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Energy Transition in Barbados

Opportunities for Adaptation of Energy Taxes to Mitigate Loss of Government Revenue

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Energy Division

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ENERGY TRANSITION IN

BARBADOS: OPPORTUNITIES FOR ADAPTATION OF ENERGY TAXES TO MITIGATE LOSS OF GOVERNMENT REVENUE

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Abstract:

Barbados through its Barbados National Energy Policy (BNEP) 2019-2030 announced its commitment to achieving 100 percent renewable energy and carbon neutrality by 2030. This commitment creates an opportunity for the GoB to manage the impact of the transition toward renewable clean energy by introducing measures to transform the way revenue from energy is collected thereby avoiding unnecessary fiscal costs. The purpose of this study is to calculate the revenue gap derived from Barbados' 2030 energy transition goal of having a revenue-neutral transition, propose and evaluate various policy measures that could help seize opportunities to close that gap.

The simulation model suggests that the energy transition would result in an estimated BBD$105 million in revenue losses a year by following the BNEP. Such a reduction would create a significant fiscal gap that would need to be addressed through the introduction of new forms of taxes or changes to current taxes in order to adapt tax collection to revenue creation from the new clean energy economy. A wide range of tax policy options and issues surrounding their effective implementation were discussed such as: increased taxes on fossil fuels, a change in the VAT rate, mileage taxes on electric and hybrid vehicles, and taxes on renewable energy production. Each of these new tax approaches can help address the fiscal gap estimated above. However, there is a trade-off that must be considered, as any new tax on renewable energy could reduce the speed of transition to a 100 percent energy future. Therefore, the taxation changes should be sensitive to the moment in which they are adopted in order to encourage transition at the beginning and progressively switch the burden to the new form of taxation to cover the revenue gap. Additionally, it is critical to maintain dialogue with the relevant actors involved in the energy transition to better calibrate the changes considered by the policy makers.

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Acronyms

BAU	Business as usual
BBD$	Barbados dollar
BBEP	Barbados National Energy Policy
BERT	Barbados Economic Recovery and Transformation plan
BESS	Battery energy storage systems
CO2	Carbon dioxide
EEF	Extended Fund Facility
ETR	Environmental tax reform
EV	Electric vehicle
FRPS	Full Renewable Power Scenario
GDP	Gross domestic product
GoB	Government of Barbados
GWh	Gigawatt hour
HFO	Heavy fuel oil
ICE	Internal combustion engine
IDB	Inter-American Development Bank
IMF	International Monetary Fund
ktoe	Thousand ton of oil equivalent
MT	Million tons
MW	Megawatt
OECD	Organisation for Economic Co-operation and Development
US$	United States dollar
VAT	Value added tax

Chapter 1:

Transitioning to Renewable Energy and Its Challenges: Why Should We Care About Fiscal Impact?

The Government of Barbados (GoB) has been carrying out an ambitious fiscal consolidation program, the Barbados Economic Recovery and Transformation (BERT) plan, since 2018. The plan was developed by the GoB in response to decades of slow growth and recurring fiscal deficits. Real gross domestic product (GDP) growth in Barbados slowed from 4.3 percent between 2000 and 2009 to 1.6 between 2010 and 2019. The country recorded recurring fiscal deficits over this two-decade period and its debt-to-GDP ratio increased at an average yearly rate of 6 percent between 2000 and 2017, reaching 158.3 percent of GDP in FY2017/18. The current administration developed BERT—a homegrown fiscal consolidation program—and signed a four-year Extended Fund Facility (EFF) program with the International Monetary Fund (IMF) in October 2018. Through this program, the GoB aims to bring the debt-to-GDP ratio down to 60 percent of GDP by FY2033/34 through a combination of ambitious fiscal measures and structural reforms. Early results are promising. Barbados' primary fiscal balance increased from 3.3 percent of GDP in FY2017/18 to 6.3 percent of GDP in FY2019/20 and after completing a debt exchange program with domestic and external creditors, its debt-to-GDP ratio fell to 126.3 percent of GDP in FY2019/20.

In addition to this fiscal consolidation program, the GoB is carrying out key reforms that ease structural constraints on growth. Barbados is a small island developing state (SID) that is greatly reliant on tourism. Imports have averaged 46 percent of GDP over the past decade,[1] of which 24.1 percent are fuel imports.[2] The island relies almost solely on fossil fuels for its energy, which creates both strains on the level of international reserves—Barbados is a net importer of oil and requires a minimum level of external reserves to maintain the exchange rate peg—and is harmful for the environment. Barbados reportedly emitted 1600 thousand tons of carbon dioxide (CO2) in 2019 (Ministry of Energy, Small Business and Entrepreneurship 2019). Consequently, the GoB, through its Barbados National Energy Policy (BNEP) 2019-2030 (Ministry of Energy, Small Business and Entrepreneurship 2019), announced its commitment to achieving 100 percent renewable energy and carbon neutrality by 2030. This commitment creates an opportunity for the GoB to manage the impact of the transition toward renewable clean energy by introducing measures to transform the way revenue from energy is collected thereby avoiding unnecessary fiscal costs. By engaging early with this challenge, Barbados can benefit from a more gradual adaptation and the positive impacts of this approach An important component of this vision is the goal of ending the domestic consumption of fossil fuels by 2030.[3] Although this is the most promising path for a zero CO2 emissions future, the fossil fuel phaseout raises the question: What will be the impact on revenue? Taxes on fossil fuels currently account for 2.33 percent of GDP. Given the magnitude of the fiscal consolidation program, complementary revenue collection measures that can at least ensure revenue neutrality will be needed.

The purpose of this study is to calculate the revenue gap derived from Barbados' 2030 energy transition goal of having a revenue-neutral transition and propose and evaluate various policy measures that could help seize opportunities to close that gap. Energy tax revenue has gradually reduced as a consequence of more efficient vehicles, energy generation, and energy consumption. As the clean energy transition takes root it creates an opportunity to adapt the energy tax revenue to better suit the naturally evolving situation. Similar challenges exist in some other countries. This study aims to take stock of the lessons learned from those experiences and offer recommendations for Barbados.

1. Between 2009 and 2019.

2. Data from the Observatory of Economic Complexity, MIT, (2021).

3. The energy transition plan has five key goals: (i) ensuring the provision of reliable, safe, affordable, sustainable, and modern climate-friendly energy services for all; (ii) ending the domestic consumption of fossil fuels; (iii) maximizing local participation in renewable energy; (iv) minimizing the outflow of foreign exchange; and (v) creating a regional center of excellence in renewable energy research and development.

In order to inform policy makers, we use the LINDA model to generate projections over two decades in order to provide a vision of different possible scenarios of the clean energy transition from a fiscal revenue perspective of energy revenue generating activities. The results of this model should be interpreted as approximations. Tracking the evolving situation of the variables examined would help fine-tune the policy changes that policy makers consider to be important to take decisions that accurately reflect the need to achieve a revenue-neutral energy transition. By presenting these scenarios, the model aims to showcase possible pathways and the policy options, based on international experience, to proactively and progressively curb and mitigate revenue losses naturally brought forth by a transition to clean energy. The role of the model is to provide context for the different policy options to face this challenge but does not include distributional or administrative impacts due to data limitations.[4]

The model presented below finds that the GoB could lose between BBD$105 million and BBD$223 million per year in the considered scenarios without counting the potential revenue lost from excise taxes on the purchase of vehicles that is detailed in section 2.3. The results highlight the importance of being proactive in transforming the taxation system to better suit the changing landscape of energy consumption that is brought about by the energy transition. This adaptation would ensure that Barbados can avail of the benefits of energy independence and price stabilization the transition carries with it while matching its energy fiscal structure to the new clean energy economy. This can be done by considering some of the policy options presented for policy makers' consideration that should be adapted to the administrative structures of Barbados to ensure their effectiveness. The multiple channels through which the energy transition takes place should encourage policy makers to engage in this transformation in order to look for the best-fitting solution to the energy fiscal revenue changes. Additionally, maintaining dialogue with the relevant actors in the energy transition and incorporating their views should provide insight into the more specific actions to be taken.

This report is structured as follows. Following a brief discussion of the current state of fossil fuel use and the transition revenue gap in Barbados, chapter 1 evaluates the potential revenue gap in Barbados from the transition to renewables and what the government can do to minimize it. Chapter 2 outlines the methodological approach to be employed in the study and aims to provide a quantitative estimate of the revenue gap based on various transition scenarios. Chapter 3 lays out some potential policy options for addressing the revenue gap. While this report acknowledges that general macroeconomic/tax policies can resolve the revenue gap, most of the analysis is spent on taxes and other policy changes specific to the energy sector as it is the authors' opinion that these are the preferred options for resolving the transition revenue gap. Chapter 4 focuses on the transportation sector as a case study because it is a large source of emissions/tax revenue for Barbados and a large part of the government's planned push toward renewable energy. Chapter 5 discusses some practical issues regarding implementation of the policies recommended in terms of how taxes may change incentives for renewable energy adoption. Finally, chapter 6 offers some conclusions and summarizes the policy recommendations for managing the transition to renewable energy generation and its impact on fiscal balances.

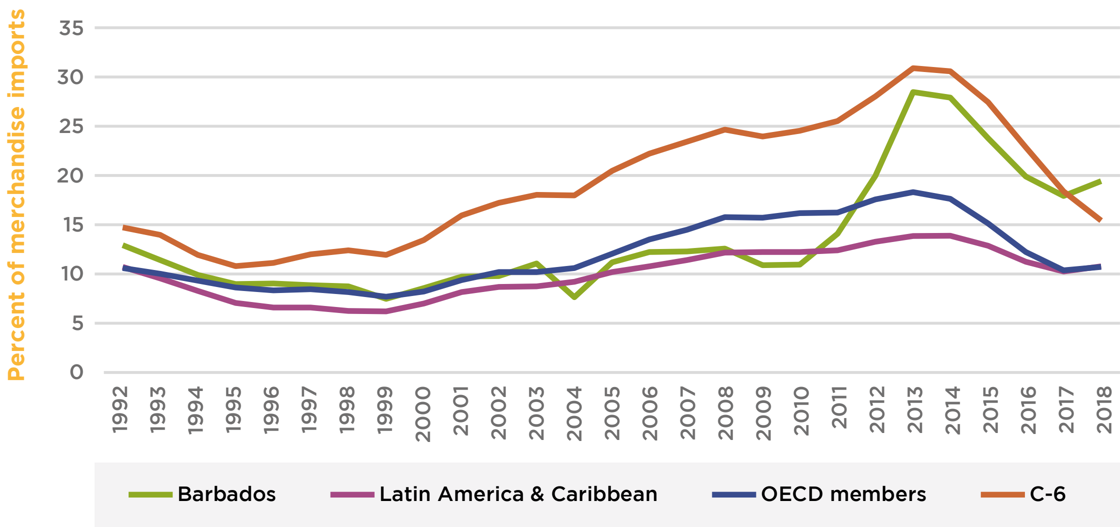
4. See table 5.5 in IEA (2020).

1.1 The Energy Transition Plan for Barbados

The BNEP 2019-2030 states Barbados' commitment to achieving zero domestic consumption of fossil fuels economy-wide by 2030. To reach this goal, the country will need to change how its energy sector functions in several dimensions. Currently, the majority of Barbados' energy needs, as is the case with other small island states in the region, are met through imported fossil fuels. During the past decade, the value of oil imports averaged 8 percent of GDP. As seen in Figure 1, Barbados' dependence on imported fuel stands above the Latin America and the Caribbean region's average and is on par with the Organisation for Economic Co-operation and Development (OECD) member states, though it has been below the IDB's Caribbean Department country average (termed the C-6 countries).[5] This dependence on imported fuel makes the island vulnerable to changes in international oil prices. As seen in Figure 2, there is a strong relation between international oil prices and the current account balance in Barbados, highlighting the economy's sensitivity to oil prices.

International oil prices impact import costs, international reserves, and overall competitiveness. The total value of oil imports for Barbados has increased over the past two decades, from an average 5.4 percent of GDP between 2000 and 2009 to 8.2 percent of GDP between 2010 and 2019. The rising costs of sustaining these imports place a burden on foreign exchange reserves and in parallel diminish the external competitiveness of local businesses that integrated the cost of oil into their operations while raising the cost of living (Compete Caribbean 2014).[6] Higher costs also impose a burden on the state and households, who rely almost solely on imported fuel for energy and electricity generation.

Figure 1: Fuel Imports in Barbados and Selected Country Groupings, Three-Year Moving Average



Source: The World Bank's World Development Indicators.

5. The C-6 countries include The Bahamas, Barbados, Guyana, Jamaica, Suriname, and Trinidad and Tobago. The fall in fuel imports (as a percentage of merchandise imports) since 2017 in the C-6 countries is due to missing datapoints for The Bahamas and Trinidad and Tobago.

6. Maintaining a minimum level of reserves—the rule of thumb is 12 weeks of import cover—is key to protecting the exchange rate peg (US$1=BBD$2) that has been in place since 1974.

Figure 2: Fuel Imports in Barbados and Selected Country Groupings, Three-Year Moving Average

Source: IMF's World Economic Outlook (October 2020) and commodities databases.

1.2 The Potential Fiscal Gap Arising from the Energy Transition

The GoB needs to consider the fiscal implications of moving away from fossil fuels as it strives to transition to renewable energy and implement its fiscal consolidation program. The structure of revenue collection in the energy sector must adapt, while striving to maintain a level of collection, access to services (electricity and transport, for example), and equity in the use of these services. There are two main sources of tax revenue from fossil fuels in Barbados: excise taxes and value added tax (VAT). A flat 17.5 percent VAT rate is applied to gasoline, diesel, and fuel oil. Excise taxes are levied on a per liter basis and differ based on the type of fuel (Table 1). The excise tax on gasoline (99.39 cents per liter) is almost twice that of the excise tax on diesel (44.0 cents per liter). The compounded value of fuel-related tax revenue in 2018 was BBD$209.8 million in excise taxes and BBD$17.7 million in VAT. This added up to BBD$227.5 million (2.2 percent of 2018 GDP)—77.1 percent of this revenue was generated from gasoline and 21.2 percent from diesel. Together, these two taxes generated approximately 7 percent of total tax revenue in 2018. In 2018, VAT revenue from taxing fossil fuels was less than 1 percent of total tax revenue, with most of this due to taxes on gasoline. Approximately, 20 percent of tax revenue collected arises due to taxes on electricity.

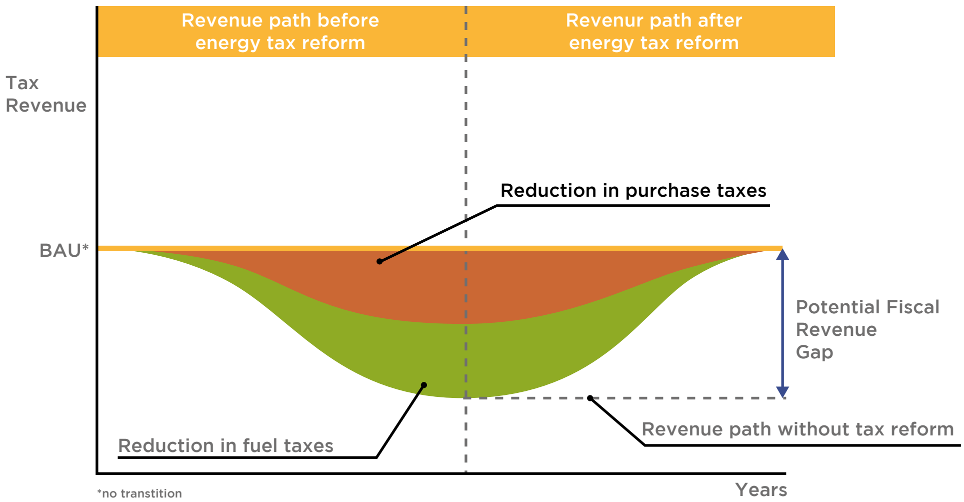
Table 1: Historical Tax Rates for VAT and Excise Taxes on Gasoline and Diesel

	2010			2017			2018		
	Gasoline	Diesel	Fuel Oil	Gasoline	Diesel	Fuel Oil	Gasoline	Diesel	Fuel Oil
VAT	17.5%	17.5%	17.5%	17.5%	17.5%	17.5%	17.5%	17.5%	17.5%
Excise Tax	53.6¢	20.0¢	NA	73.6¢	20.0¢	NA	99.4¢	44.0¢	NA

Source: Barbados' Ministry of Energy, Entrepreneurship and Small Business.
Note: corresponds to Barbados cents.

Figure 3 provides a simplified concept of how the energy transition would affect revenue collection and how inaction to adapt the fiscal policy could lead to increasing yearly losses attributable to the energy transition. These losses would potentially arise from two sources: First, the reduction in the consumption of fuel as a result of the electrification of transport and increased use of renewable energy for electricity generation in the different segments of the energy and transportation sectors would lower the amount of fuel taxes collected. Second, taxes paid on purchases, such as excise taxes or VAT, would also decrease as the sale of fossil fuel-based products diminishes and consumption patterns are affected by the energy transition. Lowering these two sources of revenue would create a revenue gap when compared to a business as usual (BAU) scenario in which the energy transition does not take place.

Figure 3: Simplification of the potential fiscal revenue gap



Source: Original figure created for this report.

The revenue gap during the energy transition could be filled by using a variety of approaches. The approach would depend on the size of the gap and on the relative decrease in the various types of taxes and fees associated with fossil fuels. During the transition, a set of new fees and taxes that create different tax burdens for those that transition early and those that do not could be used to collect revenue and progressively shift the burden as the transition progresses. Such a strategy could encourage the transition while promoting long-term sustainability as the tax burden is moved to a broader base again.

Chapter 2:

Quantifying the Energy Transition Revenue Gap

The goal of this chapter is to develop a quantitative framework for understanding the energy transition revenue gap. First, a model for predicting future energy supply and demand is developed. After describing how the model applies to Barbados, several scenarios for the energy transition are outlined based on the BNEP 2019-2030. Running this model will provide a quantitative estimate of the potential fall in revenue collection—a financing gap—due to the energy transition. The composition of this financing gap is then analyzed.

2.1 Setting Up a Model of Energy Supply and Demand—Fuel Revenue Loss

Evaluating the impact of the energy transition on fiscal revenue requires projections of both demand and supply of energy. This includes an evaluation of the cost of future energy technologies as well as an assessment of the energy needs of the country. This is complex, as the energy technologies chosen may result in the growth of new industries that are, by definition, difficult to model and predict ex ante. In addition, medium- to long-term energy demand can be greatly influenced by changes in social and economic variables, such as population, economic growth, and technological advances (Urban, Benders, and Moll 2007; Adams and Shachmurove 2008; Lozano and Gutiérrez 2008). To evaluate the costs associated with various energy plans for Barbados, this study incorporates a cost module into a model of long-term energy development.

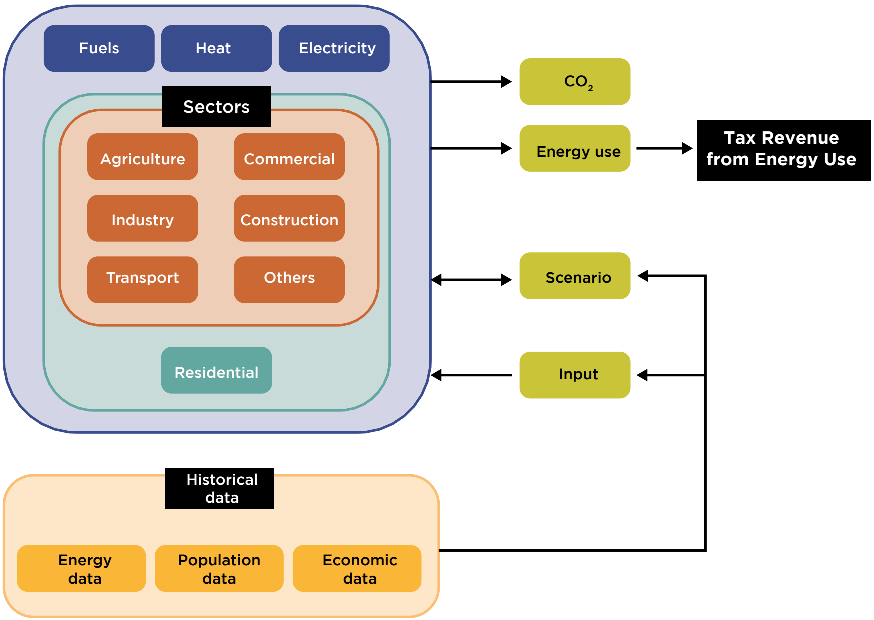
The model of energy development employed in this study utilizes the framework outlined in Luukkanen et al. (2015), the LINDA model. The LINDA model generates estimates of gasoline and diesel demand based on the assumptions of fuel use efficiency and supply. Assuming no changes in the tax rates, these fuel use estimates are combined with tax rates to generate revenue projections under each of the scenarios. This partial equilibrium model is designed to construct future scenarios for energy use in various industries based on historical data for GDP, total primary energy supply, the energy transformation process, projected sectoral economic growth levels,[7] taxes, and future changes in energy intensity.[8] The model's accounting framework is built upon a network of interconnected. preconstructed identities that enable users to track outputs such as carbon emissions by energy source, changes in a country's energy plant mix, projected changes in sectoral energy use, and the interactions between supply and demand curves.[9] Further information on the data can be found in the appendix.

7. Historical averages.

8. Revised sectoral GDP at current prices was obtained from the Central Bank of Barbados' Online Statistics Database for the period 1990-2017 for the following sectors: mining and quarrying, manufacturing, electricity, gas and water, construction, hotels and restaurants, wholesale and retail trade, transport, storage and communications, finance and business services, personal and other services, and government services. These sectors were then grouped in accordance with the energy data available by sector: industry (mining and quarrying, as well as manufacturing), commercial (agriculture and all services except hotels and restaurants), and hotels and restaurants. One notable issue is that there is an absence of energy data related to agriculture, resulting in its amalgamation into the commercial industry due to its close relationship with wholesale and retail trade.

9. All energy-related data were first converted into their kilo tonnes of oil equivalent (ktoe) measurement unit before being entered into the model, while all other subsequent conversions occur within the system.

Figure 4: The LINDA Model



Source: Original figure based on Luukkanen et al. (2015).

The LINDA model is used to develop different scenarios for the energy transition, which are presented below. The various scenarios differ based on the assumption of the speed and intensity with which Barbados will undergo the transition and are compared with the BAU scenario in final results. The paragraphs below present the basic underlying assumptions for each scenario, including those related to key modelled variables, the energy mix, and the additional required storage capacity.[10] The key assumptions used in every scenario relating to key modelled variables, the plan mix used, and the storage costs are presented in the tables in the appendix.

The BAU scenario represents how the energy system would evolve if the current situation in Barbados remains the same and no effort is made to attain fossil fuel phaseout during the period of analysis. Under this scenario, it is assumed that growth in economic output, consumption of energy, as well as production of energy are all in line with historical trends.

The BNEP (Scenario 1) is based on the energy transition outlined in the BNEP 2019-2030. The BNEP proposes achieving carbon neutrality by 2030. This would incorporate greater renewable energy in the production of electricity and to achieve the plan's objectives. There would have to be a fundamental transition, not just in terms of energy production, but also in its use, for instance in transportation—the largest user of fossil fuels. Total electrical intensity would fall from 1 percent in the BAU to -1 percent, and although transport volume would not change, road transport intensity and energy intensity would change -1 percent compared to no change in the BAU. This scenario assumes that most of electricity produced would be obtained from solid biofuels (45 percent versus 0 percent in the BAU scenario) and wind power (21 percent versus 0 percent in the BAU scenario). Comparatively, the use of solar energy would fall from 16 percent in the BAU scenario to 15 percent in this scenario and natural gas would fall from 84 percent of energy generation in the BAU scenario to 20 percent in this one. This would mean utilizing more electric vehicles in the transportation sector, enhancing energy efficiency, and investing in human resource development, among other things. Biomass storage would be required (UNDP 2009), yet the amount and its costs are not included in these calculations. [11]

10. Renewables generation is an intermittent source. In order to guarantee security of supply, energy storage tools are necessary.

11. The BNEP does not include specific targets, so these assumptions are based on the authors' estimations.

The Full Renewable Power Scenario (FRPS) (Scenario 2) is based on Hohmeyer (2015) and envisions the complete transition to 100 renewable energy by 2030, excluding the transport sector. In this scenario, electricity intensity falls further to -3 percent, compared to 0 percent in the BAU scenario. Although the transport volume remains unchanged, this results in a -3 percent and a -2 percent change in the road transport energy intensity and the energy intensity, respectively, compared to a 0 percent change in both variables in the BAU scenario. Energy generation is largely met through wind (50 percent versus 0 percent in the BAU scenario), solar (45 percent versus 16 percent in the BAU scenario), and solid biofuels (5 percent versus 0 percent in the BAU scenario), with the support of utility-scale pump storage.[12] Natural gas use is projected to decrease from 84 percent in the BAU scenario to 0 percent in this one. This would imply that Barbados would have to install 200 megawatts (MW) of wind power capacity, 195 MW of solar energy (photovoltaic) capacity, biomass volume of 35 Gigawatt hours per annum (GWh/a), and a pump storage hydro plant with a storage volume of 3 gigawatt hours (GWh). Additionally, some changes are considered in the excise tax and VAT rates for fossil fuels.[13]

The Full Renewable Power and Electrified Transport Sector scenario (Scenario 3) assumes that a greater use will be made of public and private transportation that is run on renewable energy as well as electrified freight transport. This final scenario also considers the 100 percent renewable energy scenario in electricity generation as well as public and private transportation. The electrical intensity is expected to change -4 percent, compared to 0 percent in the BAU scenario. Although transport volumes are expected to remain the same as in the BAU scenario, road transport energy intensity and energy intensity are expected to change by -4 percent and -3 percent, respectively, compared to a 0 percent change in the BAU scenario. This scenario also assumes that the use of wind energy would increase to 55 percent (compared to 0 percent in the BAU scenario), solar power would provide 45 percent of the energy needs (compared to 16 percent in the BAU scenario), and natural gas would not be used. A small quantity of biomass is used in electricity production as utility-scale storage is employed. This would imply that 10 GWh of additional battery energy storage systems (BESS) would be required, which would cost US$500–US$600 million; 3 GWh of pump storage would be required at an estimated cost of US$300 million; and 10 GWh of vehicle-to-grid integration would cost approximately US$6 billion (Hohmeyer 2015).

2.2 Predictions of the LINDA Model for Barbados in the Absence of Tax Changes

This subsection presents the results of the LINDA model for each of the scenarios described above. These results focus on the energy and costs associated with the transition. The appendix of this report includes some energy-specific results that can help experts gather specific insights from the model. For the BAU and each of the three scenarios, this subsection presents projections of electricity installed capacity, fuel use, VAT collected from fuel sales, and excise taxes collected from fuel sales. The table below provides a summary of the findings for the three scenarios, comparing the result for each variable in 2030 for each scenario to the BAU scenario. Electricity installed capacity increases in all three scenarios compared to the BAU scenario. This is particularly true for Scenario 1, where electricity installed capacity increases 70.5 MW in 2030. Annual energy consumption decreases in all three scenarios, ranging from -289 thousand ton of oil equivalent (ktoe) in 2030 in Scenario 1 to -535.4 ktoe in 2030 in Scenario 3. The fiscal gap, measured as the difference between the BAU scenario fossil fuel tax collection and each respective scenario, would range between BBD$105 million in Scenario 1 to BBD$223 million in Scenario 3.

12. See Figure 14 in the appendix of this report.

13. In Scenario 2, VAT for gasoline, diesel, LPG, and natural gas would be raised 1.5 points in 2020, one point every year from 2021 to 2023, and five points every year from 2024 to 2030. The excise rate for gasoline and diesel would be raised BBD$0.02 from 2020 to 2023 and then BBD$0.1 every year from 2024 to 2030.

Table 5: Summary Findings—Difference between Each Scenario and the BAU Scenario for 2030

	Change in Electricity Installed Capacity (MW)	Annual Energy Consumption (ktoe)	Annual Energy Tax Revenue (BBD$, millions)
Scenario 1 (BNEP 2019-2030)	70.5	-289	-105 (0.7% GDP)
Scenario 2 (100% renewable energy in electricity generation)	59.5	-417	-110 (0.8% GDP)
Scenario 3 (100% renewable energy with conventional backup)	59.5	-535.4	-223 (1.6% GDP)

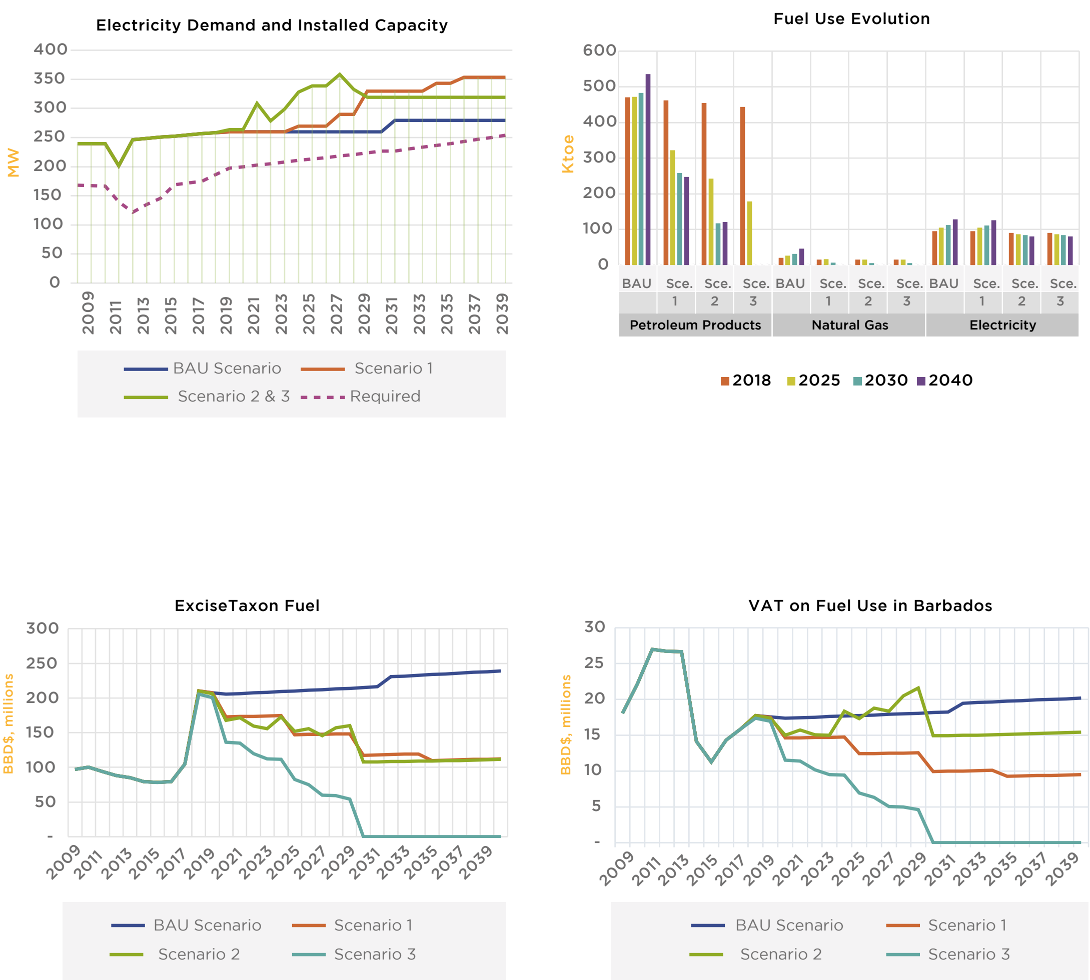
Source: Authors' calculations.
Note: The projected nominal GDP for 2030 is BBD$14,246 million.

A more in-depth look into each scenario reveals that the BNEP scenario (Scenario 1) would lead to an approximately BBD$105 million loss in tax revenue. This scenario assumes efficiency gains in most sectors, thereby reducing total energy consumption by 20 percent by the end of 2030, as envisioned in the BNEP. The increased utilization of renewables in the energy mix/matrix, however, would mean that the installed capacity of renewables and fossil fuels would have to be greater than in the BAU scenario, particularly given that the load factors for renewables are below that for fossil fuels—the installed capacity would be 330 MW by 2030 compared to 259.5 MW in BAU scenario. Fuel use would also fall with time, from approximately 626 ktoe a year in the BAU scenario to 337 ktoe a year in 2030. CO2 emissions would fall from approximately 1.4 million tons (MT) in the BAU scenario in 2030 to approximately 0.9 MT. As a result of both the transition to more renewable sources of energy and the increased energy efficiencies in various sectors, tax revenue from fossil fuels would fall significantly. By 2030, VAT revenue from fossil fuels would fall to BBD$9.9 million, compared to BBD$18.2 million in the BAU scenario (Figure 5). Excise tax revenue from fossil fuels would fall even more, from BBD$215.0 million in the BAU scenario to BBD$117.4 million (Figure 5). Overall, this represents a fall in the contribution of taxes on fossil fuels to total tax revenue from 7 percent in 2018 to just 4 percent by 2030. Looking at the composition of this revenue gap for 2030, foregone revenue would stem from gasoline (BBD$81.5 million), followed by diesel (BBD$22.5 million) and fuel oil (BBD$1.6 million). Conversely, while the revenue coming from fossil fuels would decrease, electricity supplied by renewables would rise over the period (from 937.2 GWh consumed in 2017 to 1,338.2 GWh in this scenario). This implies that there could be an opportunity to reduce some of the fiscal gap by transferring oil taxes to the electricity service.

Scenario 2 assumes more ambitious energy efficiency targets, reaching 100 percent renewable energy use by 2030, excluding the transport sector. In this scenario, electricity installed capacity increases to 319 MW by 2030, compared to 259.5 MW in the BAU scenario. Fuel use in this scenario falls at a faster pace than in Scenario 1, reaching approximately 209 ktoe by 2030 (mostly composed of transportation consumption), compared to just over 626 ktoe in the BAU scenario. Efficiency gains in electricity consumption are expected to be offset by greater electrification of various industries in the economy (e.g., cooking in hotels and restaurants). As a result, the installed capacity of renewables will have to rise to 320 MW by 2030 compared to 225 MW in the BAU scenario. CO2 emissions would further decline, compared to Scenario 1, with projected emissions reaching 0.4 MT of CO2 by 2030, compared to approximately 1.4 MT of CO2 in the BAU scenario. Scenario 2 would lead to further reductions in revenue collection than those projected for Scenario 1. VAT on fuel use would fall to BBD$14.9 million by 2030, compared to just under BBD$18.2 million in the BAU scenario (Figure 5). Similarly, tax receipts from excise taxes would fall to BBD$107.9 million by 2030, compared to approximately BBD$215 million in the BAU scenario (Figure 5). Combined, this would result in an approximately BBD$110.1 million revenue loss in 2030—BBD$95.2 million would be from gasoline, BBD$14.3 million would be from diesel, and BBD$0.6 million would be from fuel oil.

In Scenario 3, Barbados transitions to 100 percent renewable energy in terms of electricity generation by 2030, including the transport sector, but still maintains conventional power as backup. As a result, the consumption of fossil fuels falls significantly, but not to zero, since conventional power would still be in place as backup (Figure 5). With the electrification of the transport sector, CO2 emissions would fall to less than half the emissions in the BAU scenario (Figure 12), improving the quality of air in urban areas and around the island. Electricity installed capacity increases to 319 MW by 2030, compared to 259.5 MW in the BAU scenario, whereas fuel use falls to 90.6 ktoe from 2030 onward, compared to 626 ktoe in the BAU scenario. In this scenario, revenue collection from fossil fuels reaches zero by 2030 for both VAT and excise taxes, creating the largest fiscal space of all scenarios analyzed in this paper (approximately BBD$233 million). Foregone revenue would stem from gasoline (BBD$179.8 million), followed by diesel (BBD$49.9 million) and fuel oil (BBD$3.6 million).

Figure 5: Scenario Comparison—Installed Capacity, Fuel Use, Fuel Excise, and Fuel VAT Collection



Source: Authors' model estimates.

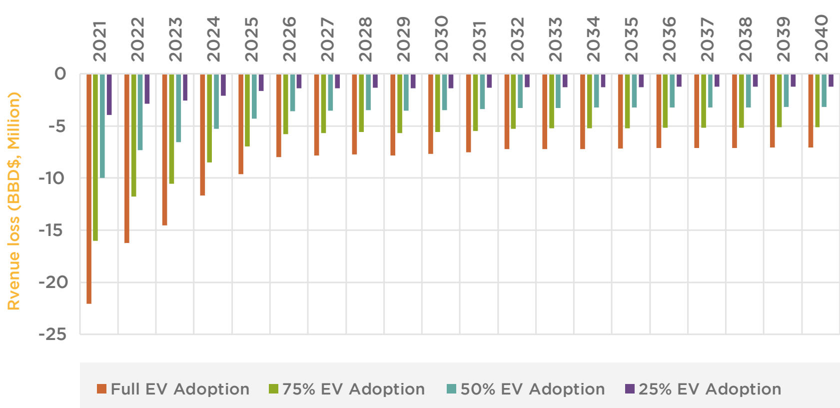
2.3 EV Purchasing Revenue Gap-Vehicle Purchase Tax Losses

In Barbados, duties and VAT are a significant component of the price of vehicles. While the price range varies depending on the age, the energy capacity (measured in cubic centimeters (cc)), and the value of the vehicle, there is a misalignment between vehicles that run on gasoline or diesel and electric vehicles (EVs). This leads to a loss of revenue for the GoB. This gradual reduction in revenue is not uncommon in other countries (IEA 2020). The difference in value is, of course, justified in the pursuit of a faster transition from internal combustion engine (ICE) vehicles allowing for less duties and excise taxes to be levied on EVs and supporting the energy transition.

There are three types of taxes on vehicle imports in Barbados: VAT, excise, and duties. Duties tend to be similar for most residential use. A 45 percent duty is charged on the value of gasoline and diesel cars. Excise taxes vary according to the vehicle's engine capacity and range between 12 and 90 percent of the vehicle's value. VAT is universally applied at 17.5 percent of the value of the vehicle. An environmental fee is also charged on all newly registered vehicles in Barbados. The taxation regime is different for EVs. An excise duty of 20 percent is levied on EVs, which are exempt from paying the environmental fee at registration and are not required to pay the marginal tax on fuel.

The different taxes paid by EV and ICE vehicle owners constitute a collateral fiscal revenue gap of the energy transition. An estimate of the impact on revenue in future scenarios where EV market share reaches up to 100 percent of the market share is presented below. In the most extreme case of full EV adoption, the GoB would lose an average of BBD$9.2 million a year in revenue in the 2021–40 period due to a loss of tariffs and license fees. However, even under a more conservative assumption of 25 percent EV adoption, the average revenue loss would be BBD$1.6 million a year on tariffs and license fees. One option to curb this revenue loss is increasing taxes on EVs over time (as discussed in chapter 3). A second option would be to increase taxes on ICE vehicles to offset the loss of revenue from the penetration of EVs. The timing for implementing each measure should be carefully considered so as not to make EVs more expensive than ICE vehicles. A more in-depth discussion of different possible strategies for tax substitution and proposals for alternative taxation for EVs and ICE vehicles can be found in chapter 3.

Figure 6: Government Revenue Loss as a Result of EV adoption—Compared with a No-Adoption Scenario

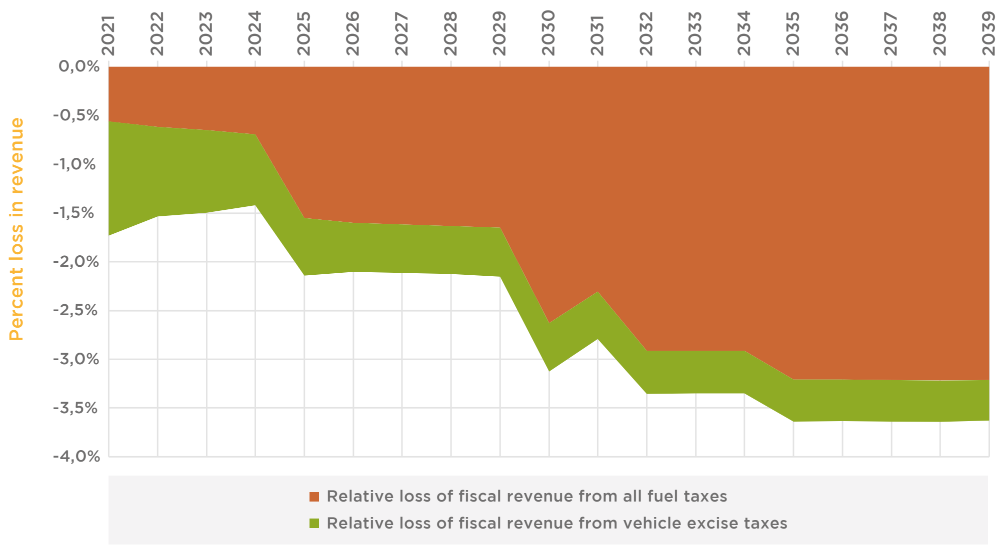


Source: Authors' calculation based on modelled data from the Barbados Ministry of Transport and Works and Maintenance.

2.4 The Combined Fiscal Revenue Gap-Fuel and Vehicle Purchase Taxes

In this section, we introduce the assumption that 25 percent of all the vehicles that are purchased in Barbados are EVs and discuss the added exposure this would create to the government's revenue. The reduced excise tax on the purchase of vehicles is done using the BNEP policy targets to introduce it over the already government formulated plan for the transition. The policy options chosen to fill in the transition fiscal gap must be closely linked to the objectives of the transition. Reaching taxation corrective levels that minimize the fiscal revenue gap is essential. Figure 7 shows the loss of fiscal revenue assuming the BNEP's goals and a conservative 25 percent transition to EVs (or equivalent) by 2040. (The report uses a longer time period than 2030 here given the likely life cycle of ICE vehicles). The added costs are incremental over those shown in blue that correspond to the abovementioned BNEP scenario of transition, as a result of the lack of adjustment of the fiscal policies to other taxation methods for the new technologies. While tax policy decisions are up to policy makers, the levels of taxation required to reduce the gap could be set to match the situation yearly as shown in Figure 7.

Figure 7: Loss of Fiscal Revenue Under the Barbados National Energy Policy Scenario Assuming a 25 Percent Adoption of EVs in 2040 Relative to the BAU Scenario with No EV Adoption



Source: Authors' calculations.

Following the national transition policy would create an average drop in tax revenue of BBD$94.5 million per year in the 2021–39 period. Adding a 25 percent transition to EVs would increase the total amount of revenue lost to BBD$1.890 million over the same period. This is, however, just a projection. A periodic review of the taxation levels is recommended to ensure that the effects of taxation are not inducing other preference and consumer choices that can create problems in the long run.

Chapter 3:

Policy Options to Close the Fiscal Gap

As the previous chapter indicated, the GoB faces a potentially significant loss of revenue from taxes related to fossil fuels. This chapter aims to present some pertinent policy options for mitigating these losses. The chapter is broken down into two parts. First, generalized options for raising revenue (i.e., general taxes/VAT) are presented. The second part of the chapter looks at specific targeted tax measures for the energy sector stemming from other international experiences of this challenge. In each section we define several different policy options and the general idea behind why they would be a solution to reducing the revenue gap and present a brief assessment. Special care must be taken when considering the imposition of taxes that would affect households more broadly. For example, higher taxes on electricity might impact household budgets and produce unforeseen distributional and welfare impacts. As EVs become more common, technological solutions that enable a targeted approach to taxing EV electricity consumption/storage would likely become available and these would offer a better solution than general electricity taxation.

3.1 General Taxes

Complementary Electricity Generation Taxes

The justification of taxing the generation of electricity is based on the idea that the energy transition should be financed by those who are benefiting from the system—those persons consuming the most electricity by using a system that generates negative environmental externalities. Applying the tax or levy specifically to energy consumers allows for the implementation of a degree of proportionality on the fiscal impacts of the transition. This ensures that the transition fiscal gap is compensated by those who use its outcome more.

The current taxation structure addresses this problem by taxing the fuels that arrive in Barbados at different rates. As explained in previous sections, taxes on fuels are charged on the basis of selling price (VAT) and volumetric terms, per liter (excise tax). These taxes are imposed before generation, consumption, or any other activity. This creates an incentive to increase the utility extracted from each liter of fuel. In other words, it incentivizes the efficiency of combustion. For example, an owner of an ICE vehicle is encouraged to get the most kilometers from every gallon, while a generator owner would be encouraged to obtain the most out of every gallon put into the turbines. However, with renewable energy it is not as easy to identify the optimal moment to tax it, as the generation of electricity uses a wide range of resources that are difficult to tax. This is not the case with solar or wind energy. Nonetheless, the absence of a tax prior to the generation of electricity in the case of renewables does not necessarily entail a loss of the incentive to maximize efficiency. The cost recovery incentives of installing new renewable capacity would still encourage the periodization of renewable technologies that shorten the period of cost recovery. As seen in the equation below, the current total revenue of fuel taxes (Rt_(Current Generation Fuel)) can be constructed by adding the revenue from the excise tax (TaxFuels excise) by the total volumetric imports (VFuel liters) of each fuel (j) and the VAT (TaxFuels VAT) of each fuel (j) by the selling price (P Fuel price) of each fuel

$$Rt_{Current\ Generation\ Fuel} = \sum TAX_{Fuels\ excise_j} \times V_{Fuel\ liters_j} + \sum TAX_{Fuels\ VAT_j} \times V_{Fuel\ liters_j} \times P_{Fuel\ price_j} \qquad (A)$$

The energy transition progress is measured in terms of electricity generated as well as the amount of emissions that derive from the execution of all the activities that take place with the fossil fuels. Therefore, there is a dual objective to both reduce the amount of energy that comes from fossil fuels as well as encourage efficiency increases within the combustion-based activities that still take place during and after the transition. The latter objective can be achieved through taxation on fuels. The incentive toward efficiency could be increased with a rising tax over those fuels over time. This gradual tax increase would need to match the losses from fuel revenue that take place due to the reduction of fuel consumption, particularly in transportation and electricity generation. The excess energy could be directed to the installation of new renewable energy.

$$
\begin{aligned}
Rt_{Electricity\ Generation\ Fuel} &+ SUB_{Renewables} \times \varepsilon_{renewables\ kWh} \\
&= \sum TAX_{Fuels\ excise\ j} \times V_{Fuel\ liters\ j} + \sum TAX_{Fuels\ VAT\ j} \times V_{Fuel\ liters\ j} \times P_{Fuel\ price\ j} \\
&+ \sum TAX_{Fuels\ energy\ j} \times \varepsilon_{Fuel\ energy\ j} + \sum TAX_{Renewable\ energy} \times \varepsilon_{Renewable\ energy} \qquad (B)
\end{aligned}
$$

This type of general tax deviates from the goal of taxing only those who are undergoing—or are subject to—the energy transition. The case of EVs is closely interlinked with the ownership and use of a vehicle. However, in the case of the transition of electricity generation, the impact is more generalized and, therefore, it is more justifiable to use general taxation to compensate for the expected progressive loss of revenue that would take place. Still, since the energy sector is the one undergoing the transition, it would follow that those who use more energy should be the ones that are proportionally taxed. This targeted taxation would help first execute the transition and then stabilize the revenue loss as fuel-based taxation is no longer enough to do so. The following section will explore the theoretical framework to support taxation on generation before looking at how taxation on vehicle related taxes could be levied. Next, an overview of the different options will be presented.

Another option is to create a tax on electricity generation that ensures a proportional burden of the energy transition is placed on the consumers. The tax should first be levied on fuels and move gradually to renewables (once costs allow for this transition) in order to create a longer-term revenue stream that helps stem the fiscal gap. However, this tax should respect the principles of technological neutrality for renewables as long as these technologies are provided from renewable sources and are in agreement with the BNEP.

Pollution

A second approach grounded in economic theory looks at the issue as a market failure stemming from the cost of pollution. Under this framework, the justification for taxing is the lack of pricing of pollution within carbon-intensive /ICE vehicles. This motivates an increase in pollution-related taxes and has led many countries (the United Kingdom and Finland, for example) to consider policies such as higher gasoline or oil excise taxes that help ensure pollution costs are priced in when the consumer decides to purchase a vehicle. This tax can also take the form of a carbon tax on producers based on the carbon output of the vehicles. While this would not be based on the equalization between EV and ICE vehicles, it would help bridge the gap for a number of years while those polluting activities are reduced. However, it must be noted that this approach will not help close the revenue gap once the transition is realized.

In addition to revenue losses, issues relating to traffic congestion and air pollution would still be important challenges as Barbados transitions to more fuel-efficient forms of transportation. One way of addressing problems related to revenue loss and logistics is the use of green tolls (Serrano-Hernández and Faulín 2019). Green tolls, i.e., congestion charges, can be used to encourage more efficient route logistics. An efficient toll system can encourage households to carpool and minimize unnecessary trips during peak hours of the day.

Fundamentally, the decision on what approach to take depends on the speed and scale at which vehicles based on renewable energy, or EVs, need to be adopted. It also depends on how the cost of incentives for these vehicles should be distributed and on who should pay in the end. Generally, more generous incentives for these vehicles will provide faster adoption rates with the government footing a larger cost. Spreading more of that cost throughout the economy and on the purchasers of vehicles will likely result in slower adoption rates and less market share for EVs. A summary of these policy options is presented in Table 3, which shows the advantages and disadvantages of the various taxation policies.

Other Generic Taxes

There are different options for alternative revenue generation that could compensate for the fiscal gap created by the energy transition. Perhaps the most obvious option to address the revenue gap would be a broad-based general tax increase. For example, the setup of an additional indirect tax, such as VAT, would ensure higher revenue at a lower cost of collection, since it would be ingrained into an existing revenue administration system.[14] However, this might not be the most desirable option, since it would put a burden on the taxpayers of Barbados who may either not own a car of their own or own an ICE vehicle. This type of tax increase would imply a cross subsidy for the owners of EVs, since the general population would have to cover for the revenue gap created by the EV switch during the transition. Those who do not own a vehicle would still be burdened by this tax eventually. Based on the literature review, this seems to be an uncommon solution to the revenue gap. This cross subsidy tends to create shifts in the overall patterns of consumption and must, therefore, be accounted for (Andrikopoulos et al. 1993). An ideal solution is one that can be targeted to those who have transitioned to an EV, or to those who have not and could be induced to do so. Since the GoB raised the VAT within the past few years, this option may not be politically feasible in the short term.

Due to the generic character of the tax, the amount of the increase could be easily derived from equation 1, where RtVAT is the VAT revenue total, i is the specifically taxed product, n is the amount sold, x its price before taxes, and VAT the rate.

$$Rt_{VAT} = \sum_{i=1}^{i} n_i \times x_i \times (VAT_i) \quad where\ VAT \geq 0 \tag{1}$$

$$\%\Delta VAT = \frac{\%\Delta Tax_{Vehicles}}{Rt_{VAT}} \tag{2}$$

The simulations suggest that the reduction in revenue from fuel taxes could be offset by relatively moderate changes in other tax rates.[15] Looking first at VAT rates necessary to maintain tax revenue at the BAU levels, Equations 1 and 2 suggest that in the worst-case scenario, if tax revenue falls by BBD $223 million, VAT rates could be raised to approximately 19 percent. In the case of a BBD $100 million loss in tax revenue, the VAT rate would only need to increase to about 18 percent. These tax rates would still be below VAT rates that exist in some other countries.

Finally, there is always the option of looking for new revenue sources to make up for the cost of the potential renewable financing. One point of consideration would be to utilize income taxes as a source of revenue. If this is undesirable, a second option would be to look at where import levies may be increased. This would function as an across-the-board sales tax again spreading the cost of the EV incentives across all consumers and would be administratively easier to implement

As discussed above, there are also new potential levies based around EVs that could be considered if their market share increases substantially (more than 50 percent). For example, levying a tax on charging stations or increasing registration fees for EVs may not be appropriate in the initial stages of the transition (as this will run counter to EV promotion), but may over time be phased in as adoption increases if revenue shortfalls become a problem. Another measure that could be implemented is a mileage tax. This could allow the government to raise revenue while managing external costs more effectively, such as emissions in the case of ICE vehicles.

14. Although this benefit is not exclusive to this policy option, it is a substantial benefit.

15. In FY2017/18, the Government of Barbados collected BBD$891 million in tax revenue from the VAT or approximately 9 percent of the country's GDP.

3.2 Policies Specific to the Energy Sector—Transport

Aside from broader taxes aimed at decreasing the revenue gap, there are a number of tax options within the energy sector that can help fund the transition to renewables. Broadly, these options have the advantage of avoiding the most egregious cases of cross subsidization and potentially helping to control the pace of the transition to renewables (an issue of implementation discussed further in chapter 5). However, because of their effect directly on the transition itself, they must be carefully managed. Special care must be taken when considering the imposition of taxes that would affect households more broadly. For example, higher taxes on electricity might impact household budgets and produce unforeseen distributional and welfare impacts. As EVs become more common, technological solutions to enable a targeted approach to taxing EV electricity consumption/storage instead of the whole household's electricity consumption would likely become available. These solutions would be a better option than general electricity taxation. Policy options discussed below include taxes on fuel/electricity, pollution, and taxes in the transport sector.

Any changes to addressing the problem of revenue losses due to the adoption of EVs must regard the sources of taxation that are diminishing because of the transition taking place such as lost revenues coming from diminishing used in fuel due to renewable generation. Therefore, it is best to consider all the different options of taxing EVs and ICE vehicles to adapt to those other lost revenues. These tax transformations offer a targeted approach by burdening only those who own a vehicle. The rate of change of the different potential increases can be summarized by the formula below.

$$\%\Delta Tax_{Vehicles} = \frac{\Delta Rt_{VAT} + \Delta Rt_{Fuel} + \Delta Rt_{Excise} + \Delta Rt_{Duty} + \Delta Rt_{RoadTax} + \Delta Rt_{Registration}}{Rt_{Vehicles}} \quad (3)$$

ΔRt is the difference in total revenue from EVs and fuel/ICE vehicles of different taxes and Rt is the total revenue of all those taxes. $\%\Delta TaxVehicles$ is the relative increase in vehicle taxes necessary to cover the gap. Alternatively, if a political choice is made to cover for the gap via a general tax increase, the equation would remain the same placing in the denominator the total revenue for all taxes. If taking a gradual approach to the tax increase is favored, there would be yearly increases as the volume of EVs increases. $\%\Delta TaxVehicles$ should ideally be as close to zero each year as possible to ensure a revenue-neutral path of transition year to year. Additionally, the burden of covering the gap can at first be shifted from EV owners to ICE vehicle owners, or to the general population, in order to keep fostering the transition. However, it ought to be shifted back to the EV owners progressively to balance out the revenue gap covering burden as adoption of EVs increases.

Vehicle Purchase Taxes

In the economics of taxing vehicles, consumers are taxed once during the acquisition of the vehicle and then pay yearly taxes and marginal taxes based on use. Taxes at the time of purchase of a car are composed of excise duties and VAT, which in Barbados amount to 62.5 percent of an EV's pretax price. This difference between yearly and marginal taxes offers a 5 percent reduction in duty and an additional reduction in the excise tax ranging between 36.3 percent and 80 percent for EVs versus their ICE peers depending on their engine's capacity. VAT gap compensation could be attained by ensuring that the VAT rates for EVs and ICE vehicles are attained by ensuring they are taxed at the same rate as they are currently. The same situation applies analogously to duties and excise tax, which are one-time payments made at the time of purchase of the EV and can easily be matched to its fuel-based peers.

However, the matching of EV and ICE vehicle purchase-related taxes to cover the gap increases the upfront acquisition cost of an EV. This is one of the main barriers of adoption and should, therefore, be addressed to avoid disincentivizing the adoption of EVs (Langbroek et al. 2016). Hence, for several years, the burden of covering the payment of the revenue gap could be shifted to other more marginal and less upfront taxes. If the goal is to foster the adoption of EVs by altering their price via fiscal measures, taxes would be at higher levels for ICE vehicles than for EVs to induce adoption via the lowering of purchase costs—as is the case in Barbados today. Additionally, applying a registration fee could be a one-time tax that is paid at the time of purchase. Although it must be kept in mind that since it does not depend on the price of the vehicle, the registration fee imposes a flat cost on the purchasing of vehicles. Any shift between onetime taxes from EV to ICE vehicles must aim to minimize the ratio between the scenario where the purchase-related taxes are equivalent for both types of vehicles and the one where the burden is shifted from the EV to the ICE vehicle's purchase price.

$$Tax\ Ratio_{purchase} = \frac{\sum_{j=1}^{j}[n_{FV_j} \times x_{FV_j} \times (VAT_{FV}+Ex_{FV}+Duty_{FV})+Reg_{FV} \times n_{FV_j}]+\sum_{k=1}^{k}[n_{FE_k} \times x_{FE_k} \times (VAT_{EV}+Ex_{EV}+Duty_{EV})+Reg_{EV} \times n_{FE_k}]}{\sum_{v=1}^{v=j+k}[N_V \times x_V \times (VAT_V+Ex_V+Duty_V)+Reg_V \times N_V]} \quad (4)$$

j represents each fuel-based vehicle that is sold, k represents every EV sold, and FV represents EVs and ICE vehicles. n is the number of cars sold at a given price x. VAT, Ex, and Duty represent the VAT, excise, and duty taxes, respectively. V is the addition of all the cars and represents all cars under a scenario where taxes are equal for both types of vehicles. Lastly, Reg represents the registration fee for a new vehicle. Under this formula, a rebalancing of the upfront tax burden can ensure that the purchase revenue gap is closed if the tax ratio approaches zero.

As Barbados transitions to a 100 percent renewable energy future, it is possible to consider higher taxes on cleaner technologies. For example, as more EVs and hybrid vehicles are purchased, it might be necessary to introduce a tax on these vehicles to offset the loss of revenue from road taxes on these vehicles. One option would be to introduce a mileage tax on EV owners (Davis 2019). At present, the road tax is applied at a rate of BBD$0.40 per liter on gasoline and diesel and BBD$0.05 per liter on kerosene. Because drivers of EVs do not use these fossil fuels, they do not pay any road tax. This policy provides an incentive for persons to transition to EVs and is important in the short run. However, in the long run (after 2030), as the penetration rate of EVs rises, the GoB could consider introducing a small tax on the mileage driven by EVs. In the United States, this tax is as high as BBD$0.017 per mile. Introducing a tax on mileage has the benefit of encouraging people to reduce the use of their vehicle and even consider using public transportation. If one uses a rate of BBD$0.034 per mile in Barbados, assuming each driver's commute is 20 miles per day (Edghill and McGregor 2015), then the total annual revenue collected from each driver would be approximately BBD$248. As in the previous section, through an analogous application of formula 3, it is possible to charge a higher rate to EV owners, as long as the ratio between the taxes charged to the EV owners and to the ICE vehicle owners allows for the fiscal gap to be covered with the result of the above formula remaining close to zero. Lastly, a fixed yearly tax on EV ownership could be proposed. However, as in the case of the registration fee, this option should be carefully considered since it would not be dependent on the use of the vehicle or its price.

Taxes on use

A transport tax would offer an alternative or supplement the aforementioned mileage tax by creating a tax that incentivizes the increase of efficiency of EVs. This would benefit those EV models that drive longer distances for the same amount of energy. This tax should be weighed against the marginal tax equivalent for ICE vehicles. Some issues arise in this case. If the goal is to target only those persons that own an EV, an arrangement could be made with the electricity provider, Barbados Light and Power Company (BLPC), to collect taxes via the electricity bill. This approach would avoid generalized increases in the cost of electricity that would make those who do and do not own cars alike pay for the electricity that EV owners consume. However, these options should be taken with care as an increase in the price of electricity could raise the cost of the use of electricity for all of the household appliances of EV owners. This would entail higher taxation of EV owners than ICE vehicle owners. From a metrics perspective, a gallon of fossil fuel is not equivalent to a kWh in energetic terms or in the use that each type of vehicle can extract from it. Therefore, the equivalency should be made on the basis of what is collected via fuel taxes versus the electricity that is consumed by an EV during the same period. An average approach to estimating the total gap of fuel EV taxes can be seen in the next formula.

$$\overline{\Delta Rt_{transport\ fuel}} = \bar{x}_{gas} \times TAX_{gas} - \bar{x}_{load} \times (\eta_{EV})^{-1} \times TAX_{EVelec} \qquad (5)$$

$\bar{x}$ is the average consumption of each type of fuel (gasoline and electricity for each vehicle), assuming an equivalence of both taxes. TAX is the tax ratio for each fuel. η_EV symbolizes the efficiency of the EV, i.e., the miles per kWh it can go on a full battery. By taking averages, the aim is to calculate the best way to approximately estimate an individual EV's consumption of kWh. However, since the load consumed varies, an average $\bar{x}_{load}$ consumed is assumed. An efficient EV would require a lower load per mile. Therefore, as can be seen in formula 5, this tax rewards innovation by taxing less those who operate more efficient EVs. It offers a way to tax for the use of the roads (which fulfills the purpose of the road tax) and for the use of the energy (which is the purpose of the fuel tax). Due to the characteristics of the EVs, this duality cannot be integrated in the same tax.

A mileage tax, could also help set an individual rate of taxation for the owner in order to ensure that the owner of an EV does not experience a generalized tax increase on the use of electricity as whole, since the electricity bill would add up both household and vehicle usage. The vehicle's consumption should be studied vis-a-vis the increase in consumption of a household in comparison with the past years to establish the approximate consumption of the EV and its cost or alternatively install a separate counter for the vehicle. Under this combination of fuel and mileage tax, the delta of taxes per vehicle should remain close to zero. Alternatively, a special connection point could be provided for the vehicle, but this would entail technical difficulties to install, maintain, and monitor. This would also imply that in order to avoid the incentive for EV owners to plug their vehicle into a home charging system, the electricity inputted into the car should be cheaper than the household electricity. This would incur a loss of revenue for the electric company and the government via the VAT collected from that bill. In combination with (5) would result in (6).

$$\overline{\Delta Rt_{transport\ fuel/millage}} = \bar{x}_{gas} \times TAX_{gas} - \bar{x}_{load}(\eta_{EV}) \times TAX_{EVelec} + \bar{x}_{miles} \times TAX_{millage} \qquad (6)$$

The establishment of yearly taxes can help divert part of the upfront costs into a less pernicious upfront burden of taxation. For example, a mileage tax on EVs would compensate for the absence of fuel taxes on those vehicles. A mileage tax would collect taxes on the number of miles that an EV has been driven between two consecutive yearly technical inspections.

$$\overline{\Delta R_{Mileage}} = \bar{x}_{gas} \times TAX_{gas} + \bar{x}_{miles} \times TAX_{millage} \qquad (7)$$

In the above equation, $\bar{x}_{gas}$ is the average consumption of gasoline, $\bar{x}_{miles}$ is the average of miles driven, and TAX is the tax rate for each fuel, and mileage. Under a full equivalence between both taxes, $\overline{\Delta R_{Mileage}}$ should be close to zero but, as we discuss below, this would result in some undesired consequences if it would match the revenue of both taxes (milage and gas) per vehicle in an equal manner.

To create this tax and set it at the appropriate level, a study of the miles driven by a sample of the population should be conducted. This would allow for the resulting taxation to respond accurately to the driving done by vehicle owners. Additionally, another point that must be considered is how much fuel tax should be levied on ICE vehicle owners. This would allow balancing the tax rates for ICE vehicles and EVs and, through a periodic review of both taxes, ensure their equivalence.

The imposition of such a tax must involve some calibration, since in the absence of other taxes it would tax all miles equally. A fuel tax would collect revenue based on the amount of fuel purchased. This type of tax fosters efficiency per gallon since the lesser amount of fuel you expend the lower the taxes you pay for the same number of miles. In the case of the mileage tax, every mile is flatly taxed, diminishing the incentive to acquire efficient vehicles. A mileage tax could induce an increase in electricity consumed from the national grid by those who own an EV. The effect of a mileage tax on efficiency can be curtailed by the inclusion of a supplementary or alternative tax that responds to the energetic commodity that EVs use: electricity.

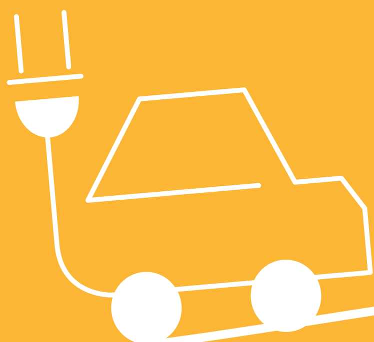
Table 3: Summary of Tax Options

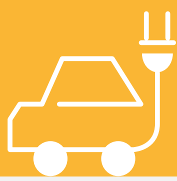
Type of Tax			Observations
General taxation	Pollution	Carbon tax	Carbon taxes charge the emission of pollutants by the economic activity across the economic system. Depending on how a carbon tax is implemented, it would create an incentive to move to less polluting practices across the economy. However, measuring its implementation is difficult and the tax would not create a specific incentive for car owners since its impact would be spread across the economy.
	Generic taxes	VAT/ corporate tax	These taxes would put the burden of transition on society as a whole or at least on a wide sector of it. The implementation of these taxes could significantly reduce the cost perception of the transition since the necessary increase to cover the fiscal gap would be relatively lower when compared with more specific taxes. This tax creates a burden that shifts between those who choose to embark on the transition and the rest of society, which has the potential of creating political backlash.
Taxes on energy sources	Taxes on generation	kWh-bound taxes	This tax would place a greater burden on those consumers who use more electricity and offer a progressive option to close the revenue gap. This tax is targeted at those to use the electricity system more, internalizing the negative environmental externalities and systemic cost of the transition. The implementation of this tax might not be as effective at encouraging efficiency in fuel-based activities.
	Taxes on fuel volume	Excise tax	This tax is collected as a flat amount per liter of fuel imported into Barbados. This tax is already in existence. It would be a matter of adjusting its value to encourage the energy transition. Additionally, it encourages energy efficiency in fuel-related activities. This tax cannot be applied to renewable technologies since they do not depend on the volumetric consumption of fossil fuels.
Transport-specific taxation	Vehicle purchase taxes	Price-bound taxes	This category includes taxes associated with the purchase of a vehicle. VAT, duty taxes, and excise taxes fit in this category. Price-bound taxes offer proportional taxing and direct burden shifting from EV adopters and non-adopters. However, it imposes an upfront cost on the purchase of a vehicle, which could have an impact on the decision to buy a new vehicle.
		Fees	This category comprises those taxes that are fixed and collected as a fee at the time of registration or purchase of the vehicle. The revenue only depends on the number of cars purchased and not on their price. However, this independence from price, use and income creates a distributional impact in the consumers.
	Taxes on use	Fuel	This tax category encompasses taxes levied on the fuel used by vehicles whether that is fossil fuels or electricity. This tax places a specific burden on ICE vehicles to be more efficient. However, it has long run challenges as ICE vehicles reduce so do their revenues and it is difficult to create a replacement equivalent tax on electricity for EV drivers due to it being billed along with Household utilities.
		Road tax	A road tax is an annual tax levied on vehicle owners who use a country's road network. This tax imposes a specific amount for the use of the country roads that due to its fixed nature has a clear expected yearly revenue. Conversely, its fixed nature does not offer proportional pricing incentives to the driver or reward vehicle efficiency.

Source: Authors' observations.

Chapter 4:

An Assessment of Pathways for Vehicle Electrification





Barbados' transition to a more sustainable future will require the electrification of a portion of the vehicles that are operating in the country today. The switch to EVs depends heavily on policies that facilitate their acquisition and charging. This chapter examines international experiences as well as the potential fiscal revenue loss that stems from the misalignment of excise taxes on ICE vehicles and EVs. Although this misalignment is justified at the beginning of the transition, it should be addressed over time as the price of EVs falls and the market becomes more competitive.

4.1 International Experience with the Transition to EVs

The development of regulation for EVs has started to take root in many countries. Wang, Tang, and Pan (2019) conducted a statistical analysis of the determinants of EV market share in 30 countries, which included factors such as subsidies via tax breaks, income, and other social economic factors, as well as some non-purchase price incentives such as preferential road treatment and electric charging subsidies. They found that increased investment in charging stations and non-financial benefits, such as parking and carpool lane access, have a high impact on the EV market share. Government tax breaks and subsidies also have a positive effect though this is smaller according to their estimates (Wang et al. 2019). One key tool governments employ in creating an economic environment that is conducive/receptive to further greening is fiscal policy. Fiscal policy that is geared toward greening the economy refers to the pricing of environmentally harmful behavior. This policy measure is useful because of its ability to achieve a range of goals, which can be broken down into three broad categories: (1) environmental benefits; (2) raising fiscal revenue and increasing fiscal efficiency; and (3) encouraging economic growth, innovation, and job creation (Schlegelmilch and Joas 2015). These goals are achieved via explicit price instruments, such as taxes, levies, and charges on various products and pollutants.

There is some research on the fiscal impact across different countries. One such study is an analysis of Iceland done by Shafiei et al. (2019). These authors utilized a comprehensive model of Iceland's economy and energy sector to simulate the effect of policy changes on both EV adoption rates and the government's budget. They tested the following scenarios: (1) carbon and excise tax on oil imports; (2) a subsidy of 20 percent on the purchase price of EVs; (3) the tax and the subsidy scenario; (4) a scenario where there is a higher carbon/oil tax and an imposed 20 percent tax on traditional vehicles (what they call feebate); and (5) a scenario that combines the tax, the 20 percent subsidy on EVs, and the 20 percent tax on ICE vehicles. In terms of government revenue, they found that, compared to no change in policies, revenue increases in the carbon and excise tax-only scenario, while it falls in the rest. Generally, when the carbon tax is included, government revenue falls less regardless of the additional subsidies. However, in terms of EV adoption, the opposite tends to be true. The scenarios with carbon taxes tend to have less EV adoption in the future than when the tax is not included. It appears that a carbon tax is enough to nudge some people toward purchasing EVs and a way to keep government revenue stable, but it is much less effective at encouraging adoption than subsidies which tend to be much more costly (Shafiei et al. 2019).

Another study on the impact of tax revenue from EV adoption is the OECD's report on the implications of decarbonization of the transport sector in Slovenia. This report estimates the evolution of EV adoption in Slovenia and how the dependence of the existing tax framework on vehicles, fuel, and roads could be detrimental to the government's budget. This study assesses the different tax policy options to mitigate dependence and slow down losses derived from the current tax system and the adoption of EVs. The table below presents a summary of the main categories of transportation taxation highlighted in this study.

Table 7: Types of Transportation Taxes in Slovenia

	Fuel or carbon tax	Vehicle tax	Distance-based charges
Long-run revenue stability		X	X
External cost management			
CO_2	X		X
Air pollution			X
Driving-related external costs			X
Administrative/ implementation costs	X	X	

Source: Elaborated from OECD (2019).

There are advantages of a distance-based tax over other systems. This advantage derives from the ability to differentiate by type of vehicle, region, and time, allowing for better distributional effects and a better allocation of the tax. In a separate study done in Canada, Wong (2017) estimates the impact on revenue nationally and in the province of British Columbia if the government were to replace all ICE vehicles with EVs. He notes that there are several important taxes the Canadian government collects that would be impacted, including taxes on gasoline sold (excise tax), an additional 5 percent sales tax on gasoline, a carbon tax on gasoline, and a tax that covers maintaining road infrastructure. On these taxes there would be a 33 percent loss of taxable value, which, he suggests, may be recovered by reducing spending in other areas (Wong 2017). For the United States, Jenn et al. (2015) find that a midsize compact car such as a Toyota Camry is expected to generate between US$2,000 and US$4,000 in tax revenue over its lifetime from gasoline taxes, while an all-electric car (Nissan Leaf) would generate only US$400 to US$1,300. These authors propose several methods for making up for lost revenue, including increasing car registration fees for EVs, moving to a fee per mile driven to implementing a small tax on EV charging stations among other issues (Jenn et al. 2015). Finally, Lavalleja and Scalese (2019) studied how Uruguay's policies to stimulate demand/adoption for EVs might impact government revenue. The government of Uruguay has in place several incentives for the purchase of EVs, including reductions in import taxes and tariffs to reduce purchase price and an exemption from vehicle license fees. There is also a corporate tax credit in place for companies that purchase EVs (Lavalleja and Scalese 2019).

Chapter 5:

A Review of Potential Policy Implementation Issues

This chapter focuses on the implementation aspect of fiscal policy during the energy transition. It starts with a literature review of evidence and lessons learned from the implementation of the types of taxes discussed in the previous chapters. It then examines aspects of the evolution of the tax substitutions.

5.1 Theoretical Issues with Implementation

The implementation of fiscal policy during the energy transition has inherent problems that must be accounted for in order to be avoided. Environmental tax reform (ETR) refers to reform efforts aimed at shifting the application of taxes from conventional bases (e.g., labor and capital) toward environmentally harmful behavior (European Environment Agency 2005). In such a system, the burden of taxes falls on those areas and activities that have a negative impact on the environment. This encourages consumers and producers to adopt more sustainable consumption and production habits.

Schlegelmilch (2010) provides an overview of fiscal policies currently employed in Barbados. The report found that the few policy initiatives already implemented are highly concentrated in the transport sector. These initiatives take the form of excise and import duties and VAT on the importation of vehicles, excise and import duties on the importation of petroleum, a highway tax on motor vehicles, and an environmental levy. Outside of the transport sector, initiatives such as land and property taxes, quarry licenses, and a tax on sugar imports are employed in the country. However, Schlegelmilch notes that Barbados' experience with green fiscal policy initiatives is still limited when compared to other Latin American and Caribbean countries.

Pearce (1991) introduced the term "double dividend" to describe the two benefits that arise when the tax burden is shifted to behavior that is harmful to the environment. The first dividend is represented by a direct improvement in the environment and the second represents greater economic efficiency as green tax revenue is used to reduce other traditional taxes. Schlegelmilch (2010) notes that Barbados does not capitalize on the opportunity to earn the double dividend as green tax revenue is not linked with the reduction of other traditional taxes. Ligthart (1998) found that any ETR will yield dividends for both the environment and the labor market, but only if revenue from green taxes is used to reduce the tax burden on the labor market. Oueslati (2013) further notes that the magnitude of the double dividend is a result of the type of ETR. Utilizing an endogenous growth model based on human capital accumulation to analyze the impact of different ETRs on welfare, the author concluded that only when green tax revenue is used to reduce income tax and increase spending on programs to promote depollution, welfare and economic growth improve in the long term. He goes further to note that any EFR initiative that uses green tax revenue to reduce physical capital tax will not improve economic growth and welfare. Therefore, when attempting to earn the double dividend, it is important to consider that shifting the tax burden from traditional tax bases to the environment cannot simultaneously achieve the goals of raising significant revenue for the government and promoting environmental sustainability. Roy-Chowdury (2012) explains this simply as any tax system aimed at reducing what it is taxing, i.e., environmentally bad behavior, if formulated efficiently and effectively, will undermine its own tax base.

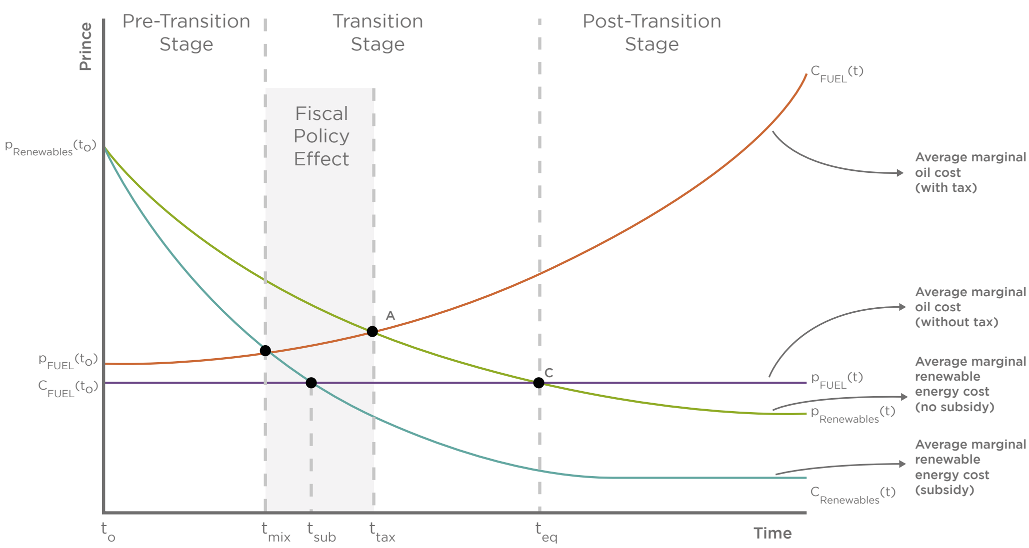
Schlegelmilch and Joas (2015) state that if an environmental tax is set at the Pigouvian rate, one would expect the environmentally harmful behavior to decline to an optimal level. Such a Pigouvian rate would be that in which consumer behavior is not altered by the tax. The authors show that tax revenue depends both on the tax rate, as well as the behavioral effect due to income elasticity. The implication of this is that the higher the elasticity, the greater the response, and so less tax revenue is raised. Therefore, when developing environmental tax policies, policy makers need to ensure that the policy has the desired environmental impact and that they do not rely on this revenue to fund fiscal decisions in the long term.

Any of the proposed reforms should always be done via a stakeholder consultation with the interested parties in Barbados to acknowledge any potential disruption that this reform can have on the economic activity and the lives of the citizens of Barbados. Additionally, to put in place new taxation, it is necessary to consider the burden placed on the tax authority and administration capacity which would require proper adaptation to be effective in its collection and registration. Estimating the impact of the reform shall always be considered against the costs and impact that this can have on different industries that might not be easily electrifiable such as is the case of heavy machinery of heavy trucks. Exemptions can be made for those industries since by not being subject to electrification there is currently no reason to increase taxes, considering the sectoral concerns as well as the accomplishments of the new taxation is fundamental for the creation of proposals that fit the case of Barbados specifically. In the short to medium term, alternative fuels can be an important path on the road toward 100 percent renewable energy as they allow ICE vehicle owners to use their vehicles for their normal life cycle.

A simplified model of the taxation of energy can illustrate the fiscal policy effect of the energy transition (Figure 8). In this model, we consider an average marginally decreasing cost of producing renewable electricity over time. In this model, the evolution of the average marginal cost of producing renewable energy progressively decreases over time until it meets the average price of producing oil at point C. Once point C has been surpassed, the rise of renewable generation would respond to market dynamics. However, this situation can be offset by fiscal policy through various options. First, the government could impose a marginally increasing fuel tax, which could target specific fuels at different rates. Second, a marginally increasing subsidy toward renewable energy could be set. Third, a combination of both could be established, which could balance the policy effort. Fourth, no fiscal action could be taken, which would retain the original equilibrium of transition at point C. As we can see in Figure 8, the imposition of the first policy strategy would mean that the tax on fuels would hasten the selection of renewable sources in time. The equilibrium point would be brought earlier to point A by increasing the equilibrium price with fuels and the marginal cost of fuel. In the second strategy, the subsidy on renewables would have the same effect, increasing the equilibrium price by lowering the marginal price of renewables, bringing forward the point of equilibrium to point B. The third strategy, which combines both, would have the highest effect of the strategies discussed so far leading to point D, besides providing for a fiscal transfer system that could compensate the cost of one with the partial revenue of the other.

Point of equilibrium in time under different policies: $t_{mix} \ll t_{tax} \sim t_{sub} \ll t_{eq}$

Figure 8: The Fiscal Policy Effect of the Energy Transition



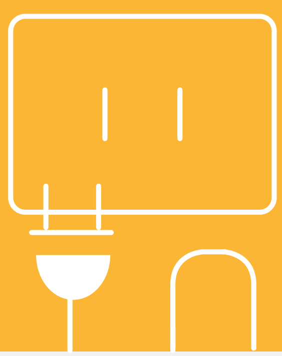
Source: Author's elaboration.

These policy measures create three decision areas where the incentives for policy action change. First, there is the pre-transition stage where no policy action has had the desired effect of reaching the equilibrium point. At this point, either tax, subsidy, or both would have the desirable effect of bringing about an earlier transition. A transition stage where the policy of subsidy or tax could be lessened progressively could generate a slowdown of the adoption of renewable energy. The impact of policy is set to bring sooner the transition to renewables and represents the variations this policy can create. The options during this period can include the implementation of a small tax on renewables, as long as it would set the price below that of the fuel alternative option. Lastly, in a post-transition phase (where the marginal cost of renewables is below the marginal cost of fuel), setting a tax on renewables might be justified to create an alternative revenue stream that can make up for the loss of revenue on fossil fuels in the long run while modulating the marginal tax on fuels to obtain the desired transition.

This simplified model helps understand that while closing the fiscal revenue gap of the energy transition is the main goal, the solution needs to enable the transition itself. Any fiscal change is bound to affect both the fiscal revenue gap and the speed of transition, and, therefore, both must be considered in tandem. In the next sections, we hope to shed light on the different, more specific, policy options that can be taken to close the fiscal gap while enabling the transition.

Chapter 6:

Conclusions



The dependence of island states such as Barbados on imported fossil fuels to supply their energy needs makes these economies highly vulnerable to fluctuations in international oil prices, with consequent implications across the economy. Incorporating renewable energy and increasing energy efficiency can, therefore, be an effective strategy for addressing these vulnerabilities. Utilizing greater domestic sources of renewable energy, however, can have implications for the tax revenue base of the government. This report analyzes the fiscal gap that will be created when Barbados advances in its transition toward renewable energy. It simulates the implications of considering a 100 percent renewable energy future, estimates the tax revenue losses from pursuing such a future, and puts forward some policy options to offset the fiscal gap that will develop.

Barbados' early commitment to the energy transition gives the island an opportunity to tackle challenges that have faced other countries. By undertaking its commitment to the energy transition, Barbados enables its policy makers to seize on the opportunity to minimize the revenue loss stemming from the transition by engaging in proactive strategies of fiscal adaptation to the changing ways energy is consumed and produced at both the vehicle and household levels. This report has provided an estimation of different possible pathways that can be taken to achieve the energy transition on the island from the fiscal point of view of the energy-related revenue of that transition. The focus is to show the adapted case of Barbados in this transition via these estimates as well as provide for policy options for consideration on the basis of both academic literature and international experience. This study aims to provide estimates specific to the losses in revenue, but it does not focus on the distributional impact or the administrative burden of these changes, which remain important and should be considered by policy makers in the option considered.

The simulation model suggests that the energy transition would result in an estimated BBD$105 million in revenue losses a year by following the BNEP. (Within the next 10 years, 635 MW of renewable energy capacity will have to be installed to meet the target of a 100 percent renewable energy future by 2030.) Such a reduction would create a significant fiscal gap that would need to be addressed through the introduction of new forms of taxes or changes to current taxes in order to adapt tax collection to revenue creation from the new clean energy economy.

A wide range of tax policy options and issues surrounding their effective implementation were discussed in this study. The tax policy options considered included: increased taxes on fossil fuels, a change in the VAT rate, mileage taxes on electric and hybrid vehicles, and taxes on renewable energy production. Each of these new tax approaches can help address the fiscal gap estimated above. However, there is a trade-off that must be considered, as any new tax on renewable energy could reduce the speed of transition to a 100 percent energy future. Therefore, the taxation changes should be sensitive to the moment in which they are adopted in order to encourage transition at the beginning and progressively switch the burden to the new form of taxation to cover the revenue gap. Additionally, it is critical to maintain dialogue with the relevant actors involved in the energy transition to better calibrate the changes considered by the policy makers.

This study, however, suggests that the revenue gap can be closed through relatively moderate changes in both traditional taxes and new forms of taxation that adapt to the specific process of the energy transition. The progressive removal of tax incentives, once the transition has a foothold, and in the long run the establishment of taxes on clean technologies will likely help close the revenue gap. As for the short term, further increases in taxes of fossil fuels could provide a double dividend, i.e., hasten the incentive of persons to purchase equipment that is less dependent on fossil fuels and generate additional revenue. Alternatively, a one to two percentage point increase in the VAT rate could also offset potential losses in revenue from the adoption of renewable sources of energy into the energy mix/matrix. This study is not based on a dynamic stochastic general equilibrium (DSGE) model due to data limitations. We cannot, therefore, include considerations of demand or consumption change or distributive impacts. The taxes modelled are limited to VAT and excise. Therefore, the results must be considered with care and interpreted by policy makers within the bounds of this model.

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Appendix

A. EV Adoption Model Assumptions

1. The model assumes that the number of cars in Barbados is stable and that it will remain stable.

2. It assumes that as cars get older, they are deregistered and disappear from the list, leading us to the current distribution curve.

3. We considered the distribution of car model years constant (no vehicles disappear), growing older the entire distribution by one year. Considering the owners of cars years where the overall vehicle stock grew potential buyers for a new vehicle.

4. It assumes that an owner with a particular characteristic (fuel and CC) in their car would repeat the same choice when replacing it. Preferences are, therefore, invariant.

5. It considers that the owner of a car that has reached his estimated maximum lifetime would buy a new one. However, it does not assume that every new car is bought from outside the country and considers that only half of them would come from abroad .

6. The model considers that the buyer of a new car does not have to buy the latest model of the car put in the market on the same year allowing for the second-hand cars to have an age distribution. This assumption seems to be backed by the data as indicated by a slow increase in the counts for vehicles from recent years. We aim to replicate this pattern in the acquisition of new cars. Therefore, we distribute the age of the new cars bought, considering the last five years vehicle age distribution.

7. The new vehicle acquisitions of a particular year are dispersed over a range of model years that miming the original distribution and including a minimum amount of ownership years. This assumption prevents a situation where the new owner would sell the car. We considered that despite overshooting the original distribution, those cars would remain in the hands of their owner for at least seven years, which coincides with the period of stabilization for the distribution.

8. A new car owner cannot sell their car before the first six years have passed. With this assumption in mind, we decided that since we are considering the invariance of the preference for a new car, it was important to take each grouping of preferences for a vehicle characteristic into account. Therefore, we simulated in the EV adoption model characteristics for each possible combination of fuels and engine CCs.

B. Additional Data Sources for the LINDA Model

Information about the indigenous production of natural gas and crude oil between 2004 and 2017 as well as the importation of gasoline, diesel, and fuel oil for the 2006–17 period was obtained from the Ministry of Energy, Small Business and Entrepreneurship[16] and the Ministry of Finance, Economic Affairs and Investment.[17] Fuel requirements for the generation of electricity, which encompasses the consumption of AV jet fuel, diesel, heavy fuel oil (HFO), and natural gas, along with the electrical outputs of various plant types, including gas turbines, low-speed diesel plants, and steam plants, for the 2006–17 period were also obtained from the Ministry of Energy, Small Business and Entrepreneurship.

Information on the transport sector was amassed through several means. First, information on the consumption of gasoline and diesel for the 2000–17 period was sourced from the United Nations Statistics Division's Energy Statistics database,[18] while estimates for the number of passengers and goods transported were derived from OECD averages[19]. Consumption data for both natural gas and electricity were obtained using various issues of Barbados Economic and Social Reports [20], resulting in a database ranging from 2000 to 2017.

Data on the investment and operation and maintenance costs of the various energy technologies are obtained from the International Energy Agency's World Energy Outlook.[21] Finally, fuel cost projections were obtained from the U.S. Energy Information Administration's Annual Energy Outlook for the period 2019 to 2050.[22]

C. Considerations in the Path to Fossil Fuel Phaseout for Barbados

At present, fossil fuels, primarily HFO, are the main source of energy in Barbados. HFO is primarily used in the generation of electricity. Diesel and gasoline, on the other hand, are primarily used in the transport sector. Most of the other sources of energy account for less than 10 percent of energy, including such sources as natural gas, solar power, and kerosene. Energy generated from these sources is largely used for residential purposes and to support the island's main industry, tourism. As more renewable energy is installed, the demand for fossil fuels will decline. This decline will have an impact on the revenue normally obtained from taxing these fuels. The revenue impact will be felt particularly in transportation. As this industry transitions to 100 percent renewable energy, the revenue impact will be significant as most vehicles will be powered by renewable fuels or electricity.

16. See website of Barbados' Ministry of Energy, Small Business and Entrepreneurship at http://www.energy.gov.bb.
17. See website of Barbados' Ministry of Finance, Economic Affairs and Investment at https://www.gov.bb/Ministries/finance-economic-affairs.
18. See website of UN Statistics Division at https://unstats.un.org/unsd/energystats/data/.
19. https://data.oecd.org/transport/passenger-car-registrations.htm
20. Available in the Barbados parliament
21. See the IEA's World Energy Outlook at https://www.iea.org/weo/.
22.

Although a small oil and gas producer, Barbados relies heavily on imported oil products to supply its energy needs. Imported fossil fuels account for 94.63 percent of Barbados' total primary energy supply and the remaining share being locally produced: oil (0.6 percent), natural gas (2.27 percent), biomass (2.44 percent), and solar (0.06 percent). Nearly 37 percent of the total energy supply is consumed by transportation. Approximately 96.2 percent of the electricity is generated using liquid fossil fuels and 3.8 percent from solar photovoltaic (PV). The dependence on imported fossil fuels has serious implications for energy security, balance of payments, the environment, and energy-dependent sectors, such as tourism, which is the country's main economic driver and accounts for 13 percent of GDP, 40.6 percent when considering indirect spillovers.

One of the core challenges of implementing a fully renewable transition in Barbados is achieving a reliable supply of electricity through the use of intermittent sources (renewable energy intermittent and baseload) of energy such as solar and wind sources among others. Barbados has a high potential for these sources of generation due to its high natural endowment of these resources. However, this source is bound to seasonal variations in weather patterns. Heide et al. (2010) investigate how one might design a power supply system based on renewables while accounting for seasonal weather changes. Using historical data on wind and solar energy power generation by month in Europe, the authors calculate the seasonal optimal mix between two sources with the mismatch accommodated using storage. The authors report that when mixed in a specific ratio, the seasonable patterns of wind and solar power generation sync quite well and, therefore, reduce the need for stored energy by a factor of two. Similar studies should be conducted in order to adjust Barbados' expansion plan to include renewable energy in the island's energy mix to avert potential disruptions. In recent years, the frequency and intensity of hurricanes have increased. These natural disasters can damage the equipment used to generate renewable energy, disrupt production, and cause damage to surrounding infrastructure. The impact of hurricanes and other natural disasters on renewable energy is an area that will require further research before significant investment is made in renewable energy equipment.

The dependence of small island states on imported fossil fuels for their energy needs is relatively common. Research has shown how this dependence makes these states' economies highly vulnerable to international oil price fluctuations, with implications for their balance of payments and inflation (Weisser 2004). Examining the case of electricity production, Weisser argues that most small states have relevant potential to attain cost savings through renewable energy integration.

Integrating more renewable energy sources can also be a key step on the road toward sustainable development. On this point, Dincer (2000) provides some illustrative examples of the link between renewable energy and sustainable development. Dincer notes the case of the city of Saarbrücken in Germany, which was able to reduce its energy consumption as well as lower its CO2 emissions using a solar roof program in combination with hydropower installation. Dincer argues that the integration of renewable energy is, therefore, a cost-effective and environmentally responsible alternative to conventional energy sources when used in combination with some form of storage. The benefits from such systems can be enhanced by integrating the expansion with research and development and technology transfer programs. Weight (2009), using Germany as a case study, estimates that the potential cost savings of wind-based generation are large enough to exceed the subsidies provided to the wind turbine industry due to the indirect economic activity resulting from its operations. An adaptation in the scale and specific aspects of these programs of these programs might be beneficial to the expansion of renewable energy in Barbados. If implemented, training programs specifically can create indirect employment in some segments of the renewable economic activity due to the installation of certification and maintenance schemes resulting from the policies implemented (IRENA 2019).

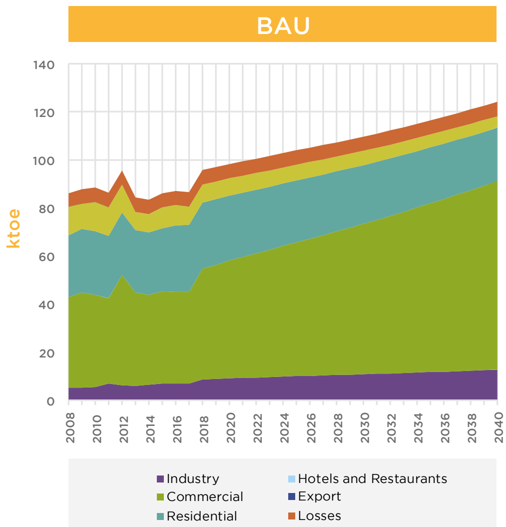
While reaching the fossil fuel phaseout goal in 2030 does imply a switch in the electricity generation matrix, this must be accompanied by government policies that foster and incentivize the adoption of energy efficient practices by public and private parties. This would help diminish the energy required to be sustained by the system by the system making transition affordable and more sustainable. Atwa et al. (2010) examine the possibility of incorporating distributed renewable energy technologies (e.g., wind power, photovoltaic, solar thermal systems, biomass, and various forms of hydraulic power) into distribution systems to this end. The model of the energy sector also accounts for the various operating conditions of different renewable energy units optimally allocating renewable energy systems into the distribution network while taking account of voltage limits, feeder capacity, maximum penetration limits, and the size of available renewable energy systems showing significant reductions in annual energy losses.

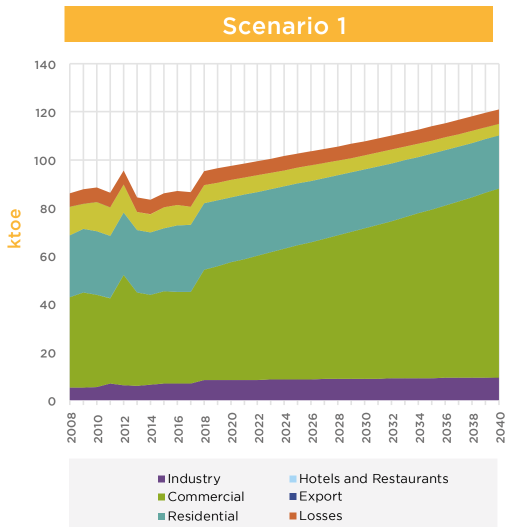
Integrating renewable energy into the energy industry must take into account demand- as well as supply-side considerations (Lund 2007). On the demand side, the switch to more renewable energy sources must be supported by user-adopted efficiency improvements, while on the supply side, fossil fuels would be replaced by various sources of renewable energy and enhancements to the efficiency of energy generation and distribution. Given the intermittent nature of more renewable energy sources, the achievement of 100 percent renewable energy systems will always be somewhat challenging. Lund argues, however, that if an integrated approach to energy planning is utilized—one that incorporates transportation as well as flexibility in terms of the renewable energy technology used—such targets can be achieved.

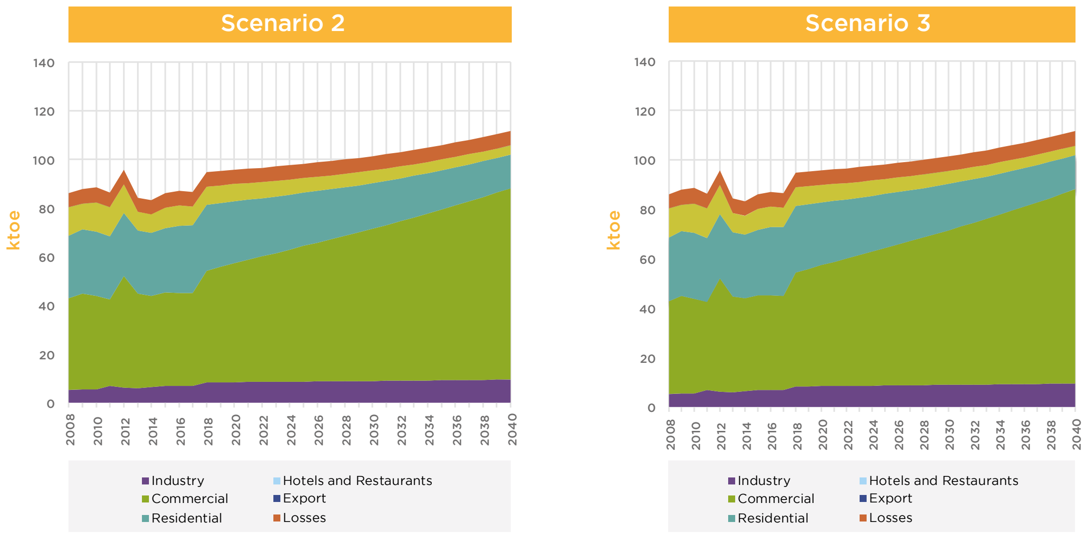
The integration of intermittent renewable energy sources, such as wind and solar, would not significantly affect the efficiency of energy supply, even in small, remote island states like Barbados. Looking at the case of Barbados, GE Energy Management Energy Consulting (2015) investigates the technical and economic impact of adding more intermittent renewable energy sources to the national grid by conducting detailed power system modelling. The study reports that under current operating conditions, the electric utility (Barbados power and light) could accommodate some of its supply coming from renewable sources. This level of penetration could be significantly enhanced with some technical changes to the supply infrastructure. This, however, implies that for a high supply of electricity to emanate from intermittent renewable energy sources, additional investment would have to be made in the grid as well as storage capacity, and is an expense to be considered in the transition to a 100 percent renewable energy scenario.

D. Model Results

Figure 9: Electricity Consumption in Barbados

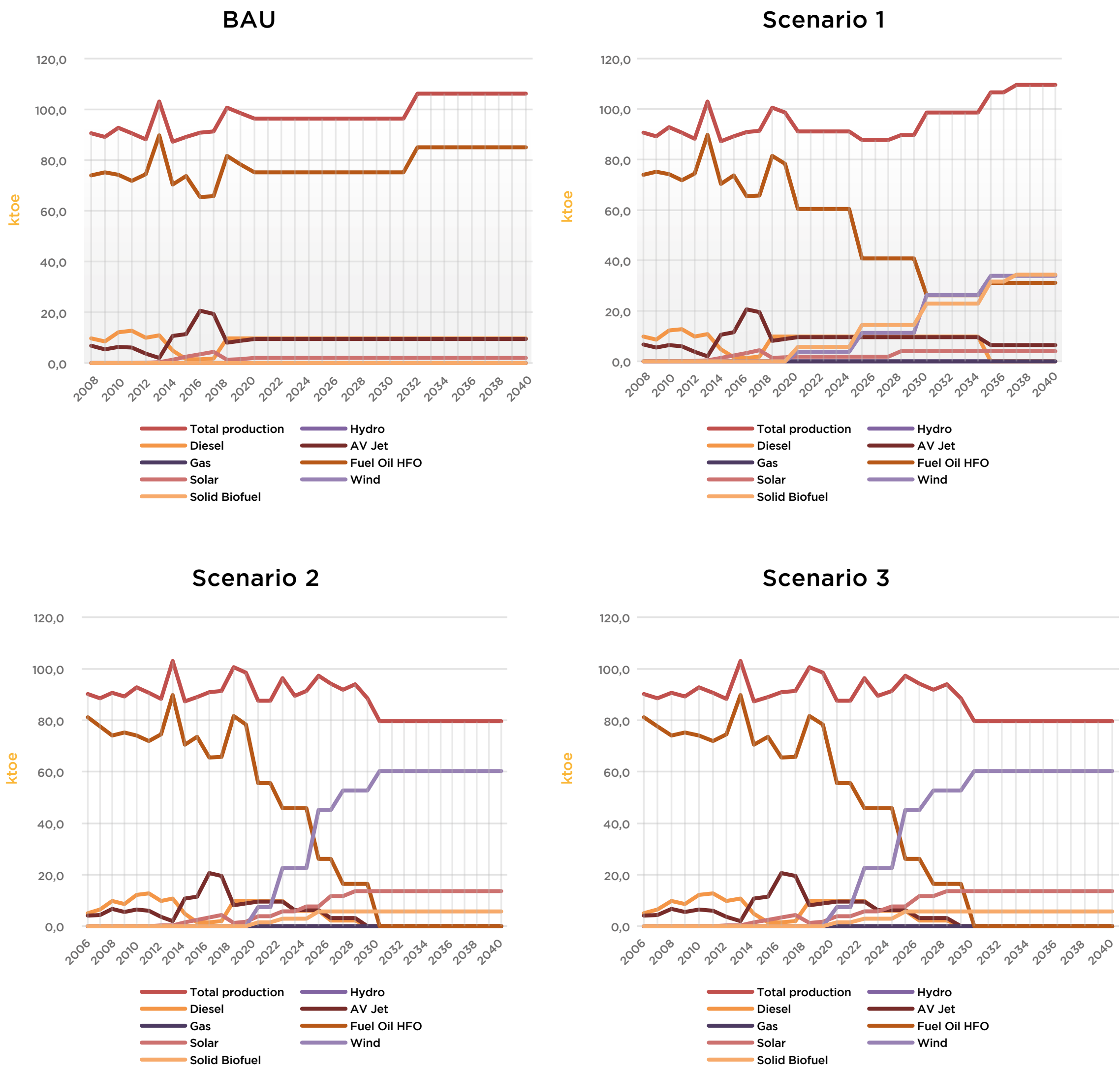






Source: Model calculations.

Figure 10: Electricity Output by Fuel Type

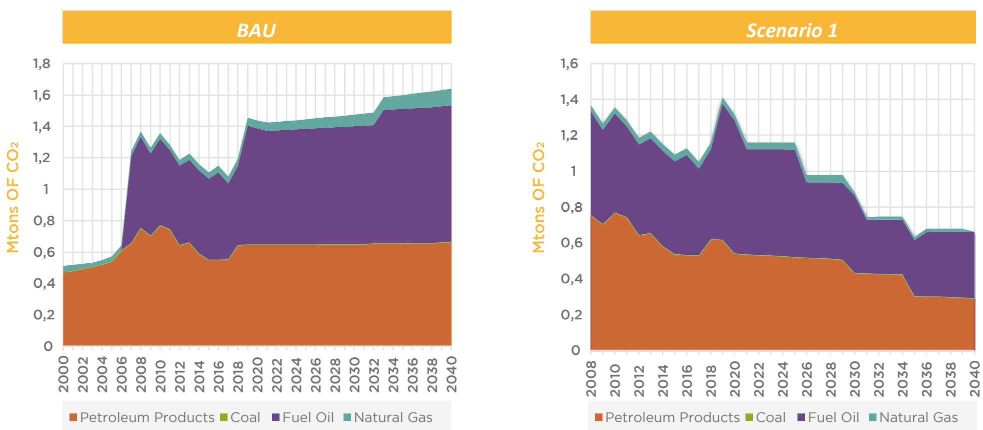


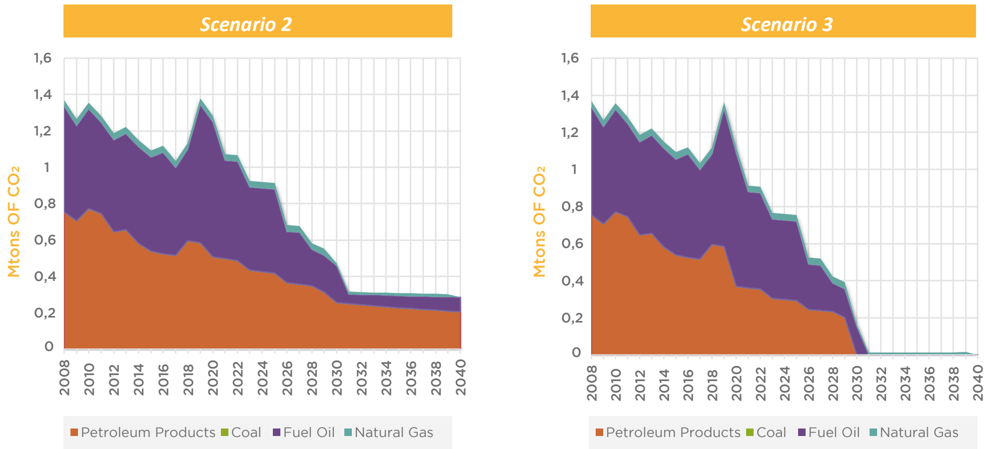
Source: Model calculations.

Figure 11: Transport Energy Demand in Barbados

Source: Model calculations.

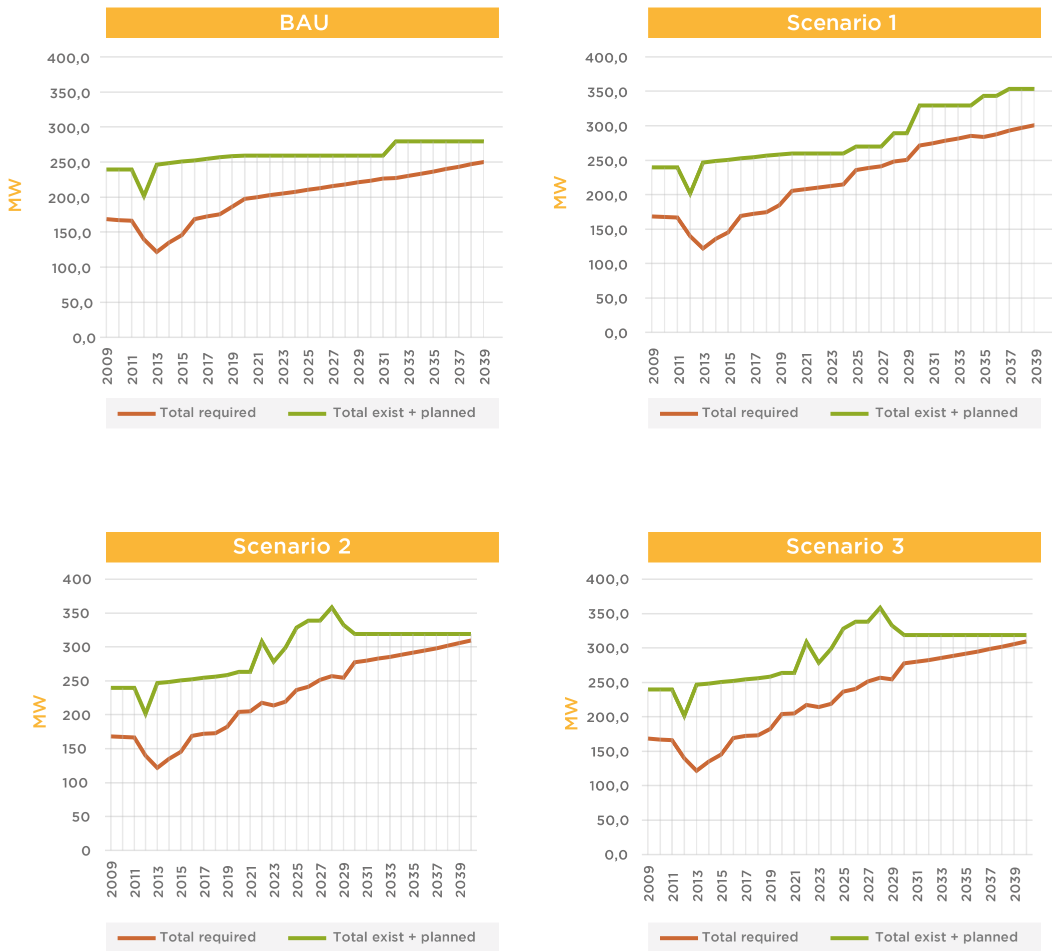
Figure 12: CO2 Emissions from Fuel Use in Barbados





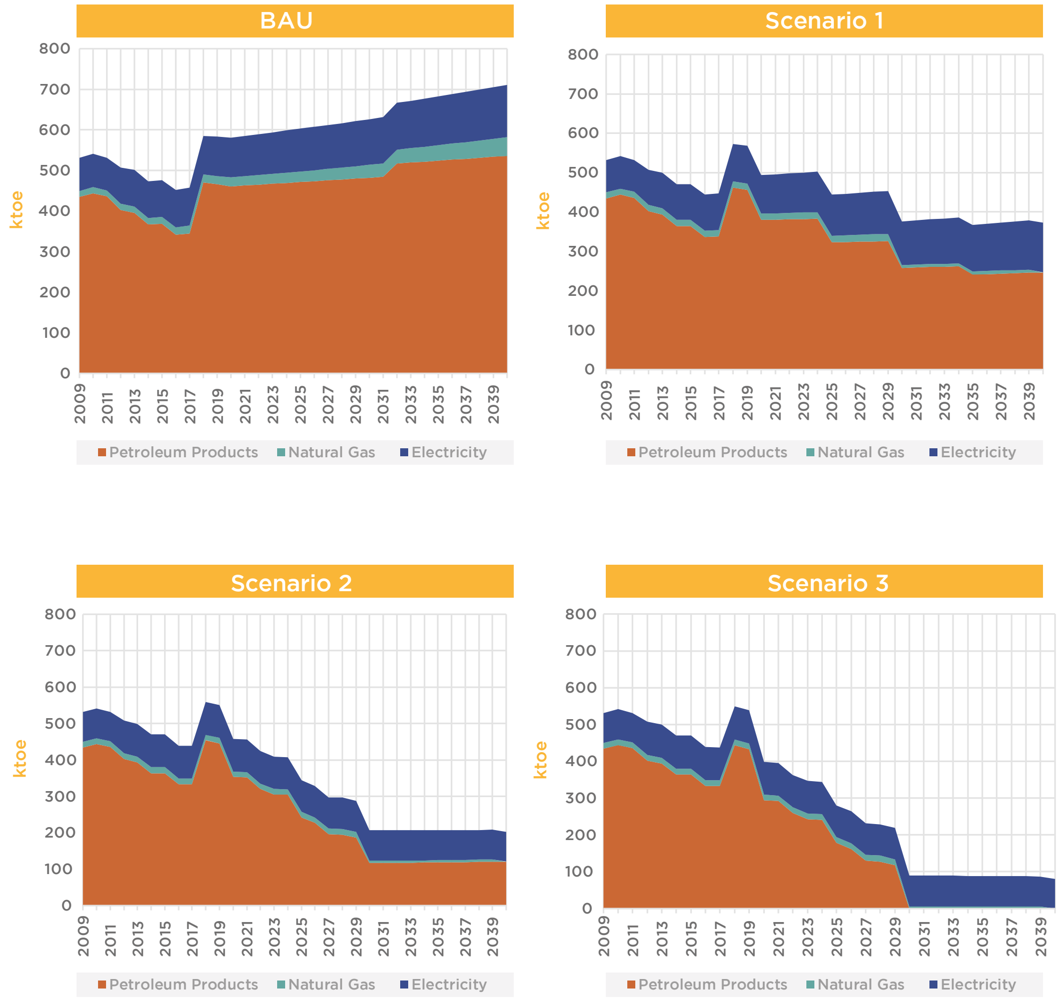
Source: Model calculations.

Figure 13: Electricity Demand and Installed Capacity in Barbados



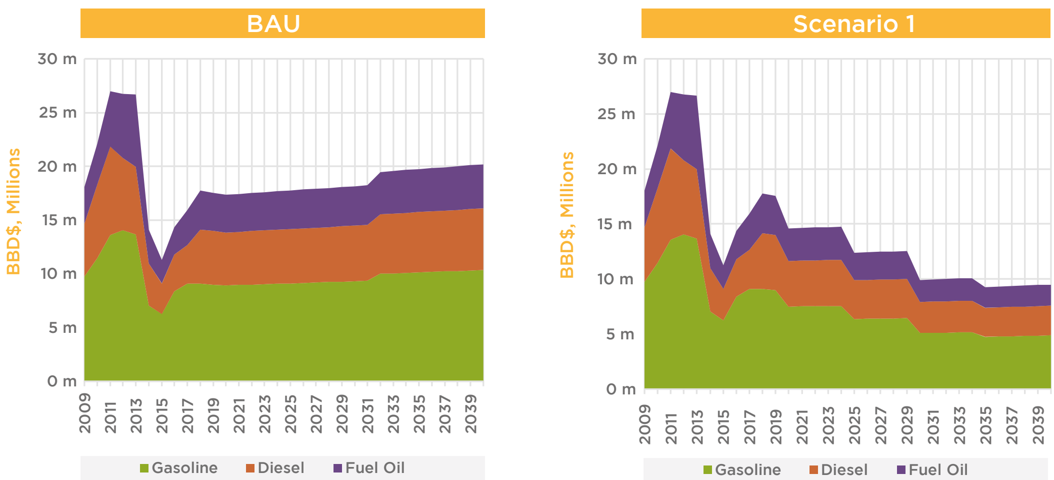
Source: Model calculations.

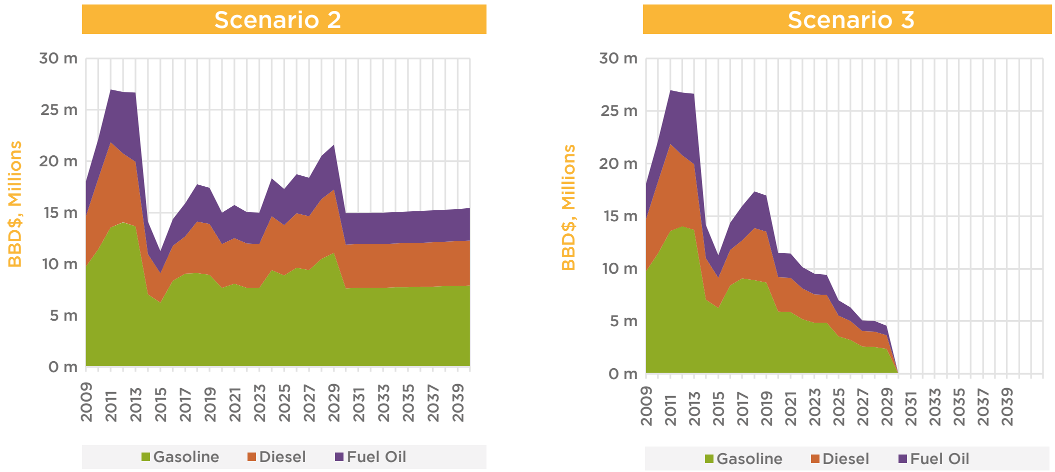
Figure 14: Fuel Use in Barbados



Source: Model calculations.

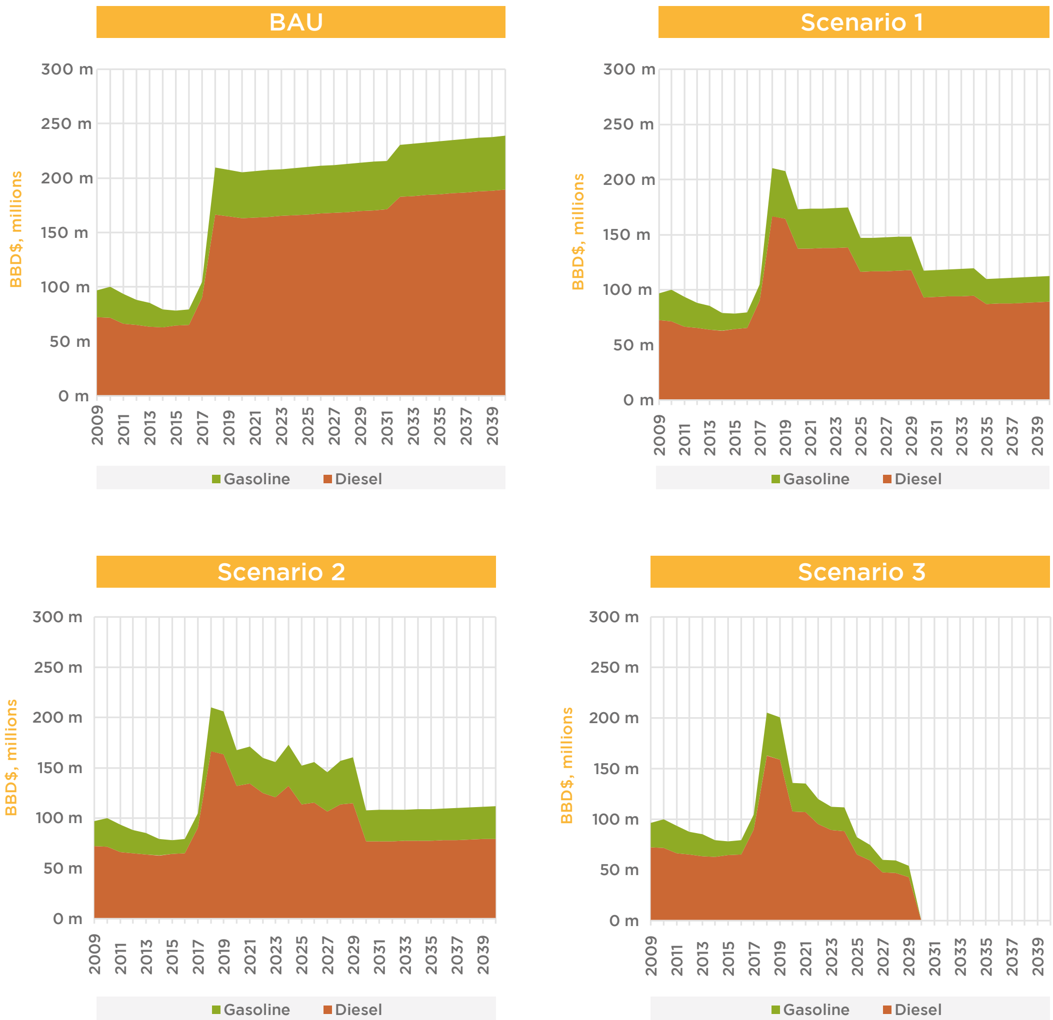
Figure 15: VAT on Fuel Use in Barbados





Source: Model calculations.

Figure 16: Excise Tax on Fuel Use in Barbados



Source: Model calculations.

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