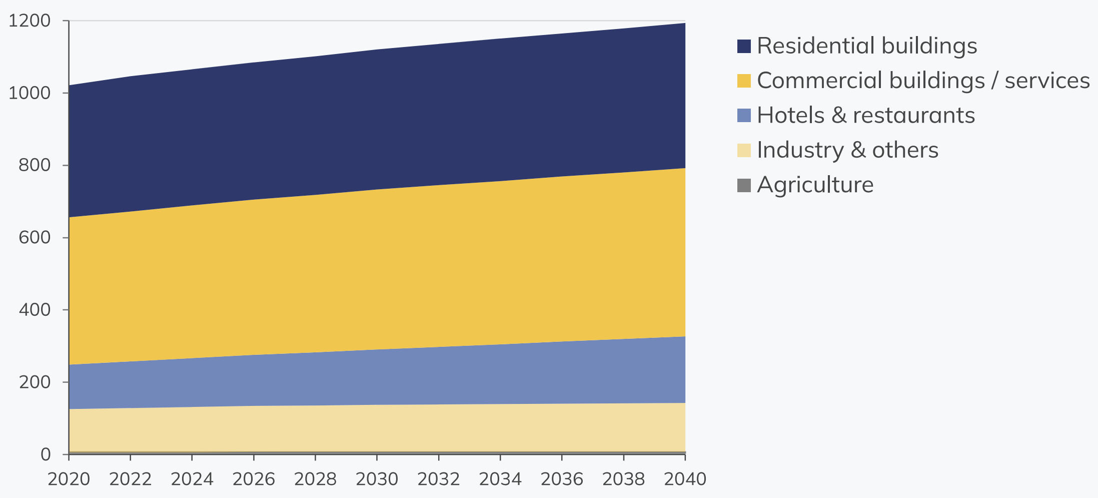
Based on population and economic growth, Barbados' total energy demand is expected to increase from 5.6 PJ in 2020 to 6.4 PJ in 2040 (Figure 2). This is driven by the electricity demand from residential and commercial buildings and both electricity and energy used for processes in the industrial sector, meaning all three sectors demand roughly equal amounts of energy. By contrast, energy use in the agriculture sector has the least impact on total energy demand. In this analysis, both residential and commercial energy demands include electricity demand and primary energy needs for cooking and water heating.

Figure 2: Total energy demand projection (PJ)



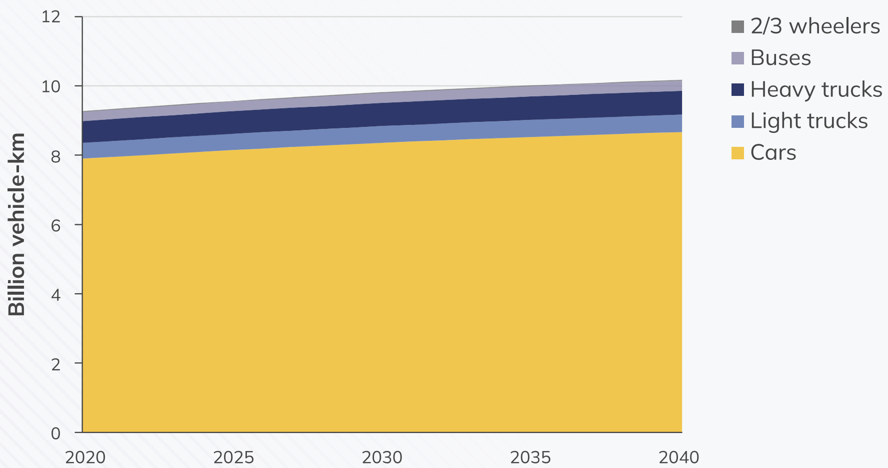
Electricity demand is expected to increase from 1,021 GWh in 2020 to 1,194 GWh in 2040 (Figure 3), mainly due to the demand from residential buildings and commercial buildings and services. By 2040, these two sectors are expected to account for approximately 34 percent and 39 percent, respectively, of the total electricity demand. The demand from the agriculture sector is projected to be the lowest, at 7 GWh. The electricity demand in hotels and restaurants (mostly driven by tourism) is expected to increase from 123 GWh in 2020 to 184 GWh by 2040.

Figure 3: Electricity demand projection (GWh)



The demand for road transportation is expected to grow significantly, by an average of roughly 10 percent from 2020 to 2040 Figure). This is mainly due to the high number of four-wheel passenger cars in the nation, accounting for approximately 85 percent of the transport demand throughout the modelling period. This study is limited to road transport and excludes aviation and shipping due to the dominance of international air travel. Previous assessments by the Government of Barbados considered possibilities of electric or hybrid cruise lines that may be powered in the ports in the future. The projections for road transportation activity are in line with the GDP growth. Further, the demand is estimated with different road transport modes based on the fleet efficiencies and annual distance that needs to be covered for passenger and freight transport services.

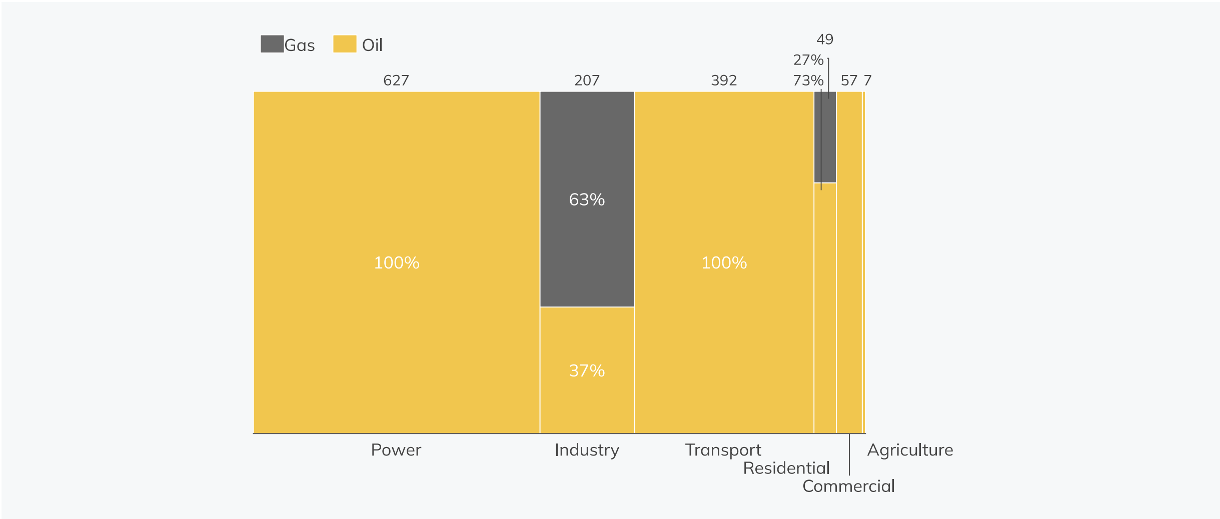
Figure 4: Transport demand projection (billion vehicle-km)



Carbon Dioxide Emissions Profile

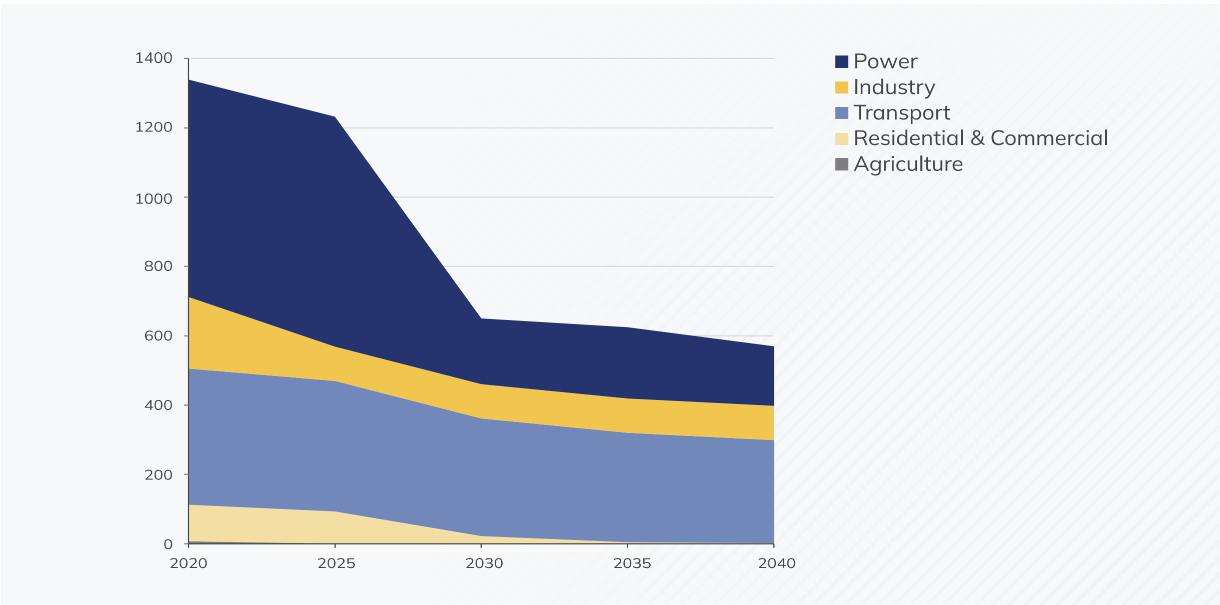
Barbados' CO_2 emissions totalled almost 1.4 Mt CO_2 in 2020, with the power sector accounting for almost half of that figure (Figure 5). Specifically, the power and transport sectors contributed 46 percent and 28 percent of overall emissions, respectively. The sector with the least contribution to CO_2 emissions in 2020 was agriculture, at 7 kt CO_2.

Figure 5: CO2 emissions per sector and fuel type in 2020 (kt CO2)



In the business-as-usual (BAU) scenario, the 2020 value of 1,400 kt CO_2 is expected to decrease to 650 kt in 2030. After this, emissions are expected to plateau and reach 569 kt in 2040 (Figure 6). This decrease in CO_2 emissions is mainly driven by the power sector due to the penetration of low-carbon technologies such as solar PV and gas to replace oil. Emissions from the building and cooking sectors decrease slightly, whilst the CO_2 levels for the transport and industry sectors are roughly the same through to 2040. Despite the reduction in CO_2 emissions, significant efforts are needed to reach carbon neutrality.

Figure 6: CO2 emissions projection by sector (kt CO2)



CHAPTER TWO

METHODOLOGY

2.1 Scenarios

In consultation with stakeholders, the Barbados Energy Transition and Investment Plan (ETIP) explores three potential scenarios: **business as usual (BAU), net-zero emissions 2030 (NZE 2030)** and **net-zero emissions 2035 (NZE 2035)**. The descriptions of each scenario are outlined in Table 1.

Table 1: Descriptions of the three scenarios analysed for the Barbados ETIP

SCENARIOS	DESCRIPTION
Business as Usual (BAU)	Demand for energy and activity is based on GDP per-capita growth and population forecast and how Barbados is expected to grow when compared to other similar country profiles Technologies are available at current costs and existing global market maturity, and they are installed based on least-cost deployment Investments in battery energy storage systems (BESS) and pumped hydro storage are not constrained No carbon emission constraints Low and high energy demand sensitivity analysis investigated
Net-Zero Emissions 2030 (NZE 2030)	NZE driven by carbon neutrality policy by 2030 Reduction in energy and electricity demand from BAU by 20% is assumed due to the implementation-related interventions for end-use appliance energy efficiency and fuel economy in passenger cars

Net-Zero Emissions 2030 (NZE 2030)	The energy needed for demand from various sectors is met by technologies under net-zero emissions constraints and least-cost deployment Early retirement of fossil fuel-based assets to decarbonize the sector is considered Supply of sustainable biofuels is limited, and bioenergy carbon capture and storage (BECCS) is allowed for emissions offsets
Net-Zero Emissions 2035 (NZE 2035)	NZE driven by carbon neutrality policy by 2035 Reduction in energy and electricity demand from BAU by 30% is assumed due to the implementation of related interventions for end-use appliance energy efficiency and fuel economy in passenger cars The energy needed for the demand from various sectors is met by technologies under net-zero emissions constraints and least-cost deployment Early retirement of fossil fuel-based assets to decarbonize the economy is not prioritised Supply of sustainable biofuels is limited, and BECCS is allowed for emissions offsets

2.2 Multicriteria Analysis

A multicriteria analysis (MCA) was conducted to evaluate and compare results of the BAU, NZE 2030 and NZE 2035 scenarios. After consultations with key stakeholders in Barbados, the criteria and weightings listed in Table 2 were considered and chosen for the analysis. Results suggested that the NZE 2035 scenario was the most feasible option for the nation in terms of the balancing objectives of cost, environment, job creation, resilience, etc. (Figure 7; Table 3). Thus, the ETIP focuses on and compares BAU and NZE 2035 in greater detail to gain insights into the potential benefits, challenges and actions associated with transitioning from the current trajectory to a more sustainable and resilient future envisioned in NZE 2035.

Table 2: Criteria and weightings considered in the MCA

CRITERIA	UNIT	WEIGHT (%)
Scenario cost	BBD (billions)	20
Water use	Litres (millions)	7.5
Land use	Acres	7.5
Bio-physical impact	Scoring	7.5
Climate resilience	Scoring	7.5
Job creation	No. of jobs	7.5
Construction ESIA impact	Scoring	7.5
Carbon emissions	Million tonnes	20
Energy security (imports)	PJ	15

Figure 7: Normalised criteria scores in the BAU, NZE 2030 and NZE 2035 scenarios

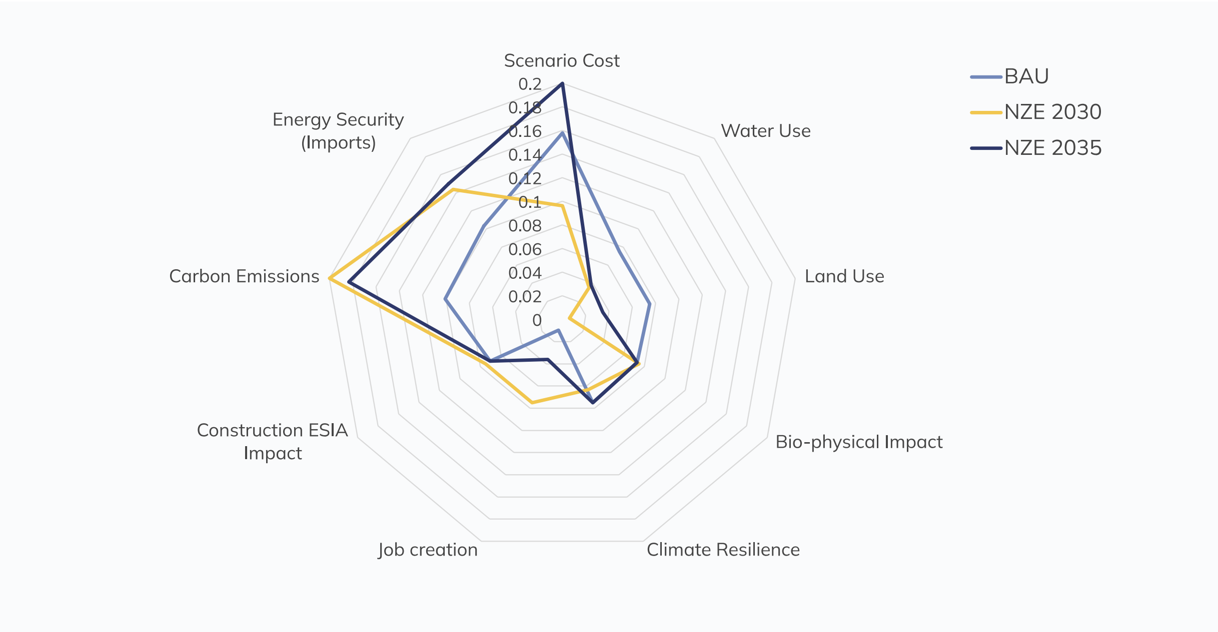


Table 3: Normalised final criteria scores in the BAU, NZE 2030 and NZE 2035 scenarios

	BAU	NZE 2030	NZE 2035
TOTAL SCORES	0.7407	0.7697	0.8606
FINAL RANKING	3	2	1

2.3 Sensitivity Analysis

A sensitivity analysis was conducted for the NZE 2030 and NZE 2035 scenarios to compare them with the BAU scenario (see Appendix). The analysis looked at: (i) low and high electricity demand levels; (ii) low and high fossil fuel prices; and (iii) higher discount rates (4 percent and 8 percent). The stakeholders identified these factors as the most crucial variables that may influence the energy transition. In summary, the NZE 2035 scenario with low electricity demand shows that the total system costs decrease by 5 percent due to lower investments in all sectors due to decreasing total power mix and particularly the need for hydrogen. Also, for high electricity demand the total system costs decrease by 4 percent as the increase in electricity demand improves load factors for solar and gas, reduces their levelized cost of energy (LCOE) and decreases the need for hydrogen. Similarly, the increase in discount rates to 4 percent and 8 percent decreases the total system costs slightly. This is mainly because higher discount rates change the total energy system mix and have varying negative effects on fossil fuel-based technologies in power and other sectors. Overall, higher discount rates do not impact renewable and clean energy technologies to achieve NZE 2035 from an overall system-cost level. Finally, changes in the fuel costs have an overall impact on the system costs, where an increase in fuel costs shows total system costs increasing by 9 percent and a decrease in fuel costs shows a reduction in total system costs by 7 percent.

CHAPTER THREE

BARBADOS ENERGY TRANSITION FOR NET ZERO BY 2035

3.1 Overview

Based on the results from the multicriteria analysis (MCA) in Section 1.4, the Energy Transition and Investment Plan (ETIP) focuses on and compares business-as-usual (BAU) and net-zero emissions by 2035 (NZE 2035) scenarios in more detail to gain insights into the potential benefits and challenges associated with transitioning from the current trajectory to a more sustainable and resilient future envisioned in NZE 2035.

Firstly, achieving NZE by 2035 will require a rapid decline in emissions between 2025 and 2030 (1,006 kt to 224 kt of CO_2), with the power sector peaking in 2025 before gradually declining (Figure 8). CO_2 emissions from the industry and transport sectors are also projected to decrease rapidly throughout the modelling period, to reach net zero by 2035 with no scope for peaking of emissions. This reduction is underpinned by renewables, electric vehicles (EVs), hydrogen, batteries and energy efficiency in the power, industry, and transport sectors (Figure 9). However, it should be stressed that to achieve NZE by 2035, carbon capture and storage (CCS) technologies will be needed in the industry sector to offset residual emissions in the power, transport, and buildings sectors from 2040 onwards. Less than 10 kt of CO_2 needs to be captured from 2035 onwards to sustain net zero.

Figure 8: CO2 emissions in the (a) BAU and (b) NZE 2035 scenarios, disaggregated by sector (kt CO2)

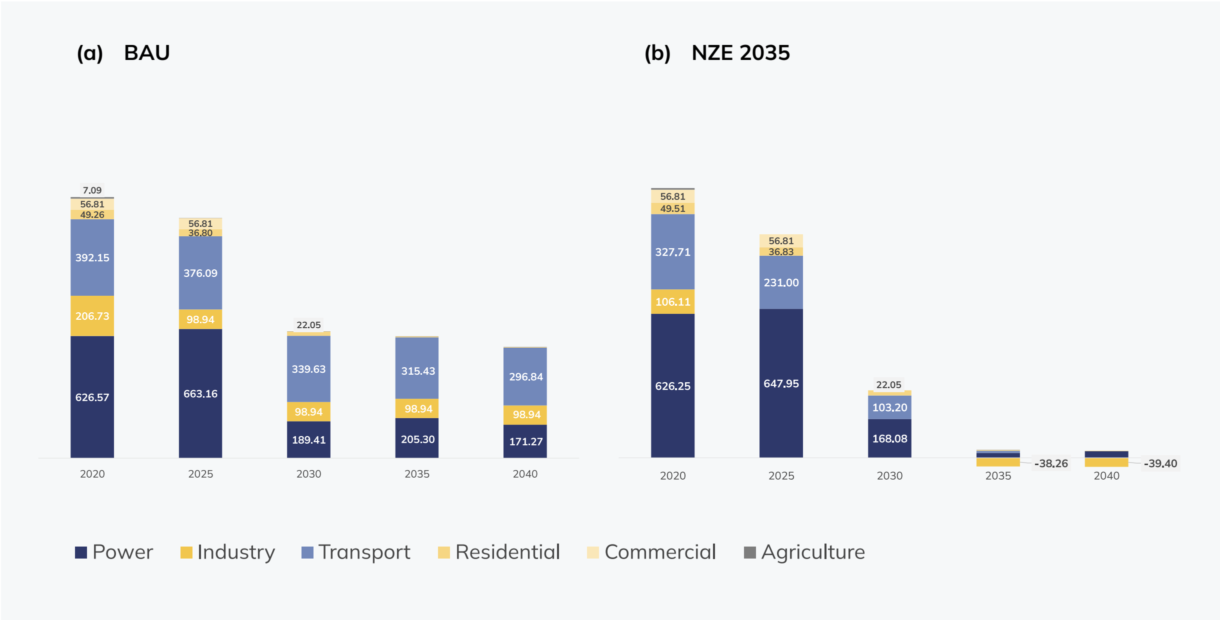
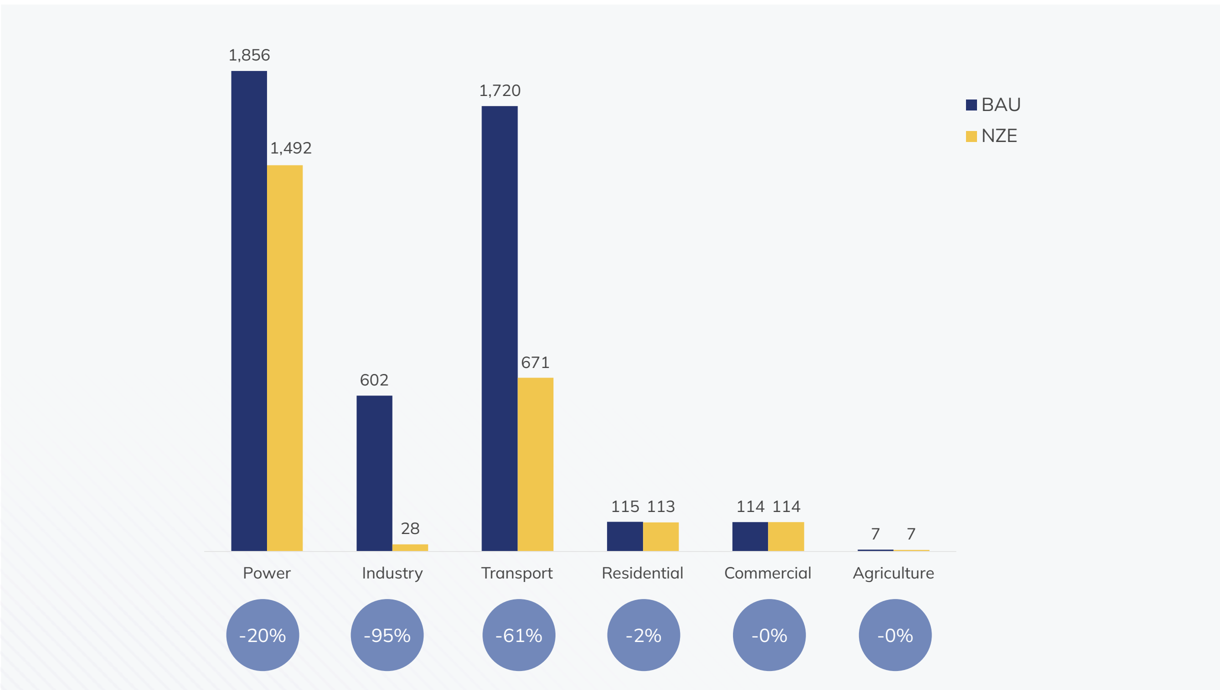


Figure 9: Cumulative (2020, 2025, 2030, 2035, 2040) CO_2 emissions by sector (kt CO_2)

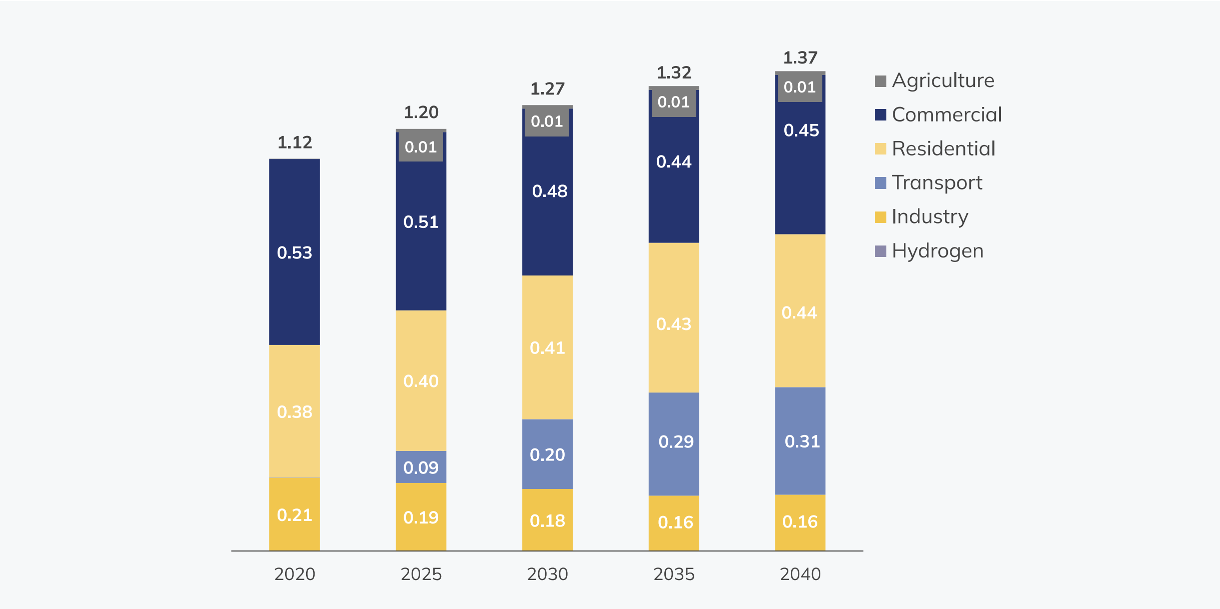


To facilitate the above emission reduction target, four sectors were explored for the ETIP: power, industry, transport and residential and commercial (buildings). These are detailed in the following subsections. It is to be noted that a 30 percent demand in reduction due to energy-efficiency interventions would reduce the burden of emissions reduction in a more cost-effective manner compared to BAU.

3.2 Power Sector

Under NZE 2035, Barbados' electricity consumption is driven by increasing GDP per capita and is expected to grow at a steady pace of 1 percent per annum. This is based on the country's current economic outlook that is primarily dependent on tourism, services, agro-food processing, and light manufacturing. In 2020–24, the main contributors to electricity consumption were the buildings and industry sectors. Electricity consumption is not increasing at a faster rate due to energy-efficiency measures. However, this is expected to shift so that buildings and transport constitute most of the electricity use by 2040. This is due to the transport sector becoming reliant on electricity from 2025; the rise of electric cars under a net-zero policy framework will account for almost 22 percent of total electricity consumption.

Figure 10: Electricity consumption by sector in the NZE 2035 scenario (TWh)



In terms of emissions, the power sector accounted for 627 kt CO_2 of emissions in 2020, which was 53 percent of Barbados' overall emissions in the same year. This figure is projected to decrease to 189 kt CO_2 by 2030 in the BAU scenario, due to the retirement of older oil power plants and the penetration of low-carbon technologies and gas. Nonetheless, concerted efforts are needed to reach the nation's target of carbon neutrality.

Figure 11: Proportion of total CO2 emissions in 2020 from the power sector

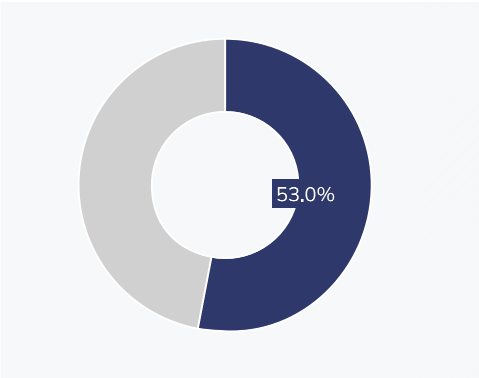
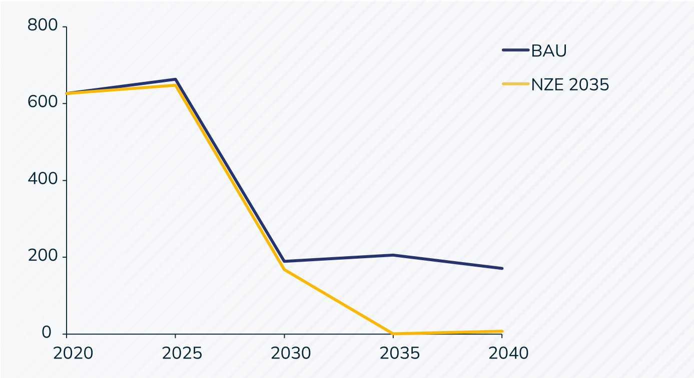
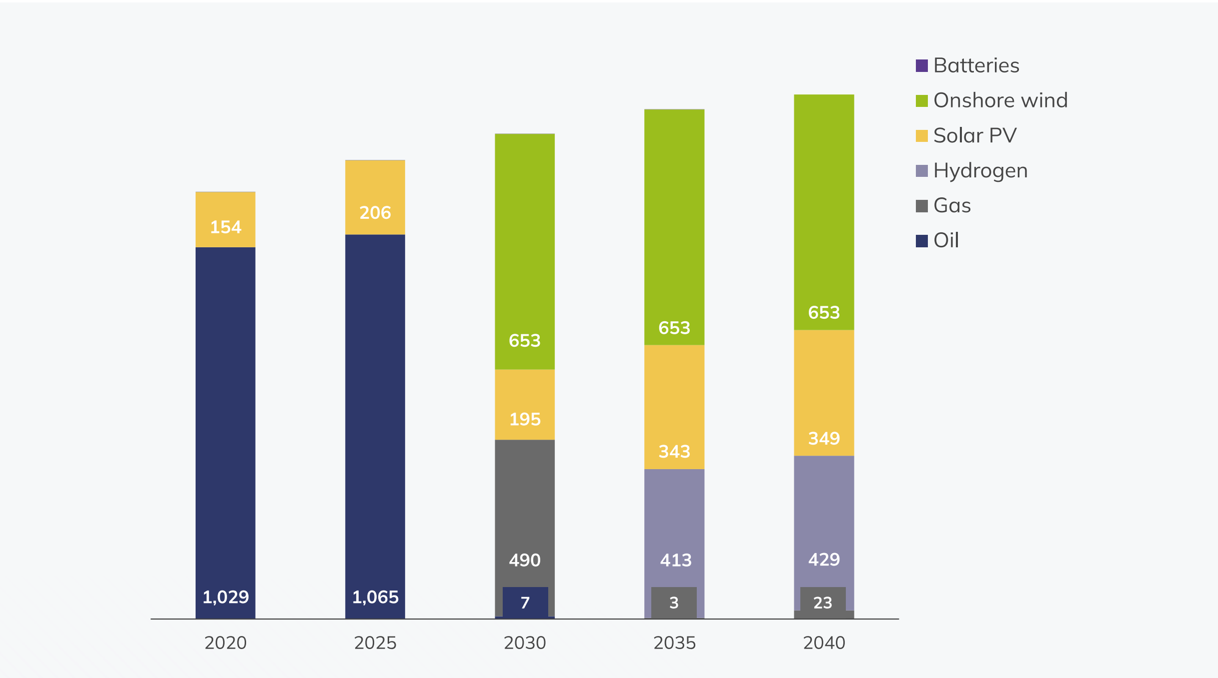


Figure 12: Projected CO2 emissions from the power sector for the BAU and NZE 2035 scenarios (kt CO2)



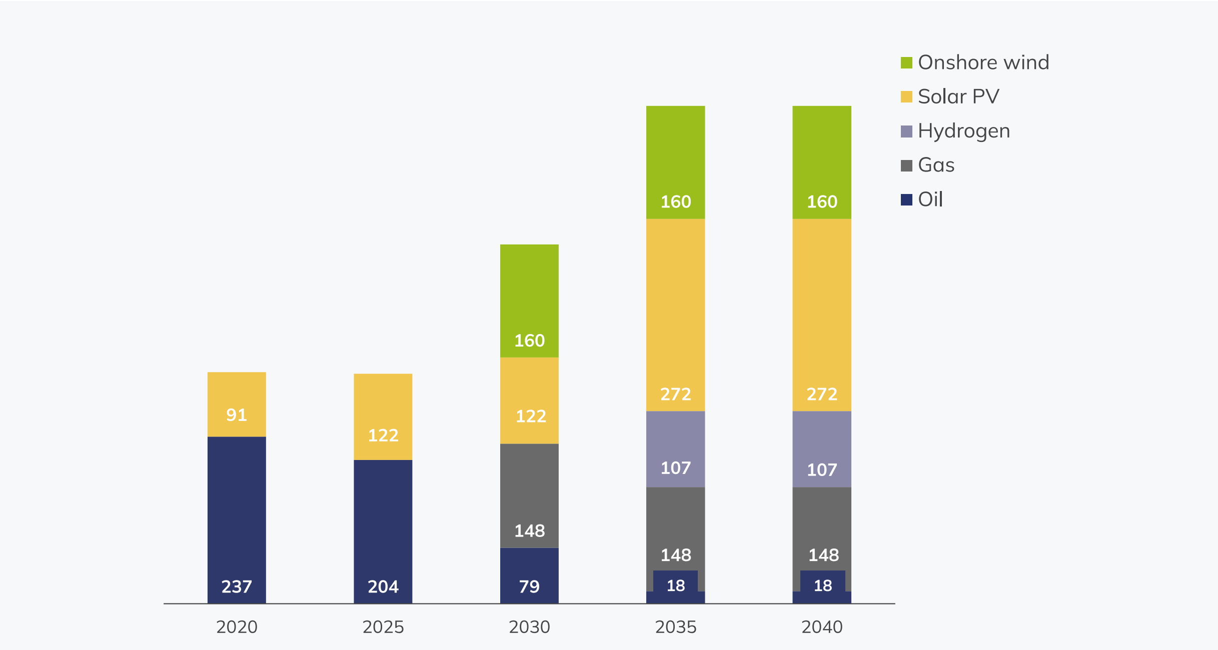
Renewables must be expanded if Barbados is to achieve NZE by 2035. Solar PV, wind and hydrogen technologies should account for 24 percent, 45 percent, and 29 percent, respectively, of the total power generation mix by 2040. In 2030, onshore wind will emerge as the most cost-competitive power generation technology. Solar PV is also a key technology for net-zero decarbonization, although it has a lower capacity factor compared to onshore wind. Offshore wind is not cost competitive, but this needs to be reassessed for its the local technical potential and cost reductions that have been witnessed at the global level in recent years. Further, existing oil-based generation will be phased out by mid-2030 and natural gas along with blue hydrogen will be used for balancing purposes. Green hydrogen will not be available because of the lack of sufficient renewable energy capacity to deliver the security of supply needs cost effectively. Electric battery storage will also be available, but its capacity and investment needs are to be balanced by ensuring effective sector coupling that relies on renewable energy rather than expensive storage technologies. It is to be noted that due to the potential unavailability of green hydrogen as a cost-effective measure there is a need to explore sustainable biofuels as alternative low-carbon fuels.

Figure 13: Electricity generation mix under NZE 2035 (GWh)



In terms of power capacity, in the NZE 2035 scenario, 590 MW of new capacity investments will be needed for solar (180 MW), onshore wind (160 MW), gas (148 MW) and hydrogen (110 MW) technologies by 2040, compared to 2020, as existing oil power plants are retired. Solar PV accounts for most of the capacity in 2040, at 272 MW, followed by onshore wind, at 160 MW. The installation of offshore wind farms is not cost effective, and the potential of offshore wind is low according to stakeholder feedback. Gas capacity rises to 148 MW by 2040, primarily used for security of supply due to increasing variable renewable electricity in the grid and for hydrogen production. This is due to unabated gas being the cheapest form of reserve capacity and the fact that the fuel can also produce blue hydrogen under net-zero emission constraints in the power sector. Further, existing oil capacity is slowly retired by 2040 although it is not used from 2030 onwards under a net-zero policy framework.

Figure 14: Power installed capacity under NZE 2035 (MW)



Battery Energy Storage System (BESS)

Battery energy storage systems (BESS) play a crucial role in energy systems by enhancing grid flexibility, reliability, and resilience, supporting the integration of renewable energy, and providing economic and environmental benefits to consumers and society. Barbados' transition to renewable energy will require investments in batteries to balance the grid (Table 4).

Table 4: Battery electricity storage (MWh) for the BAU, NZE 2030 and NZE 2035 scenarios

	BATTERIES ELECTRICITY GENERATION (MWH)			
	2020	2025	2030	2035
BAU	3	18	18	18
NZE 2030	2,500	2,520	4,720	4,720
NZE 2035	3	20	20	20

In both the BAU and NZE 2035 scenarios, the total capital investment needed for batteries is the same – approximately BBD 57 million in the period 2020–2030. However, in the NZE 2035 scenario, although the power sector has a high share of renewables, electricity consumption in the other sectors, especially the transport sector, leads the system to distribute the electricity instead of storing it and reducing the overall systems costs. Moreover, hydrogen can also be stored and used when it is cost competitive balancing the system together with batteries if more wind energy options are available.

Hydrogen

Hydrogen emerges as a low-carbon fuel source from 2035 onwards and increases to approximately 429 GWh by 2040 (Figure 15). It is mainly used in the power sector to provide security of supply under net-zero constraints, and in the transport sector for light trucks and to decarbonize the industrial captive power demand. It should be noted that the cost reductions in low-carbon hydrogen production reduce but do not balance out the cost premium of capital investments of renewable technologies. Therefore, government actions to stimulate demand for low-carbon hydrogen will be needed to attract large volumes to the market. The hydrogen supplied will be blue hydrogen, produced from natural gas with CCS (Figure 16), due to the lack of adequate renewables for green hydrogen in the country as per the current assessment. If additional potential is identified and more investments are made towards renewables, green hydrogen may be implemented in the future.

Figure 15: Hydrogen demand by sector under NZE 2035 (PJ)

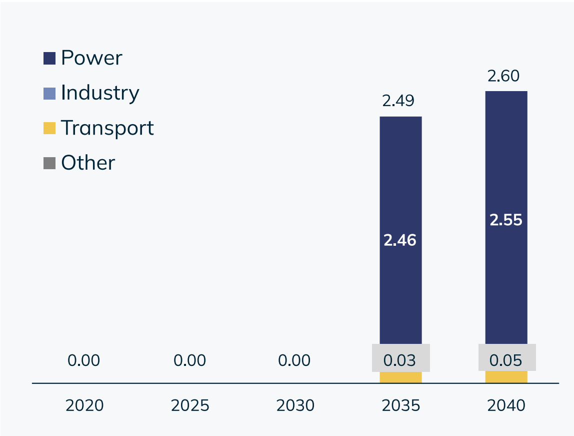
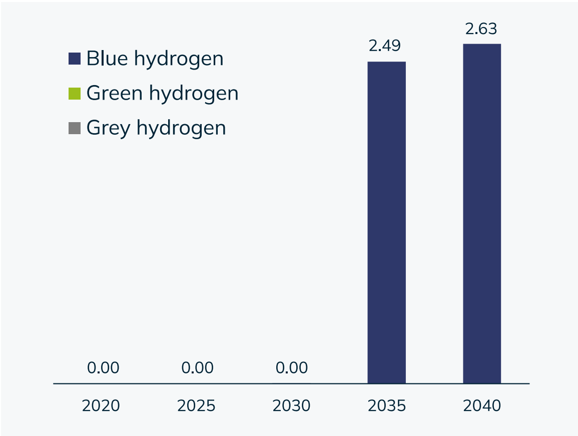


Figure 16: Hydrogen demand by type under NZE 2035 (PJ)

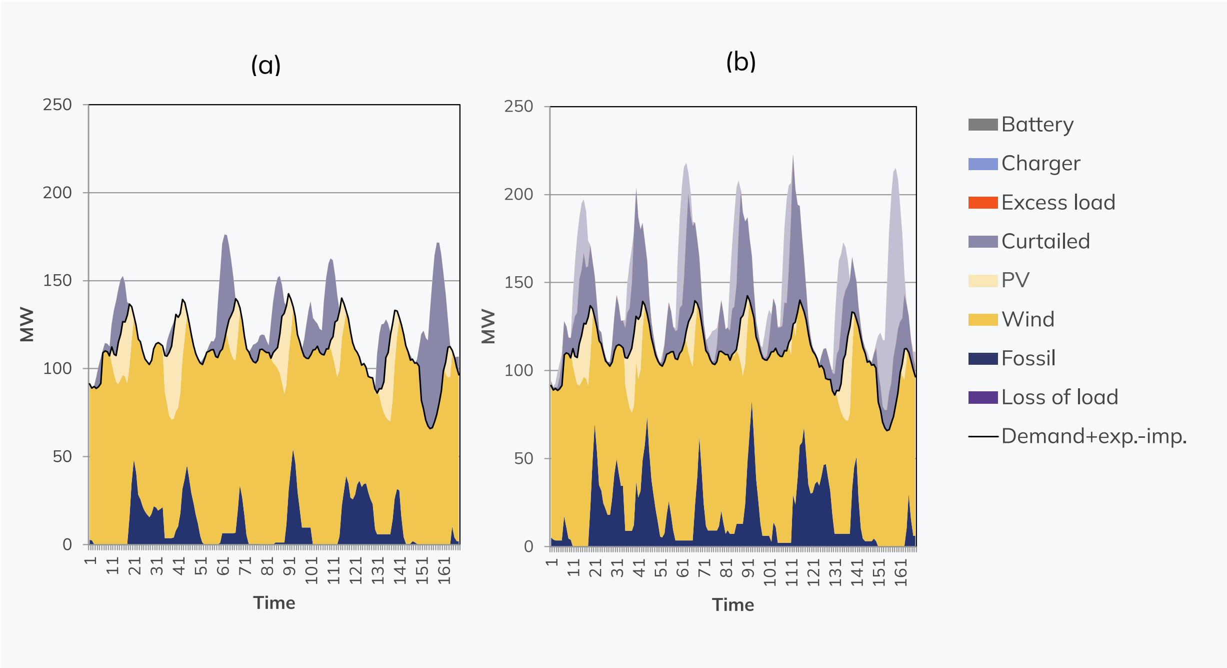


Power System Flexibility

A power system flexibility assessment for 2030 was carried out with FlexTool[2] to identify any bottlenecks in the power system for both the BAU and NZE 2035 scenarios and to understand the impact of the high share of renewables on the grid for loss of load expectation (LOLE) and curtailment. Modelling results suggest that there is no LOLE (0 percent of annual demand) in either scenario, however, curtailment of energy in both scenarios is inevitable with the increase of variable renewable technologies in 2030. In BAU, curtailment is 12 percent of variable renewable energy generation, whilst in NZE 2035, curtailment is 10 percent even with sector-coupling technologies such as EVs. Thus, a net-zero future utilising the capacity expansion plan as suggested by the ETIP will require EVs, managed through a smart charging profile, to address curtailment issues in the medium to long term.

2 A freely accessible tool by IRENA that assesses full power system dispatch and offers a detailed view of options for flexible generation, demand-side flexibility, and energy storage, alongside sector-coupling technologies such as power-to-heat, electric vehicles, and hydrogen production through electrolysis.

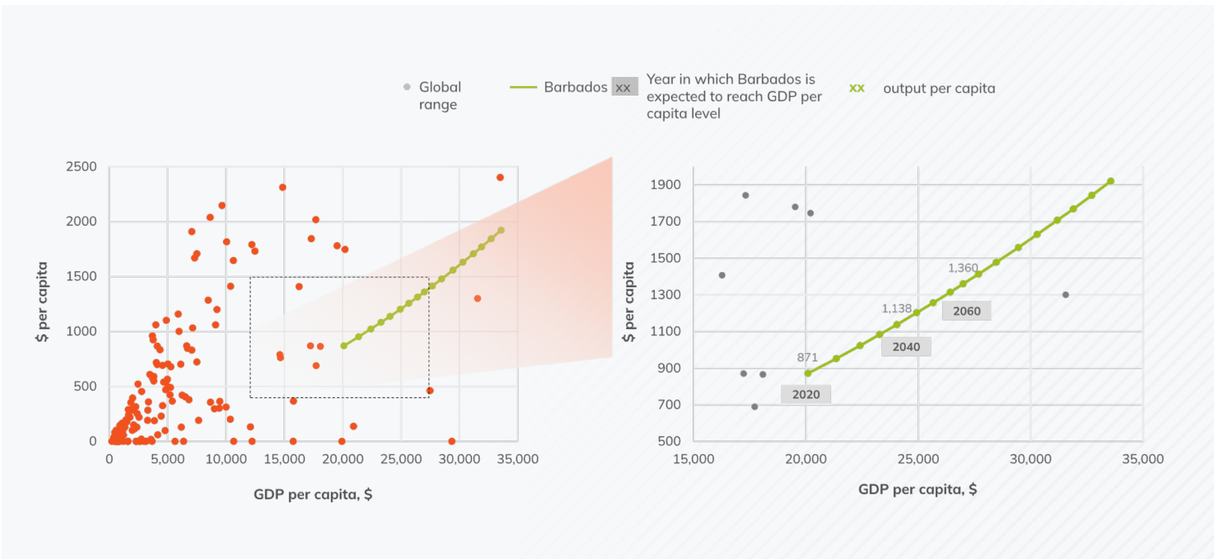
Figure 10: Power system flexibility analysis in 2030 for (a) BAU and (b) NZE 2035



3.3 Industry Sector

The demand for Barbados' industry sector is expected to match that of other Small Island Developing States (SIDS) with similar income levels vs GDP growth by 2040. The sector's profile is expected to remain as it is currently, with no projections indicating the emergence of hard-to-abate sectors. Instead, it is projected to expand to include agro-food processing and light manufacturing. The major industries in the country are rum distilleries and sugar and other agro-food industries including fisheries. There is some scrap steel processing and cement production with clinker imports, and they rely on a mix of low-temperature and medium-temperature heat processes. There is energy demand from services, and tourism is expected to grow but its transition is captured under the building sector. The gross value added per capita by 2040 is about USD 1,400.

Figure 18: GVA per capita (USD)



The industry sector accounted for 206 kt of CO_2 emissions in 2020, equal to 9 percent of Barbados' overall emissions in that year. This number is projected to decrease to 100 kt CO_2 by 2025 under the BAU scenario, where it plateaus until 2040. In the NZE 2035 scenario, CO_2 emissions are projected to achieve neutrality by 2025. By 2035, the bioenergy carbon capture and storage (BECCS) technologies in the industry sector will be needed to offset approximately 40 kt of CO_2 emissions from Barbados' other sectors that cannot be mitigated to ensure security of supply.

Figure 19: Proportion of total CO2 emissions in 2020 from the industrial sector

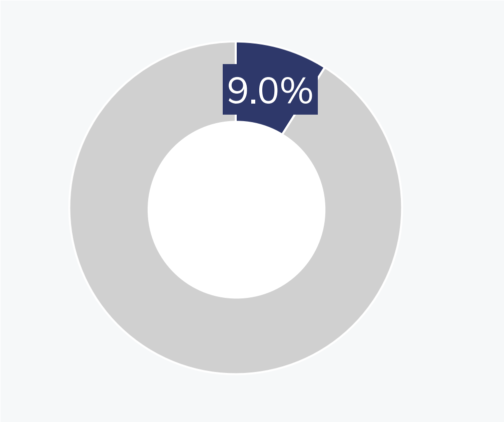
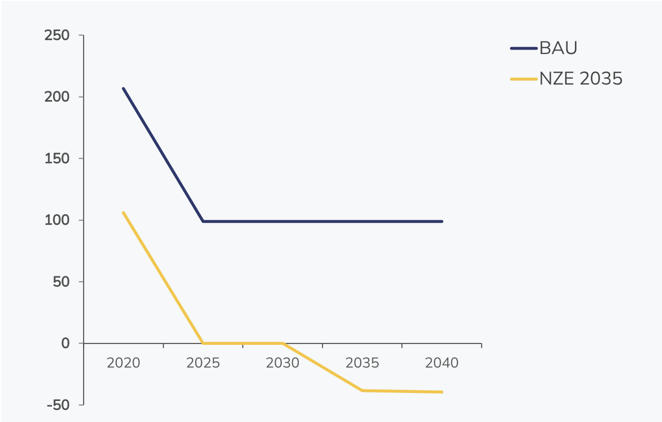
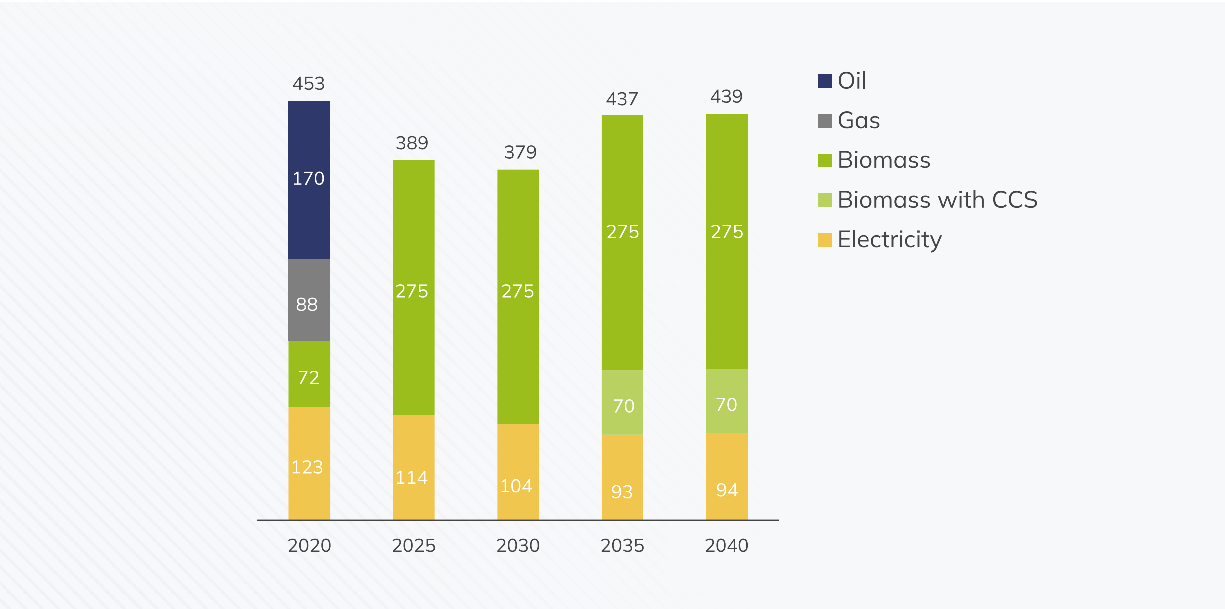


Figure 20: Projected CO2 emissions from the industrial sector for the BAU and NZE 2035 scenarios (kt CO2)



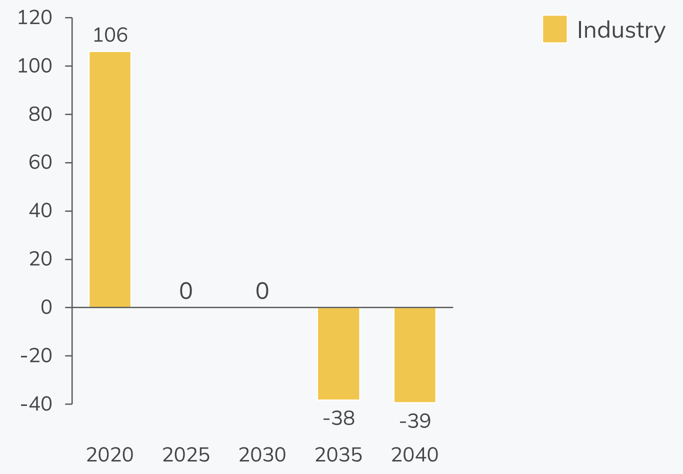
A net-zero transition would need to electrify industrial processes for decarbonization, which will drive a shift in the fuel mix. Biomass/biofuels and BECCS could replace fossil fuels and play key roles in Barbados' industry sector to offset residual emissions from other sectors such as power and transport (Figure 21). Moreover, heat pumps are expected to replace fossil fuels for low-temperature process heat applications, thereby increasing electricity consumption and presenting an opportunity to also improve energy efficiency. This transition in industries will require high availability of biomass and biofuels, as well as the adoption of innovative electric heating technologies such as electric kilns to decarbonize medium- to high-temperature heating processes in industries.

Figure 21: Industry fuel consumption (kBOE)



Overall, the industries sector would be mainly driven by electricity and biofuels, not only reducing emissions but also providing more industrial production with less fuel consumption than is currently the case, particularly fossil fuels that are sensitive to global price shocks that can endanger businesses. Further, the biomass-driven CCS technology within the sector will offset 38 and 39 kt CO2 emissions in 2035 and 2040, respectively (Figure 22).

Figure 11: Industry CO2 emissions (kt CO2)



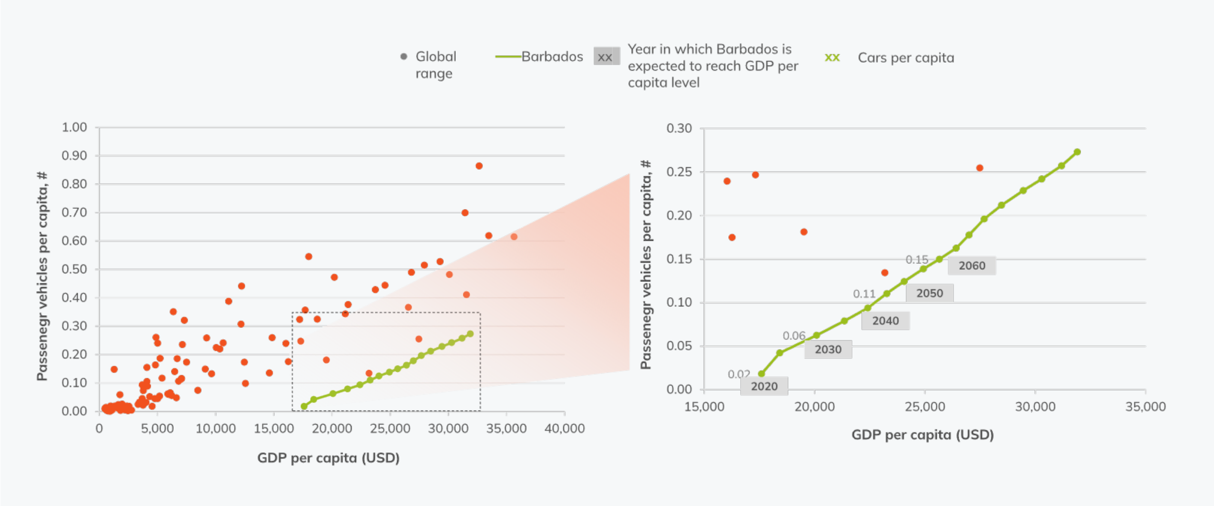
Biofuels

Biofuels are an important low-carbon alternative to oil-based fuels in the power, transport, and industries sector. According to stakeholders, there is the potential for domestic biofuels to be developed locally using rum waste and sargassum, but quantities of both are insufficient to meet the needs in all sectors of a low-carbon fuel under net-zero constraints. Existing literature has shown that about 685.3 million litres of rum waste and 106,000 tons of sargassum are needed to satisfy the transport demand for biofuels in the country per year. In the current modelling assumptions, biofuel potential is restricted from 1.5 PJ in 2020 to 3.5 PJ by 2040. In the NZE 2035 scenario, the consumption of biofuels peaks in 2035; approximately 2.7 PJ of biofuels are needed to satisfy the demand in the transport and industries sectors, corresponding to 159,000 tons of fresh sargassum per year. Hence the role of biofuels needs to be explored in a more robust manner to ensure that Barbados has adequate domestic availability of sustainable biofuels as an alternative low-carbon fuel.

3.4 Transport Sector

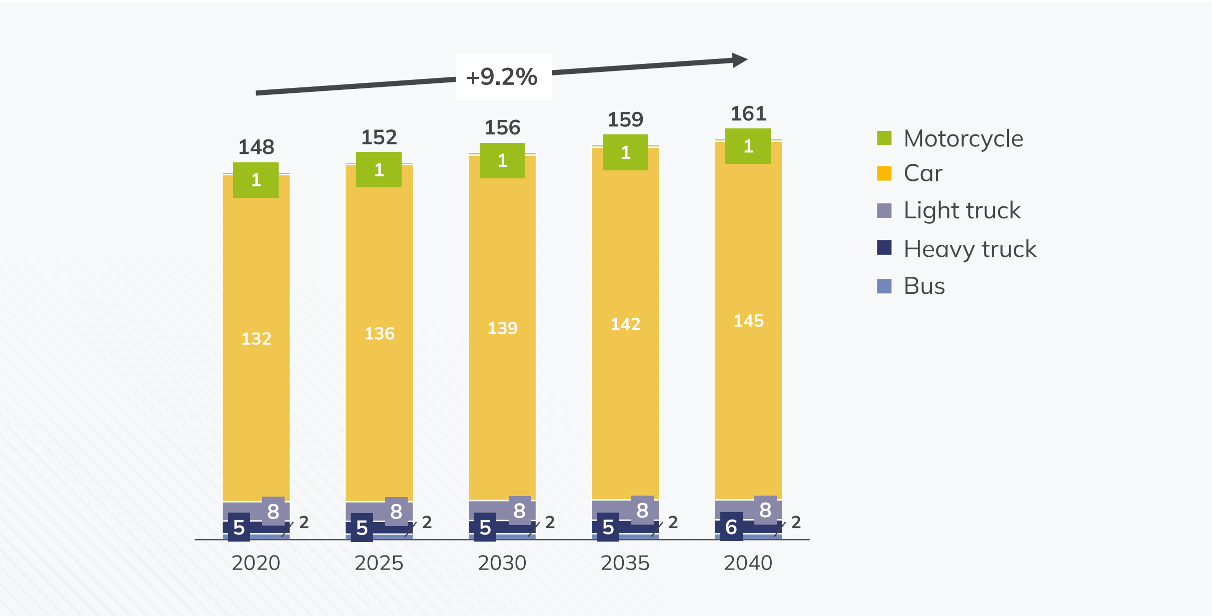
The demand for passenger car ownership in Barbados is expected to follow a similar trend of vehicle ownership to other countries in a similar economic range (Figure 23), particularly considering the population's heavy reliance on private transport. Within a net-zero policy framework, along with the necessary consumer incentives and charging infrastructure, EVs are expected to replace fossil fuel-based cars entirely by 2040, with the passenger vehicle ownership per capita expected to be 0.11 in 2040.

Figure 23: Passenger cars per capita



A 9 percent increase in the number of vehicles on the road by 2040 is projected (Figure 24). An average number of 10,000 four-wheel passenger cars are expected to be imported annually between 2020 and 2035. The number of motorcycles, light trucks, heavy trucks, and buses is also expected to increase in the next decade, but demand for these is lower than that for cars. Further, it is not expected that there will be any major modal shifts in transport demand by vehicle mode in the next decade. However, given that transport is a major source of emissions, a strategy to encourage a shift away from private vehicles to public transport is important for a net-zero policy to be successful.

Figure 24: No. of vehicles by mode to meet the road transport demand (thousand units)



The transport sector also accounted for 328 kt of CO_2 emissions in 2020, equal to 28 percent of Barbados' overall emissions in the same year (Figure 25). This figure is projected to decrease to 297 kt CO_2 by 2040 under the forecasted demand and BAU scenario (Figure 26) owing to improved vehicle fleet efficiency in the global markets. In the modelled NZE 2035 scenario, CO_2 emissions are projected to decrease significantly to 9 kt CO_2 by 2035 but there would still be some emissions that cannot be further reduced without early retirement on some assets. The remaining emissions in 2035 could be offset by BECCS within the industrial sector to achieve carbon neutrality.

Figure 25: Proportion of total CO2 emissions in 2020 for the transport sector

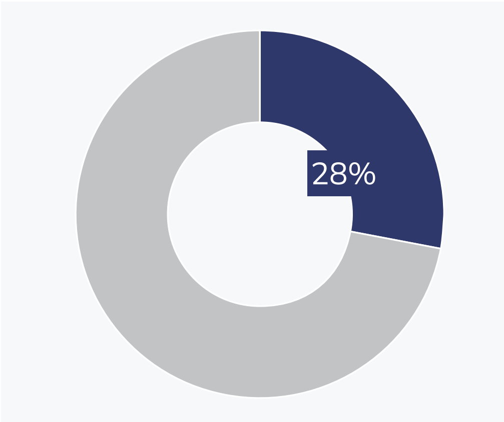
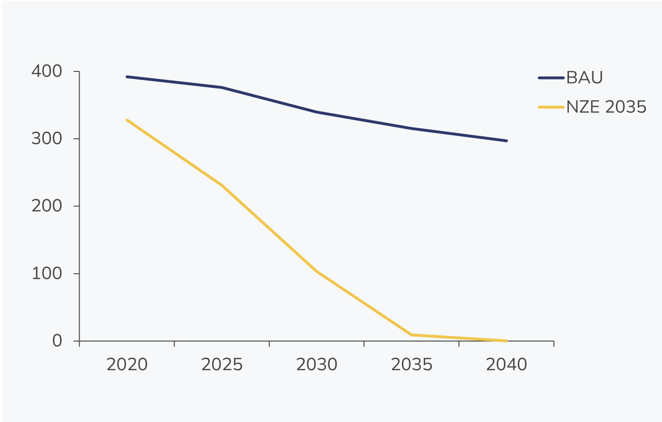


Figure 26: Projected CO2 emissions from the transport sector for the BAU and NZE 2035 scenarios (kt CO2)



A net-zero transition in the transport sector requires electrifying vehicle fleets and moving away from internal combustion engines (ICE) that operate on fossil fuels. Specifically, passenger cars produce the bulk of total emissions at around 60 percent each year (Figure 27). The total road transport sector could decarbonize at a steady pace, mainly through vehicle electrification and biofuel, along with support from hydrogen and ammonia. These fuels are projected to replace 93 percent of oil-based transport in 2035, reaching 100 percent in 2040 (Figure 28). Further, total fuel transport demand is expected to decrease due to a declining population and the rise of efficient electric and hydrogen vehicles. The subsections below delve into the changes for each road transport mode and how they are moving towards a net-zero pathway.

Figure 27: CO2 emissions in the transport sector (kt CO2)

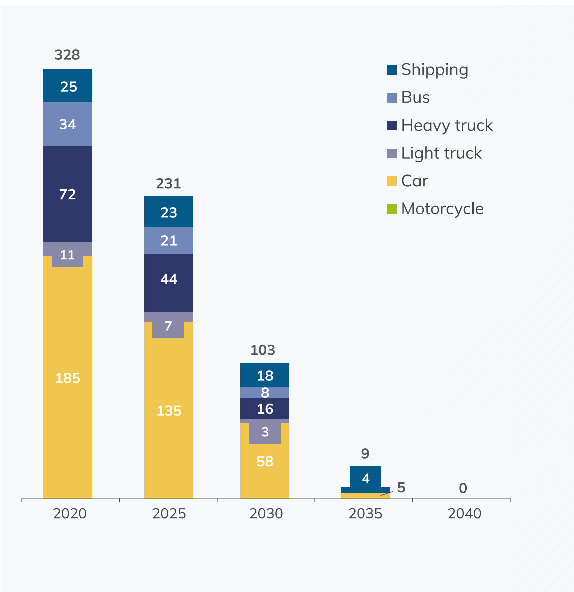
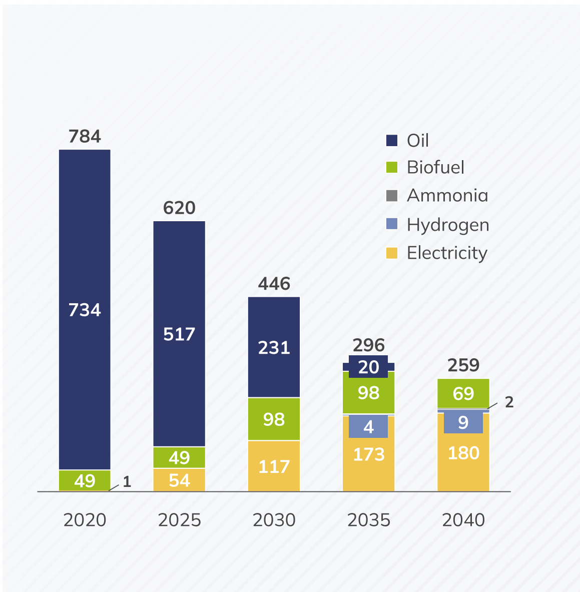


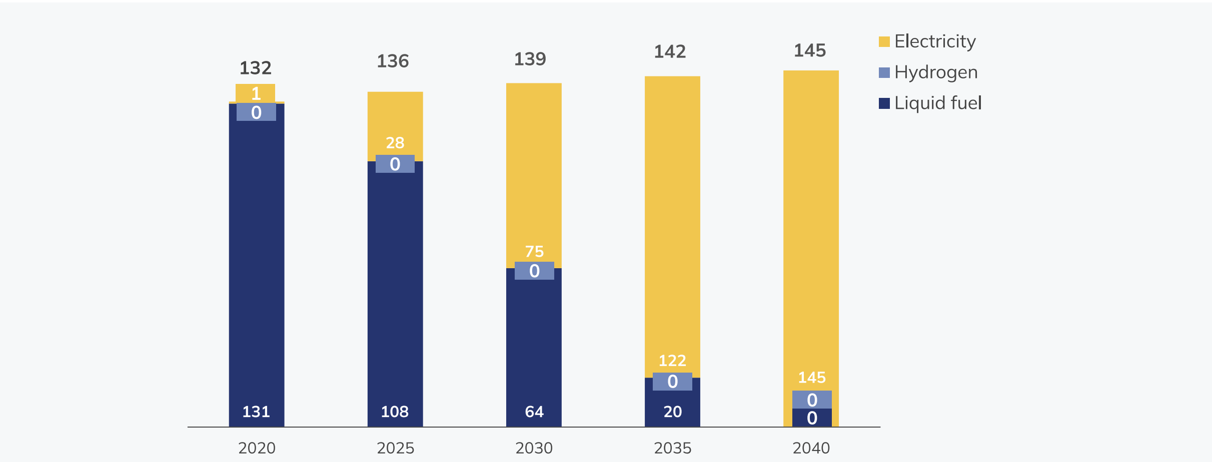
Figure 28: Transport demand by vehicle mode (kboe)



Cars

Passenger car ownership is expected to grow by 10 percent by 2040 due to rising incomes. The transport mix is currently dominated by ICE cars, primarily due to the prevailing cost premium associated with EVs and their limited availability, particularly within Barbados' significant used vehicle market. However, a shift is expected by 2030 when new and/or used EVs become cost competitive and readily accessible in the local market. Within a net-zero policy framework, EVs are projected to outnumber fuel-powered cars by 2035, with complete saturation anticipated by 2040. The introduction of flexible fuel cars (flex cars) utilising biofuels could decarbonize the transport sector in 2035. An underlying assumption is that battery cost reductions drive a shift to EVs in the international automobile market and that second-hand EVs will be cost competitive with ICE vehicles by 2030, although market availability is limited. A shift from used vehicles in the market would be needed to accelerate the transition to EVs.

Figure 29: Car technology mix (thousand units)

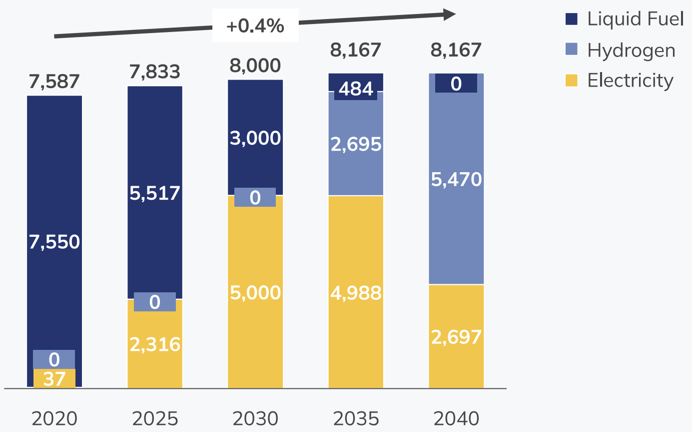


Biofuel-operated cars will need to enter the market for Barbados to achieve NZE by 2035. Furthermore, EV battery recycling needs to be considered to ensure the sustainability of the transition. This assumption considers the used vehicle market due to the current high reliance on used vehicles as per stakeholder feedback and consumer behaviour that is highly sensitive to upfront costs. However, a used vehicle fleet may not be a cost-optimal solution and awareness regarding the lifetime costs of vehicles should be promoted for an effective and accelerated transition.

Light trucks

Barbados' fleet of light trucks is expected to grow around 8 percent from 2020 to 2040 as rising incomes drive a greater volume of freight. Conventional oil-based trucks dominate up until 2025 as the global market for low-carbon trucks remains small and carries a significant cost premium. The deployment of hydrogen trucks begins in 2035, supplying 33 percent of the mix, and then dominating with 67 percent in 2040. Penetration of flex light trucks is then needed by 2035 to decarbonize the transport sector. An underlying assumption is that low-carbon light trucks continue to carry a significant cost premium and strong policy support will be needed to deliver them at the scale needed. Equally, electric light trucks are expected to play a key role with the falling costs of EVs and battery technology for longer drives becoming more affordable and available. However, hydrogen-fuelled light trucks have become a slightly more dominant solution because of the lower efficiency of battery trucks for short distances. Secured hydrogen supply or sustainable biofuels as alternatives in the transport sector also need to be considered to ensure the transition's sustainability.

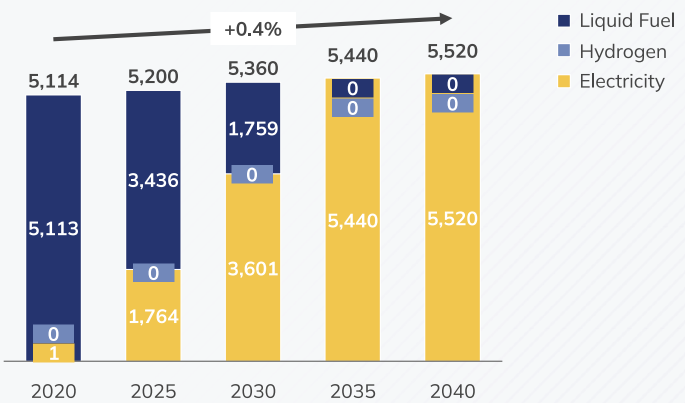
Figure 30: Light truck technology mix (thousand units)



Heavy trucks

Heavy truck fleets are projected to grow around 6 percent from 2020 to 2040 as rising incomes drive a greater volume of freight. Conventional liquid fuel trucks dominate up until 2025 as the global market for low-carbon trucks remains small and the vehicles carry a significant cost premium. By 2030, 55 percent of the fleet is expected to be electric, a figure that increases to 89 percent in 2035. By 2040, the heavy truck fleet is expected to be fully electric. There is no penetration of hydrogen vehicles. The underlying assumption is that low-carbon heavy trucks carry a significant cost premium and strong policy support will be needed to deliver them at the scale needed. Electric battery trucks are preferred for longer distances due to their greater efficiency, although in the future hydrogen-based battery trucks could be available.

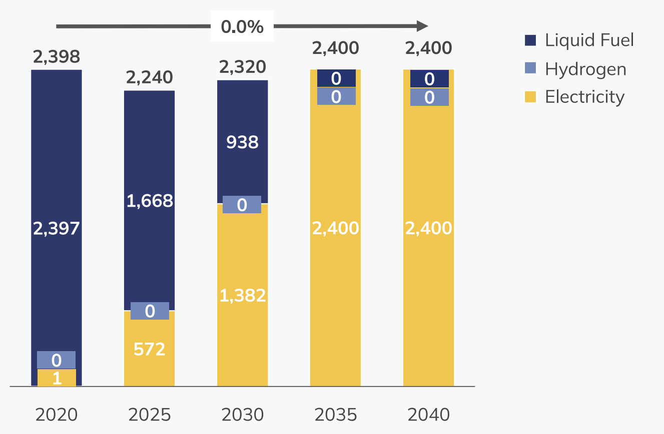
Figure 31: Heavy truck technology mix (units)



Buses

Electricity becomes the main fuel source for the Barbados bus fleet by 2035. Fossil fuel buses continue to dominate until 2025, before low-carbon buses begin to play a role. During this period, there is no penetration of hydrogen buses. An underlying assumption is that the rise in demand for buses does not outpace the transition to electricity. Hydrogen-powered buses also carry a significant cost premium. The declining upfront investment cost of electric buses and the fact that electricity prices will be lower than fossil-fuels are factors to be considered when striving towards achieving NZE. Most of Barbados' buses are used for public transportation, and the incentive and charging infrastructure needs to be optimised and well-structured to benefit from lifecycle cost and emission reduction and ensure maximum utilisation of the fleet.

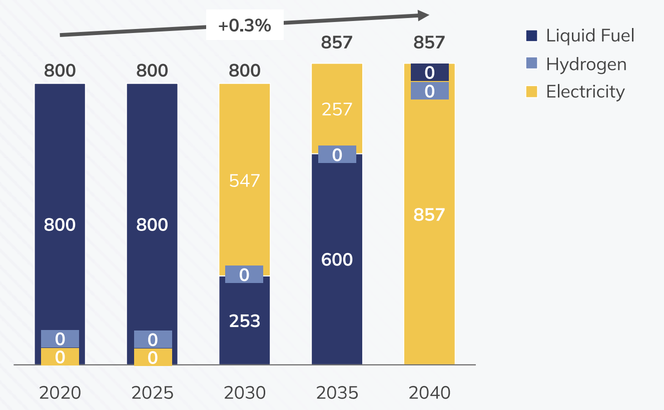
Figure 32: Bus technology mix (units)



Motorcycles

Fossil-fuel motorcycles continue to dominate until 2035, before there is a large uptake of electric motorcycles (e-motorcycles). A rapid shift to e-motorcycles is projected to take place between 2030 and 2035. By 2035, e-motorcycles take up to 70 percent of the stock mix and by 2040, the fleet will be completely electrified. An assumption is that the switch to electrify motorcycles points to their cost-competitiveness. The import of e-motorcycles is also prioritised and incentivised. There is also an opportunity to localise the assembly of e-motorcycles in Barbados for it to be a potential supply chain hub for the Caribbean region.

Figure 33: Motorcycle technology mix (units)



3.5 Residential and Commercial (Buildings) Sector

Overall, energy demand is reduced by 34 percent from 2020 through the implementation of energy-efficiency measures in buildings. Electricity use will reach almost 100 percent of the energy mix by 2035, while oil will decrease to zero percent, and gas to close to zero percent. It is assumed that oil-derived cooking fuel is primarily LPG. Following this, CO_2 emissions from buildings will also decrease over time as the building sector becomes fully electrified and supplied by renewables. Energy-efficiency measures are shown to be the key to decarbonizing the building sector in Barbados. It is also imperative to note that emissions from electricity, including buildings, are accounted for in the power sector. Further, the study assumes that the residential and commercial fuel consumption mix closely follows the fuel choices of cooking and water heating technology trends.

Figure 34: Fuel consumption in residential buildings (kboe)

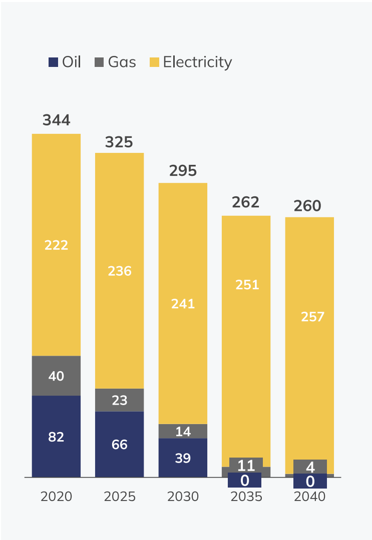


Figure 35: Fuel consumption in commercial buildings (kboe)

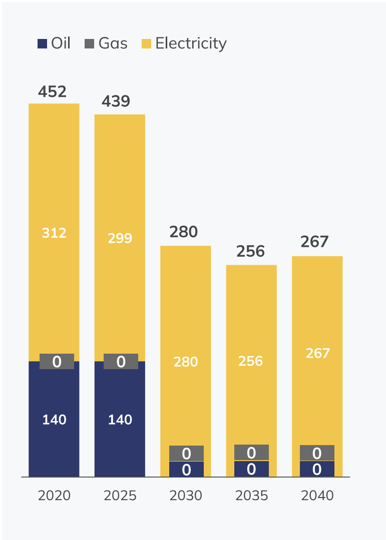
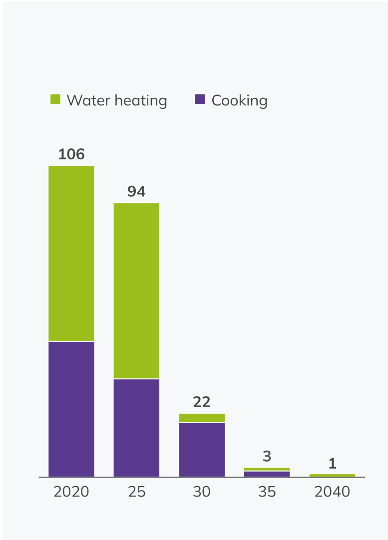


Figure 36: Buildings' CO_2 emissions (kt CO_2)



The residential and commercial sectors accounted for 106 kt of CO_2 emissions in 2020, which was 9 percent of Barbados' overall emissions in the same year. This number is projected to decrease to 2.3 kt CO_2 by 2040 under the forecasted demand and BAU scenario. This is a similar trend to the modelled NZE 2035 scenario, where CO_2 emissions are projected to decrease significantly, but to 1.2 kt CO_2 by 2040 – 1.1 kt CO_2 less than BAU. The remaining emissions in 2035 are offset by BECCS within the industrial sector. One of the key electricity demand drivers in commercial buildings is tourism, increasing from 123 GWh in 2020 to 184 GWh in 2040.

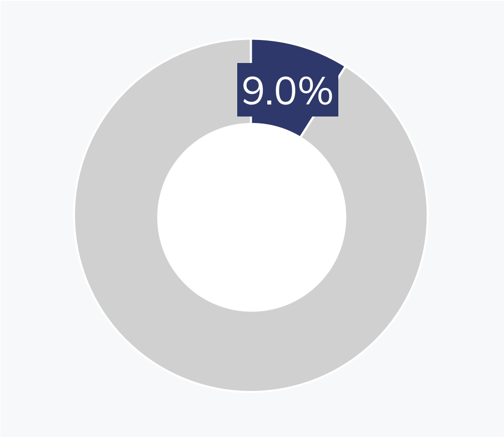


Figure 37: Proportion of total CO_2 emissions in 2020 from the residential and commercial sectors

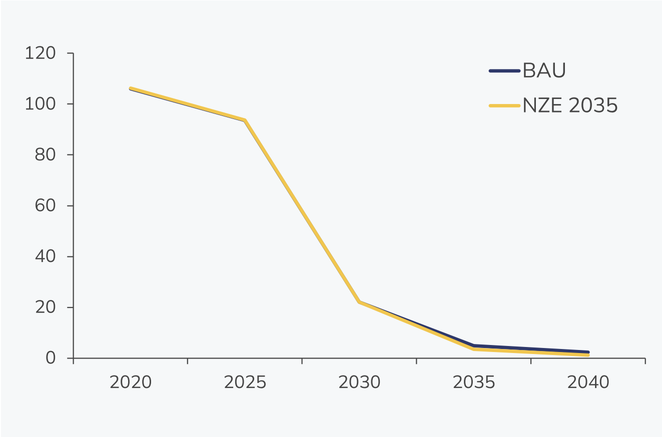


Figure 38: Projected CO_2 emissions from the residential and commercial sectors for the BAU and NZE 2035 scenarios (kt CO_2)

Electric cooking and water heating

LPG is currently the dominant cooking fuel in Barbados, with gas and electricity playing a smaller role. Gas will be phased out in the early 2030s as electric cooking (e-cooking) emerges as a key low-carbon solution. By 2040, cooking technology will be fully electrified. From this, investment and improvement in grid densification may be needed to support a massive electric cookstove penetration, especially for the commercial cooking energy service. Electric cookstoves do not usually require distribution transformer densification where the distribution grids are optimally sized and maintained, but some upgrade might be needed for commercial-scale e-cooking. Policy incentives to reduce the energy cost premium of e-cooking solutions compared to fossil-derived fuels may also be needed to facilitate the transition. Overall, it is highly likely that electric cookstoves will play a key role in decarbonizing the sector, but if they are not fully deployed, then biofuel-based cooking will have to be utilised. One of the greatest benefits of moving towards e-cooking is reducing LPG imports and import tariffs.

Figure 39: Cooking technology mix (thousand units)

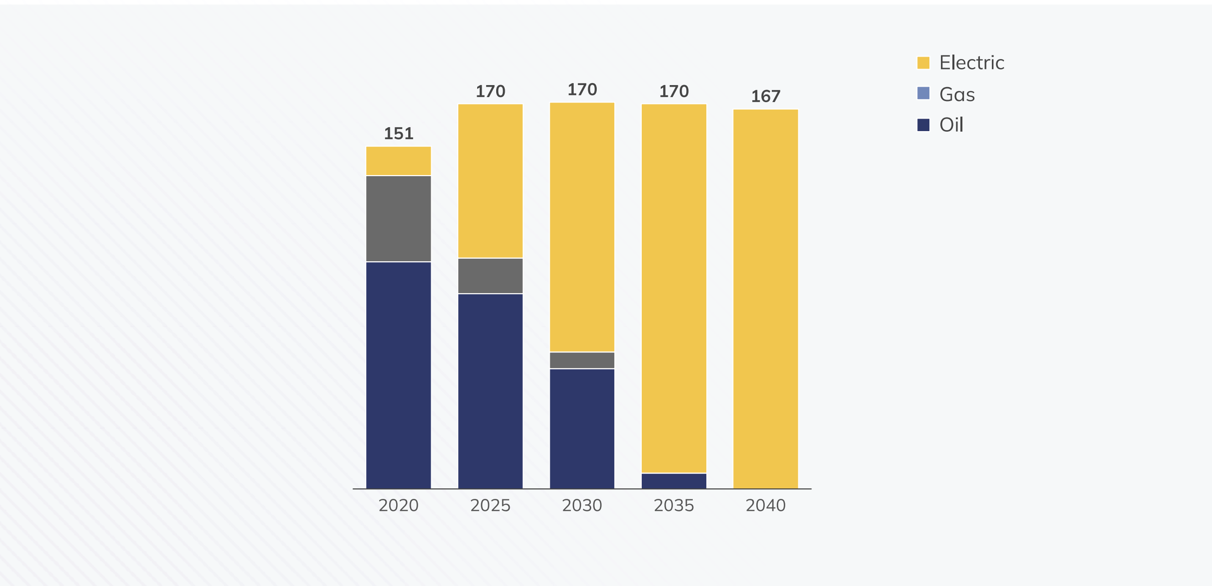
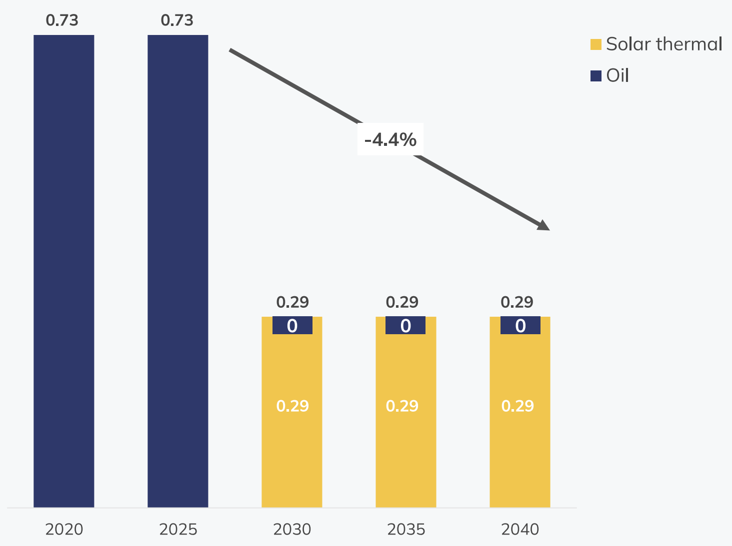


Figure 40: Water heating mix in NZE 2035 (GW)



The demand for cooking and water heating is anticipated to grow at 0.5 percent per annum, extending through to 2040, due to population growth and increases in GDP per capita. By 2040, cooking demand is projected to surge by 12 percent, accounting for a substantial 60 percent share of the total non-electricity demand in the buildings sector. An underlying assumption is that the average household size, estimated at 2.85 people per household, serves as a driving factor for the cooking and water heating demand. Additionally, it is presumed that the number of households will rise with population growth. As of 2020, the total number of households in Barbados stood at 95,000, with the cooking and water heating needs per household (measured in PJ/household) remaining constant throughout the period spanning from 2020 to 2040.

Lighting and Cooling

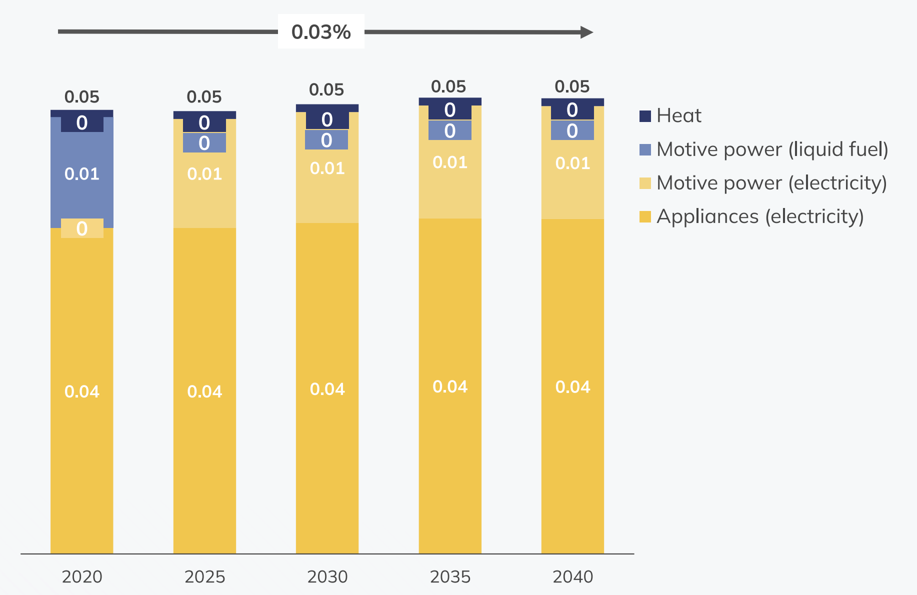
The use of more complex electrical appliances in residential and commercial buildings is natural with the growth in GDP per capita. The climate in Barbados is warm and humid, increasing its need for space cooling as global temperatures rise this need is not expected to decline. The electricity use in residential and commercial buildings from lighting and appliances was 908 GWh in 2020 and decreases to 892 GWh in 2040 as modelled through potential energy-efficiency improvements. The major driver for electricity demand from buildings is the need for lighting and space cooling. According to the IEA, cooling particularly takes about on average a fifth of the energy demand in buildings, and its applications range from the use of air conditioners in houses and hotels to cold storage for the fisheries sector.

Under NZE 2035, while electricity supply will be from clean fuels and renewables, the role of energy efficiency in reducing the overall total system cost cannot be emphasised enough. Barbados would need to implement major end-use energy-efficiency interventions such as mandatory building energy codes, minimum energy performance standards (MEPS) for lighting and cooling appliances and demand response/flexibility programmes with major consumers to not only reduce the waste of useful energy but also manage peak demand; reduce the need for costly storage; and utilise maximum renewable energy sources.

3.6 Agriculture Sector

The agriculture sector energy use only considers motive power and irrigation used for crop production; other indirect energy inputs including emissions from land use, land-use change, and forestry (LULUCF) are not considered. Fuel consumption levels remain steady between 2020 and 2040 as production is not expected to change too much, and the sector is fully electrified from 2025 onwards through electric tillers for motive power. The use of electricity for pump sets and other appliances for crop production remains. CO_2 emissions in the sector for motive power are also expected to reach zero by 2035. It is assumed that Barbados' agriculture sector growth aligns with that of countries of similar income levels.

Figure 41: Agriculture fuel consumption (PJ)



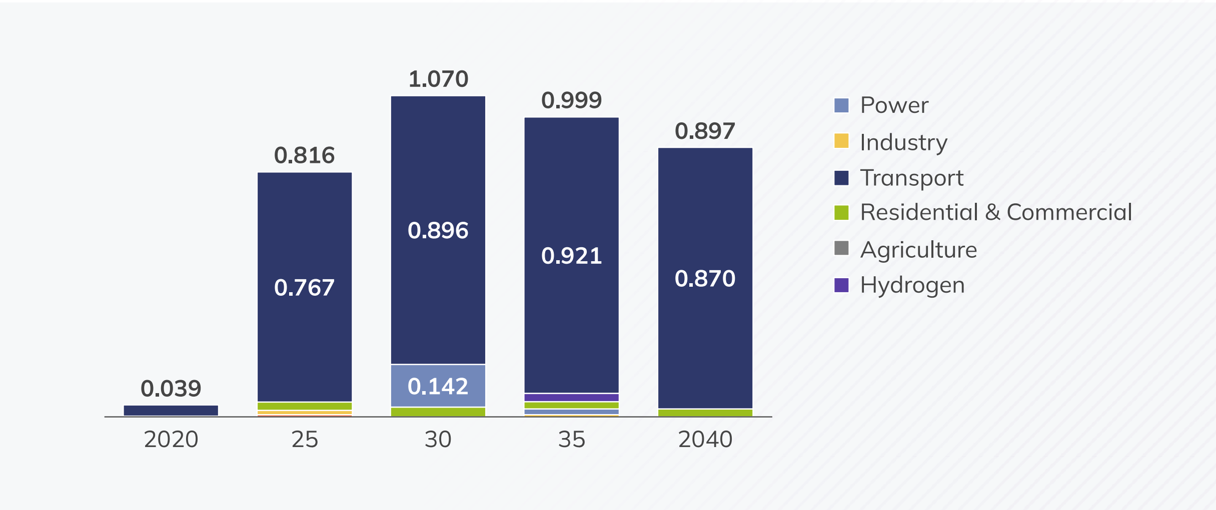
CHAPTER FOUR

INVESTMENT OUTLOOK OF A NET-ZERO TRANSITION

4.1 Overview

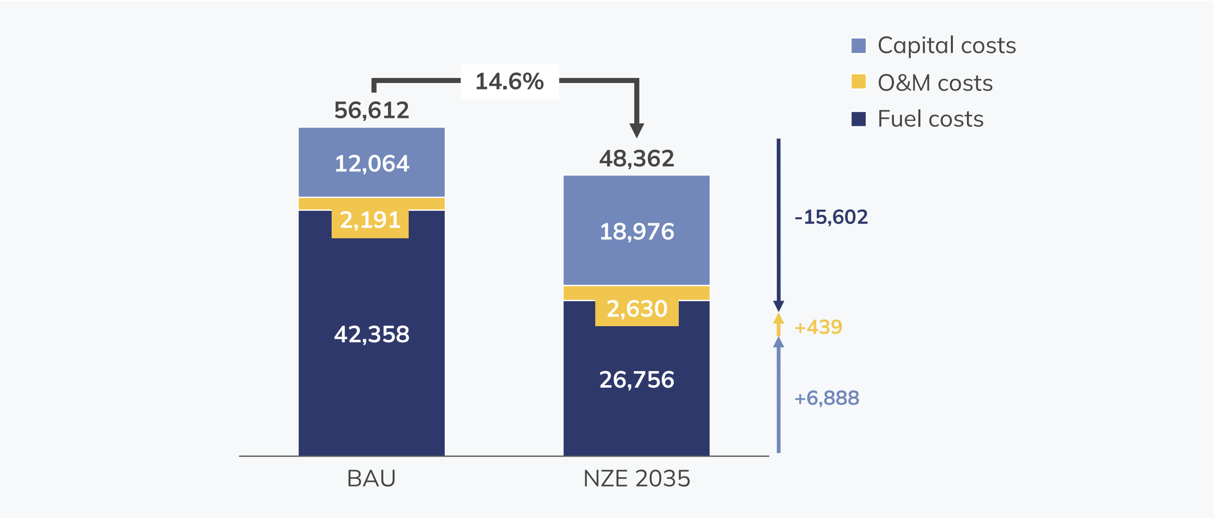
Under the net-zero emissions 2035 (NZE 2035) pathway, annual investment needs are projected to increase more than 25 times from 2020 levels, reaching approximately BBD 1 billion in 2030. Overall, cumulative investments are expected to reach almost BBD 19 billion from 2020 to 2040. The increase in investments will primarily be driven by income and population growth as well as a shift to more capital-intensive low-carbon technologies. Throughout the period, transport accounts for the largest share of cumulative investment, at around 91 percent. The high share of capital investment in transport is driven by the costs of private cars and other vehicles, with ownership growing significantly as incomes grow. Power and hydrogen account for a joint 5 percent of the cumulative investment, while industry and buildings account for a smaller share, at around 1 percent and 3 percent of the total, respectively.

Figure 42: Total annual capital investment required by sector under NZE 2035 (billion BBD)



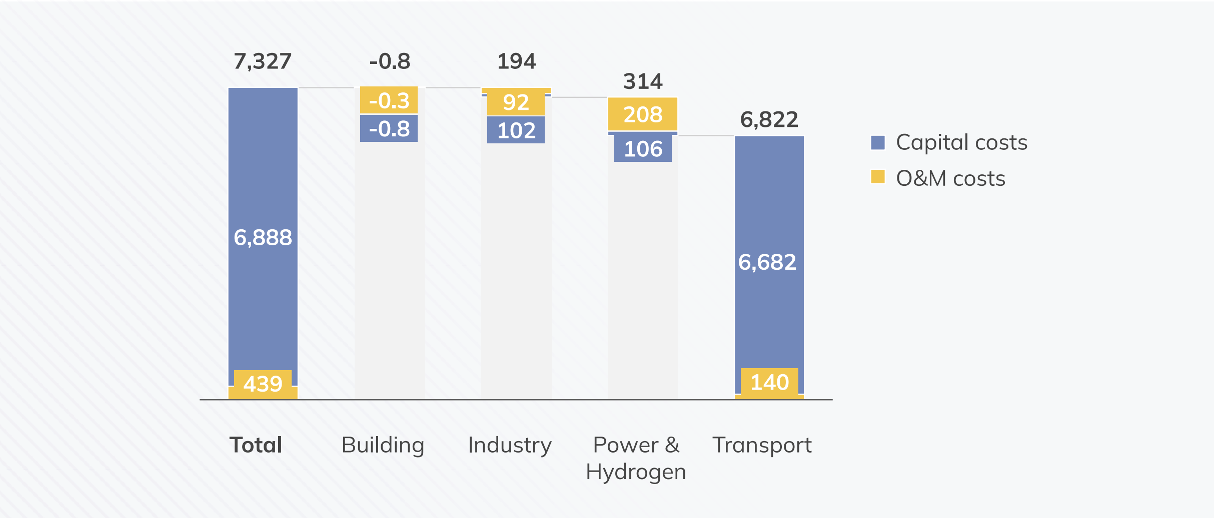
Cumulatively over 2020–2040, total spending in the NZE 2035 scenario is estimated to cost 15 percent less than in a business-as-usual (BAU) scenario, as higher upfront capital investments are offset by substantial fuel cost savings. However, mobilising the required finance will be a major challenge, requiring decisive policy action to de-risk and incentivise investment in low-carbon solutions, as well as innovative financial instruments to catalyse private capital and maximise the impact of public resources. Between 2020 and 2040, capital and operation and maintenance (O&M) costs in the NZE 2035 scenario are 51 percent and 20 percent, respectively, higher than in the BAU scenario, while fuel costs are 37 percent less. Effectively, fuel costs in BAU contribute more than 75 percent of the cumulative spending, with gas being the major contributor. This is due to gas becoming the second most dominant fuel in the power sector under the BAU scenario, while gas is used for hydrogen production under the NZE scenario. The fuel cost savings in the NZE scenario are mainly due to the switch from oil to cleaner fuels in the transport and power sectors.

Figure 43: Cumulative spending of BAU and NZE 2035 (BBD, million)



Between 2020 and 2040, 93 percent of the additional spending is incurred to electrify the transport sector. This is followed by power and hydrogen, and it requires 4 percent of the total additional spending to decarbonize the sector through onshore wind, solar PV, and blue hydrogen. Further, only a 2 percent share of additional capital and operational spending is required for industry while there is a net saving of BBD 1 million in the buildings sector.

Figure 44: Additional spending on capital and O&M costs across sectors for NZE 2035 (BBD, million)



To unlock the necessary investment at scale, Barbados must act on three key fronts:

Address the *green premium* challenge through carbon pricing, subsidies, regulations, and market design reforms that make low-carbon solutions competitive with fossil fuels.

Reduce investment risks through stable revenues, public-private partnership models, de-risking instruments and patient capital, while also tackling supply-side bottlenecks in infrastructure, skills, and supply chains.

Mobilise and catalyse finance through a combination of domestic resource mobilisation, international public finance, and private-sector investment, supported by innovative financial instruments and institutional arrangements.

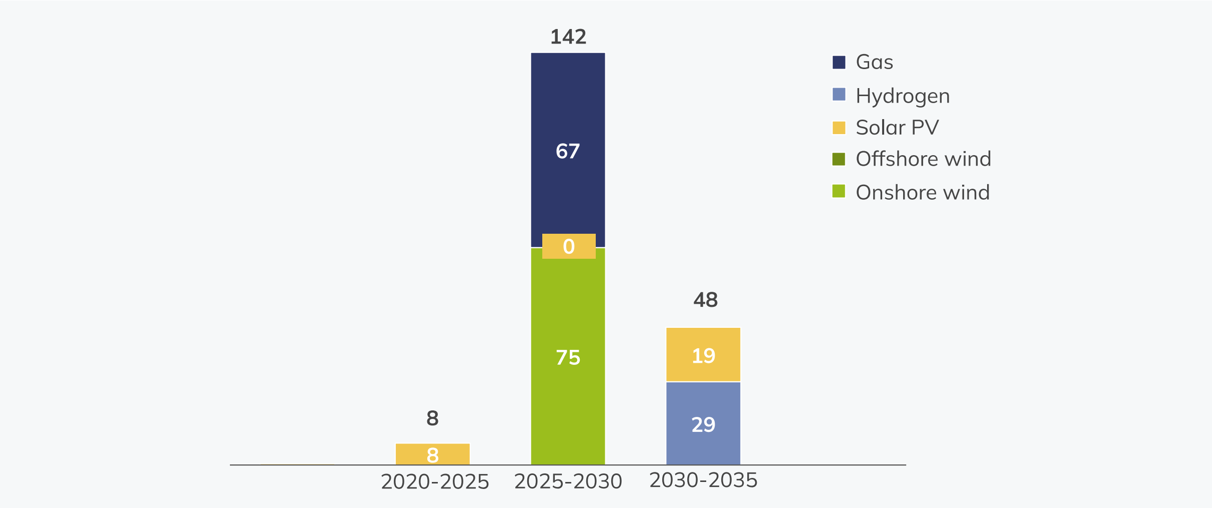
4.2 Power Sector

A relatively large capital investment is required in the period 2025–2035, an average annual investment of BBD 134 million, 17 times more than in the period 2020–2025. This is due to the need to increase the capacity of more capital-intensive low-carbon technologies such as onshore wind but also of natural gas. 53 percent of the average annual investment needed in 2025–2030 (BBD 75 million) stems from the construction of onshore wind turbines. This is closely followed by the investment required for the construction of gas power plants, the remaining 47 percent (BBD 67 million).

The average annual investment needed in 2030–2035 then drops by 67 percent compared to 2025–2030, to BBD 48 million. 60 percent of this amount is needed for capital-intensive hydrogen technologies and 40 percent for solar PV. Under the NZE 2035 scenario, capital-intensive blue hydrogen is expected to contribute to the energy mix in 2035, bringing in BBD 29 million in investments.

Unlocking these investments will require creating and maintaining a stable and attractive environment for renewable energy developers and investors, including through establishing clear targets, competitive procurement guidelines, enabling power market reforms and streamlining permitting procedures.

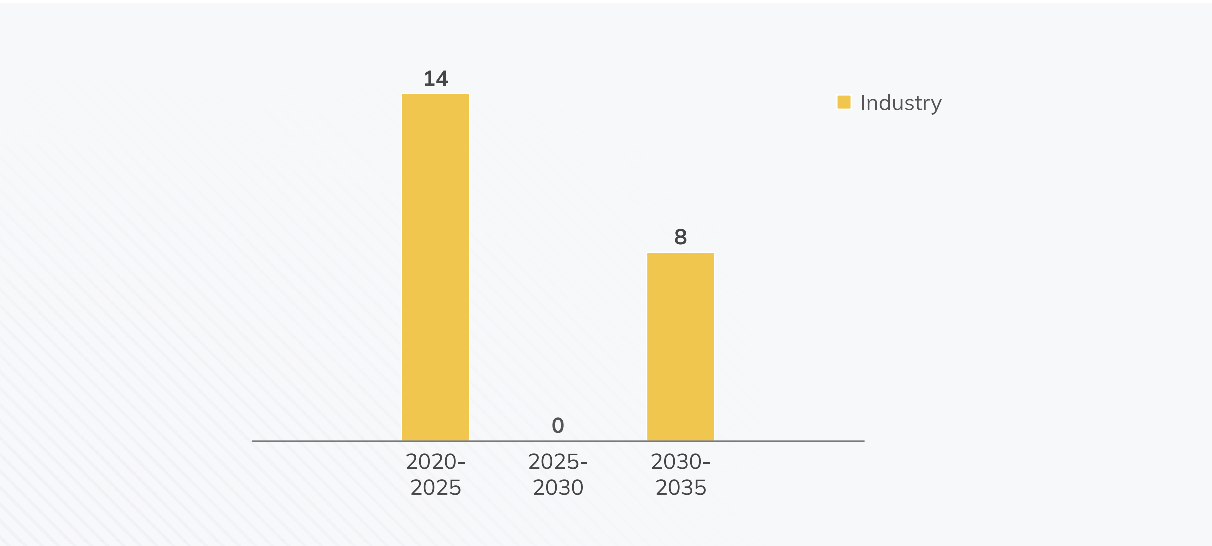
Figure 45: Annual capital investment required in the power sector under NZE 2035 (BBD million)



4.3 Industry Sector

Under the NZE 2035 scenario, investment costs for industry will account for a smaller share of Barbados' net-zero investment needs, but targeted action in these sectors will be critical to achieving the country's climate goals. The industry sector will require capital investments in the periods 2020–2025 and 2030–2035. In total, BBD 109 million will be needed from 2020 to 2035. Roughly BBD 22 million in investment will be needed between 2020 and 2040, concentrated in energy efficiency, low-carbon heat and power and carbon capture and storage (CCS). Average annual investments of BBD 14 million will be required in 2020–2025 and BBD 10 million in 2030–2035.

Figure 46: Annual capital investment required in the industry sector under NZE 2035 (BBD millions)



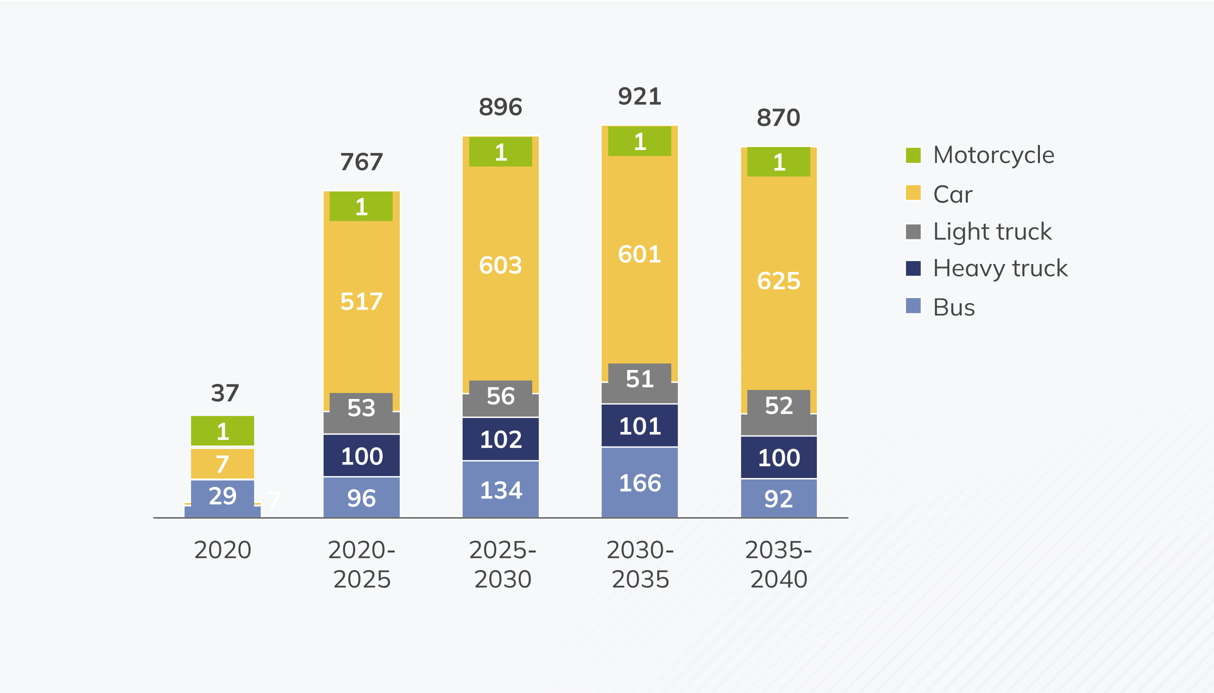
4.4 Transport Sector

Under the NZE 2035 scenario, average annual capital investments in transport are projected to rise steadily from BBD 767 million in 2020–2025, to BBD 896 million in 2025–2030, and to BBD 921 million by 2030–2035, totalling approximately BBD 17 billion over the period 2020–2040.

Transitioning the car fleet will dominate the transport investment profile. Between 2020 and 2040, approximately BBD 2.3 billion will be spent on the purchase of cars. During this period average annual capital expenditure on cars will comprise around ~68 percent of the total annual investments in the transport sector. Buses and heavy trucks require the second and third largest share of annual capital investments averaging around 15 percent and 12 percent, respectively, annually between 2020 and 2040. This is primarily driven by the electrification of public transport.

To enable this massive scale-up of EVs, major investment will be needed in charging infrastructure and grid reinforcements. The government is expected to play a key role in planning and coordinating this infrastructure rollout, while also creating an enabling environment for private-sector investment through fiscal incentives, streamlined permitting and public-private partnerships. Investment will also be needed to develop local manufacturing and assembly capacity for EVs and their components, creating new opportunities for industrial diversification and job creation.

Figure 47: Annual capital investment required in the transport sector under NZE 2035

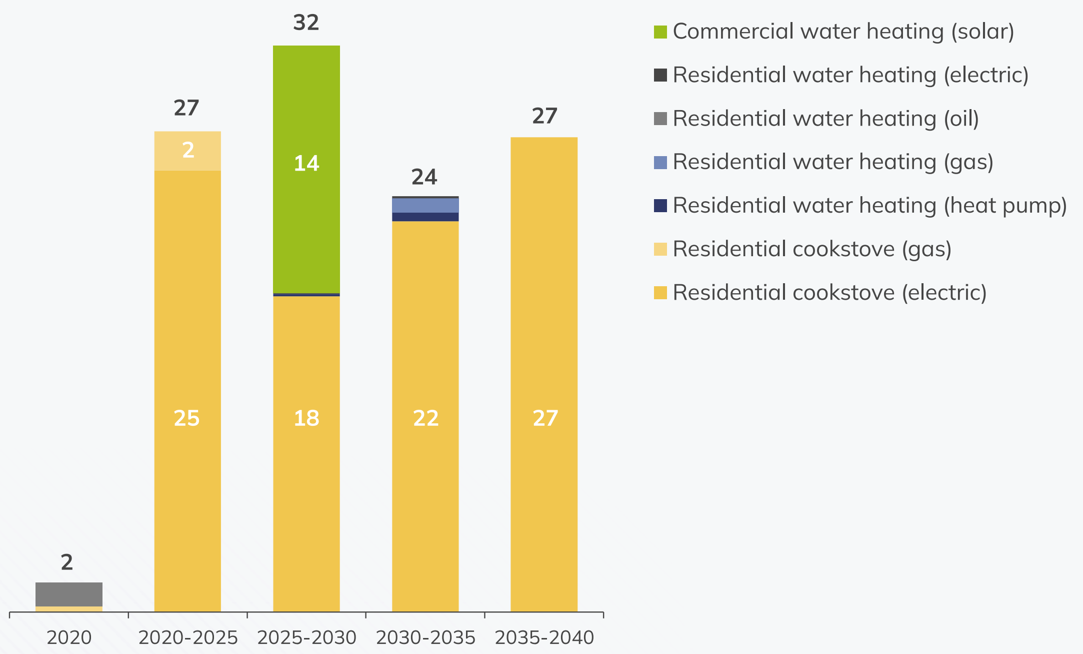


4.5 Residential & Commercial (Buildings) Sector

Under the NZE 2035 scenario, annual investments for the residential and commercial sectors will require average annual investments of BBD 27 million between 2020 and 2025, 93 percent of these on residential electric cookstoves and 7 percent on residential gas cookstoves. As gas is phased out, annual investments are expected to peak in the period 2025–2030, at BBD 32 million. Of this, 56 percent is dedicated to residential electric cookstoves and the remaining 44 percent to commercial solar water heating. Residential electric cookstoves continue to dominate in the years up until 2040, whilst residential heat pump heating and residential gas water heating hold relatively small investments of 2 percent and 3 percent of the total annual amount, respectively.

Incentivising investment in industry and buildings will require the introduction of a comprehensive package of policies and regulations, including ambitious building codes and appliance standards, fiscal incentives for low-carbon technologies, public procurement, and capacity-building programmes.

Figure 48: Annual capacity investment required for the residential and commercial sectors under NZE 2035



CHAPTER FIVE

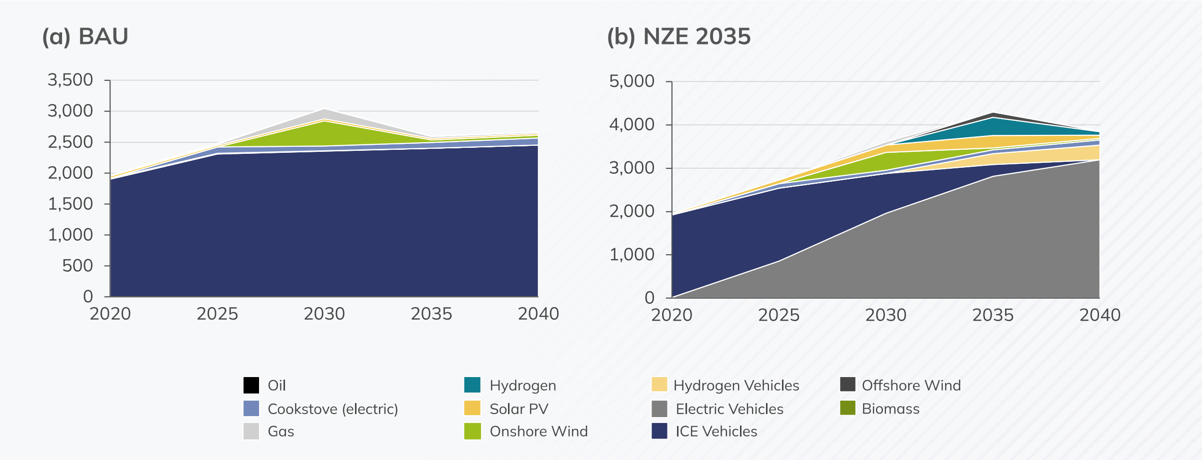
BROADER IMPACTS OF A NET-ZERO TRANSITION

5.1 Job creation

The net-zero 2035 (NZE 2035) scenario will see an increase in direct and indirect jobs of 57 percent (1,440 more jobs) over the business-as-usual (BAU) scenario, largely due to the transition of the transport sector. In 2040, the investment will support around 3,190 direct and indirect jobs in the construction and maintenance of electric vehicle (EV) charging and hydrogen-fuelling jobs – 586 in the construction of renewable generation assets (solar PV and onshore wind) in 2030, and 114 jobs in 2040.

Women and youth are integral to the energy transition. With adequate planning, Barbados' educational institutions can be positioned to provide local women and youth with the skills required to drive this transition.

Figure 49: Direct and indirect job projections by technology for (a) BAU and (b) NZE 2035



An increase in renewable energy generation and the growth of the EV market with local capacity will require the development of a wide array of skills. Certain skilled energy sector personnel such as electricians, mechanical and electrical engineers and energy auditors will be in high demand across the sector. For example, a rise in onshore wind capacity will create demand for jobs such as wind technicians, mechanical engineers, electricians, civil engineers, and site managers. This is similar for solar PV and battery installations where jobs for electricians, PV installers, electrical engineers, site managers and renewable energy specialists will be created. The transport sector will be key in creating direct jobs. Examples include urban and regional planners, electricians and electrical engineers for EV infrastructure, and mechanics, data scientists, electrical engineers and electricians for EV repair and maintenance. With the expansion of new technologies, jobs such as energy auditors, grid technicians, electricians and engineers directly related to grid development will also be developed. Apart from the above, indirect jobs will also be introduced; these include trainers and teachers, project managers, general contractors, construction managers, environmental scientists, sales and marketing people, business managers, legal and policy experts, energy modellers, cybersecurity experts, compliance officers and energy economists.

Supporting personnel will also be critical to enable the transition, with particular focus on the trainers and teachers needed to deliver the capacity building and education required for NZE. However, significant changes are required for Barbados' education sector to be ready to provide the skills needed for the net-zero transition.

Table 54: Barbados' current energy education and a proposed plan for NZE 2035

	STATUS OF ENERGY EDUCATION IN BARBADOS	WHERE BARBADOS NEEDS TO BE BY 2035
Primary	Foundations of Sustainable Energy Education concentrated close to the subject matter	Cross-cutting foundational knowledge surrounding renewable energy sources, energy efficiency and climate change
Secondary	Green Engineering for the Caribbean Advanced Proficiency Examination (CAPE) currently exists as an option on the high school syllabus, and Sustainable Energy Education is concentrated in related subjects (Geography, Physics, etc.)	Students should gain increased exposure to career pathways that contribute to the wider sectoral needs, and curricula should be reformed where possible to build core skills needed to pursue careers in the sector
Vocational	Solar water heating - Barbados Community College - Barbados Vocational Training Board - Samuel Jackson Prescod Institute PV installation - Samuel Jackson Prescod Institute - Barbados Community College Auto electronics - Barbados Vocational Training Board - Electrical engineering - Samuel Jackson Prescod Institute Energy management - Barbados Institute of Management - Hybrid electric vehicles - Samuel Jackson Prescod Institute	**Vocational institutions can benefit from programmes that deliver the following skilled personnel:** - Grid technicians - Energy auditors - Automobile electricians - Construction managers - Electricians - Wind technicians - Mechanics - PV installation specialists

Tertiary	Electrical Engineering, Mechanical Engineering Electronics (BSc), Sustainable Energy Management (MSc) - Barbados Community College - University of the West Indies	**Tertiary institutions can benefit from programmes that deliver the following skilled personnel:** - Mechanical engineers - Civil engineers - Electrical engineers - Wind technicians - Grid technicians - PV installation specialists - Data science specialists - RE managers - Business managers - Environmental science specialists - Construction managers - Urban and regional planning experts - Specialists in capacity building for educators - Project managers - Trainers for mechanics - Energy auditors - Lawyers

A range of actions can drive the development of local skills and the empowerment of women and youth to contribute to the achievement of NZE. Barbados is not starting from zero. Several studies have already mapped the country's key gaps in integrating renewable energy into curricula at all levels. The following actions can prove effective in developing the skills needed to deliver NZE using local capacity. At the primary and secondary level, support the integration of sustainable education into the curricula to drive early interest and lay the foundation for students to understand and pursue careers related to the energy transition from an early stage. Adopt a targeted approach in sensitising students at the high-school level to the areas key to Barbados' energy sector needs, including roles related to solar PV and onshore wind development and installation, the EV Sector, electric cookstoves and hydrogen. At the vocational level, develop new programmes/training courses in the technical and vocational education and training (TVET) institutions aligned with the expected sectoral needs through to 2035. Facilitate mechanisms for south-south exchange of best practices to provide TVET institutions with guidelines for course development. Develop education and employment programmes specifically targeted to underrepresented groups including young women to ensure equity of opportunity, particularly in STEM fields. At the tertiary education level, where possible, build sustainable energy modules and considerations into key degrees such as project management, construction management and data science. For priority technologies such as EVs, the development of tailored programmes to build capacity in line with projected demand is required.

5.2 Gender Equality

There is a complex relation between energy poverty, gender equality and development. Women play a multifaceted role: they are both direct beneficiaries of policies and active players in driving the transition forward. Globally, women are the primary energy managers within households, often relying heavily on energy for essential tasks like cooking and cleaning. Lack of access to modern energy services disproportionately burdens women in many communities. Reliable lighting extends working hours, creating flexibility for women to engage in income-generating activities beyond domestic chores. Energy-based technologies such as water pumps, irrigation systems, refrigerators and other appliances significantly reduce the manual labour that typically falls to women and girls, freeing up valuable time and boosting overall productivity. Promoting inclusive policies can ensure that the benefits from the net-zero transition reaches all members of society. Barbados' Energy Transition and Investment Plan (ETIP) is an opportunity for women and youth to access technical and leadership training, skills development, and new job opportunities. Job opportunities for women can cover installation, maintenance, and management of renewable energy systems, as well as entrepreneurship and leadership positions in the field. Some of the following steps could be considered for a more gender-mainstreamed approach towards the ETIP:

CONTEXTUAL ANALYSIS

Collect and analyse sex-disaggregated data and qualitative information to understand needs, priorities, and opportunities for both women and men in the job market.

Examples:
What percentage of STEM students are women?

What are the specific skills and qualifications currently in demand by employers in this region, and how do these requirements differ between genders?

Identify existing gender inequalities, broader benefits from the ETIP and opportunities to ensure women's full access and utilisation of modern energy services.

Examples:
How much time do women typically spend on domestic chores per day in the country or in specific communities?

How does this time allocation affect women's ability to participate in education, income-generating activities, or leisure?

PLAN INTERVENTIONS BASED ON THE LOCAL CONTEXT

Map key stakeholders and allocate human and financial resources needed to implement activities and track progress.

Develop gender-specific targets and performance indicators that track gender results and impact based on the contextual analysis.

Incorporate mechanisms to ensure gender-balanced representation and participation in project activities and decision-making processes.

ENGAGE WITH THE LOCAL COMMUNITY

Encourage local companies to hire and retain more women.

Raise awareness among women and their families about new job opportunities in the energy sector.

Partner with gender focal points (women's groups, international organisations, local community) throughout all planned activities.

PREPARE A TAILORED CAPACITY-BUILDING AND AWARENESS PROGRAMME

Provide targeted training opportunities for women and youth in clean energy technologies and related fields based on the contextual analysis.

Promote women's enrolment in STEM fields and support traineeships and mentorship programmes.

Define a monitoring and evaluation plan. The monitoring process can achieve a more robust understanding of gender disparities by including a gender expert in the implementation team or by prioritising gender sensitisation training for partner organisations.

Integrate gender impact in regular communications including newsletters, reports, social media platforms and websites.

CHAPTER SIX

FINANCING THE NET-ZERO TRANSITION

Financing Barbados' net-zero transition is envisioned through a combination of **private- and public-sector capital and de-risking instruments**. Meeting Barbados' net-zero investment needs will require a concerted effort to mobilise finance from a range of sources, both domestic and international. Barbados will need to increase domestic resource mobilisation through fiscal reforms and the development of local capital markets; it could consider establishing a National Climate Fund to effectively blend and deploy climate finance. International public finance, including from multilateral development banks and climate funds, could be used to catalyse private investment through blended finance instruments and risk-sharing mechanisms. The creation of the Blue-Green Investment Corporation (BGIC), supported by USAID and Green Climate Fund, to channel funding towards climate-related projects is a welcome step in this regard. Finally, private-sector investment would need to be encouraged through the development of green financial products and services, and the BGIC can help coordinate and facilitate investment. Barbados should investigate developing a green finance strategy to facilitate mobilisation of private capital into green technologies while providing transparency and information to market participants to assess opportunities and risks effectively.

Key private-sector contributors include commercial financial institutions such as the Barbados Commercial Bank, First Caribbean International Bank, and The Bank of Nova Scotia, as well as corporations like Marriot International and Sagicor Life Insurance. Households and individuals would also play a role mainly in the transport and buildings sector. Public-sector involvement comes from domestic institutions like the Barbados Ministry of Finance, which will be crucial in providing foundational support. All these institutions are expected to contribute to financing the transition, with a focus on economic returns.

International institutions are expected to play a role regarding de-risking instruments. This includes international multilateral development finance institutions (DFIs) like the World Bank, the Inter-American Development Bank, and the Caribbean Development Bank, alongside bilateral DFIs such as the EU and the UK Foreign, Commonwealth and Development Office (FCDO). Furthermore, multilateral green finance funds including the Green Climate Fund, Global Environment Facility, and the Adaptation Fund, would need to provide targeted green financing. The recently established BGIC is also expected to play a key role in financing private and public projects through the financing of green bonds and other capital market instruments. Along with the above, private foundations, such as The Rockefeller Foundation, ClimateWorks Foundation, and the Bezos Earth Fund, can contribute to the financing of net zero with a focus on both economic returns and environmental impact.

The above-mentioned list of investment and financing stakeholders may not be comprehensive, and a more detailed stakeholder mapping should be considered as an exercise to develop a targeted engagement strategy based on the stakeholders and their investment and financing interest in the energy transition of Barbados.

6.1 Capital Markets

Capital markets could provide the largest funding pool for Barbados' energy transition projects, although some of these projects would require de-risking measures to attract investment. The power sector would require significant investments of up to BBD 413 million in the period 2020 to 2030 for scaling up utility-scale renewables with state-owned enterprises (SOEs) and private companies taking the lead in deploying the investment, and commercial financial institutions, corporations, and the domestic public sector as sources to fund the archetype. This may also be supported by existing government-owned grid infrastructure. The main source of financing for this would need to be from commercial finance institutions and corporations, with SOEs and private companies leading the deployment and de-risking required from public-sector sources. In the same period 2020–2030, utility-scale fossil power plants would require BBD 337 million and it is expected that medium- to large-scale projects would continue to remain attractive to investors. This archetype is expected to have the same funding sources as utility-scale renewable power plants and would require de-risking. Cost-effective battery storage for balancing is forecasted to need BBD 57 million by 2030; a public-private model deploys these investments. Between 2030 and 2040, investments requirements in utility-scale renewables would ramp down to BBD 94 million mainly for solar PV projects. No investment requirements are foreseen for utility-scale fossil fuel power plants or battery-storage technologies in this period, as hydrogen production and storage would enter the power mix.

The transport sector requires substantial investment for the adoption of electric vehicles (EVs), including BBD 4,828 million for electric cars and motorcycles, BBD 1,151 million for battery electric vehicle (BEV) bus fleets and BBD 1,530 million for electric trucks. Households would be the primary consumers for deploying EVs and motorbikes, while SOEs and private companies would be the primary drivers for deploying the investments for BEV bus fleets and electric trucks. The deployment of these vehicles will mainly rely on commercial financial institutions and corporations, with the household sector financing electric cars and motorbikes. Hydrogen-powered light trucks are expected to require BBD 512 million in investments over the period 2030–2040 mainly driven by balance-sheet financing from private companies. EVs and motorbikes will rely on the domestic debt market, complemented by government subsidies. A key area of government and public-private partnership spending would be charging infrastructure. Expanding the BEV bus fleet would require public-private partnerships with SOEs and private companies being the primary drivers of investments. Electric trucks and hydrogen-fuelled vehicles, in particular, present scalable opportunities that could be suitable for capital markets, especially with government incentives from 2030 onwards.

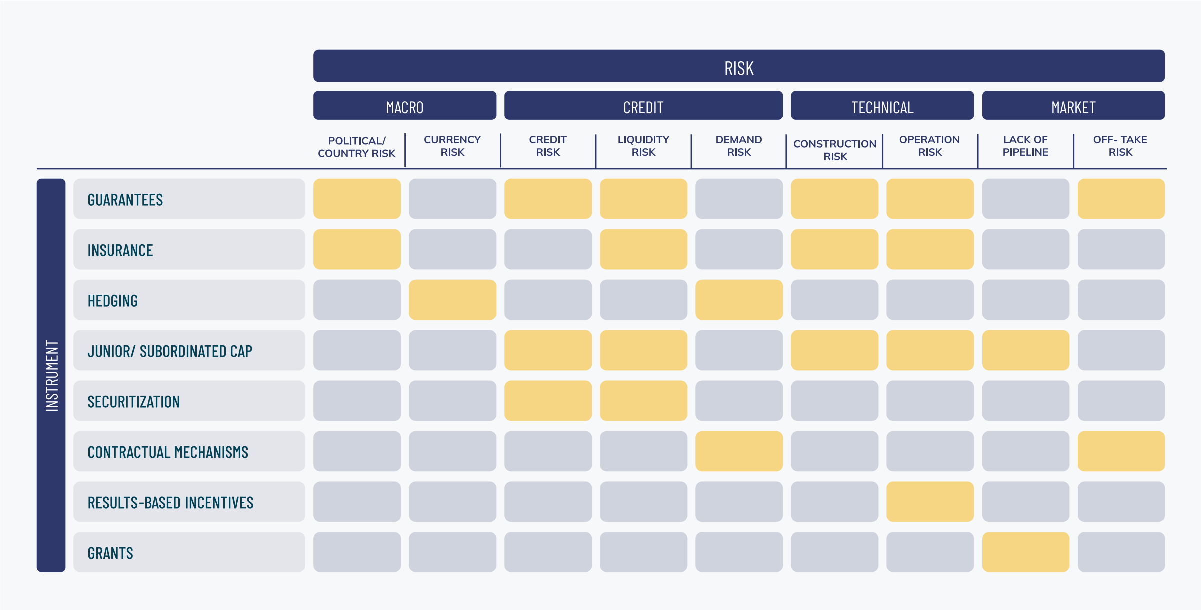
From 2020 to 2030, the industry sector needs BBD 71 million for projects like industrial biofuels, energy efficiency and bioenergy with carbon capture and storage (BECCS), which is expected to decrease to BBD 38 million from 2030 to 2040. SOEs and private companies, supported by commercial financial institutions and corporations, are the main sources for deploying this investment. These projects may be appealing to international capital as the technology matures but will require de-risking and incentives.

For clean cookstoves, BBD 107 million is required from 2020 to 2030, and BBD 123 million from 2030 to 2035, with private companies and consumers from the household sector driving the investment, with support through de-risking instruments and subsidies. Hydrogen production and storage would require BBD 143 million in the period 2030–2040, with private companies expected to invest with financing from commercial financial institutions. Further, these scalable projects would be attractive for capital markets but would require de-risking measures from the public sector.

6.2 De-risking Instruments

To achieve a net-zero transition, blended finance and other de-risking instruments can help reduce perceived investment risk and attract private capital. There is a suite of de-risking instruments available, and each instrument addresses a particular type of risk. The instrument must be designed closely in discussion with relevant stakeholders. Eight de-risking instruments have been identified for Barbados: **guarantees, insurance, hedging, junior/subordinated cap, securitisation, contractual mechanisms, results-based incentives, and grants**. These de-risking instruments address a range of risks within the nation such as country risk, credit risk, construction risk and off-take risk, and are summarised in the diagram below.

Figure 50: List of de-risking instruments and the risk they address



In the power sector, the establishment and upgrade of grid infrastructure, the development of utility-scale renewable and conventional power plants, and the integration of batteries for energy balancing all require substantial de-risking, particularly from macro and market perspectives. Potential de-risking for all these archetypes includes guarantees, insurance, hedging, junior or subordinated capital, contractual mechanisms, and grants.

In the transport sector, the introduction of EVs and e-motorcycles, BEV bus fleets, electric trucks and hydrogen light trucks require guarantees, insurance and hedging to mitigate macro and credit risks. Some, like EVs, electric trucks, and hydrogen light trucks would also benefit from junior or subordinate capital, securitisation, and contractual mechanisms to further alleviate investment concerns. Hydrogen vehicles, facing high overall risk, may also need grants as an additional de-risking measure.

For the industry sector, specifically for industrial biofuel projects that incorporate carbon capture and storage (CCS), there is a high requirement for de-risking across macro and technical aspects. Suitable de-risking interventions include guarantees, insurance, hedging and the provision of junior or subordinated capital.

Clean cookstove projects within the cooking sector face a high level of macro, credit, and market risks. To address these risks, potential de-risking interventions include guarantees, insurance, hedging, junior or subordinate capital, contractual mechanisms, and grants.

Hydrogen production and storage of green and blue hydrogen is expected to have a high macro, technical and market risk. This requires a range of de-risking interventions such as guarantees, insurance, hedging, junior or subordinated capital, contractual mechanisms, and grants to attract investment.

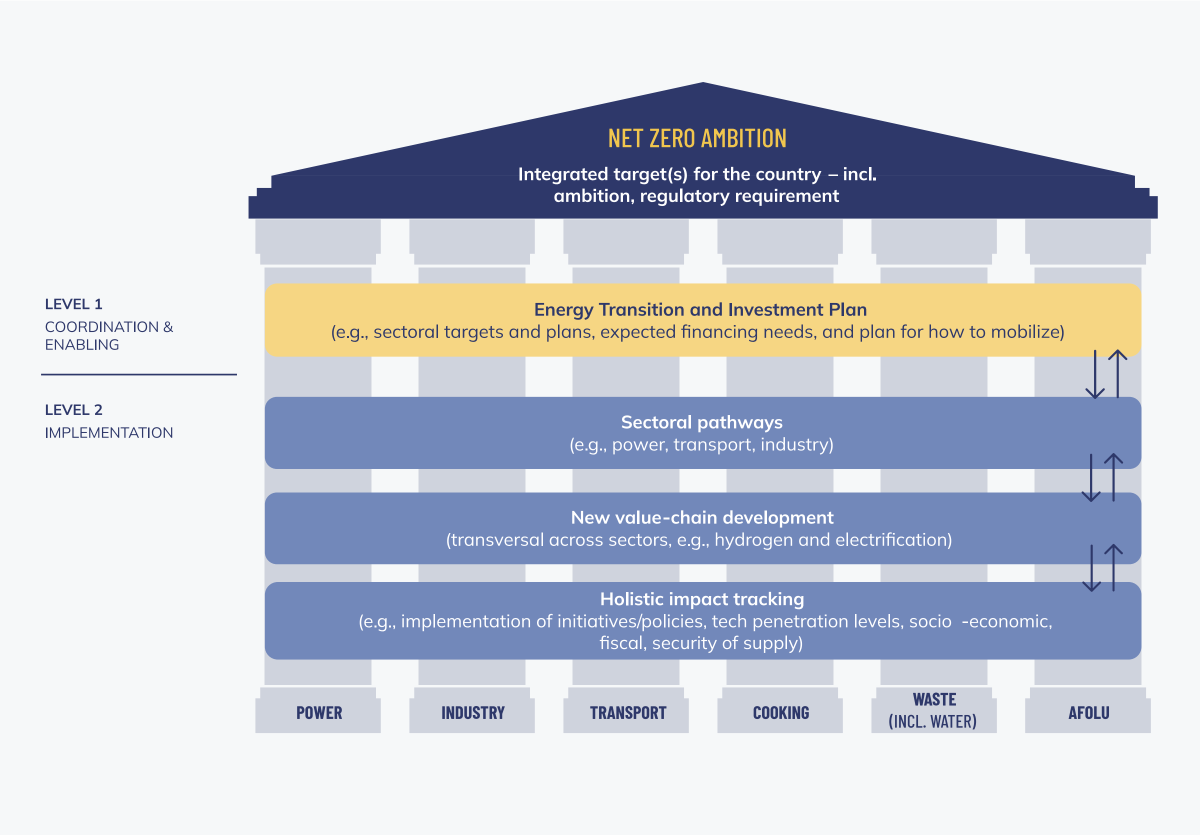
CHAPTER SEVEN

THE PATH FORWARD

7.1 Institutional Structure

To successfully implement the net-zero emissions (NZE) ambition, a best-practice governance structure, process and action plan is required. Figure 51 presents a two-level framework for achieving NZE by 2035. At Level 1, *Coordination and Enabling*, an Energy Transition Investment Plan (ETIP) should be established to ensure transparency and coordination across ministries, aligning sectoral policies with national objectives. This level further requires the need for an energy transition office to drive progress. Level 2, *Implementation*, requires action from both private and public actors responsible for implementing sector-specific mandates. This includes developing sectoral pathways with clear mechanisms for accountability owned by relevant ministries and working collaboratively towards the overall national target. It also involves the development of new technology and fuel platforms, like carbon capture and storage (CCS) and holistic impact tracking, including emission impacts and ensuring a just transition economically and fiscally. The framework should be applied across all sectors for a successful energy transition.

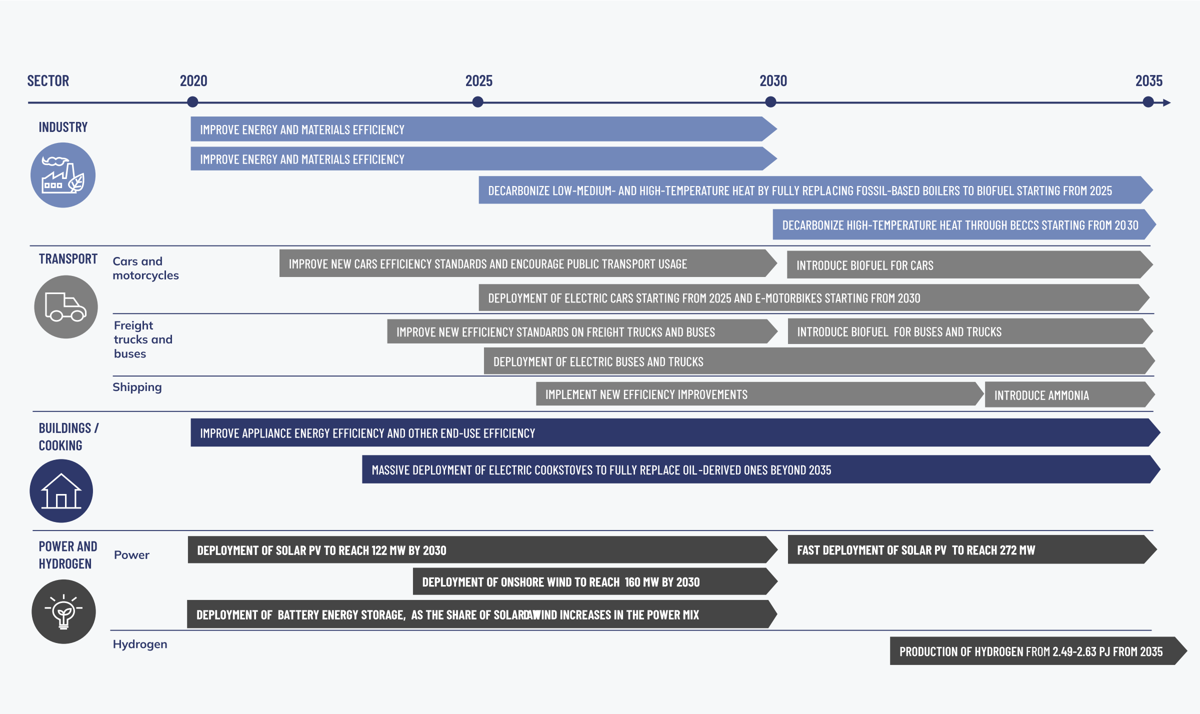
Figure 51: Potential governance structure for a net-zero ambition



7.2 Policy Actions

A set of technology transitions will also be needed to aid Level 2 *Implementation and* achieve NZE. In the industry sector, the goal is to improve efficiency and start using biofuel for heat processes. Adopting biomass CCS in 2030 will further reduce emissions. For transport, the plan includes introducing more efficient cars and public transport, with a transition to electric vehicles (EVs) and biofuels. The efficiency standards of freight vehicles are also projected to rise with a switch to biofuels and hydrogen. In the building sector, there are plans to increase appliance efficiency, with a move towards electric cookstoves by 2035. Finally, the power sector aims for high growth in solar and wind energy, while hydrogen strategies will focus on storage solutions and produce green and blue hydrogen to supply 20 percent of power by 2035. These high-level action plans are summarised with a timeline schedule below. Further, the following subsections highlight the Level 2 *Implementation* key sectoral policies highlighting the possible obstacles that come with them and further explore them though subsector action plans as a separate exercise.

Figure 52: A set of technologies and their timelines to achieve NZE



Power

The power sector faces significant obstacles including the need for battery storage to accommodate the large-scale implementation of intermittent solar PV and wind energy. This leads to a high-cost premium and potential suppression of electricity market prices, which may deter investors.

To address these challenges, a combination of economic incentives, enabling programmes and regulatory actions are crucial. Price incentives or regulatory measures should build on the ambition of the Barbados National Energy Policy (BNEP) to speed up the adoption of solar PV and wind technologies. As per stakeholder feedback, the Barbados Fair Trade Commission has assessed the levelised cost of storage (LCOS) for battery energy storage systems (BESS) and further policy incentive frameworks for BESS could be explored. There could be an option for solar PV and BESS combined reverse auction for which a framework would need to be developed with the support of the international community. CCS technology also carries a high capital investment and may need additional land and water needs. There is a need to request more support from technology providers and technology platforms to pilot CCS for the context of Small Island Developing States (SIDS).

Policies and programmes should also focus on grid efficiency and strengthening, incorporating other programmes to enhance demand flexibility to better manage solar and wind energy integration. In addition to a robust transmission and distribution expansion and strengthening plan, a demand flexibility assessment needs to be undertaken for Barbados to understand the in-depth effective policy, programmes and price that are available to manage peak demand and utilise its renewable energy sources to the fullest extent possible.

Localisation of key supply-chain technologies such as assembly of solar PV modules, batteries and e-motorcycles can greatly reduce the capital and operation and maintenance (O&M) costs for renewable projects not only in Barbados but also in the entire region. For this it is recommended to further explore a renewable energy manufacturing strategy for the country.

Transport

Obstacles in the transport sector include the high costs of low-carbon shipping fuels, and high capital costs of electric and hydrogen vehicles. Additionally, consumer preferences heavily influence the adoption of electric vehicles (EVs), and the limited availability of charging infrastructure could slow the market growth for low-emission vehicles.

A combination of economic incentives and enabling programmes is essential to navigate these obstacles. Price incentives or regulations could be utilised to encourage the use of low-carbon fuels, especially near ports and airports. A national electric mobility roadmap could also offer incentives that motivate consumers to shift to electric and fuel-cell vehicles, such as tax credits, low-emission zones and benefits like free parking or lower vehicle registration costs. Enabling programmes are also important for developing and implementing a delivery plan for EV charging infrastructure. This plan would include grid assessments, establishing a supportive regulatory framework, incentivising home charging, and fostering partnerships with the private sector. Furthermore, vehicle efficiency and public transport, like buses and trains, should be promoted where possible.

It is also important to address the impact of used vehicles on the Barbados economy and the environment. Public policy needs to raise awareness of the lifetime costs of such vehicles. Additionally, the need to promote a modal shift from private to public road transportation cannot be understated, not only in the interest of energy and climate but also for road traffic management for the island nation in the future.

There also needs to be a policy in place to promote green tourism to address the environmental effects of shipping and cruise lines and encourage shipping companies to participate in them.

Industry

The industry sector has several obstacles that need to be overcome. These include the costs associated with hydrogen processes and biofuel integration; the high expense of applying bioenergy with carbon capture and storage (BECCS); and the high capital investments required for heat pumps used in low-temperature heat processes.

To address these challenges, a combination of regulatory actions, economic incentives and enabling programmes in the form of energy-efficiency standards, technology transfer collaborations and programmes driven by energy service companies (ESCOs) are proposed. Regulations and standards are needed to mandate leak detection and repair gas-fired and oil boilers to cut methane emissions and to set strict energy-efficiency standards, particularly for industrial motors and boilers. There should also be an insistence on using heat pumps where possible for new industries or major renovations.

Economic measures should include the development of a framework that encourages industries to shift from fossil fuels to electricity in their operations along with process efficiency. An ESCO programme targeting specific industries could be considered to drive such measures and reduce technological and financial risks. A technology collaboration programme would be essential to demonstrate and mobilise investments in clean technologies like BECCS and CCS. This is particularly important based on the Barbados' Industry 5.0 outlook,[3] if the country is expecting to develop more energy-intensive industries such as pharmaceuticals, hydrogen for export and cleantech.

Additionally, enabling programmes should be implemented to build a market for decarbonized products for domestic and international markets, which includes collaboration with manufacturers and distributors to reduce costs and improve supply chains. To further aid this, mid-term infrastructure plans that account for new value chains could be developed to help private-sector players anticipate the decarbonization options available.

Residential & Commercial (Buildings)

The cooking and building sectors have a set of obstacles that include high energy costs of modern, low-carbon cooking equipment such as electric cookstoves. Additionally, consumers may not be fully informed about the long-term benefits and cost savings that energy-efficient appliances offer. The market itself also has limited options available for energy-efficient appliances, limiting consumer choice. Lastly, existing regulations and standards may not reflect the latest advancements in energy-efficient technologies.

To counter these obstacles, a combination of economic incentives, regulatory actions, public-private partnerships, and enabling programmes is key. Firstly, financial incentives such as providing grants, loans and subsidies could help reduce the cost of capital-intensive appliances like electric stoves. On the regulatory front, setting policies to reinforce the adoption of modern cooking solutions, such as mandating electric stoves in new buildings could be beneficial. A national e-cooking strategy could be explored to identify further how these actions could be set up.

For other major appliances such as lighting, refrigerators and air conditioners, standards for both commercial and residential consumers could establish and enforce mandatory energy performance standards. These should be accompanied by clear energy labelling to further improve the energy efficiency of electrical appliances.

Public-private partnerships can be crucial by fostering collaborative efforts between the government, utility companies, manufacturers, and other stakeholders to promote and support

3 As discussed with EXPORT BARBADOS in the national stakeholder workshop on Barbados ETIP in April 2023.

energy-efficiency initiatives. Additionally, public awareness campaigns can be implemented to educate consumers and businesses about the benefits of energy-efficient appliances, which can not only lead to cost savings but also contribute to the NZE goals.

Lastly, Barbados needs to develop a mandatory building energy code and implementation strategy and ensure that both new buildings and existing ones are performing under a specific energy consumption framework to reduce their energy bills and their carbon footprint. These mandatory national standards could be built on the CARICOM Regional Energy Efficiency Building Code (CREEBC) and air conditioner, refrigerator, and appliances standards. The energy-efficiency standards for the refrigerants in cooling equipment and insulation blowing agents should be synergised with the Kigali Amendment to phase out hydrofluorocarbons (HFCs) – very powerful, short-lived climate pollutants.

Agriculture

The key obstacles to enabling energy efficiency and adoption of renewable energy for motive power and irrigation in the agriculture sector are the high upfront costs of energy-efficiency pumps and tillers. Additionally, if these systems are not supplied through electricity there are limited options for low-carbon alternative fuels such as sustainable biofuels.

More detailed assessments of the sector's major agro-food production and processing industries and assets need to be undertaken to evaluate baseline energy consumption and processes to identify where large ESCO-led programmes could be undertaken to address waste to energy, energy efficiency of end-use equipment and electrification of motive power. Green financing could also be developed for enterprises that would like to upgrade their operations and become more cost competitive.

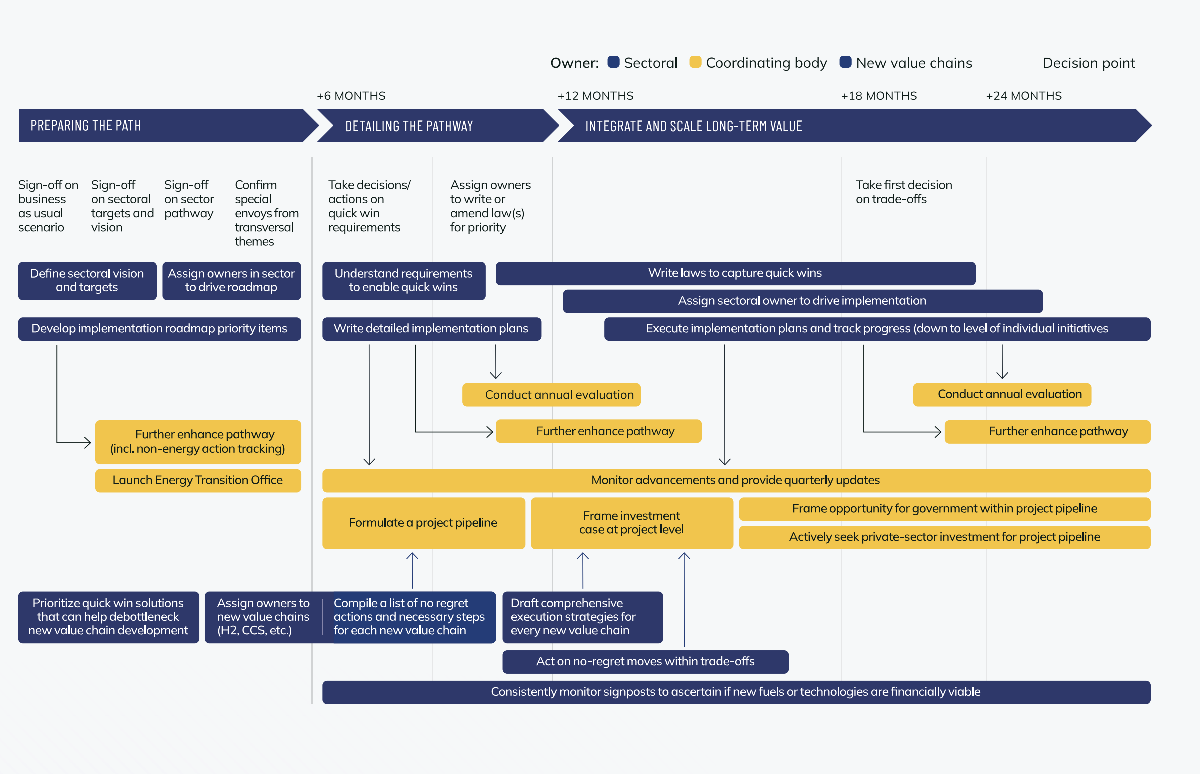
Finally, the role of sustainable biofuels needs to be further investigated and elevated in the energy transition policy framework for Barbados. It is important that there is a long-term strategy that ensures domestication of sustainable biofuels with sufficient supply for energy security and cheaper transition to net zero.

7.3 Roadmap for action

Figure 53 details a potential strategic roadmap for the government's coordinating body, relevant ministries and new value chains over 24 months that can support Barbados in achieving net zero by 2035. Initially, the *Preparing the path* phase involves a sign-off on the business-as-usual (BAU) scenario, sectoral targets, and sectoral pathway visions. This sets the groundwork for developing implementation roadmap priority items within the relevant government ministries and launching the Energy Transition Office. Further, prioritisation of quick-win solutions would help debottleneck new value chain development.

In the subsequent six months, *Detailing the pathway* involves making quick-win decisions and assigning owners to arm or execute priority laws. Detailed implementation plans are crafted by the relevant sectors, whilst considering the quick wins. At the 12-month mark, during the *Integrate and scale long-term value* phase, efforts focus on writing laws to capture quick wins, formulating a project pipeline, assigning sectoral owners to drive implementation, and executing plans. Tracking progress down to individual initiatives is essential, and this is complemented by annual evaluations and continuous enhancement of the pathway. After 18 months, the roadmap emphasises making decisions on trade-offs and framing investment cases at the project level. This includes actively seeking private-sector investments and framing opportunities for government involvement within the project pipeline. The final six months focus on executing no-regret actions and consistently monitoring for new, financially viable fuels or technologies, ensuring ongoing enhancement and responsiveness to the evolving energy landscape.

Figure 53: Indicative roadmap for a net-zero implementation rollout



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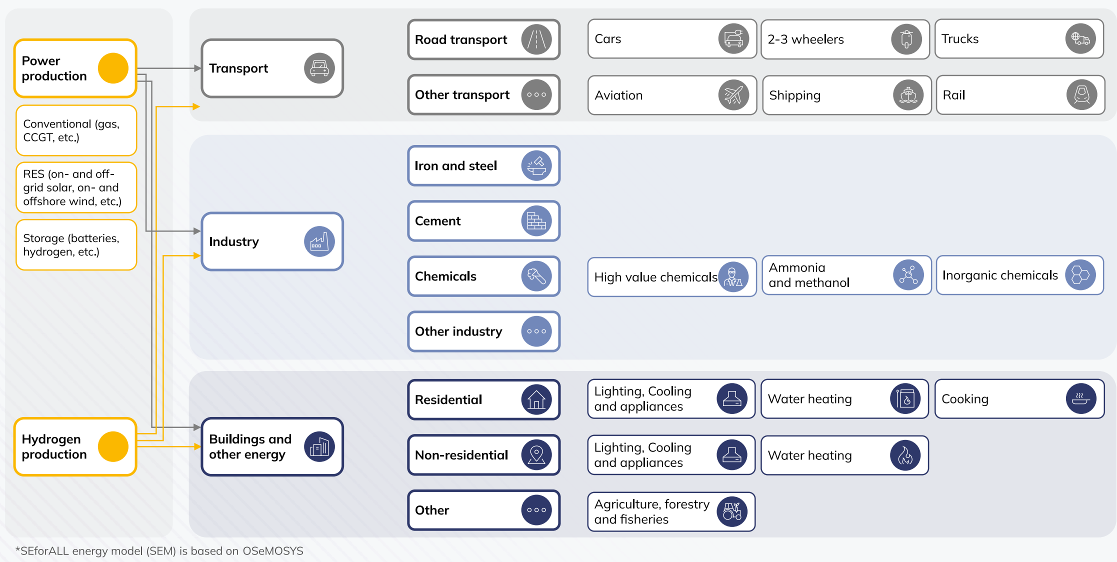
Monetary values in USD were converted to BBD and 2020 prices using the GDP deflator.

APPENDIX A:
Sustainable Energy for All Energy System Model (SEM)

The Sustainable Energy for All (SEforALL) Energy System Model (SEM) is an open-access optimisation modelling framework for medium- to long-term energy planning that covers all sectors of the economy (power, transport, industries, buildings, cooking, and agriculture). It can provide insights on possible transformation pathways of large energy systems and their impacts on the economy, society, and the environment. It is a bottom-up modelling framework that uses linear-optimisation techniques to satisfy exogenously defined energy demands for the various sectors. The objective function equation consists of the sum of discounted operational and capital costs. The energy system consists of final energy demands distinguished between various end-use services, power generation technologies (centralised and decentralised), transmission and distribution networks, energy trade links and conversion technologies. The modelling results can include power generation capacity, production by technology, capital investments, operation, and maintenance (O&M) costs and emissions on an annual level with a timely resolution for some of the variables. The SEM model has been employed in developing energy and transition investment plans for various countries and in capacity-building activities for energy planners to provide policy insights on energy-transformation trajectories. The SEM model and the analysis are transferred to the respective countries to assist in overcoming the lack of transparency needed to address future long-term decarbonization trajectories. The structure of the SEM framework is presented below (Figure 54). The model is tailored for each sector and subsectors depending on the country's energy challenges.

Figure 54: Structure of the SEM framework



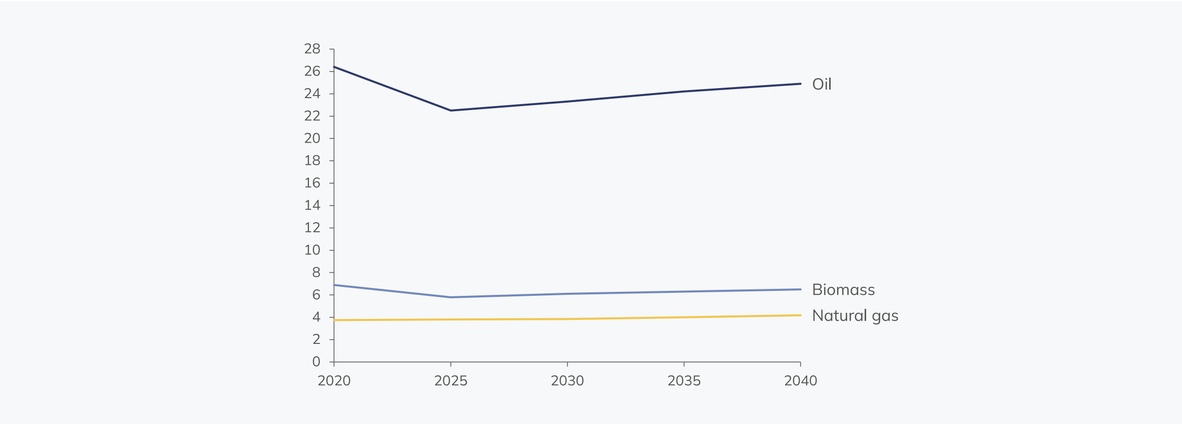
APPENDIX B:
Modelling Methodology and Key Assumptions

B.1 Overview

Fuel Cost

The fuel costs of oil, biomass and natural gas are expected to increase at a similar rate over the modelling period. Oil and biomass prices are expected to see a slight decrease in 2025, however, this value increases thereafter. Overall, oil is the most expensive fuel, and natural gas the cheapest.

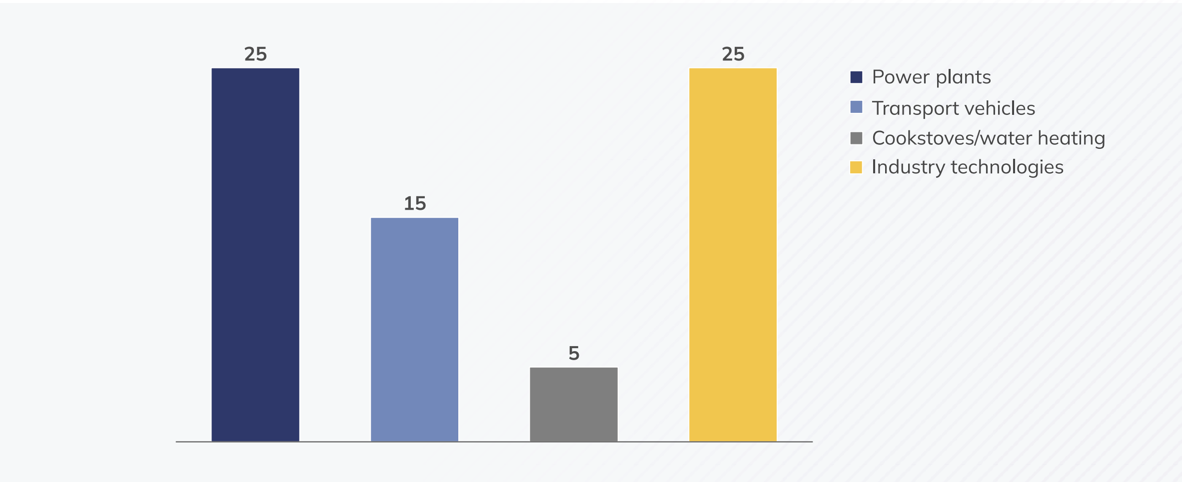
Figure 55: Fuel cost (USD/GJ)



Lifetime of Technologies

All power plant and industry technologies are assumed to have an operational lifetime of 25 years – the longest in the model. All transport vehicle technologies are modelled to have an operation lifetime of 15 years. All cookstoves/water heating technologies are assumed to have an operational lifetime of five years – the lowest in the model.

Figure 56: Lifetime of technologies (years)

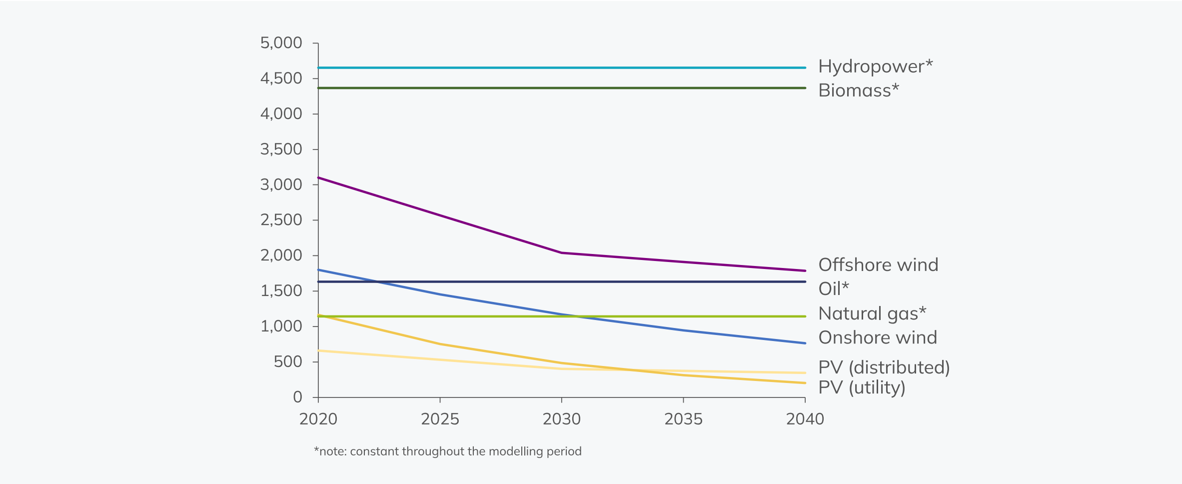


B.2 Power Sector

Capital Cost

Overall, the capital costs of offshore wind, onshore wind, solar PV (utility) and solar PV (distributed) are expected to decrease over the modelling period of 2020 to 2040. Offshore wind is expected to decrease the most in terms of capital cost, at almost a half, from USD 3,100/kW in 2020 to USD 1,785/kW in 2040. Hydropower, biomass, natural gas, and oil power plants are expected to stay at the same capital cost, at USD 4,650, USD 4,367, USD 1,141 and USD 1,631/kW, respectively.

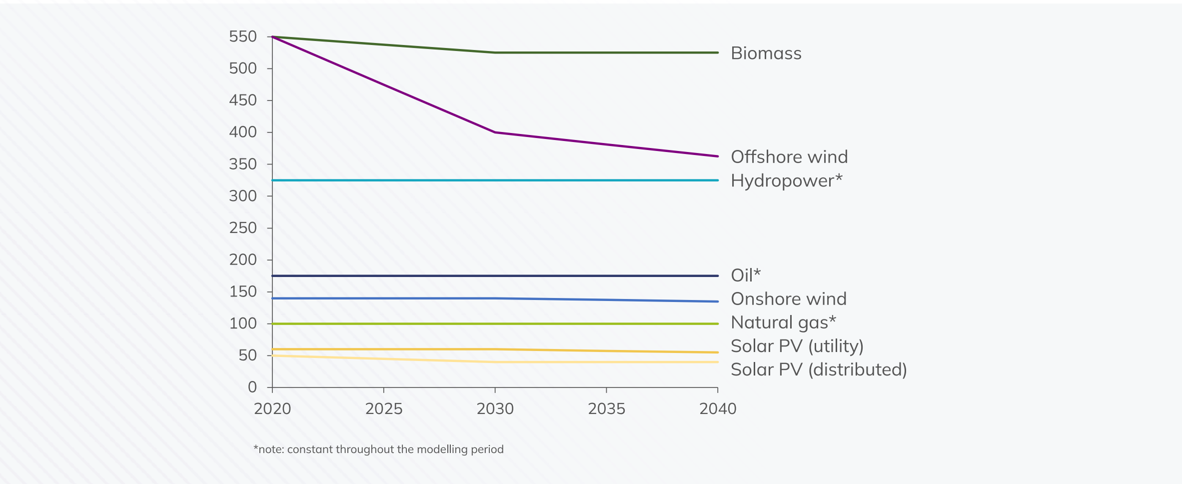
Figure 57: Capital cost of selected technologies in the power sector (USD/kW)



Fixed Cost

Overall, the fixed costs of biomass, offshore wind, onshore wind, solar PV (utility) and solar PV (distributed) are expected to decrease over the modelling period. Offshore wind is expected to decrease the most, from USD 550/kW in 2020 to USD 362.5/kW in 2040. Hydropower, oil and natural gas fixed costs are assumed to stay constant throughout the modelling period at USD 325, USD 100, and USD175/kW per year, respectively.

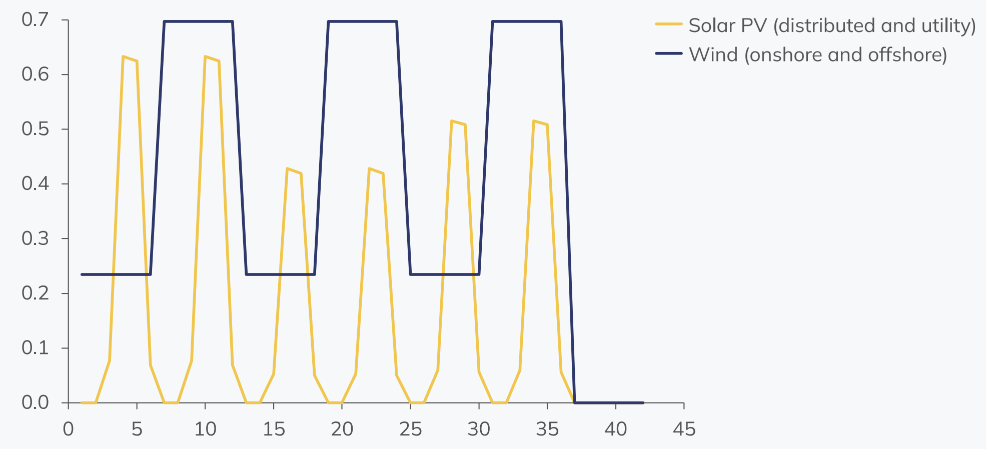
Figure 58: Fixed cost of renewable technologies in the power sector (USD/kW/yr)



Capacity Factors

Overall, wind technologies are expected to have a higher maximum capacity than solar, at 23 percent and 70 percent at various time slices. Solar PV technologies are assumed to have a varying pattern, reaching roughly 63 percent, 41 percent, and 50 percent at various time slices. From time slice 37 onwards, where renewables do not operate, the maximum capacity for both wind and solar PV technologies is expected to be 0 percent.

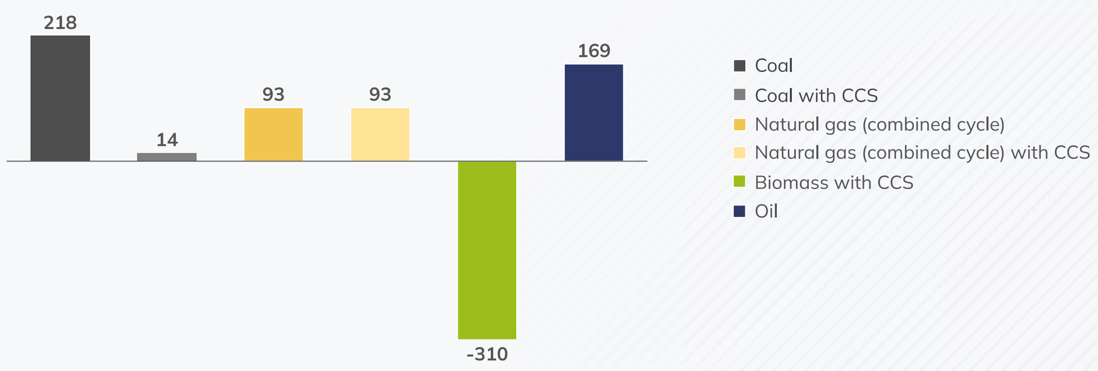
Figure 59: Maximum capacity factor of power plant technologies (%)



Emission Factors

Coal has the highest emission factor, at 218 kt CO_2/PJ. This is followed by oil, at 169 kt CO_2/PJ. Natural gas with and without carbon capture and storage (CCS) is assumed to have the same emission factor, at 93 kt CO_2/PJ. Coal emits the least amount of carbon emissions, at 14 kt CO_2/PJ. Alternatively, biomass with CCS can save 310 kt CO_2/PJ of emissions.

Figure 60: Emission factors for the power sector (kt CO2/PJ)



B.3 Transport Sector

Motorcycles

Capital and fixed costs of liquid and natural gas-fuelled motorcycles are expected to stay the same at USD 6,700 and USD 0.3 USD/per vehicle per year, respectively, throughout the modelling period. Fixed costs of electric motorbikes are also projected to stay constant, at USD 300 per vehicle. Capital costs of electric motorcycles are expected to decrease from USD 8,800 in 2020 to USD 8,200 in 2040 per vehicle.

Figure 61: Capital cost of motorcycles (thousand USD/vehicle)

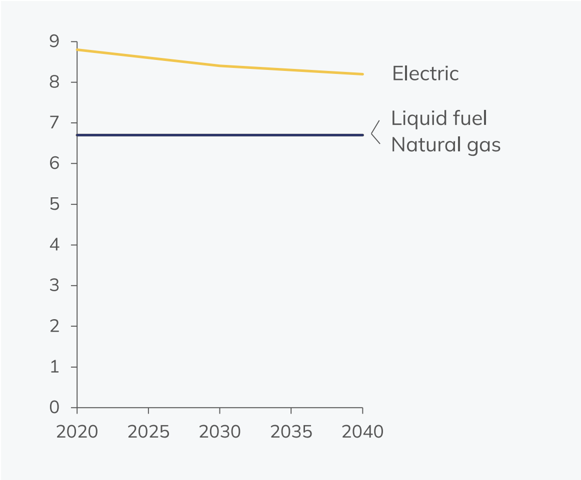
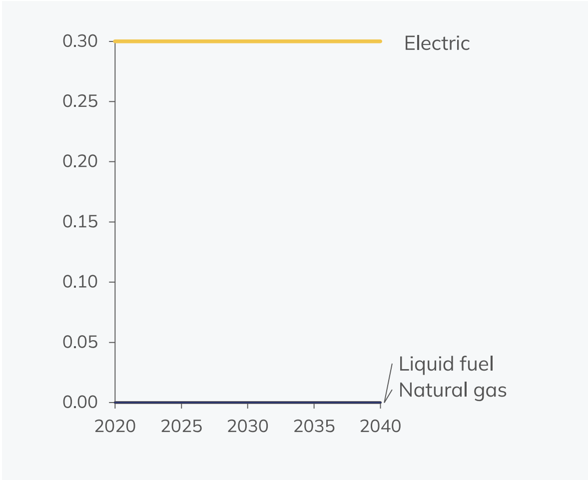


Figure 62: Fixed cost of motorcycles (thousand USD/vehicle/yr)



Cars

Capital costs of liquid fuel and natural gas cars are expected to stay the same at USD 19,500 and USD 21,500 throughout the modelling period. Capital costs of both hydrogen and electric cars are expected to decrease from USD 50,700 to USD 43,200, and from USD 33,400 to USD 31,300, respectively. Fixed costs of hydrogen cars are assumed to decrease the most, from USD 2,400 in 2020 to USD 1,400 in 2040. Fixed costs of electric cars are also modelled to decrease to USD 1,100 in 2040.

Figure 63: Capital cost of cars (thousand USD/vehicle)

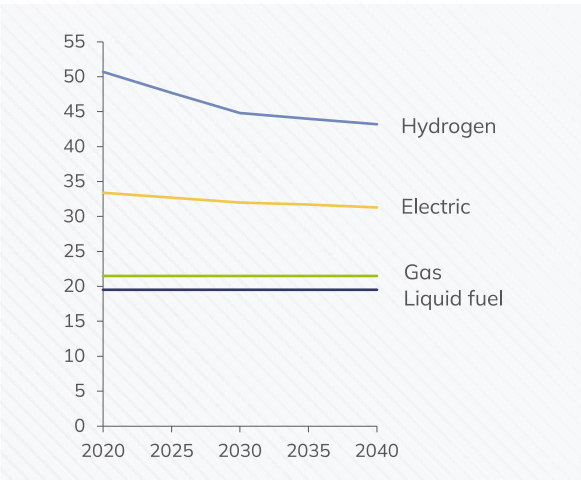
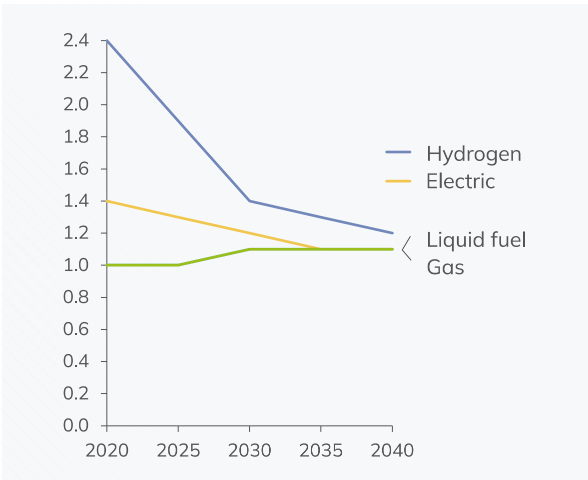


Figure 64: Fixed cost of cars (thousand USD/vehicles/yr)



Buses

Capital costs of liquid fuel and natural gas buses are expected to stay the same at USD 342,000 and USD 366,000, respectively, throughout the modelling period. Capital costs of both hydrogen and electric cars are expected to decrease to reach USD 1,364,000 and USD 404,000, respectively, in 2040. Fixed costs of hydrogen and electric cars are also assumed to decrease the most, to reach USD 7,400 and USD 7,800 per vehicle. Fixed costs of liquid fuel and gas buses are modelled to increase in costs at the same rate, with both reaching USD 6,300 in 2040.

Figure 65: Capital cost of buses (thousand USD/vehicle)

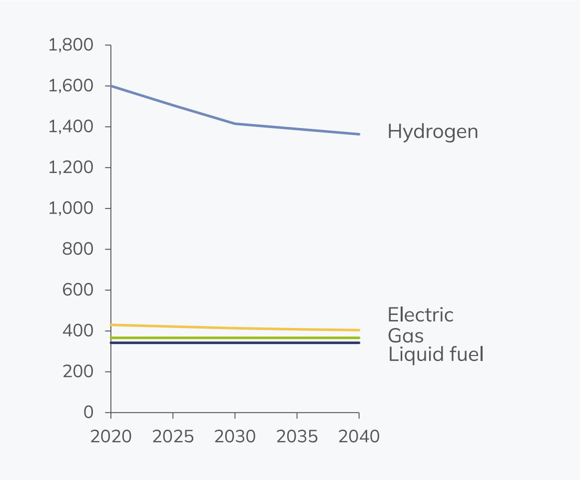
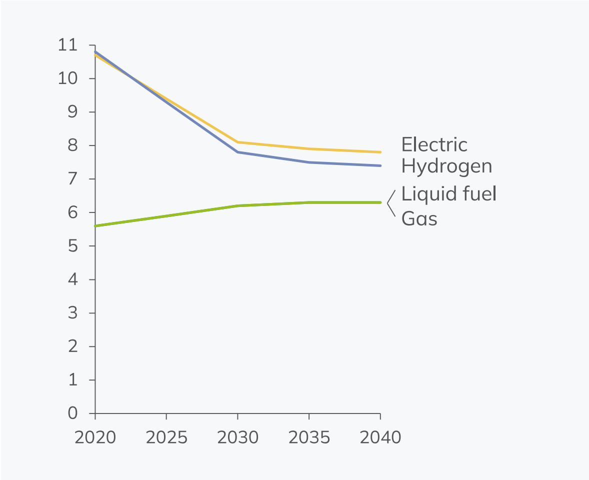


Figure 66: Fixed cost of buses (thousand USD/vehicles/yr)



Light trucks

Capital costs of liquid fuel and natural gas light trucks are expected to stay the same at USD 22,000 and USD 23,000, respectively, throughout the modelling period. Capital costs of both hydrogen and electric light trucks are expected to decrease to reach USD 46,400 and USD 50,400 respectively, in 2040. The fixed cost of H2 light trucks is expected to decrease the most, from USD 3,500 in 2020 to USD 1,700 in 2040. Fixed costs of liquid fuel and gas light trucks are modelled to increase in costs, with both reaching USD 1,400 in 2040.

Figure 67: Capital cost of light trucks (thousand USD/vehicle)

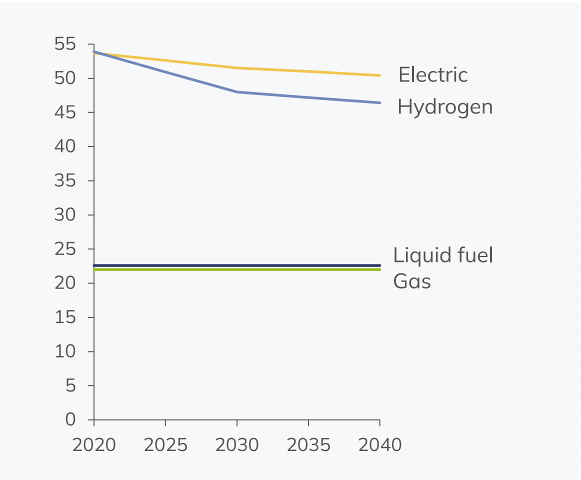
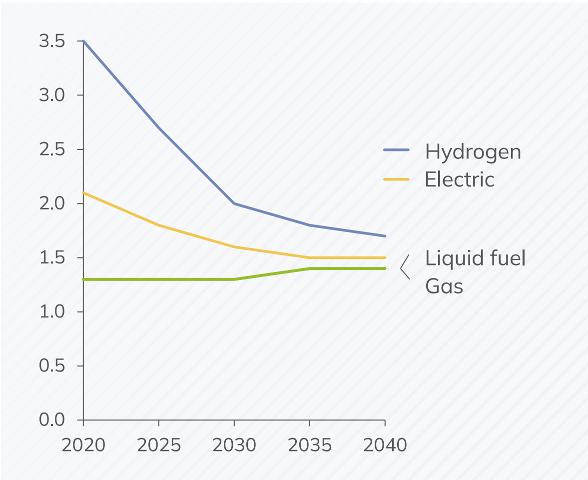


Figure 68: Fixed cost of light trucks (thousand USD/vehicle/yr)



Heavy trucks

Capital costs of liquid fuel and natural gas heavy trucks are expected to stay the same at USD 37,100 and USD 65,600, respectively, throughout the modelling period. Capital costs of hydrogen heavy trucks are expected to decrease the most from USD 290,000 in 2020 to USD 160,000 in 2040. The fixed cost of H2 land electric heavy trucks is expected to decrease to reach USD 7,100 and USD 7,000, respectively, in 2040. The fixed costs of liquid fuel and gas light trucks are modelled to increase in costs, with both reaching USD 5,300 in 2040.

Figure 69: Capital cost of heavy trucks (thousand USD/vehicle)

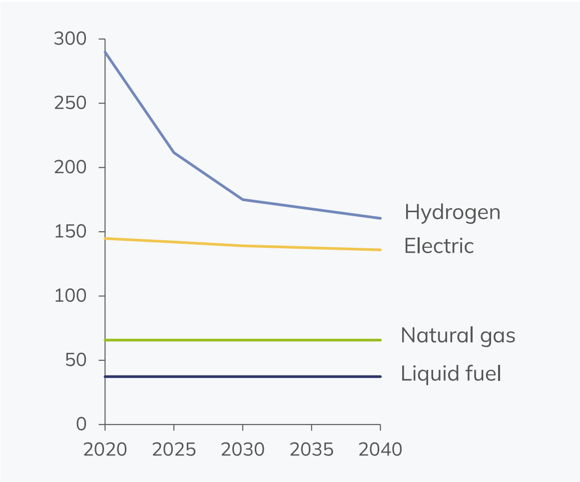
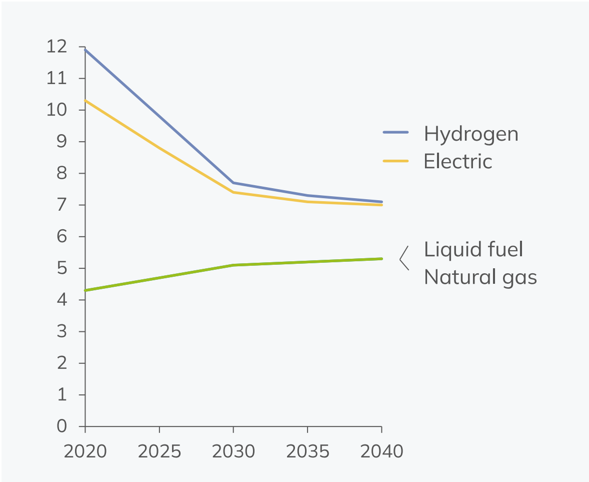


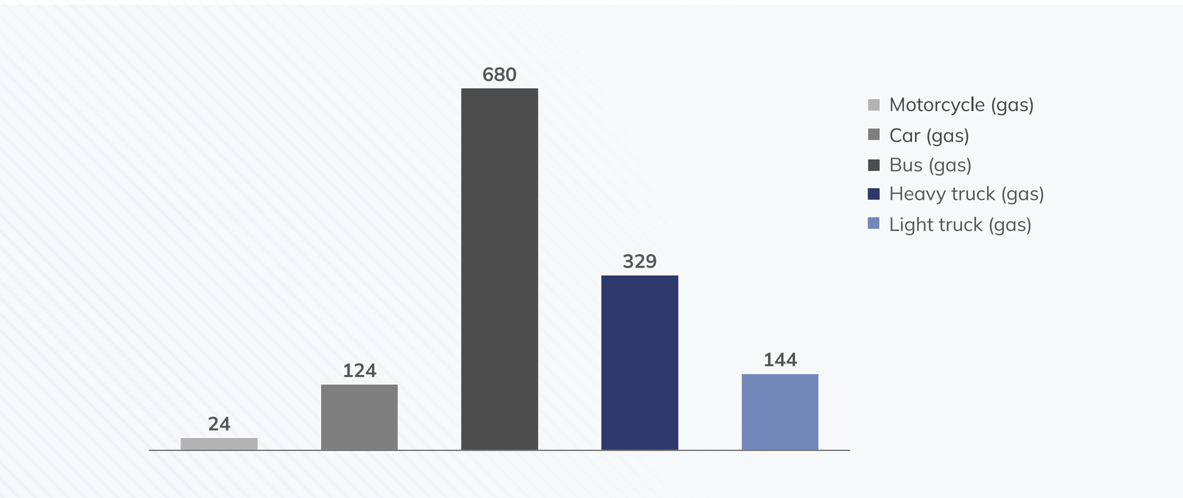
Figure 70: Fixed cost of heavy trucks (thousand USD/vehicle/yr)



Emission Factors

Only gas-fuelled transport technologies are modelled to have emission factors. Gas-fuelled buses are assumed to emit the most, at 680 kt CO_2/bn vehicle km. This is followed by gas-fuelled heavy trucks, at 329 kt CO_2/bn vehicle km. Gas-fuelled motorcycles are assumed to emit the least amount of carbon emissions, at 24 CO_2/bn vehicle per km.

Figure 71: Emission factors for the transport sector (kt CO2/bn vehicle km)



B.4 Residential & Commercial (Buildings) Sector

Residential Cooking

All residential cooking technologies are assumed to have a constant capital and fixed cost throughout the modelling period. Natural gas cooking technologies have the cheapest capital cost at USD 800 per unit but have the most expensive fixed cost at USD 250 per unit.

Figure 72: Capital cost of residential cooking (thousand USD/unit)

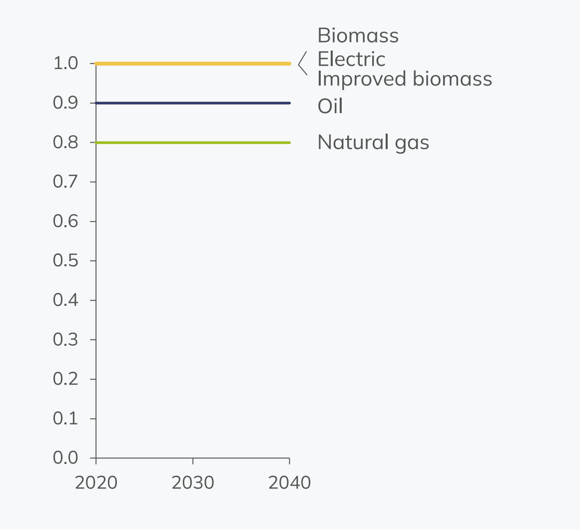
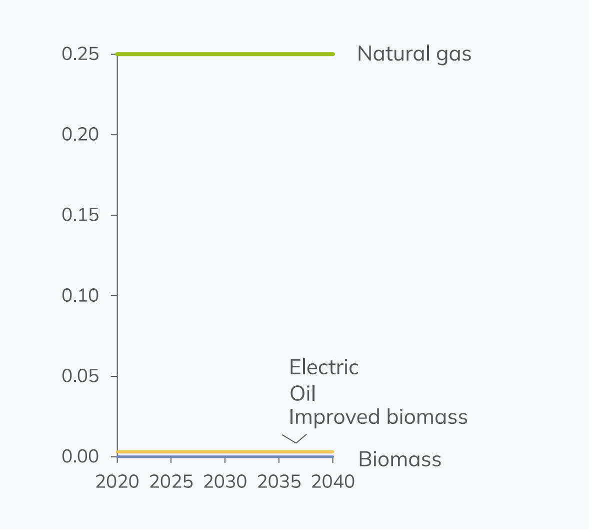


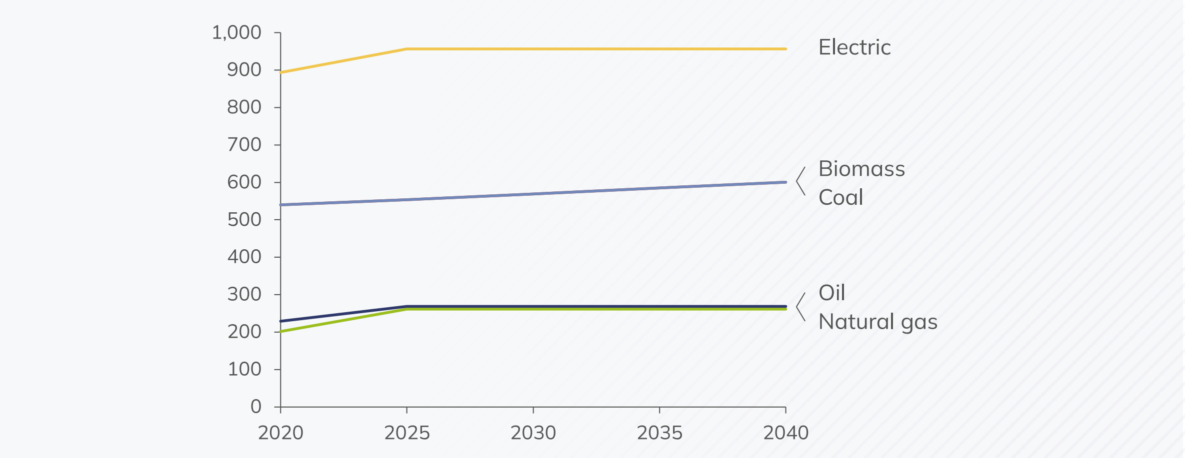
Figure 73: Fixed cost of residential cooking (thousand USD/unit/yr)



Residential Water Heating

Capital costs of all residential water heating systems are expected to increase throughout the modelling period. Overall, electric residential water heating is the most expensive technology, at USD 957/kW in 2040. Biomass and coal-fuelled residential water heating comes next, having the same growth rate and reaching USD 600/kW in 2040. Oil and natural gas-fuelled residential water heating are the cheapest, at USD 269 and USD 261/kW, respectively.

Figure 74: Capital cost of residential water heating (USD/kW)



note: no fixed cost for water heating in the residential sector was assumed

Commercial Water Heating

All capital costs of commercial water heating are modelled to increase from 2020 to 2040. Electric-fuelled commercial water heating is the most expensive in terms of capital cost, at USD 669/kW in 2040. Natural gas-fuelled commercial water heating is the cheapest, at USD 209/kW in 2040. All fixed costs for the different types of commercial water heating technologies are assumed to be the same at USD 11/kW/yr.

Figure 75: Capital cost of commercial water heating (USD/kW)

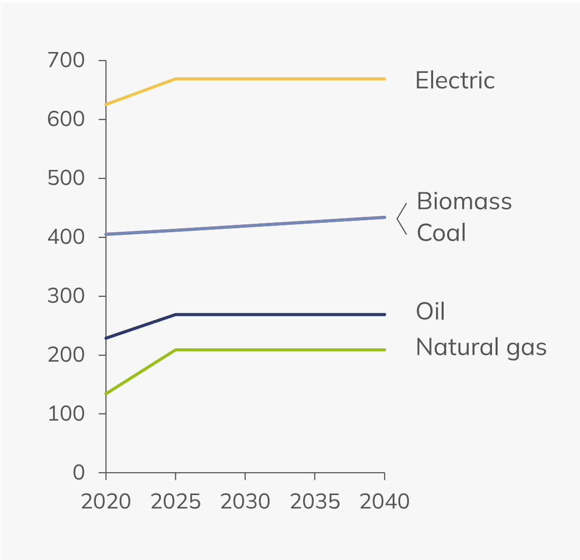
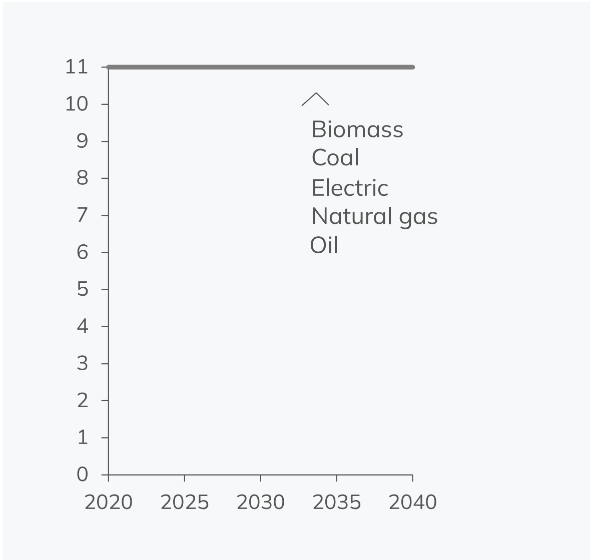


Figure 76: Fixed cost of commercial water heating (USD/kW/yr)



APPENDIX C:
Sensitivity Analysis Demand Results

C.1 Electricity Demand Levels

The growth rates used for high and low electricity demands are presented in Table 6.

Table 6: Growth rates for low and high electricity demand

YEAR	LOW ELECTRICITY DEMAND GROWTH RATE (%)	HIGH ELECTRICITY DEMAND GROWTH RATE (%)
2020	0	0
2025	-19.52	17.24
2030	-25.00	22.14
2035	-29.00	24.88
2040	-32.00	28.15

NZE 2035 with a low electricity demand: The total capacity decreases by 46 percent by 2040 due to lower investments in gas (-67 percent), solar (-29 percent) and hydrogen (-64 percent) technologies. As a result, the overall generation decreases by 28 percent by 2040. This change is primarily due to lower generation from hydrogen (-73 percent). Moreover, the overall industrial generation decreases by 29 percent due to lower demand, but the overall mix remains the same (biomass, biomass carbon capture and storage (CCS)). However, compared to the other scenarios investigated under the sensitivity analysis, there is a higher penetration of hydrogen in the transport sector from 2030 onwards when the fleet of light trucks switches to be hydrogen based, compared to hydrogen and electric in the base scenario. **Overall, the total system costs decrease by 5 percent due to lower investments in all sectors.**

NZE 2035 with a high electricity demand: The total capacity increases by only 1.4 percent due to higher investments in solar (49 percent) and lower investments in gas (47 percent) and hydrogen (45 percent) by 2040. Consequently, the overall generation increases by 17 percent due to higher generation from gas and solar PV, while hydrogen generation decreases. In industries, the generation decreases by 19 percent due to higher demand levels, but the overall profile remains the same (biomass, biomass CCS). Lastly, the total system costs decrease by 4 percent due to lower investments in the power, transport, and buildings sectors but slightly higher investments in industries as the demand increases.

NZE 2030 with a low electricity demand: The total power capacity increases by 27 percent by 2040 due to higher investments in gas (27 percent), biomass (29 percent) and hydrogen (75 percent) technologies. However, although the capacity increases between the scenarios the overall generation decreases by 33 percent by 2040. This is due to lower generation from biomass, biomass CCS, solar and wind onshore. Decreasing the industrial demand results in an overall decrease in the industrial supply mix of 14 percent by 2040 but the overall mix remains the same (biomass, biomass CCS). Consequently, the total system costs increase by 11 percent due to higher investments in the power and building sectors (water heaters).

NZE 2030 with a high electricity demand: The total capacity increases by 32 percent by 2040 due to higher investments in biomass (29 percent) and hydrogen (87 percent), however, gas capacity decreases by 54 percent. The electricity generation increases by 10 percent due to higher generation from biomass (34 percent) and solar (8 percent) as onshore wind is lower (-33 percent). In industries, the overall industrial generation slightly increases but the supply mix remains the same (biomass, biomass CCS). As a result, in this scenario, the total system costs increase by 18 percent by 2040 due to higher investments in the power, industries and building sectors.

Table 7: Demands for NZE 2030 and NZE 2035 under low and high electricity demand scenarios

	NZE 2030 (LOW)			NZE 2030 (HIGH)			NZE 2035 (LOW)			NZE 2035 (HIGH)		
PJ	Res.	Com.	Ind.	Res.	Com.	Ind.	Res.	Com.	Ind.	Res.	Com.	Ind.
2020	6.57	9.54	8.05	6.57	9.54	8.05	6.57	9.54	8.05	6.57	9.54	8.05
2025	4.92	7.36	6.02	7.16	10.72	8.77	4.92	7.36	6.02	7.16	10.72	8.77
2030	4.18	6.42	5.11	6.75	10.37	8.26	4.18	6.42	5.11	6.76	10.37	8.26
2035	4.09	6.45	4.99	7.10	11.20	8.69	3.58	5.64	4.37	6.22	9.80	7.60
2040	3.94	6.36	4.81	7.42	11.98	9.05	3.45	5.57	4.21	6.49	10.48	7.92

C.2 Fossil Fuel Prices

The growth rates used for the high and fossil fuel prices are presented in Table 8.

Table 8: Growth rates for low and high fossil fuel prices

YEAR	LOW FOSSIL FUEL PRICE GROWTH RATE (%)		HIGH FOSSIL FUEL PRICE GROWTH RATE (%)	
	Oil	Gas	Oil	Gas
2020	0	0	0	0
2025	-28.4	-10.8	4.4	13.8
2030	-53.5	-39.3	8.8	27.6
2035	-57.2	-40.1	13.1	33.2
2040	-60.8	-40.9	17.4	38.9

NZE 2035 with a low fossil fuel price: The total capacity decreases by 16 percent by 2040 due to lower gas investment (-62 percent), solar (-5 percent) and hydrogen (-1 percent) technologies. However, power generation remains constant. The overall consumption in industries increases by 13 percent due to higher penetration of biomass CCS technologies. In the transport sector, the penetration of electric trucks is slower because of the lower fossil fuel prices. **The total system costs decrease by 7** percent **by 2040 due to lower fuel costs** (-12 percent), operating costs (-3 percent) and investment (-2 percent). A slight decrease in capital costs is mainly caused by the drop in investment in power by 15 percent, followed by transport.

NZE 2035 with a high fossil fuel price: The total capacity increases only by 4% due to higher investments in solar (13 percent) followed by gas (1 percent) by 2040. However, fuel consumption in all sectors remains the same. The impact of higher fossil fuel prices is shown in the **total system costs that increase by 9** percent **with fuel costs rising by 16** percent but not that significant in operation and maintenance (O&M) and capital costs since only the power sector has higher investment, but other sectors remain the same.

NZE 2030 with a low fossil fuel price: The total capacity decreases by only 3 percent by 2040 while power generation remains constant. Like the power sector, the overall fuel consumption in industry, transport and household stays unchanged. The impact of lower fossil fuel prices is shown in the total system costs decrease by 18 percent by 2040 as fuel costs are reduced by 27 percent yet the overall capital costs and O&M costs remain the same. A minor increase in investment in power of 3 percent due to higher investment in gas (11 percent), followed by hydrogen (9 percent).

NZE 2030 with a high fossil fuel price: The total capacity and power generation remain the same as well as fuel use in residential and industrial sectors. In transport, fuel consumption is slightly lower by 3 percent by 2040 as penetration in electric light trucks is higher. As the fossil fuel price gets higher, the total system costs increase by 12 percent with fuel costs rising by 18 percent but not that significant in overall O&M and capital costs. A slight decrease in capital costs by 2 percent is due to lower investment in the transport sector (-3 percent).

Power Sector

Table 9: Installed capacity for NZE 2030 under low and high fossil fuel prices

INSTALLED CAPACITY (GW)	NZE 2030	NZE 2030 (LOW)	NZE 2030 (HIGH)
2020	0.327	0.327	0.327
2025	0.508	0.508	0.508
2030	1.014	1.014	1.014
2035	1.292	1.301	1.285
2040	1.431	1.470	1.427

Table 10: Installed capacity for NZE 2035 under low and high fossil fuel prices

INSTALLED CAPACITY (GW)	NZE 2035	NZE 2035 (LOW)	NZE 2035 (HIGH)
2020	0.328	0.328	0.328
2025	0.325	0.326	0.325
2030	0.508	0.455	0.509
2035	0.705	0.588	0.732
2040	0.705	0.588	0.732

End-Use Sectors

Table 11: Fuel consumption for NZE 2030 under low and high fossil fuel prices

FUEL CONSUMPTION (PJ)	NZE 2030			NZE 2030 (LOW)			NZE 2030 (HIGH)		
	TRA.	RES.	IND.	TRA.	RES.	IND.	TRA.	RES.	IND.
2020	10.493	10.493	10.493	10.493	10.493	10.493	10.493	10.493	10.493
2025	2.103	2.103	2.103	2.103	2.103	2.103	2.103	2.103	2.103
2030	3.274	3.274	3.274	3.274	3.274	3.274	3.274	3.274	3.274
2035	10.428	10.428	10.428	10.428	10.428	10.428	10.428	10.428	10.428
2040	2.103	2.103	2.103	2.103	2.103	2.103	2.103	2.103	2.103

Table 12: Fuel consumption for NZE 2035 under low and high fossil fuel prices

FUEL CONSUMPTION (PJ)	NZE 2035			NZE 2035 (LOW)			NZE 2035 (HIGH)		
	TRA.	RES.	IND.	TRA.	RES.	IND.	TRA.	RES.	IND.
2020	10.378	2.103	2.769	10.378	2.103	2.769	2.769	2.769	2.769
2025	8.012	1.987	2.380	8.298	1.976	10.378	10.378	10.378	10.378
2030	5.188	1.802	2.318	5.456	1.789	2.103	2.103	2.103	2.103
2035	2.643	1.601	2.675	2.888	1.588	2.769	2.769	2.769	2.769
2040	2.007	1.592	2.683	2.007	1.592	2.380	2.380	2.380	2.380

Cumulative Costs in 2040

Table 13: Cumulative costs in 2040 for NZE 2030 under ow and high fossil fuel prices

COST (M USD)	NZE 2030	NZE 2030 (LOW)	NZE 2030 (HIGH)
CAPEX	13,965	13,928	13,681
OPEX	2,238	2,248	2,226
Fuel costs	36,567	26,858	43,306
Total costs	52,770	43,034	59,213

Table 14: Cumulative costs in 2040 for NZE 2035 under low and high fossil fuel prices

COST (M USD)	NZE 2035	NZE 2035 (LOW)	NZE 2035 (HIGH)
CAPEX	9,745	9,564	9,753
OPEX	1,315	1,279	1,318
Fuel costs	13,378	11,815	15,547
Total costs	24,439	22,658	26,618

C.3 Discount Rates

NZE 2035 with a 4 percent **discount rate:** The cumulative capital costs will decrease slightly after 2030, with a decrease of around 1 percent in 2035. The change in 2040 is negligible. Similarly, the cumulative O&M costs decrease after 2030 at a very negligible percentage.

NZE 2035 with an 8 percent **discount rate:** The cumulative capital costs will decrease slightly after 2030, with a decrease of around 6 percent in 2035. The change in 2040 is negligible. Similarly, the cumulative O&M costs decrease after 2030 at a very negligible percentage.

NZE 2030 with a 4 percent **discount rate:** The cumulative capital costs decrease significantly after 2025, 13 percent lower in 2035, up until 2040. The cumulative O&M costs, on the other hand, increase to reach a value of 35 percent higher in 2035, but this decreases in the later years, ending at 17 percent lower in 2040.

NZE 2030 with an 8 percent **discount rate:** The cumulative capital costs decrease significantly after 2030, 20 percent lower in 2035, and 23 percent lower in 2040. Similarly, the cumulative O&M costs decrease to reach a value 20 percent lower in 2035 and continue to reach 39 percent lower in 2040.

Figure 77: Sensitivity analysis for discount rates for NZE 2030 (a) cumulative capital costs and (b) cumulative O&M costs (M USD)

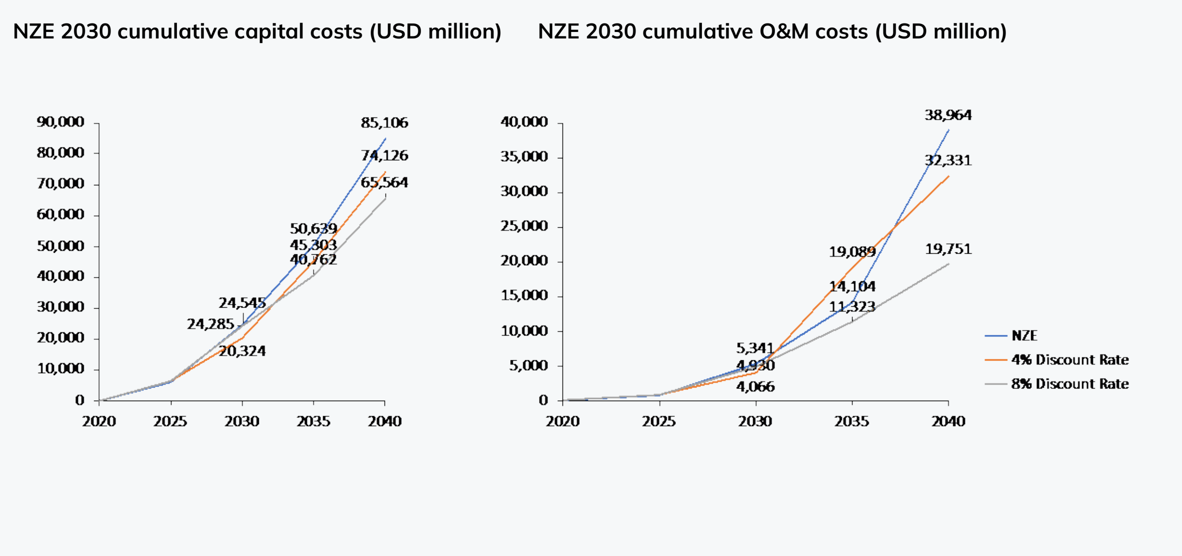
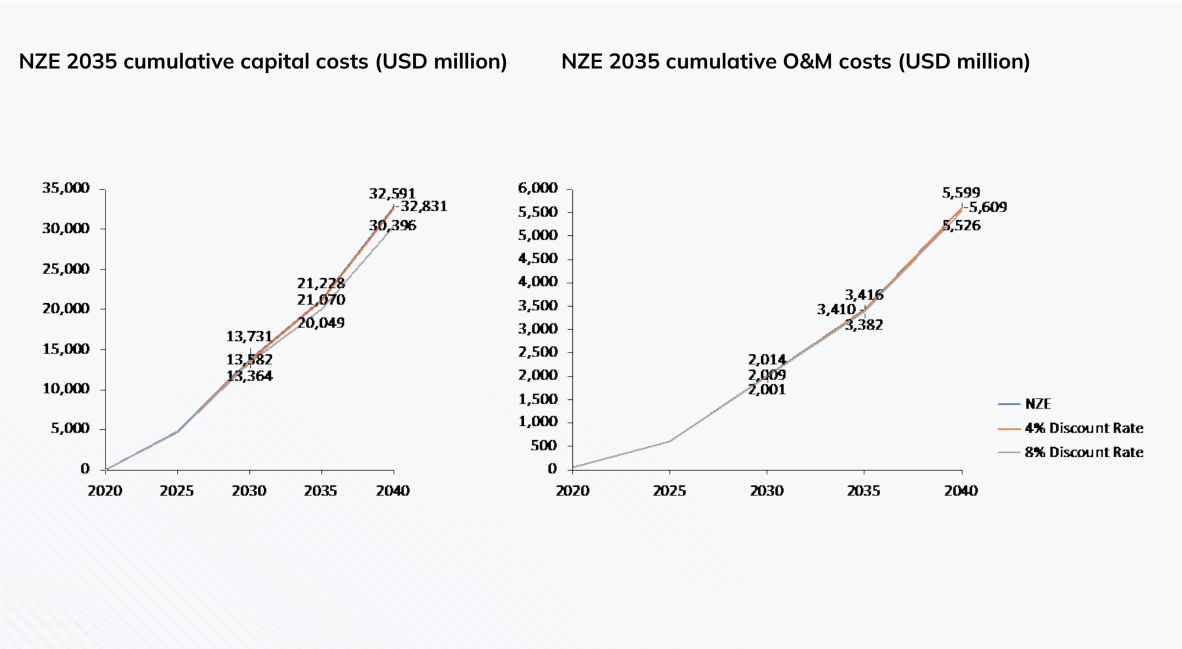


Figure 78: Sensitivity analysis for discount rates for NZE 2035 (a) cumulative capital costs and (b) cumulative O&M costs (USD millions)



APPENDIX D:
Stakeholder Engagement

Bi-weekly stakeholder engagement meetings were held with various local stakeholders from February to September 2023 to develop the energy systems model for Barbados. The various stakeholders are listed below:

1. Ministry of Energy and Business (MEB), Government of Barbados
2. Ministry of Transport and Works and Water Resources (MTWW), Government of Barbados
3. Barbados Light and Power Company (BLPC)
4. Barbados Fair Trade Commission (FTC)
5. Transport Board
6. Barbados Renewable Energy Association (BREA)
7. Universities of Bridgetown

PARTICIPANTS
CORE INTERMINISTERIAL AND STAKEHOLDER WORKING GROUP

1. Mr Mark Millar, MEB
2. Mr. Alton Best, MEB
3. Mrs Claire Best, MEB
4. Mr Bryan Haynes, MEB
5. Mrs Destine Gay, MEB
6. Mr William Hinds
7. Mr Frank Branch, MEB
8. Dr Marsha Atherly-Ikechi, FTC
9. Mr Horace Archer
10. Mr Mark Durant, MTWW
11. Mr Stephen Worme, BREA
12. Mr Robert Goodridge, BREA
13. Mr Mark Griffin
14. Ms Lynda Holder, Transport Board
15. Mr Rohan Seale, BLPC
16. Mr Charles Harris
17. Mr Carlos Echeveria, Inter-American Development Bank

In April 2023, a two-day stakeholder engagement workshop was held that allowed the team to gain various insights from wider public, private, and civil society actors in Barbados, which then contributed to the understanding of the energy sector and its interaction with other sectors in Barbados. The organisations and individuals who contributed to the stakeholder engagement workshop are listed below:

PANELLISTS
STAKEHOLDER ENGAGEMENT WORKSHOP

1. Mr Bryan Haynes, MEB
2. Ms Destine Gay, MEB
3. Mr Ricardo Marhsall, Prime Minister's Office (PMO)
4. Mr Didier Trebucq, United Nations Resident Coordinator for Barbados and the Eastern Caribbean
5. Mr Ron Goodridge, Ministry of Environment and Natural Beautification (MENB)
6. Ms Gina Belle, MENB
7. Mr Patrick McCaskie, Ministry of Finance, Economic Affairs, and Investment
8. Mr Gerald Lindo, RTI International
9. Mr Rohan Seale, BL&PC
10. Mr Roger Blackman, BL&PC
11. Mr Stephen Worme, BREA
12. Mr Aldan Rogers, BREA
13. Dr Marsha Atherly-Ikechi, FTC
14. Mr Mark Durant, MTWW
15. Mr David Green, Megapower Ltd
16. Prof. Winston Moore, UWI Cave Hill
17. Dr Legena Henry, UWI Cave Hill
18. Ms Lynda Holder, Transport Board
19. Mr Mark Hill, Export Barbados
20. Mrs Loreto Duffy-Mayers, Independent Consultant
21. Dr Devon Gardener, Caribbean Centre for Renewable Energy & Energy Efficiency (CCREEE)
22. Mr Ian Drakes, Samuel Jackson Prescod Institute of Technology
23. Mr Trevor Headley, Barbados Community College
24. Ms Meisha Clarke, UNDP
25. Mr Sheldon Marshall, Youth Representative
26. Ms Ivanna Odle, Commonwealth Youth Environment Network (CYEN)
27. Ms Shannon Weekes (CYEN)

Upon finalisation of the first draft of the Energy Transition and Investment Plan (ETIP), several wider stakeholder meetings were held between September and October 2023 to share and validate the outcomes with key stakeholders, steered by the MEB. These meetings facilitated the securing of any missing data pieces and the sensitisation of sector stakeholders to the initial outcomes and allowed for the finalisation of the ETIP modelling process.

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