PATHWAYS TO LOW-CARBON DEVELOPMENT FOR THE PHILIPPINES

ASIAN DEVELOPMENT BANK

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Foreword

The Philippines is widely recognized as among the most climate vulnerable countries of Asia. It is frequently affected by extreme storms, has periods of the year where temperatures already are high enough to limit labor productivity, and has extensive areas that are susceptible to the effects of sea level rise. For these reasons, strong action to limit climate change is in the country's long term interest. As Chair of the Climate Vulnerable Forum, the Government of the Philippines has done much to raise international awareness about the expected adverse impacts of unmitigated climate change.

To date, per capita greenhouse gas (GHG) emissions from the Philippines have remained far lower than global or Asian averages. However, GHG emissions have large potential to expand, as a result of rapid economic growth and an energy system that is rapidly becoming more carbon intensive. To avoid large future emissions, early action can help to put the country on a low-carbon development trajectory.

In recognition of the importance of avoiding GHG emissions growth, the Government of the Philippines has enacted an array of policies to promote low carbon development. The 2009 Climate Change Act led to a National Framework Strategy in 2010 and Action Plan on Climate Change in 2011, which emphasizes promotion of energy efficiency, renewable energy, and sustainable transport systems. Ambitious goals for scaling up renewable power have been outlined in the 2010 National Renewable Energy Program. Following on this legacy, in 2015, the government announced an ambitious Intended Nationally Determined Contribution to the Paris Agreement of 70% GHG emissions mitigation relative to business as usual by 2030, conditional on sufficient international support. In 2017, the Philippines ratified the Paris Agreement.

This study helps to assess how a low-carbon development pathway can be achieved, so as to realize the ambitions of the Intended Nationally Determined Contribution and other national polices related to climate change. It draws on detailed consultations held with a range of concerned Government of the Philippines Departments to identify a series of concrete mitigation measures in the energy and transport sectors that are consistent with existing programs and goals. Based on agreed characteristics of these measures, they have been reflected in a detailed "bottom up" model to assess mitigation potential and associated costs.

Modeling for the study finds that the assessed measures can avoid 80% of GHG emissions growth through 2050, and that they can do so at nearly zero net direct cost. The vast majority of mitigation comes from measures to make the power sector less carbon intensive, followed by improvements to transport systems. Renewable energy deployment is found to be key to power sector mitigation potential, and fostering this mitigation depends upon suggested reforms to power sector incentives and contracting procedures.

ADB is collaborating with the Government of the Philippines to go beyond analysis of potential of low-carbon growth options and actively support making low-carbon development a reality. Key areas of cooperation include sustainable transport systems, including both mass transit and transit electrification, renewable power development, energy sector reform and energy efficiency enhancement. This report identifies potential areas for broadened collaboration, as the partnership between ADB and the Philippines continues to grow.

We would like to thank the National Economic and Development Authority and the National Technical Working Group that it convened for support and active input throughout the implementation of this study. It is hoped that this study will stimulate dialogue among stakeholders about how low-carbon development can be achieved via specific actions and policy measures.

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A National Technical Working Group chaired by Kathleen Mangune (Director III) and Francis Coballes (Division Chief) of the Infrastructure Staff of the National Economic Development Authority provided guidance for the report. Gilbert Ofina (Senior Economic and Development Specialist) of the National Economic Development Authority coordinated activities of ADB and the the working group. The following members comprised the working group: Joyceline Goco (Deputy Executive Director) and Sandee Recabar (Senior Science Research Specialist) of the Climate Change Commission; Eva Ocfemia (Officer-in-Charge [OIC]-Assistant Director, Environmental Management Bureau) and Eligio Ildefonso (OIC-Executive Director, National Solid Waste Management Commission) of the Department of Environment and Natural Resources; Jesus Tamang (Director IV) and Marietta Quejada (Senior Science Research Specialist) of the Energy Policy and Planning Bureau of the Department of Energy; Ildefonso Patdu, Jr. (Assistant Secretary of Transportation) and Lemar Jimenez (Senior Transportation Development Officer) of the Department of Transportation and Communications; Constante Llanes, Jr. (Director, Planning Service) and Rosemarie del Rosario (OIC-Division Chief) of the Department of Public Works and Highways; and Paula Collado (interim Deputy National Statistician) and Dulce Regala (OIC) of the Industry Statistics Division of the Philippine Statistics Authority.

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Abbreviations

BRT	bus rapid transit
CCGT	combined-cycle gas turbine
CFL	compact fluorescent lamp
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COPERT	Computer Programme to Calculate Emissions from Road Transport
DOE	Department of Energy
EFFECT	Energy Forecasting Framework and Emissions Consensus Tool
EPIRA	Electric Power Industry Reform Act
ESCO	energy service company
EU	European Union
FIES	Family Income and Expenditure Survey
FTKT	freight-ton-kilometer traveled
GDP	gross domestic product
GHG	greenhouse gas
Gg	gigagram
GWh	gigawatt-hour
INDC	Intended Nationally Determined Contribution
IPP	independent power producer
km	kilometer
ktoe	kilo ton of oil equivalent
kWh	kilowatt-hour
LCD	low-carbon development
LED	light-emitting diode
LNG	liquefied natural gas
LRT	light rail transit
MEPS	minimum energy performance standards
MPCE	monthly per capita expenditure
MRT	metro rail transit
$MtCO_2e$	million metric tons of carbon dioxide equivalent
MW	megawatt
NPC	National Power Corporation

NREP	National Renewable Energy Program
NTWG	national technical working group
PKT	passenger-kilometer traveled
RPS	Renewable Portfolio Standards
SCGT	single-cycle gas turbine
SNC	Second National Communication
tCO_2e	metric ton of carbon dioxide equivalent
TWh	terawatt-hour

Executive Summary

The Philippines has a large stake in mitigating climate change

The Philippines is among the most climate-vulnerable countries of the world. A range of models shows that the country is expected to experience effects of climate change on catastrophic risks, labor productivity, agriculture, energy, and tourism that are well above the rest of the world and much of Asia. For this reason, a low-carbon future is in the country's own interest.

Greenhouse gas emissions are low, but rising rapidly

The Philippines has per capita greenhouse gas emissions that are far below the world average. However, emissions are growing at an increasing rate, with 4% annual growth between 2006 and 2012. Much of this rise is driven by a fall in the renewable share of primary energy from 55% in 1990 to 38% in 2013, as well as accelerating growth in energy consumption. Given that energy use levels are still low, the country has an opportunity to follow a low-carbon development trajectory—if the right actions are taken soon.

The Philippines' climate goals can potentially be met through a limited set of actions

In its Intended Nationally Determined Contribution to the Paris Agreement on Climate Change, the Government of the Philippines provided a pledge of reducing 2030 emissions by 70% relative to business as usual sufficient international support were provided. This study explores options that can provide much of that mitigation at an aggregate near zero cost—without counting any of the benefits from reduced climate change or co-benefits, such as improved air quality.

Greenhouse gas emissions will rise at an increasing rate without low-carbon policies

This study takes a detailed bottom-up modeling approach to assess the potential of mitigation options for the Philippines in the power generation, household electricity, and transport sectors. Such an approach relies on the use of extensive consultations with experts to frame the characteristics of each option in terms of feasible levels of deployment, costs involved, and compatibility with existing policies and plans. Based on these consultations, options are selected and represented in an engineering-type model. First, those options that affect energy demand are modeled and, subsequently, supply options are modeled to meet demand.

In the "reference scenario" without concerted low-carbon development efforts, greenhouse gas emissions from energy-related sectors may rise by more than 500% between 2015 and 2050, due to rapid growth in fossil fuel–based energy. In contrast, this study finds that a low-carbon development strategy can avoid 80% of this growth over the period.

The cost of deep decarbonization can be modest

Modeling of all emissions mitigation measures under this study finds that the Philippines' greenhouse gas emissions in 2050 can be reduced by about 70%, relative to the reference scenario. The aggregate direct cost of this mitigation is an average of –$0.1 per metric ton of carbon dioxide equivalent.

Much mitigation potential is concentrated in a few low-carbon measures

The power generation sector is found to contribute 73% of potential modeled mitigation. Renewable power is found to contribute about half of the power sector reduction in emissions, with hydropower having the largest share. Over the longer term, large mitigation depends on the deployment of backstop mitigation options, which may potentially include biomass or other alternatives.

Transport improvements are the second-largest sources of mitigation. More than half of identified transport emissions reduction can be achieved by establishing carbon dioxide standards for vehicles. Much of the remaining mitigation is possible by substituting electricity and biofuels for petrol- and diesel-fueled mobility.

Because household appliance efficiency is likely to improve as a spillover effect from other larger markets and residential power is a small share of total electricity, contributions from efficiency improvements in household appliances are relatively modest. The combined mitigation contribution of promoting efficient household appliances is found to be 3%, with more efficient refrigerators accounting for half of the contribution.

Low-carbon development can offer many benefits

Although most low-carbon development options assessed have higher initial capital investment requirements than under the reference scenario, over the long term they yield many additional benefits. Nearly all low-carbon power options reduce the long-term cost of electricity generation. The combined effect of efficient appliances offers greater benefits from reduced electricity consumption than initial costs. Sustainable transport both saves fuel and reduces congestion. Moreover, although not captured in this analysis, less fossil fuel combustion also means less air pollution and improved human health.

Large greenhouse gas mitigation depends upon escalating renewable energy targets

The Philippines has set important goals to strongly increase renewable capacity through the National Renewable Energy Program. At the same time, this study finds that clean energy deployment needs to go beyond these goals for emissions reduction closer to levels targeted by the Philippines' Intended Nationally Determined Contribution to the Paris Agreement. To attain a 70% reduction in energy emissions from the reference scenario by 2050, the long-term rate of clean energy deployment needs to be more than doubled relative to goals set to date.

Renewable power expansion can be better supported by energy policies

Achieving this high potential for mitigation depends upon addressing barriers and challenges to the deployment of low-carbon development options, especially in the power sector. Current feed-in tariffs for renewables are limited in scope and are not sufficient to incentivize large renewable power generation. There is opportunity to escalate renewable portfolio standards to require more renewable generation, and it is possible to directly mandate the development of identified large hydropower and geothermal power plants.

Contracting reforms may help to facilitate more renewable deployment

Current procurement policies for independent power producers tend to favor coal plants as the lowest-cost and least risky option. Small distribution utilities that service much of the country may have trouble integrating intermittent power from renewables or large efficient power plants unless innovations, such as renewable certificates or aggregated contracting, are introduced. Approval processes are slower for geothermal and hydropower than for coal, and restrictions on foreign market participation limit applications by operators that are more experienced in renewable energy.

Transport efficiency can be substantially improved

In the transport sector, there are currently no fuel efficiency or greenhouse gas emissions standards for vehicles. These can be created and supplemented by measures to facilitate greater adoption of electric vehicles and higher biofuel blending mandates. Efficiency can be further improved by creating infrastructure that facilitates modal shifts to public transport and increases vehicular speeds.

An expanded array of instruments can foster residential energy efficiency

For the household sector, appliance efficiency standards may be increased, linked to those of larger markets, and supplemented by green building codes. Efficiency labeling can be improved to cover more electricity-consuming devices. Instruments, such as tiered pricing, may also help to incentivize selection of efficient devices, as well as efficient behavior.

Cross-sectoral approaches to low-carbon planning are needed

There are important complementarities and interaction effects among these policies. Increased adoption of more efficient household appliances may reduce power demand, whereas wider use of electric vehicles will increase it, particularly during charging periods. Meanwhile, increased deployment of renewables may facilitate technology learning curves that reduce costs of application, operations, and maintenance. Substitution of gas for coal depends on development of ports and other transport infrastructure, and more sustainable transport often depends on improved patterns of spatial development. Strong intersectoral coordination is needed to ensure that synergies in low-carbon strategies are exploited.

1. Introduction

1.1 The Philippines Has a Large Stake in Climate Change

The Philippines is highly exposed to the effects of unmitigated climate change. Over 30% of its labor force is employed in agriculture and the country is frequently affected by weather-related natural disasters. As an archipelago with over 7,000 islands and 36,000 kilometers of shoreline, the country is subjected to the effects of storm surges and sea level rise. For 2015, the Climate Change Vulnerability Index ranked the Philippines as the fourth most climate-vulnerable country in the world (Kreft et al. 2014).

With a position in the Pacific "typhoon belt," the Philippines experiences an average of 20 typhoon landfalls annually. These can cause massive economic loss. For example, in 2013, Typhoon Haiyan had the highest sustained wind speed at landfall of any typhoon to date globally and led to over 6,000 deaths and affected 13 million people. Such destructive storms are expected to be more frequent as the mean global temperature rises.

Agricultural production in the Philippines is at risk from climate change. Rice is the country's staple crop and has the largest share of national production value of any agricultural product. Peng et al. (2004) observed a 10% rice yield decline for every 1-degree Celsius rise in night temperatures in the Philippines. As nighttime temperatures have risen faster than daytime temperatures, this implies a potential loss of 15% for every 1-degree rise in average temperatures, which may rise by more than 2 degrees by 2050. This will be exacerbated by more concentrated and variable rainfall, which will cause more drought and flood damage. In addition, pest and disease epidemics may increase as temperatures rise.

The Philippines has a hot tropical climate, and during portions of the year humidity-adjusted temperatures already exceed thresholds for intensive labor. This is projected to increase under climate change, such that 6% of labor man-days may be lost by 2050 because of excessive heat (Kjellstrom et al. 2015). Where possible, extra cooling will be installed to offset temperature increases, but this will come at a cost of about 11% more electricity consumption than without climate change by 2050 (Bosello, Eboli, and Pierfederici 2012).

With a hot climate, further temperature rises may exceed attractive ranges for tourist arrivals and may adversely affect tourism. By 2050, tourist arrivals may be negatively impacted by 12%, with an associated loss of nearly 1% of gross domestic product (GDP) (Raitzer et al. 2015).

When catastrophic risks, health and ecosystem losses, labor productivity losses, and market impacts on agriculture, energy, and tourism are considered, GDP loss may exceed 3% by 2050 (Raitzer et al. 2015). This is far above the world average, and suggests that the country has much stake in whether climate change is contained.

1.2 Greenhouse Gas Emissions are Low but Rising Rapidly

The Philippines has not been a substantial source of greenhouse gas emissions historically, but it may contribute more in the future. The country had 1.6 tons of average per capita carbon dioxide equivalent (CO_2e) emissions in 2012, which is far below the global average of 6.5 tons. However, emissions are rapidly rising. Between 1992 and 2012, emissions rose 3% annually and, between 2006 and 2012, this growth rate accelerated to 4% (Figure 1.1). More than half of 2012 emissions were from the energy and transport sectors, and the energy sector has been the main source of emissions growth.

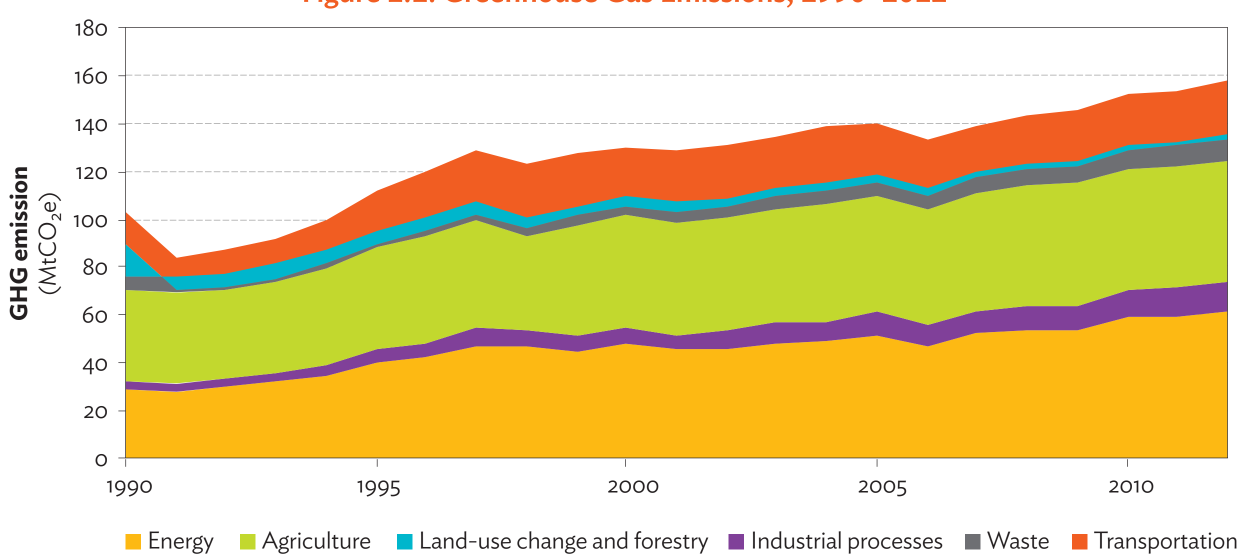
1.3 Energy Supply is Increasingly Carbon Intensive

As of 2013, 38% of the Philippines' primary energy supply was from renewable sources, principally geothermal power and traditional biomass (Figure 1.2). Although the share of renewables is relatively high, it has been declining over time. In 1990, 55% of primary energy was renewable. In fact, the share of primary energy from "modern renewables," such as geothermal power and hydropower, peaked in absolute terms in 2001, and has fallen even as overall energy supply increased dramatically. Moreover, the rate of increase is accelerating, with a decline between 2000 and 2009 contrasting with 5% annual growth between 2009 and 2014. The increase in energy is from coal and oil, rendering the energy system more carbon intensive.

The largest share of energy consumption is transportation, followed by the industry and residential sectors (Table 1.1). Increases in oil consumption are largely driven by growth in transportation, which is a substantial source of fossil fuel energy demand.

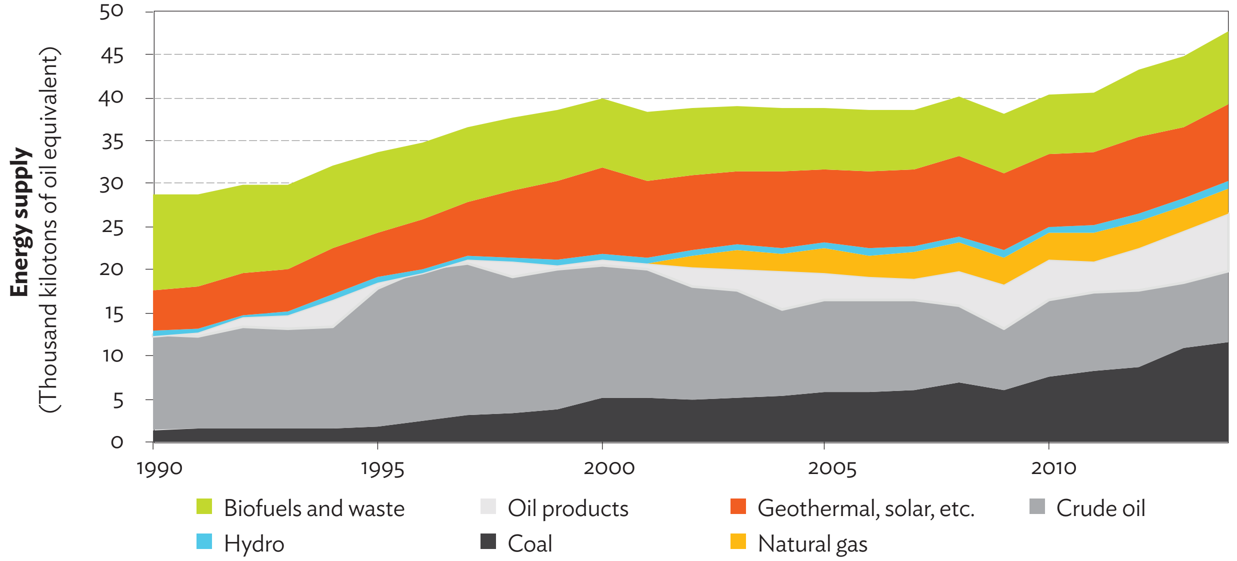
Rising electrification rates will increase household energy demand. As of late 2013, the country has achieved a 79% household electrification rate, which means that 4.5 million households remain unelectrified. Electrification is also spatially concentrated, as the main island of Luzon has 89% electrification while only 56% of households in Mindanao have been electrified. This may change rapidly. The Department of Energy (DOE) has formulated the Accelerated Household Electrification Program to achieve 90% household electrification by the end of 2017 (Table 1.2) (DOE n.d.).

Figure 1.1: Greenhouse Gas Emissions, 1990–2012



GHG= greenhouse gas, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Source: World Resources Institute. CAIT Climate Data Explorer. http://cait.wri.org

Figure 1.2: Primary Energy Supply, 1990–2014



Source: International Energy Agency. Statistics. http://www.iea.org/statistics/statisticssearch

Table 1.1: Final Energy Consumption by Sector (2010)

Sector	Final Energy Consumption (ktoe)	% Share
Industry	6,364	26.0
Transport	9,023	36.8
Residential	6,125	25.0
Commercial	2,664	10.9
Agriculture, forestry, and fishery	347	1.4
Total	**24,522**	**100.0**

ktoe = kilo ton of oil equivalent.
Note: These figures exclude power and nonenergy-use applications.
Source: Department of Energy. Key Energy Statistics 2010. https://www.doe.gov.ph/key-energy-statistics-2010 (accessed 15 March 2016).

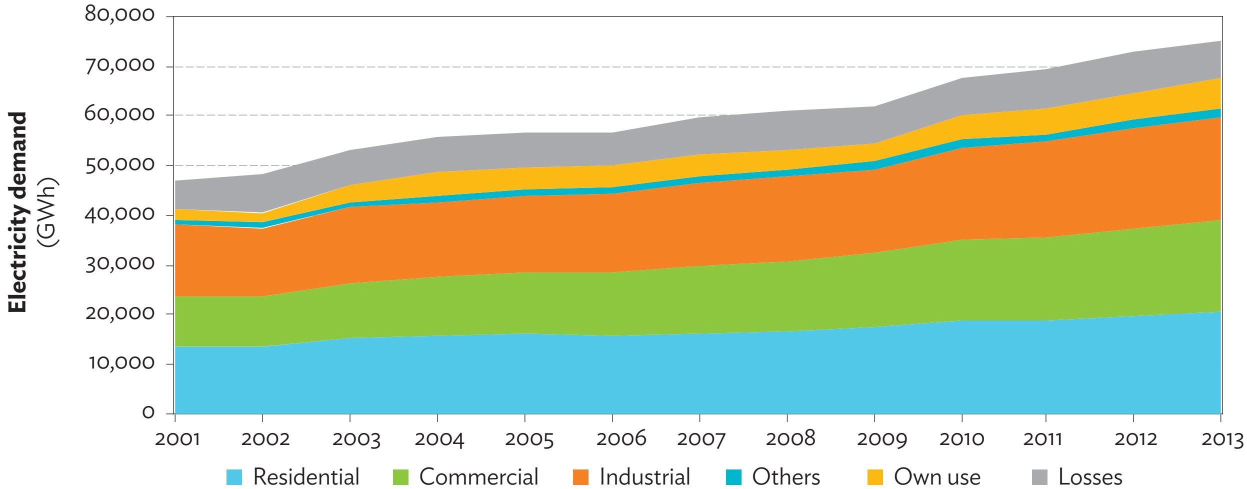
As a result of more electricity connections and greater electricity use, electricity consumption has grown at a rapid 4% annual rate between 2001 and 2013 (Figure 1.3). The 33% residential share of electricity is only slightly exceeded by industrial consumption (34%), while commercial (30%) and other shares (3%) are smaller. Fast growth in electricity and transport energy use, along with more carbon-intensive electricity generation, will lead to quick growth in emissions, unless the Philippines changes course.

Table 1.2: Accelerated Household Electrification Target

Philippines	2014	2015	2016	2017
HH electrification level	79.6%	82.7%	86.2%	90.0%
Total HH population (Census 2010)	21,827,265	22,247,154	22,675,122	23,111,290
No. of electrified HHs	17,327,558	18,392,477	19,545,183	20,801,838
No. of unelectrified HHs	4,454,707	3,854,677	3,129,940	2,309,451
Annual connections	801,618	1,019,919	1,152,706	1,256,656
AER	4.8%	5.9%	6.3%	6.4%

AER = annual electrification rate , HH = household.
Source: Department of Energy, Energy Policy and Planning Bureau. 2014–2017 Household Electrification Development Plan. E-mail correspondence to author. 28 October 2014.

Figure 1.3: Historical Electricity Demand, 2001–2013



GWh = gigawatt-hour.
Source: Department of Energy. 2014. 2013 Philippine Power Statistics. https://www.doe.gov.ph/2013-philippine-power-statistics (accessed 19 October 2015).

1.4 The Philippines Has a Range of Important Climate Change Policies

The Government of the Philippines recognizes the importance of changing these trends to stem potential growth of greenhouse gas (GHG) emissions. In late 2015, the Government submitted an Intended Nationally Determined Contribution (INDC) to the Paris Agreement on Climate Change (UNFCCC 2015). The Government ratified the Paris Agreement in late April 2017, but deferred formalization of its Nationally Determined Contribution until 2018 or 2019. The INDC includes a pledge to reduce emissions by 70% relative to business as usual by 2030, if sufficient international financial and technical support is provided. When compared with the INDCs of other countries, the 70% goal is among the highest relative reduction values pledged. However, 2030 business-as-usual GHG emissions are not defined in the INDC. This makes it difficult to discern what the INDC means in terms of targeted 2030 emissions levels. The amount of international support required for this goal is also unspecified, and no goal is set in the absence of international support. There is no breakdown of how the goal is to be achieved among sectors.

Prior to the INDC, the Philippines had established a range of policies related to climate change (Table 1.3). The 2009 Climate Change Act in 2009 (Republic Act No. 9729) called for the establishment of a framework strategy and programs on climate change. This act also created the Philippines' Climate Change Commission under the Office of the President, to actively coordinate, monitor, and evaluate programs and action plans on climate change.

In 2010, the National Framework Strategy on Climate Change was established, which focuses principally on adaptation, but also promotes mitigation, particularly through adaptation–mitigation synergies. The accompanying National Climate Change Action Plan for 2011 to 2028 includes a focus on sustainable energy among other measures to reduce climate vulnerability. Under Executive Order No. 43, the Government formed the Cabinet cluster on Climate Change Adaptation and Mitigation to coordinate across departments. In 2014, Executive Order No. 174 created a more standardized and updated GHG inventory system.

Strategies to limit GHG emissions are also embedded in various sector plans, particularly those of the energy and transport sectors. The Department of Energy started the National Energy

Efficiency and Conservation Program in 2004 to help reduce excess energy use. Following the 2008 Renewable Energy Action Plan, the 2010 National Renewable Energy Program (NREP) aimed to triple by 2030 the renewable capacity in geothermal, hydro, biomass, wind, solar, and ocean power. Biofuel blending in transport was initiated in the 2006 Biofuels Act. At the same time, despite ambitious targets to help reduce emissions growth, progress on individual low-carbon plans has remained modest.

1.5 Bottom-Up Modeling Can Portray a Low-Carbon Future for the Philippines

The Philippines has low per capita GHG emissions currently, but it is on track for a future that is potentially more carbon intensive. This study aims to assess how such a future might be avoided through specific technical measures. The study draws upon a bottom-up model that represents the detailed characteristics of options to reduce emissions.

Thus, the objectives of this study are as follows:

1. Identify the potential evolution of the power, residential electricity, and transport sectors in the absence of low-carbon policies.
2. Identify technically and politically feasible low-carbon development options that have potential to mitigate GHG emissions growth.
3. Assess the mitigation potential of low-carbon options, as well as attendant costs.
4. Propose policy options that can help to realize the mitigation potential quantified.

Table 1.3: Philippine Laws Relating to Climate Change

Republic Act	Short Title	Brief Description
No. 7156	Mini-Hydroelectric Power Incentive Act of 1991	Promoted renewable energy sources by providing incentives for minihydro projects Source: Congress of the Philippines. Republic Act No. 7156. An Act Granting Incentives to Mini-Hydroelectric Power Developers and for Other Purposes. 12 September 1991. https://www.doe.gov.ph/sites/default/files/pdf/downloads/ra_no_7156.pdf
No. 9136	Electric Power Industry Reform Act of 2001	Provided a framework for restructuring of the power industry Congress of the Philippines. Republic Act No. 9136. An Act Ordaining Reforms in the Electric Power Industry, Amending for the Purpose Certain Laws and for Other Purposes. 8 June 2001. http://www.gov.ph/2001/06/08/republic-act-no-9136/
No. 9367	Biofuels Act of 2006	Provided incentives for biofuels and mandated the use of biofuel blends Source: Congress of the Philippines. Republic Act No. 9367. 24 July 2006. An Act to Direct the Use of Biofuels, Establishing for this Purpose the Biofuel Program, Appropriating Funds Therefor, and for Other Purposes. 24 July 2006. https://www.senate.gov.ph/republic_acts/ra%209367.pdf
No. 9513	Renewable Energy Act of 2008	Promoted the development, utilization, and commercialization of renewable energy sources Source: Congress of the Philippines. Republic Act No. 9513. An Act Promoting the Development, Utilization and Commercialization of Renewable Energy Resources and for Other Purposes. 28 July 2008. https://www.doe.gov.ph/sites/default/files/pdf/issuances/20081216-ra-09513-gma.pdf
No. 9729	Climate Change Act of 2009	Created the Climate Change Commission, a policy-making body under the Office of the President Source: Congress of the Philippines. Republic Act No. 9729. An Act Mainstreaming Climate Change into Government Policy Formulations, Establishing the Framework Strategy and Program on Climate Change, Creating for this Purpose the Climate Change Commission, and for Other Purposes. 23 October 2009. http://www.gov.ph/2009/10/23/republic-act-no-9729/
No. 10174	People's Survival Fund and Amendments to Republic Act No. 9729	Established the People's Survival Fund for use in climate change adaptation and mitigation activities of local government units; also amended Republic Act No. 9729. Source: Congress of the Philippines. Republic Act No. 10174. An Act Establishing the People's Survival Fund to Provide Long-Term Finance Streams to Enable the Government to Effectively Address the Problem of Climate Change, Amending for the Purpose Republic Act No. 9729, Otherwise Known as the "Climate Change Act of 2009, and for Other Purposes. 25 July 2011. http://www.gov.ph/2012/08/16/republic-act-no-10174/

Source: Authors.

1.6 Report Structure

This report describes the pathways to low-carbon development (LCD) for the Philippines from 2010 to 2050. The reference scenario uses the business-as-usual trajectory, in which only the present programs and plans of the Government and the private sector are taken into account, as well as the most likely trends for technologies and energy consumption if no external mitigation programs or actions are adopted and applied to reduce GHG emissions. The LCD scenario was compared with the reference scenario to evaluate the benefits and costs of mitigation options for three sectors: household appliance, electric power generation, and land transport.

Following the background presented in Chapter 1, Chapter 2 of the report gives an overview of the input data and the methodologies applied to each of the three sectors. Chapters 3 to 5 discuss each sector, their reference and LCD scenarios, and the results of the marginal abatement cost curve analysis. Chapter 6 summarizes the combined mitigation potential and abatement costs of the sectors, identifies obstacles to the low-carbon development pathways, and recommends implementation strategies to address the barriers.

2. Data, Models, and Methodology

2.1 Data and Assumptions

This study analyzes the long-term energy consumption and GHG emissions of the land transport, household electric appliances, and electric power generation sectors in the Philippines. The base year for all the analyses is 2010. Whenever available, historical data were used for 2010 to 2013, drawing on different sources.

The data and models used to simulate the reference and alternative scenarios for low-emissions development strategies were developed under a national technical working group (NTWG), which included technical staff from various departments of the Government of the Philippines, including the National Economic Development Authority, Climate Change Commission; Department of Environment and Natural Resources; Department of Energy; Department of Transportation and Communications; Department of Public Works and Highways; and Philippine Statistics Authority. The intention was to ensure that modeling assumptions were appropriate to field conditions and that options assessed were relevant to the Government's policy interests.

The reference (or business-as-usual) scenario was modeled to reflect only existing plans and policies. For electric power generation, only existing and committed power plants were included in this reference scenario, and the NREP was excluded. Technology learning curves (changes in costs due to technological improvement) were incorporated into the reference scenario when data or models were available.

For the LCD scenario, forecasts from other studies when available were validated and used. The short-term assumptions (up to 2020) and some medium-term ones (up to 2030) for the mitigation options were sourced from in existing documents and reports.

Underlying assumptions of the reference scenario and the LCD scenario were harmonized. That is, all scenarios used the same data set for the following variables:

- Annual GDP and sectoral contribution to GDP
- Exchange rate
- Annual population and urbanization
- Household sizes and household population
- Annual per capita real consumption
- Fuel prices and the price of electricity
- Household ownership of appliances and vehicles

The population growth rate is assumed to decline from 2.7% in 2010 to 0.5% in 2050 following the projections of the Philippine Statistics Authority (2012). The urbanization rate is projected to increase from 45.3% in 2010 to 56.3% in 2050, consistent with the projections developed by the United Nations Population Division (2014).

GDP growth rates of up to 7.5% are utilized up to 2017 to be consistent with the targets of the current administration and, are subsequently sustained between 5% and 6% up to 2050 based on the simulations in Raitzer et al. (2015).

2.2 The Energy Forecasting Framework and Emissions Consensus Tool

The model used for this study is the Energy Forecasting Framework and Emissions Consensus Tool (EFFECT), which is a transparent, bottom-up, detailed, Excel-based model for forecasting GHG emissions of energy development scenarios.[1] EFFECT was initially developed by the Energy Sector Management Assistance Program of the World Bank for analyzing low carbon development options in India (World Bank 2010) and since been adapted to many other countries. The model has five main modules: electric power generation, land transport, household electricity, nonresidential, and industry. The three relevant modules corresponding to household appliance, electric power generation, and land transport were used in this study.

EFFECT is used to evaluate the costs and benefits of specific policies and plans by comparing the reference scenario, which models the normal development process if no mitigation option is adopted, and the LCD scenario, which models the development scenario wherein mitigation options are adopted. Costs and benefits are discounted to a 2010 present value using a 12% social discount rate.

2.3 Methodology for the Land Transport Sector

Fuel consumption and the resulting CO_2e emissions of the land transport sector are assessed using the transport module of EFFECT, which represents vehicular fleet characteristics in a survival model. Total fuel consumption and emissions are estimated by multiplying the number of vehicles by the fuel consumption and emissions for each vehicle type, taking into account usage patterns.

EFFECT projects the future number of privately owned vehicles using ownership models derived from the household ownership module of the 2012 Family Income and Expenditure Survey (FIES) (Philippine Statistics Authority 2014; see Box 1 for more details).

The number of light commercial vehicles (passenger and freight) and three-wheeled vehicles are projected using the historical growth rates. Populations of buses and trucks are projected using the demand for passenger movement and freight transport which in turn are assumed to grow as fast as the GDP.

Fuel consumption depends on vehicular fuel economy and average annual mileage of vehicles. The emissions factors module of EFFECT computes the fuel economy of different vehicle classes and the emissions factors of these vehicles. This module computes the fuel efficiency and emissions of each vehicle per kilometer traveled, considering the driving conditions, biofuel blending percentage, and vehicle weight. The computations within the emissions factors sheet are made using the Computer Programme to Calculate Emissions from Road Transport version 4 (COPERT), a model that computes pollutants and emissions in the land transport sector (Ntziachristos et al. 2009).

Annual emissions of vehicles are estimated in the reference year using the known total fuel (gasoline and diesel) consumption and the number and fuel efficiencies of all vehicle types on the reference year. The disaggregation of vehicles on the base year is computed using historical vehicle sales and stock mortality models based on modified Winfrey S3[2] survival curves. The vehicles are grouped according to engine displacement, technology, weight, age, and fuel use.

Passenger-kilometers traveled (PKT) and freight-ton-kilometers traveled (FTKT) in the reference year are estimated using an assumed age-sensitive annual kilometrage for each vehicle type and average passengers or weight of freight for each vehicle type per trip. PKT and FTKT are estimated after the kilometrage for each vehicle type is adjusted such that the resulting fuel consumption (diesel and gasoline) matches actual reference year values.

The future population of vehicles, according to type, is estimated using the projected number of new vehicles, and stock survival analysis of new and old vehicles

1 EFFECT is available at Energy Sector Management Assistance Program. http://esmap.org/EFFECT.

2 The Winfrey S3 survival curve is a function used to estimate vehicle mortality based on the calibrated average maximum vehicle scrappage age.

using Winfrey S3 survival curves. It is also assumed that the new vehicles introduced in the future would follow stricter pollution emission requirements.

2.4 Methodology for the Household Appliance Sector

Electricity consumption in the household sector is estimated by multiplying the number of appliances by each appliance's energy consumption. Table 2.1 shows the data requirements for this sector and the corresponding sources used in this study.

In the EFFECT model, households are divided into 100 income groups (called centiles) each for urban and rural households. Each centile is characterized by its mean monthly per capita expenditure (MPCE). The MPCE of households grows in proportion to GDP growth.

The MPCE directly affects household size, household electrification, and type and number of appliances owned by a given household. The relationship of the MPCE with these parameters is captured using appliance specific regression models developed from household surveys (see Box 1 for details). In general, as the MPCE grows with GDP, there is a resulting higher percentage ownership of appliances and higher number of appliances owned per household in the future.

Each appliance, regardless of age or efficiency, is associated with a constant usage parameter, such as the average number of hours used per day. Appliances, which may be made more efficient in the future through technological improvements, are introduced into the current appliance population using a stock-turnover model. New appliances are introduced into the mix in one of two ways: (i) new households purchase appliances in the market, or

Table 2.1: Data Requirements of and Sources for the Household Electricity Sector

Data Requirement	Source	Year
Population	Analysis using PSA projections	2010–2050
Gross domestic product	WDI historical values, NEDA targets, and ICES model projections	2010–2050
Urbanization	World Urbanization Prospects, 2014 Revision	2010–2050
Emission factors	IPCC emission factors	2010–2050
Household electrification	DOE historical data and household electrification targets	2010–2050
Urban and rural household size	Analysis	2010–2050
Urban and rural monthly per capita expenditures, 100 income groups each	Analysis using FIES 2012	2010
Regression models on household size versus monthly per capita expenditures	Analysis using FIES 2012	2010
Regression models on household electrification versus monthly per capita expenditures	Analysis using FIES 2012	2010
Regression models on appliance ownership versus monthly per capita expenditures	Analysis using FIES 2012; for selected appliances analysis using ASEAN household surveys	2010
Regression models on no. of appliances owned per household versus monthly per capita expenditures	Analysis using FIES 2012; for selected appliances analysis using ASEAN household surveys	2010
Typical appliance wattages or efficiencies across standards	Desktop survey of appliances including existing efficient appliances	2010–2050
Appliance subtypes sales mix	Expert opinion	2010–2050
Typical appliance usage parameters	Expert opinion	2010–2050
Average life span of appliances	Expert opinion	2010–2050
Average life of the existing appliance population	Expert opinion	2010–2050

ASEAN = Association of Southeast Asian Nations, DOE = Department of Energy, FIES = Family Income and Expenditure Survey, ICES = Intertemporal Computable Equilibrium System, IPCC = Intergovernmental Panel on Climate Change, NEDA = National Economic Development Authority, PSA = Philippine Statistics Authority, WDI = World Development Indicators.
Source: Authors.

Box 1: Modeling of Ownership of Energy-Consuming Goods

The reference scenario of the Energy Forecasting Framework and Emissions Consensus Tool forecasts household energy use partially as functions of shifts in income and urban versus rural populations over time. Income is considered the determinant of electrification rates, ownership of specific appliances, and ownership of specific vehicle types. To incorporate urbanization, the effects of income on these variables are identified separately for rural and urban populations, and forecasting employs identified relationships separately for projected urban and rural populations.

The specific relationship between income and the ownership of energy-consuming units is derived from cross-sectional regressions of primary data covering 40,171 households from the 2012 Family Income and Expenditure Survey (FIES). This is done via two functional forms—a gompertz model and a logistic model. In each, ownership (or electricity connectivity) is regressed against mean monthly household expenditure (as a proxy for income). For appliances and vehicles, separate gompertz and logistic regressions are run for number of units owned per household, as well as percentage ownership, for both rural and urban households.

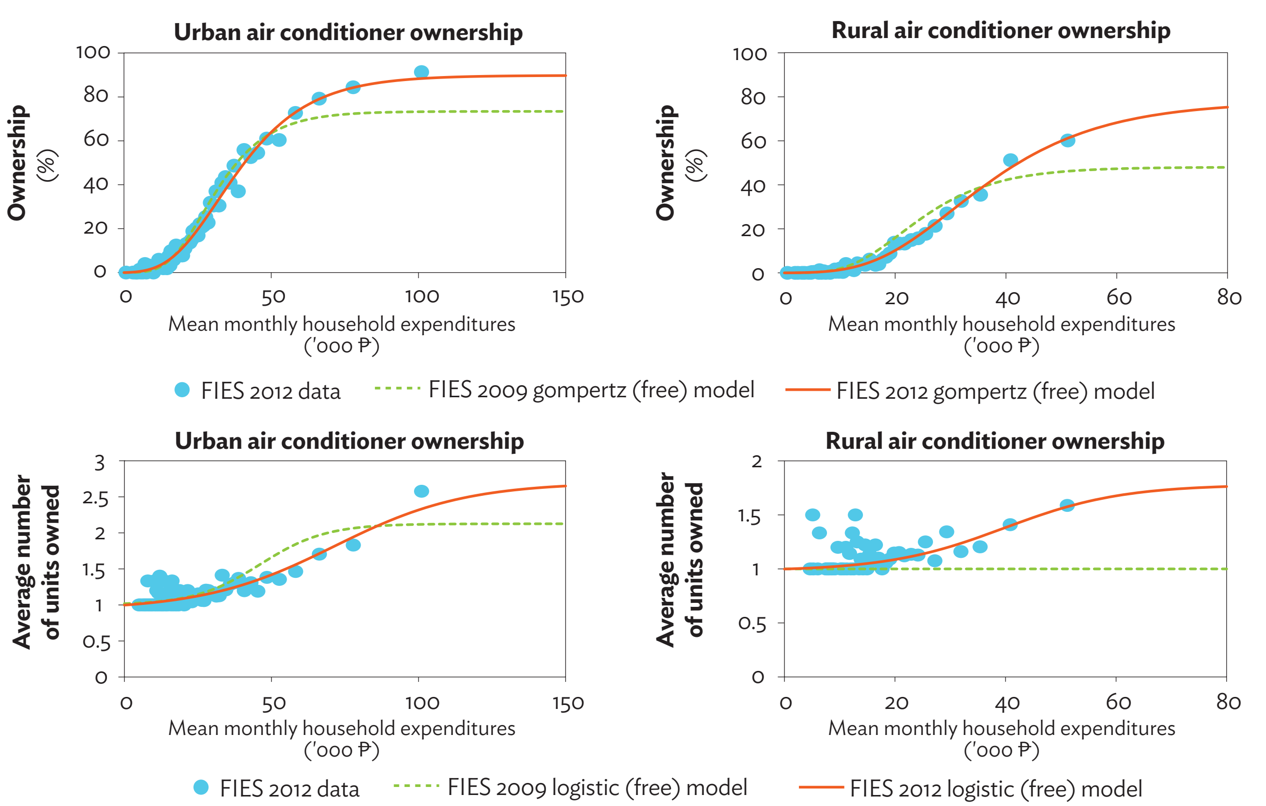
Gompertz model $$f(x) = \beta_0 + \beta_1 e^{-e^{-B_2(x-\beta_3)}}$$

Logistic model $$f(x) = \beta_0 + \beta_1 \frac{1}{1-e^{-B_2(x-\beta_3)}}$$

Where f(x) is the dependent variable (ownership), x is the independent variable (mean monthly expenditure of the household), and B_0, B_1, B_2, and B_3 are the regression coefficients identified.

Either a logistic or gompertz specification is ultimately selected for each regression, depending on which model has more explanatory power. For triangulation of results, FIES 2012 regressions were also compared with similar specifications for the 2009 round of FIES. An example of model fit against observations is found below in Box 1 Figure 1 for air conditioning.

Box 1 Figure 1: Air Conditioner Ownership Modeled as Function of Monthly Household Expenditures



FIES = Family Income and Expenditure Survey.
Source: Authors.

(ii) existing households replace their appliances in accordance to a Winfrey S3 survival model. The sales of new and replacement appliances provide the opportunity for reducing electricity demand in the household sector.

Based on the number of appliances owned and each appliance's energy consumption characteristics, the model can easily compute the annual electricity demand of households. GHG emissions are then computed using the emissions factors of the fuel burned to meet the needed electricity demand and system losses. Table 2.2 lists the documents consulted to benchmark the results of the model.

Table 2.2: Source Documents for Validating Model Results in the Household Electricity Sector

Document	Use
Department of Energy Power Statistics	Total residential demand should be within acceptable limits of historical residential demand for 2010–2013.
Household Energy Consumption Survey 2011	Appliance ownership and percentage share of appliance consumption in total residential demand in 2011 should be within acceptable limits.

Source: Authors.

Key energy-intensive appliances that have significant potential for electricity use reduction and, hence, GHG emission reductions, were identified. Enhanced appliance efficiencies are simulated to identify potential reductions in electricity demand and GHG emissions. Direct costs, such as the incremental cost of more efficient appliances, costs associated with the implementation of appliance standards, the cost of deferred fuel use, and the cost of deferred power plant capacity, were incorporated.

Table 2.3 shows the additional data inputs for the analysis. Fuel costs and power plant costs are consistent with the assumptions used in the power generation sector. Indirect costs, such as infrastructure and changes in manufacturing plants and co-benefits, such as improvement in health, energy self-sufficiency and security, and new employment opportunities, are excluded in the analysis.

Table 2.3: Additional Data Requirements for the Marginal Abatement Cost Curve Analysis in the Household Sector

Data Requirement	Source
Incremental cost of more efficient appliances	Desktop review of published literature
Cost of implementing efficiency standards	Analysis using the Philippines' Department of Trade and Industry–Bureau of Product Standards budget

Source: Authors.

2.5 Methodology for the Electric Power Generation Sector

EFFECT first models the annual demand for electrical energy of end users before assessing the supply necessary to meet demand. For this study, only grid-supplied electricity is considered. To calculate the end-user demand, EFFECT uses the results of all the demand-side modules, which for this study include the household and transport modules. EFFECT also calculates the transmission and distribution losses, and then the total amount of electrical energy that must be generated every year.

EFFECT uses three broad categories for power plants: (i) existing power plants; (ii) committed power plants, that is, power plants that are not yet operational but are either being constructed or already committed (from financing point of view) for construction; and (iii) power plants to be built in case additional capacity is still needed. The optimal generation mix between baseload and peaking plants was determined based on plant costs and characteristics, and this optimal mix was used for the target generation mix for all years.

The required capacity is determined based on the load curve and plant characteristics. When the existing generation capacity does not meet the demand requirement, new power plants are added until the demand is met. Power plant dispatch is then performed to determine the annual energy outputs of each plant and the corresponding annual cost. The dispatch prioritizes the available hydroelectric capacity, followed by the must-run non-dispatchable power plants, and then the available power plants with the lowest variable cost, until the load-curve demand is met. This process is repeated until the demand is satisfied by the total power generation for each planning year until 2050. As actual dispatch may not follow these optimized criteria, modeled generation may not exactly match actual generation for the same capacity mix.

2.6 Limitations of the Study

The EFFECT model developed for the Philippines covers only three sectors: land transport, household appliances, and electric power generation. This means that the mitigation potential represented is partial, as agriculture, industry, and waste are also substantial sources of emissions that are omitted from mitigation analysis.

Within the selected sectors, the low-carbon development scenarios modeled consist of only those options that were identified by the NTWG and the Philippines' EFFECT team. The options considered are all technical, and do not include incentive or fiscal policies, such as carbon taxation, that change consumer behavior. In addition, advanced technologies that are not yet fully developed but still projected to disrupt the power sector in the future were also not considered, such as energy storage. In the electric power generation sector, biomass technologies were excluded as a development scenario, since the Department of Energy had not set targets for its development after 2016, and data that would allow accurate estimates of potential were not available at the time of the study.

EFFECT is a bottom-up partial equilibrium model that represents detailed technical characteristics of mitigation options, which include stock and turnover of specific generation and energy-consuming units. Such an approach can give good understanding of technical potential. However, it does not include behavioral aspects, such as usage response to price signals. Substitution effects among markets are excluded, as are rebound effects from reduced costs of using more efficient energy-consuming devices. Such effects are better captured in general equilibrium approaches. Transport modeling omits system level effects on congestion and fuel usage beyond the directly displaced transport modes. The costs reflected also do not incorporate broader economy-wide effects, as well as externalities, and thus are more akin to financial than economic costs of mitigation.

Bottom-up models require significant quantities of parameters to obtain accurate results, since they depend on end-use data, such as the projected number of appliances and appliance usage, projected number of vehicles and kilometers traveled, or capacities of power plants by technology. Some data specific to the Philippines were also not available at the time of the study. For these cases, data were either computed based on other data (for example, the regression models in the household appliance sector) or assumed based on data from existing literature (for example, the technology learning curves). In all cases, data were validated against historical data when available and consulted with the members of the NTWG when applicable.

3. Transport Sector

3.1 Road Network and Vehicles in the Philippines

Although recent emissions statistics are relatively modest, transport has the potential to become a source of rapidly increasing GHG emissions. The carbon dioxide equivalent (CO_2e) emissions of the transport sector of the entire Philippines amounted to around 23.5 million metric tons of carbon dioxide equivalent ($MtCO_2e$), or 15% of the total in 2010.

As the Philippines' economy has grown, the population of vehicles has risen as well, along with GHG emissions. There were about 4.7 million registered vehicles in 2004, 39% of which were motorcycles and tricycles. Of these vehicles, 79% were privately owned and 19% were for hire, while the Government of the Philippines owned the remainder. By 2013, motor vehicle population increased to 7.7 million, 56% of which comprised motorcycles and tricycles. The percentage of private ownership also increased to 87% of the total.

The average annual growth rate of road transport vehicles from 2007 to 2013 is 5.7%. Table 3.1 shows the annual vehicle population from 2007 to 2013. In the base year of 2010, the total number of vehicles was 6.6 million.

The drastic increase in vehicle population has led to a deteriorating traffic situation in the country, especially in urban centers. Metro Manila, for example, has only 0.2% of the country's total land area, but more than 27% of registered vehicles ply its roads.

A light rail network with a total length of 48 kilometers (km) also serves Metro Manila. The network consists of three rail lines, two of which are already operating beyond capacity. In 2013 alone, the entire network served a total of 418 million passengers.

3.2 Legal and Regulatory Framework

The Government of the Philippines has an array of policies that may enable reductions in GHG emissions from transportation. The 2006 Biofuels

Table 3.1: Number of Registered Vehicles, 2007–2013

Vehicle Class	2007	2008	2009	2010	2011	2012	2013	AAGR
Cars	744,830	755,108	776,155	804,825	824,829	849,047	868,148	2.6%
Utility vehicles	1,788,625	1,790,518	1,865,575	1,961,703	2,032,154	2,081,541	2,140,968	3.1%
Buses	30,113	29,703	33,006	34,909	34,434	33,564	31,665	1.0%
Trucks	281,128	296,121	311,496	317,774	329,309	341,505	358,445	4.1%
Motorcycles and tricycles	2,647,263	2,982,296	3,200,961	3,482,139	3,881,449	4,116,682	4,250,667	8.3%

AAGR = annual average growth rate.
Source: Department of Transportation and Communications and Land Transportation Office. Registered Motor Vehicles by Classification and Region, 2007–2013. http://dotc.gov.ph/images/front/Data_Sets/Registered_MotorVehiclesbyClassificationandRegion.xlsx.

Act mandates the blending of biofuels in all locally distributed diesel and gasoline. The Clean Air Act was enacted in 2009 (Republic Act No. 9729). The main impact of this act on the land transport sector is the removal of lead in gasoline and the promotion of clean alternative fuels such as liquefied petroleum gas and biofuels. The Government also laid out other strategies such as the two main activities of the National Climate Change Action Plan: the integration of environmentally sustainable transport and fuel conservation measures in development plans and programs, and the development of innovative financing schemes to promote environmentally sustainable transport. Relevant priority activities of the National Climate Change Action Plan include the following:

(i) implementation of a clean fleet program;
(ii) adoption of socially equitable and integrated land-use and transport planning processes at national and local levels; and
(iii) implementation of energy-efficiency labeling for new vehicles.

The Department of Transportation and Communications has also drafted the National Integrated Transport Plan as part of the National Framework Strategy on Climate Change. The integrated plan includes the Environmental Sustainable Transport Plan already completed in 2010 and the Philippines National Implementation Plan on Environment Improvement in the Transport Sector. The latter specifies improvements in emissions technology, substitution of biofuels and electricity in transport, more efficient infrastructure, and measures to shift passengers from private vehicles to public transport.

3.3 Reference Scenario for Land Transport Development

3.3.1 Projected Vehicle Population

The projected future vehicle population in the Philippines up to 2050 is shown in Table 3.2. The number of road vehicles is projected to increase from 6.6 million in 2010, to 24.8 million in 2030, and 65.4 million in 2050. The growth in vehicle population is driven primarily by income growth, which increases the private ownership of motorcycles initially, and passenger cars subsequently as incomes increase.

Table 3.2: Projected Vehicle Population, 2010–2050
(million)

Vehicle Type	2010	2015	2020	2025	2030	2035	2040	2045	2050
Motorcycles	2.70	3.80	5.80	9.33	11.60	13.41	15.08	16.09	16.19
Tricycles	0.76	0.85	0.95	1.06	1.18	1.32	1.47	1.64	1.83
Passenger cars	2.52	3.41	5.22	7.50	10.80	15.46	22.67	32.79	44.80
Jeepneys	0.26	0.29	0.33	0.39	0.45	0.52	0.61	0.71	0.82
Buses	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
Trucks	0.33	0.42	0.52	0.61	0.72	0.86	1.06	1.36	1.74
Total	6.60	8.81	12.85	18.92	24.79	31.61	40.92	52.62	65.42

Source: Authors.

3.3.2 Biofuel Blending and Vehicle Emissions Standards

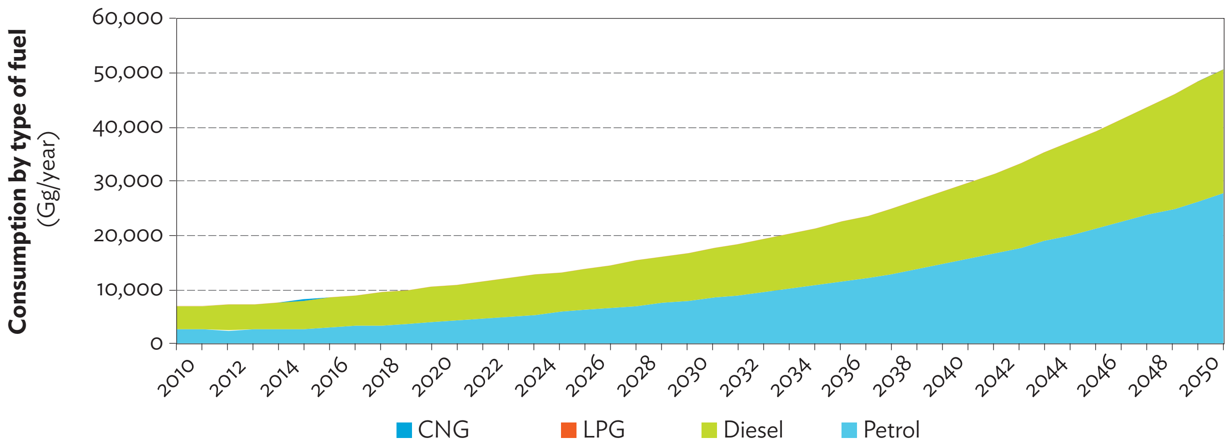
The reference scenario assumes that the current level of blending of bioethanol in gasoline (10%) remains constant until 2050. On the other hand, biodiesel blending would increase to 5% in 2020 as a result of robust coconut production. The percentage, however, would remain at 5% until 2050, because of the high price of coconut oil.

Even in the reference scenario, pollution control standards are expected to escalate. A 10-year lag in the adoption of Euro emissions standards by the Philippines compared with the European Union (EU) is also assumed. Euro 4 emissions standards are required of all new light vehicles at the start of 2016, whereas the EU has adopted Euro 4 for all light vehicles in 2005. This assumption implies that Euro 5 will be adopted at the start of 2020 and Euro 6 at the start of 2024.

3.3.3 Fuel Consumption Forecast

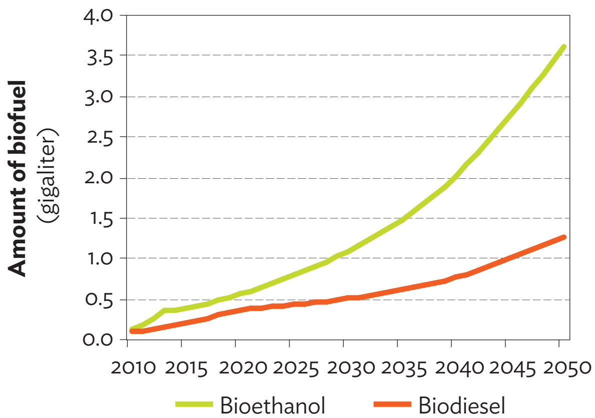
The projected fuel consumption of the land transport sector is shown in Figure 3.1. The demand for gasoline would eventually exceed the demand for diesel as a result of the projected increase in private vehicle ownership, particularly that of passenger cars. In 2050, the projected consumption of gasoline and diesel are 26.3 gigagrams and 21.9 gigagrams, which correspond to 900% and 400% increases, respectively, from 2010 values. The amount of biofuel required to achieve the blending targets is shown in Figure 3.2.

Figure 3.1: Projected Fuel Consumption of the Land Transport Sector



CNG = compressed natural gas, Gg = gigagram, LPG = liquefied petroleum gas.
Source: Authors.

Figure 3.2: Projected Biofuel Requirements for Fuel Blending in the Reference Scenario

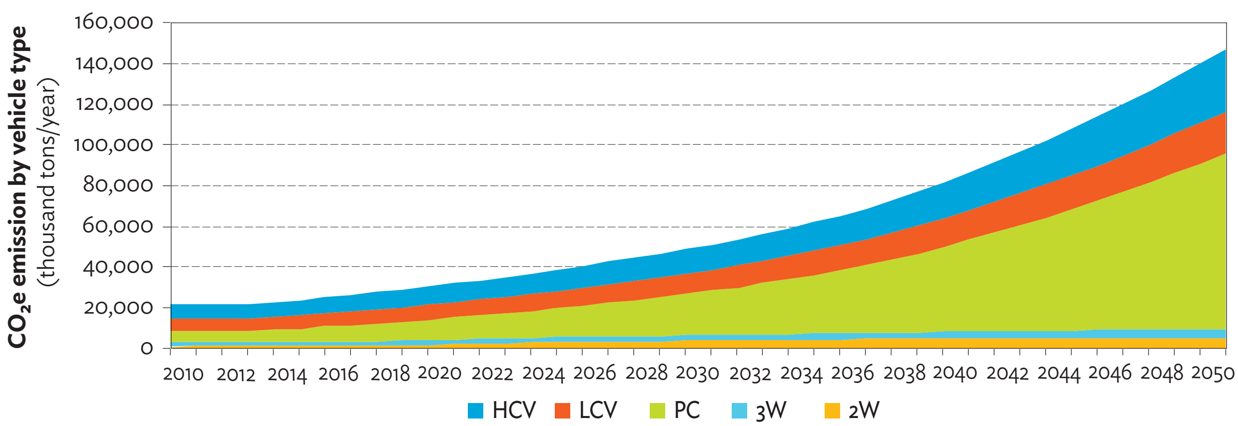


Source: Authors.

3.3.4 Projected Greenhouse Gas Emissions

Annual emissions from road transport vehicles are expected to increase to 48.8 $MtCO_2e$ by 2030 and to 139.9 $MtCO_2e$ by 2050, as shown in Figure 3.3. In 2030, the largest contributors to total emissions will be passenger cars (42% of total), followed by trucks (20% of total). By 2050, about 58% of road transport emissions will come from passenger cars. Trucks will contribute about 19% of the total emissions.[3] The results for the GHG emissions from the land transport sector under the reference scenario are consistent with the GHG emissions data for the transport sector found in the Philippines' Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC 2015).[4]

Figure 3.3: Projected Carbon Dioxide Equivalent Emissions of the Land Transport Sector



2W = two-wheeler, 3W = three-wheeler, CO_2e = carbon dioxide equivalent, HCV = heavy commercial vehicle, LCV = light commercial vehicle, PC = passenger car.
Source: Authors.

3 The lower emissions derived in this study when compared with World Bank (2010) are mainly attributed to the availability of more appropriate emissions factors (computed using the COPERT models) and the use of income-based ownership models for private vehicles and demand-based models for buses and trucks. The analysis based on growth rates used in the previous study resulted in higher estimates for vehicle populations, resulting to larger emissions.

4 For the transport sector, the SNC cites data from the World Bank. From the SNC, GHG emissions from the transport sector were 24.34 $MtCO_2e$ in 2000, 21.75 $MtCO_2e$ in 2007, and 23.51 $MtCO_2e$ in 2010. The GHG emissions prior to 2007 demonstrated no trend; a trend is apparent only starting 2007. Under the EFFECT model, the GHG emissions from the land transport sector, a significant contributor to the transport sector, was 21.53 $MtCO_2e$, which is 91.6% of the World Bank figure for 2010. This means that the EFFECT results and the SNC data are reasonably consistent.

3.4 Low-Carbon Development Options for the Land Transport Sector

A low-carbon transportation development strategy can be based on the "avoid–shift–improve approach" (Table 3.3), which relies on a blend of measures to reduce the use of fossil fuel in transportation.

- "Avoid" policies use city planning and travel demand management to minimize unnecessary travel. This may be complemented by logistics technology and virtual mobility programs (e.g., tele-working).
- "Shift" policies are oriented toward changing travel patterns from inefficient fossil fuel high emissions modes such as gasoline-powered automobiles, to more energy-efficient modes such as public transit, walking, and cycling.
- "Improve" policies focus on enhancing transport efficiency to reduce fuel use and emissions, which may include changes to vehicle technology, including substitution of fossil fuels with cleaner alternatives.

To "avoid" travel is beyond the scope of the present study, as this relies on changes to spatial patterns of development that can only be properly assessed in a geographic information systems framework. Hence, the focus is on "shift" and "improve" measures. To explore the mitigation potential and estimate the corresponding abatement costs in reducing GHG emissions in the land transport sector, 10 LCD options were simulated in four categories: (i) clean fuel (biofuels blending and compressed natural gas [CNG]-fueled bus) development; (ii) mass transport (promotion of buses and light rail transport infrastructure) development; (iii) electric vehicle (tricycle, jeepney, and motorcycle) development; and (iv) vehicle standards (motor vehicle inspection system and EU vehicle standards). The LCD options for land transport are summarized in Table 3.4.

In the Philippine Energy Plan 2012–2030 (DOE n. d.), the DOE identified sustainable fuels for road transport as one of its priority programs. The Philippine Energy Plan 2012–2030 includes the use of sustainable fuels for 30% of all public utility vehicles by 2030. In particular, the plan intends that by 2030, 15,000 buses will run on CNG supported by 150 refilling stations, 23,000 vehicles will run on

Table 3.3: Avoid–Shift–Improve Policies for the Land Transport Sector

"Avoid" Policies	"Shift" Policies	"Improve" Policies
Pricing regimes	Bus/BRT usage promotion	CNGV promotion
ICT	Bus/BRT infrastructure development	Hybrid promotion
Tele-activities	Rail/LRT usage promotion	EV mass supply
Travel plans	Rail/LRT infrastructure development	EV promotion
Improved travel awareness	Rail usage promotion for freight	Biofuel development
	Rail infrastructure development	Biofuel promotion

BRT = bus rapid transit, CNGV = compressed natural gas vehicle, EV = electric vehicle, ICT = information and communication technology, LRT = light rail transit.

Source: J. R. Regidor and S. F. D. Javier. n. d. The Philippines: A Study of Long-Term Transport Action Plan for ASEAN. http://cleanairasia.org/wp-content/uploads/portal/files/philippines_0.pdf.

Table 3.4: Low-Carbon Development Options for the Land Transport Sector

Low-Carbon Development Option	Brief Description
Biofuels blending	20% bioethanol by 2020, 20% biodiesel by 2025
CNG-fueled buses	30% of all buses to run on CNG by 2030
Buses and bus rapid transit	Promotion of buses, including bus rapid transit systems
Light rail transit infrastructure	Development of light rail transit system
Electric tricycles	230,000 electric tricycles by 2030
Electric jeepneys	50% of all jeepneys in 2030 are electric
Electric motorcycles	20% of all new motorcycles are electric starting 2020
Hybrid buses	30% of all buses are equipped with hybrid-diesel technology by 2030
Motor vehicle inspection system	Motor vehicle inspection and compliance to emissions requirements before vehicle registration
Vehicle carbon standards	Adoption of EU carbon dioxide emissions standards but with 15-year lag compared with EU implementation

CNG = compressed natural gas, EU = European Union.
Source: Authors.

auto-liquefied petroleum gas, and the number of electric tricycles will amount to 230,000. The plan also targets a biodiesel blend of 20% by 2025, and bioethanol blend of 20% by 2020.

3.4.1 Biofuel Blending

Republic Act No. 9367, or The Biofuels Act of 2006, imposes the mandatory blending of biofuels to gasoline and diesel, the fuels used by the transport sector. Under this act, the DOE targets massive expansion of bioethanol production (Table 3.5). If this option proves feasible, the avoided emissions by 2050 would be 244.8 $MtCO_2e$ at an abatement cost of $7.8 per metric ton of carbon dioxide equivalent (tCO_2e). The abatement cost is positive since the blending of biofuels slightly reduces the fuel economy of vehicles, requiring more fuel to cover the same distance.

Table 3.5: Biofuel Blend Targets of the Department of Energy of the Philippines

Year	Biodiesel	Bioethanol
2013	2%	10%
2014	2%	10%
2015	5%	10%
2020	10%	20%
2025	20%	20%
2030	20%	20%

Source: Authors.

3.4.2 Natural Gas–Fueled Buses

The DOE plans to expand the use of natural gas, especially for public utility vehicles. In particular, the agency is aiming for the use of CNG and other alternative fuels in 30% of all public utility vehicles by 2030.

This is reflected in a low-carbon option in which 30% of all buses (old and new) will be running on CNG by 2030. It is assumed that the percentage of new buses running on CNG increases uniformly, starting in 2015, until 30% of all buses run on CNG by 2030. The projected import price of liquefied natural gas (LNG) in Japan is used as reference for future CNG prices.

However, the higher emissions factors of CNG-fueled buses according to the COPERT model resulted in higher total emissions if this option is pursued. Comparing a CNG-fueled bus and a conventional diesel bus of the same weight and capacity, the emissions per kilometer traveled by the CNG-fueled bus are 15% higher than that of the conventional bus, and it consumes 30% more fuel by volume.[5] The simulation of this option results in 5.9 $MtCO_2e$ more emissions than the reference scenario in 2050.

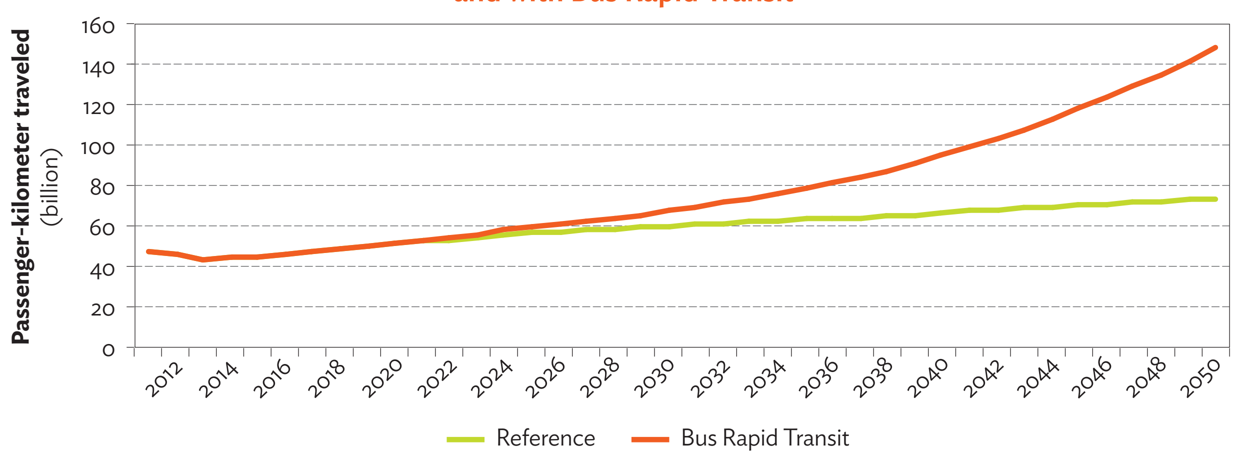
3.4.3 Buses and Bus Rapid Transit System

Modal shifts from passenger cars and motorcycles to buses and bus rapid transit (BRT) systems are an important mitigation option. This option investigates the impact of promoting buses to encourage modal shifts from private cars and motorcycles. It is assumed that there is a doubling of routes in place, compared with the reference scenario and construction of BRT systems. This option constructs two BRT lines every 3 years, from 2021 until 2050. This rate of development will result in having around 4,000 buses servicing BRT lines in 2050. The option cost of development of these BRT lines is found to be ₱30 million for each new BRT bus.[6]

In the reference scenario, there will be 41,160 buses in 2050. Under this option, there will be 82,300 buses by 2050. This increase in buses can accommodate up to 11% of PKT modal shift from private vehicles.

This option is found to avoid a total of 63.2 $MtCO_2e$, at a cost of –$24.4 per tCO_2e. Figure 3.4 compares the number of PKT in the reference scenario and this mitigation option. The trend closely follows the increase in number of buses being added to realize the modal shift. Figure 3.5 shows the reduction of average annual distance covered by motorcycles and passenger cars. The results suggest that the utilization of privately owned vehicles may be reduced by more than 10%. There is a potentially substantial reduction in gasoline consumption as a result of the modal shift, but there is very slight increase in diesel consumption because of increased bus demand (Figure 3.6).

Figure 3.4: Passenger-Kilometers Traveled of Buses in the Reference Scenario and with Bus Rapid Transit



Source: Authors.

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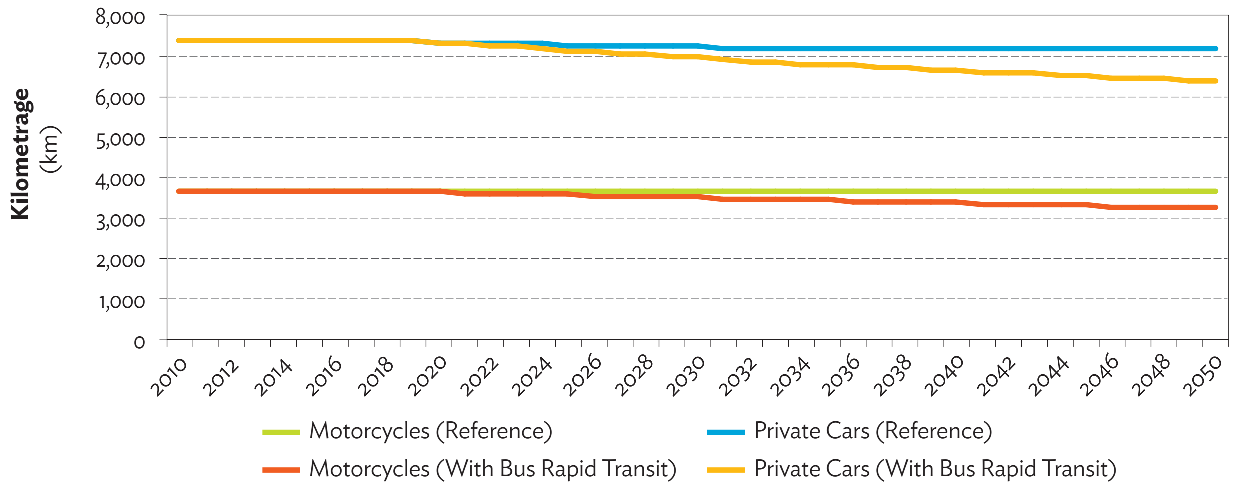
5 The computation of emissions factors using EFFECT was calibrated to the Philippines' weather and driving conditions. The computation of emissions factors follows the COPERT 4 procedure. See http://emisia.com/products/copert-4/versions.

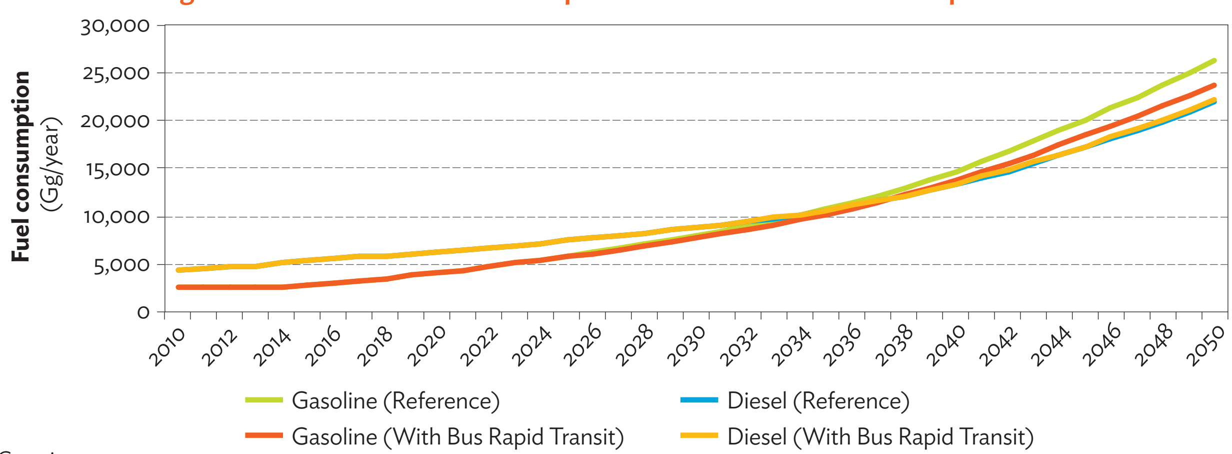
6 Cost estimate based on the development costs of the Cebu BRT (₱10.62 billion) and Quezon Avenue–España Boulevard BRT (₱4.9 billion) systems.

Figure 3.5: Average Annual Kilometrage of Motorcycles and Passenger Cars with Modal Shift from Private Vehicles to Bus Rapid Transit



km = kilometer.
Source: Authors.

Figure 3.6: Annual Fuel Consumption with and without Bus Rapid Transit



Gg = gigagram.
Source: Authors.

3.4.4 Expansion of Light Rail Transit

Another type of "shift" mitigation option is the development of light rail infrastructure to encourage modal shift from private passenger vehicles. This option investigates the impact of modal shift to light rail transit, at a PKT level equal to half of the modal shift to buses. Calculations for this study have found that the present value of the development cost for light rail is ₱3 billion per kilometer, including the cost of rolling stock and annual maintenance and operating expenses.

Several light rail transit projects are currently in the planning stage: the Metro Rail Transit (MRT) 7, a 22.8-kilometer rail line to connect the MRT 3 and the Light Rail Transit (LRT) 1 North Expansion through a common terminal in North Epifanio de los Santos Avenue (EDSA). Another project is the 11.7-kilometer south extension of LRT 1 from Baclaran to the town of Niog in Cavite province (NEDA 2013).

These projects, however, are still not sufficient to support the target modal shift level. Using the current loading levels of the three light rail transit lines, an equivalent of 483 km of light rail transit lines has to be built. This development option is found to result in a reduction of 2.2 billion vehicle-kilometers traveled in 2030, 7.9 billion in 2040, and 20.8 billion in 2050. The modal shift to light rail can avoid up to 34.7 $MtCO_2e$ of emissions, at an abatement cost of $144.3 per tCO_2e. The high abatement cost reflects the high initial investment cost to realize this option. However, it should be recognized that these results are only for direct effects. LRT development may have synergies with other types of public transport developments, such as feeder bus lines, which would increase mitigation beyond what is quantified here.

3.4.5 Electric Jeepneys

Jeepneys are a principal form of public transit in the Philippines, and initial trials of electric jeepneys have been initiated in and around metro Manila since 2007. This option takes electric jeepney adoption much further and models achievement of 50% of the jeepney fleet as electric by 2030, with electric jeepneys initially sold in large numbers in 2021. All sales after 2030 are modeled as electric. The number of jeeps is adjusted upwards to account for charging times, and the simulation includes costs for associated charging infrastructure, as well as battery replacement costs.

Modeling of these assumptions leads to an all-electric national jeepney fleet by 2050. Total mitigation found to be a substantial 168.7 $MtCO_2e$ at a cost of $6.4 per tCO_2e. The cost is positive due to the charging times and charging infrastructure costs.

3.4.6 Electric Tricycles

Tricycles play an important role in public transit in the Philippines, and electric tricycles can help to reduce their emissions. The DOE targets that by 2030, there will be a total of 230,000 electric tricycles on the road out of a total population of 1 million tricycles in service. Under that target, the number of new electric tricycles sold in 2030 is equivalent to 33% of all new tricycles. It is assumed under this option that the 33% sales mix continues until 2050.

Modeling of these assumptions leads to a national tricycle fleet that is 33% electric in 2050. This is found to generate 33.6 $MtCO_2e$ mitigation over the period, at a mitigation cost of –$5.6 per tCO_2e. The abatement cost is negative because electricity costs less as fuel than gasoline.

3.4.7 Electric Motorcycles

Electric motorcycles may replace gasoline-fueled models and thereby reduce emissions. This option initiates adoption of electric motorcycles in 2020, so that in that year, around 1.8% of all new motorcycles are electric. The penetration rate is assumed to increase linearly and, by 2030, 20% of all new motorcycles are electric. This market share for new motorcycles is assumed to hold until 2050.

This implies that by 2030, more than 11% of the projected 11.6 million motorcycles are electric and, by 2044, 20% of the projected 15.9 million are electric. The option is found to avoid up to 19.5 $MtCO_2e$, at a mitigation cost of –$10.9 per tCO_2e. The negative mitigation cost may be attributed to cheaper fuel costs.

3.4.8 Hybrid Buses

Part of the Department of Transportation and Communications' National Implementation Plan is to adopt more efficient vehicle technologies for buses. One such technology is hybrid electric buses, which utilize electricity storage in the form of batteries to power supplemental electric motors during acceleration and braking and charge while the vehicle is idling or cruising.

This option targets 30% of all buses by 2030, old and new, to be hybrid. Adoption initiates in 2015, and the penetration level gradually increases until the 30% target is achieved (Table 3.6). By 2030, more than half of all new buses are hybrids and this mix continues until 2050. By 2050, more than 21,500 hybrid buses are projected or about 52% of the entire population.

A hybrid bus consumes 10% less fuel compared with a conventional diesel bus (Hallmark et al. 2012). The option also takes into account differences

Table 3.6: Number of New Hybrid Buses Needed to Reach the 30% Penetration Rate by 2030

Year	New Hybrid Buses	Year	New Hybrid Buses	Year	New Hybrid Buses
2015	75	2027	1,107	2039	1,550
2016	157	2028	1,181	2040	1,568
2017	244	2029	1,259	2041	1,582
2018	335	2030	1,345	2042	1,594
2019	428	2031	1,359	2043	1,605
2020	521	2032	1,381	2044	1,617
2021	614	2033	1,405	2045	1,629
2022	705	2034	1,431	2046	1,642
2023	792	2035	1,458	2047	1,656
2024	876	2036	1,483	2048	1,671
2025	956	2037	1,505	2049	1,686
2026	1,032	2038	1,528	2050	1,703

Source: Authors.

in bus sales costs, as well as costs of battery replacement. Introduction of hybrid buses is found to avoid up to 26.1 $MtCO_2e$ at a mitigation cost of –$10.8 per tCO_2e.

3.4.9 Motor Vehicle Inspection System

Mandatory inspection of all motor vehicles before their annual registration through motor vehicle inspection centers may help to reduce emissions. World Bank (2010) suggests that annual inspection encourages frequent engine tune-ups, which could improve fuel consumption by 2%–5%. This value, which is based on a fleet including many carbureted vehicles, is modified downward to account for a higher share of fuel-injected vehicles in the Philippines. Costs for vehicle owners to comply with emission requirements, such as replacement of oxygen and mass airflow sensors and, in some cases, replacement of catalytic converters, are also included.

This option assumes that an inspection system can be operational by 2019. Such a system is found to avoid up to 20.3 $MtCO_2e$ at an abatement cost of $8.1 per tCO_2e.

3.4.10 Vehicle Carbon Standards

There is substantial potential to improve vehicle efficiency and emissions through better technology. Engines can have stop–start systems, direct fuel injection, reduced friction losses, higher compression ratios, and optimized cooling. Transmissions may have more gears, piloted gearboxes, and dual clutches that replace torque converters. Other options are body weight reduction, improved aerodynamic efficiency, regenerative braking, low-rolling resistance tires, efficient air conditioning, electric power steering, and use of electric hybrid technology.

Fleet standards can enforce adoption of efficiency measures. In 2009, the EU mandated that carbon dioxide (CO_2) emissions standards (European Parliament and Council of the European Union 2009) for new passenger vehicles be introduced in 2015. The emissions target is a fleet average of 130 grams per kilometer (g/km) for all car manufacturers, and the limit falls to 95 g/km by 2020. For light commercial vehicles, the limit in 2020 is 147 g/km (ICCT 2014).

Efficient technologies may increase the price of vehicles. EFFECT utilizes a model that estimates the resulting price of vehicles according to the emission reduction technologies incorporated into their design and manufacture.

This option mandates EU emissions standards to all passenger cars and light commercial vehicles manufactured in or imported to the Philippines. However, the standards will be adapted with a 15-year delay from those of the EU. The option finds 681.2 $MtCO_2e$ of avoided emissions at a mitigation cost of –$11.1 per tCO_2e.

3.5 Marginal Abatement Cost Curve Analysis for the Land Transport Sector

All options other than LRT development have individual marginal abatement costs under \$10 per tCO_2e, and five of the options have negative abatement costs (Table 3.7). Buses and BRT development are found to have the lowest-cost mitigation potential, but vehicle emissions standards have the largest amount of potential emissions reduction (Figure 3.7).

Some caution is needed in interpreting the high abatement costs of LRT infrastructure presented here. As noted earlier, LRT development may have synergistic effects with other modal shift measures that may further increase mitigation. In addition, the modeling performed is not spatial, and does not fully capture how congestion is affected by the options considered. LRTs achieve mitigation beyond the direct effects of modal shifts by reducing congestion, increasing travel speed, and improving fuel efficiency of remaining road transport. These indirect effects create both additional cost savings and mitigation compared with the direct values presented, so that fully accounted abatement costs are lower.

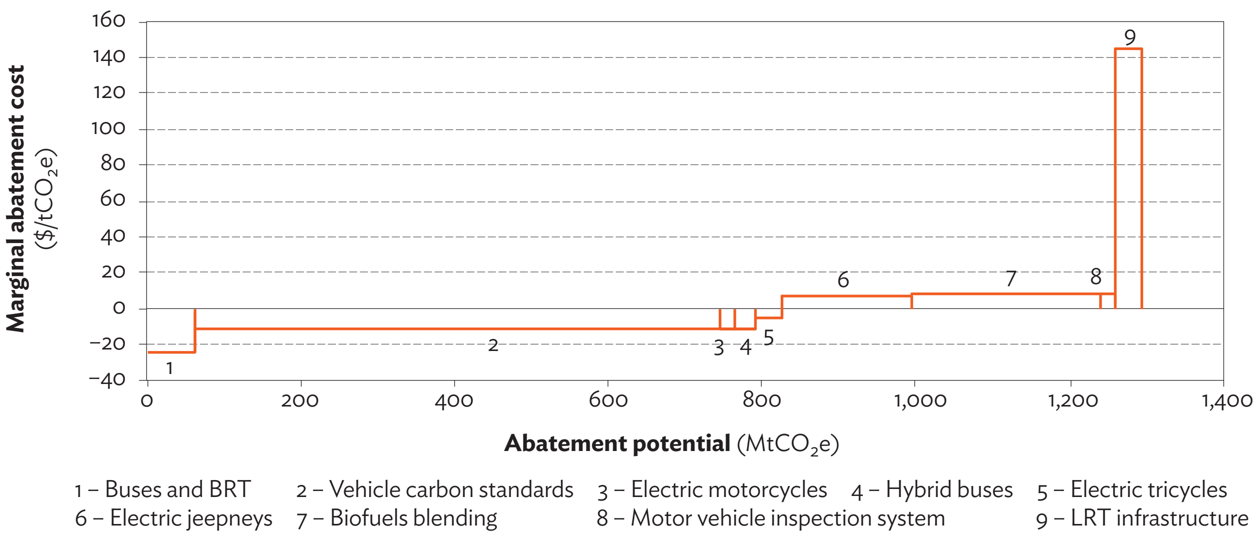
Table 3.7: Individual Mitigation Potential and Costs for the Low-Carbon Development Options in the Land Transport Sector

LCD Option		Mitigation Potential ($MtCO_2e$)	Cost of Mitigation (\$/tCO_2e)
1	Buses and BRT system	63.2	(24.4)
2	Vehicle carbon standards	681.2	(11.1)
3	Electric motorcycles	19.5	(10.9)
4	Hybrid buses	26.1	(10.8)
5	Electric tricycles	36.6	(5.6)
6	Electric jeepneys	168.7	6.4
7	Biofuels blending	244.8	7.8
8	Motor vehicle inspection	20.3	8.1
9	LRT infrastructure	34.7	144.3

( ) = negative, BRT = bus rapid transit, LCD = low-carbon development, LRT = light rail transit, $MtCO_2e$ = million metric tons of carbon dioxide equivalent, tCO_2e = metric ton of carbon dioxide equivalent.
Source: Authors.

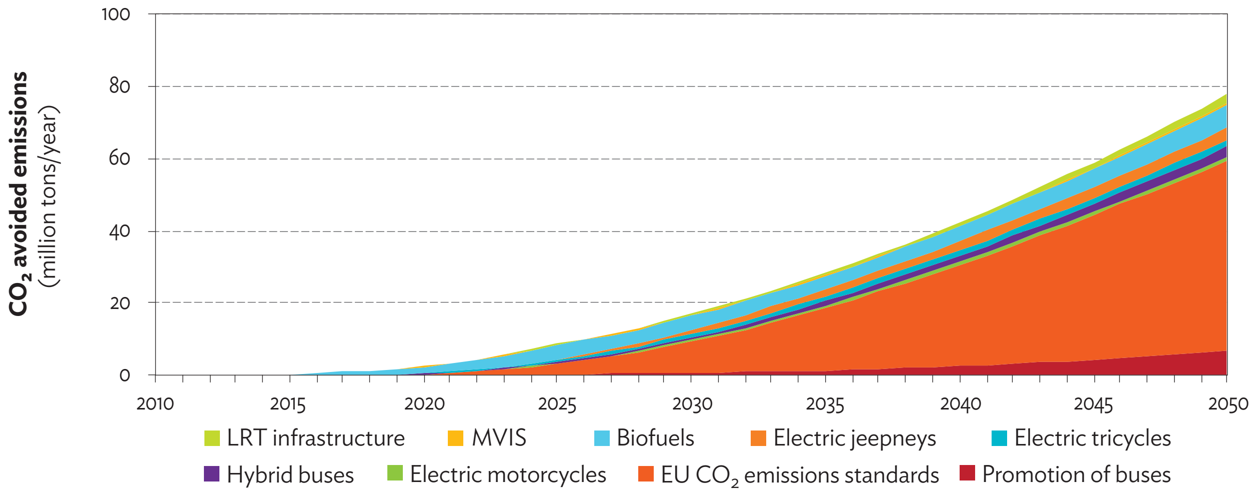
By 2050, the cumulative mitigation potential of all strategies implemented simultaneously is 1,000 $MtCO_2e$, which is lower than the total of individual options of 1,300 $MtCO_2e$ (Figure 3.8). The composite mitigation is smaller because of the interdependencies and substitution among mitigation options when jointly implemented.

Figure 3.7: Marginal Abatement Cost Curve for the Land Transport Sector ($MtCO_2e$)



BRT = bus rapid transit, LRT = light rail transit, $MtCO_2e$ = million metric tons of carbon dioxide equivalent, tCO_2e = metric ton of carbon dioxide equivalent.
Note: This figure does not reflect interaction and substitution effects among measures when implemented simultaneously, which reduce overall mitigation levels.
Source: : Authors.

Figure 3.8: Annual Potential Avoided Emissions for the Land Transport Sector



CO_2 = carbon dioxide, EU = European Union, LRT = light rail transit, MVIS = motor vehicle inspection system.
Source: Authors.

Table 3.8 shows the mitigation potential of the strategies if pursued according to increasing average cost of mitigation. Also shown are the average costs of mitigation for the combined options. Because of substitution effects and behavioral and temporal interactions among the strategies, the difference between adjacent rows in Table 3.8 is different from the individual mitigation potential in Table 3.7. To illustrate, the difference of mitigation potential between the first two rows of Table 3.8 is smaller than the mitigation potential of the vehicle carbon standards strategy in Table 3.7, mainly because the promotion of buses has already reduced the number of private vehicles. The promotion of buses as the first strategy also explains the increased mitigation potential of hybrid buses in Table 3.8. Having more buses on the road would result in more buses being converted to hybrid technology if the same penetration rate is pursued. The numbers in Table 3.8 also show that when all strategies are implemented, the overall cost of mitigation is still low.

Table 3.8: Mitigation Potential of Combined Options and Average Mitigation Costs for the Land Transport Sector

LCD Option		Composite Scenario	Mitigation Potential	Average Cost of Mitigation
			$MtCO_2e$	$/tCO_2e$
1	Buses and BRT system	1	63.2	(24.5)
2	Plus vehicle carbon standards	1 to 2	702.6	(12.3)
3	Plus electric motorcycles	1 to 3	720.6	(12.2)
4	Plus hybrid buses	1 to 4	760.2	(12.1)
5	Plus electric tricycles	1 to 5	796.8	(11.8)
6	Plus electric jeepneys	1 to 6	851.3	(8.2)
7	Plus biofuels blending	1 to 7	981.7	(5.1)
8	Plus motor vehicle inspection	1 to 8	987.4	(4.8)
9	Plus LRT infrastructure	1 to 9	1,003.2	0.4

( ) = negative, BRT = bus rapid transit, LCD = low-carbon development, LRT = light rail transit, $MtCO_2e$ = million metric tons of carbon dioxide equivalent, tCO_2e = metric ton of carbon dioxide equivalent.
Source: Authors.

4. Residential Electricity Sector

4.1 Residential Electrification and Electricity Consumption

Households in the Philippines consumed 18.8 terawatt-hours (TWh) of electricity in 2010, accounting for about 28% of the total electricity demand (DOE 2014). Residential electricity demand grew at an average annual growth rate of 3.9% between 2000 and 2010 and continued to grow at an average annual growth rate of 4.2% between 2010 and 2013.[7] Continuing economic development in the country, resulting in higher urbanization and higher standards of living, coupled with increased Government efforts to provide access to electricity will further increase electricity demand in Philippine households in the future.

The Government of the Philippines declared in 1960 "total electrification of the Philippines" as a national goal. Rural and missionary electrification development was further strengthened through the establishment of the Expanded Rural Electrification Program in April 2003, which aimed to achieve 100% barangay electrification by 2008 and 90% household electrification by 2017. A total of ₱6.3 billion was allotted for rural electrification in 2013 to help reach the 2017 target (Department of Budget Management 2012).

Electricity consumption in the household sector covaries with income. Lower-income households cannot afford expensive appliances, such as air conditioners and electric cooking devices, not only due to the high initial cost of acquiring these types of appliances but also because of the high cost of electricity in the country. The Philippines' electricity price is one of the highest in the world and comparable to prices in highly developed economies in Europe.[8] It has the highest rate among the members of the Association of Southeast Asian Nations (Del Mundo 2015).

4.2 Energy Efficiency and Conservation Initiatives for the Residential Sector

In the Philippine Energy Plan, the Government targets a 10% energy savings across all sectors, which is expected to reduce energy use by 12,500,000 kilotons of oil equivalent by 2030 (Climate Change Commission 2011). Demand-side management is part of the Government's plan to ensure a reliable supply of energy for the country in the future. Several initiatives promote demand-side energy efficiency through selected energy-efficiency standards and labeling, promotion of energy-efficient lightbulbs, and information campaigns around energy efficiency.

4.3 Reference Scenario for the Household Appliance Sector

4.3.1 Demographic, Economic, Electrification, and Appliance Trends

Key drivers of electricity demand in the household sector include population growth and economic growth as measured by GDP, urbanization, access

7 Computed from the Department of Energy. 2014. 2013 Philippine Power Statistics. https://www.doe.gov.ph/2013-philippine-power-statistics.

8 High electricity prices for poor households are partially offset by a lifeline cross-subsidy under Section 73 of the Electric Power Industry Reform Act (and extended under Republic Act 10150 in 2011), which generally lowers prices for customers consuming less than 100 kilowatt-hours per month. However, its implementation faces limitations.

to electricity, and energy efficiency of different household appliances. To develop the household energy forecast for the reference scenario, assumptions on future growth trajectories of its key drivers were required.

Household electrification follows the electrification targets of the DOE up to 2017 and is maintained at 90% onward. This leads to an urban electrification of 94% and rural electrification of 87% in 2050.[9]

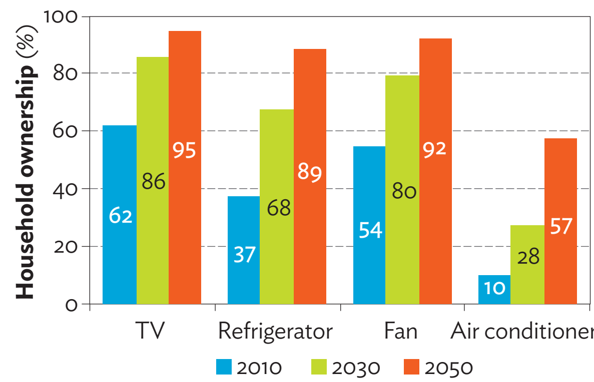
Appliance ownership of households is correlated with household expenditures using the FIES (2012) conducted by the Philippine Statistics Authority (2014). Efficiency characteristics of existing appliances are used to model the energy efficiency of appliances assumed to be available to households in the future. In the reference scenario, it is assumed that efficient technologies are introduced in the market every 8 years.

4.3.2 Appliance Ownership

As the economy grows and household expenditures increase, the percentage ownership of energy-intensive appliances is also expected to expand by 2050. Most notable is the expected percentage ownership of refrigerators, which will increase by 2.4 times, and that of air conditioners, which will grow by 5.7 times in 2050, as compared with the estimated percentage ownership values in 2010. Figure 4.1 illustrates this trend in appliance ownership.

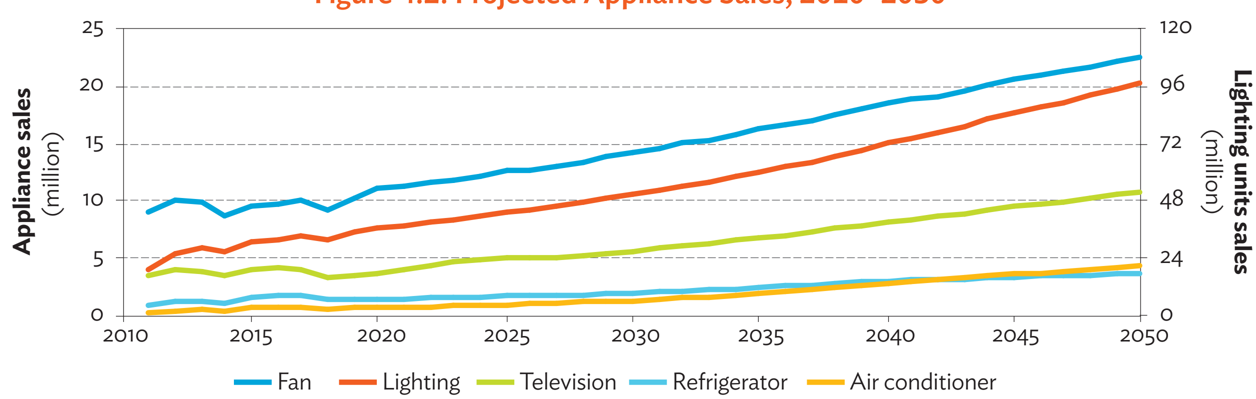
Increased ownership of appliances is coupled with the sales of new appliance units as new households buy appliances and as existing households replace their old appliances. Figure 4.2 shows new appliance sales from 2011 to 2050, which represent the potential for public sector intervention through market regulation of the energy efficiency of appliances.

Figure 4.1: Projected Ownership of Key Appliances in 2010, 2030, and 2050



Source: Authors.

Figure 4.2: Projected Appliance Sales, 2010–2050



Source: Authors.

9 Urban electrification is computed from FIES 2012 data (Philippine Statistics Authority 2014). Rural electrification is computed to meet the DOE's historical and projected electrification targets. Note that the electrification rate as used in this context includes grid-connected households only.

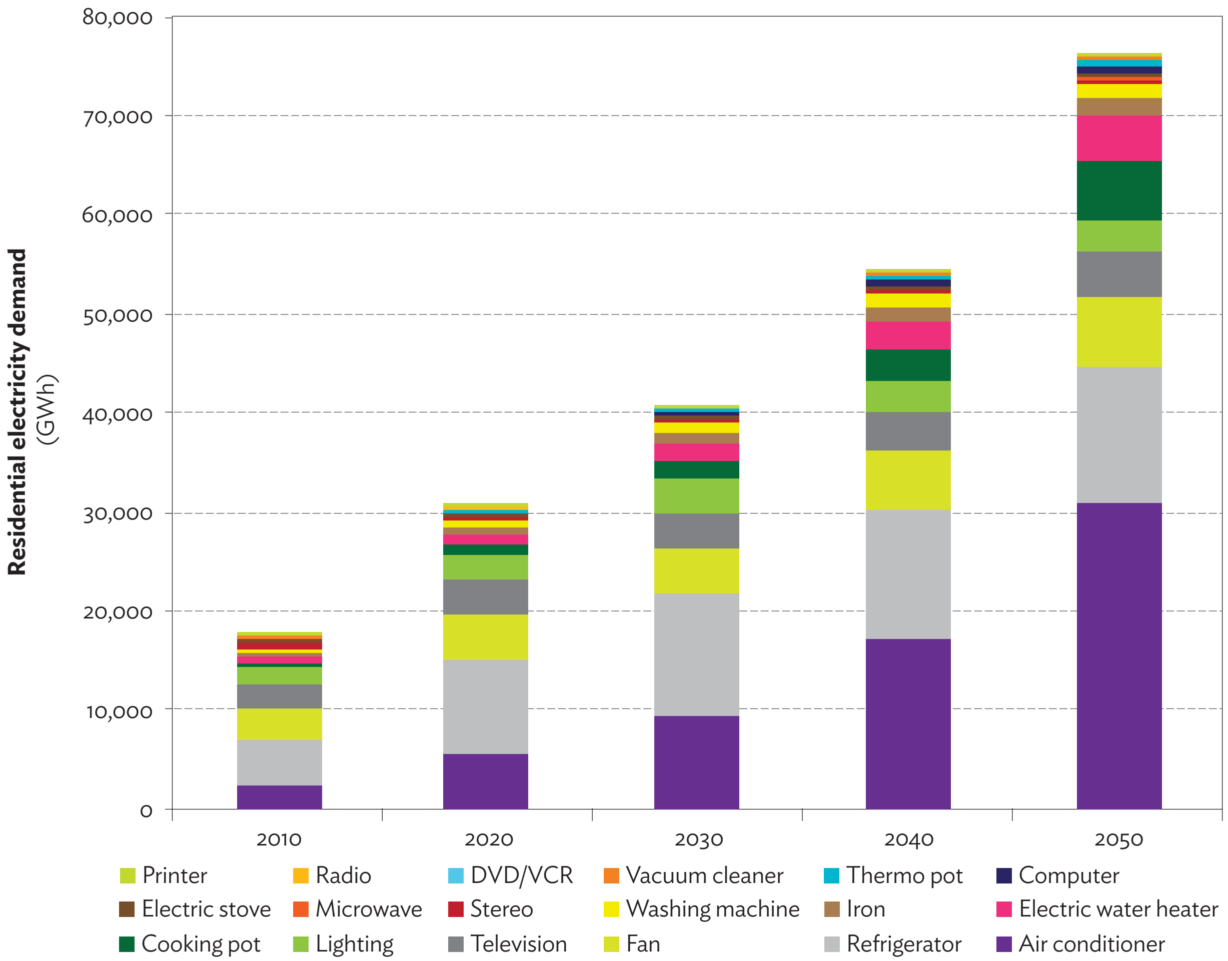
4.3.3 Electricity Demand

Figure 4.3 shows the electricity demand of household appliances in 2010–2050. Electricity demand in the household sector is expected to increase four times between 2010 and 2050, with an average annual growth rate of 3.5%, to reach 76 TWh in 2050. Refrigeration and air-conditioning load is expected to dominate electricity demand in households with a combined 41% share in 2010, which rises to 59% in 2050.

4.3.4 Greenhouse Gas Emissions

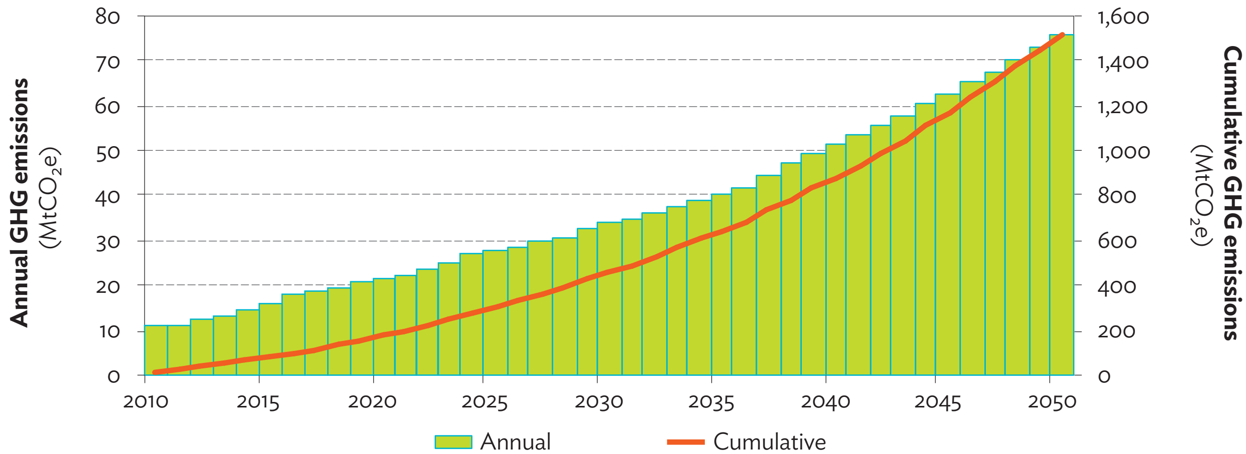
Figure 4.4 shows the projected GHG emissions for the reference scenario. A total cumulative emission of 1,513 million metric tons of carbon dioxide equivalent ($MtCO_2e$) is expected as a result of burning fossil fuels in power plants to satisfy residential demand from 2010 to 2050. The average annual growth in emissions is 4.5%.

Figure 4.3: Projected Household Electricity Demand, 2010–2050



DVD = digital video disc, GWh = gigawatt-hour, VCR = video cassette recorder.
Source: Authors.

Figure 4.4: Reference Greenhouse Gas Emissions Attributable to the Household Sector, 2010–2050



GHG = greenhouse gas, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Source: Authors.

4.4 Low-Carbon Development Scenarios for the Household Appliance Sector

This study focuses on the opportunity to reduce GHG emissions through more efficient household appliances. This may be achieved through a mixture of labeling and regulations imposed on appliance manufacturers, distributors, and retailers to ensure that only efficient appliances are available in the market.

Table 4.1 shows the top 10 energy-consuming appliances in the Philippines (NSO and DOE 2014). The top 5 appliances that contribute to more than 70% of total household demand, in order of increasing energy demand, are lighting units, TV sets, air conditioners, electric fans, and refrigerators.

Table 4.1: Top Electricity-Consuming Household Appliances, 2011

Appliance	% Share of Household Electricity Consumed
Refrigerator	19.2
Electric fan	17.1
Air conditioner	14.0
TV	13.1
Lighting	9.2
Water pump	3.4
Flat iron	2.8
Rice cooker	2.7
Stereo	2.3
Computer	2.0

Note: Computations based on the results of Household Energy Consumption Survey 2011. National Statistics Office and Department of Energy. 2014. 2011 Household Energy Consumption Survey. https://psa.gov.ph/content/electricity-most-common-source-energy-used-households.
Source: Authors.

As low-carbon development options, efficiency standards for these appliances will be escalated every 5 years until 2030 and every 10 years until 2050, as shown in Table 4.2. The first round is implemented in 2020–2024 (Efficient Appliances I), the second round in 2025–2029 (Efficient Appliances II), the third round in 2030–2039 (Efficient Appliances III), and the fourth round in 2040–2050 (New Technologies). The first three of these escalations correspond to points in the distribution of energy-efficient appliances in the United States Energy Star program.

Table 4.2: Timing of Efficiency Improvements for Appliances

Standard	Reference Scenario	LCD Scenario
Historical efficiency	2011–2014	2011–2014
Current efficiency	2015–2024	2015–2019
Philippine appliances Efficiency I (Efficiency of top 75% of US Energy Star appliances)	2025–2032	2020–2024
Philippine appliances Efficiency II (Efficiency of top 50% US Energy Star appliances)	2033–2039	2025–2029
Philippine appliances Efficiency III (Efficiency of top 25% US Energy Star appliances)	2040–2050	2030–2039
New technologies	–	2040–2050

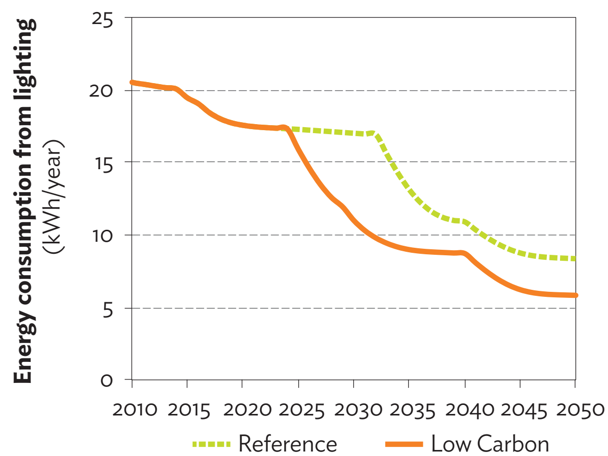
– = not applicable, LCD = low-carbon development, US = United States.
Note: Assumed timing of introduction of new models of appliances.
Source: Authors.

4.4.1 Efficient Lighting

Under this option, magnetic ballast fluorescent lamps and incandescent lamps will be phased out gradually from the market and will be replaced with more efficient compact fluorescent lamps (CFL) and light-emitting diode (LED) lamps. Light bulb energy use will improve from 65 lumens per watt in 2011–2014 to 85–215 lumens per watt in 2015–2050.

The per-unit energy consumption of lighting units starts at 20.5 kilowatt-hours (kWh) per year in 2010. For the reference scenario, the per-unit energy consumption of lighting units will be reduced to 17.0 kWh per year by 2030 and to 8.4 kWh per year by 2050. Compared with the base consumption in 2010, per-unit consumption can be reduced by 46% in 2030 and by up to 71.5% in 2050 (Figure 4.5). More efficient lighting units can potentially reduce GHG emissions by 27.4 MtCO_2e from 2020 to 2050. The estimated abatement cost for efficient lighting is $4.7 per t$CO_2$e.

Figure 4.5: Annual per Unit Energy Consumption of Lighting Units



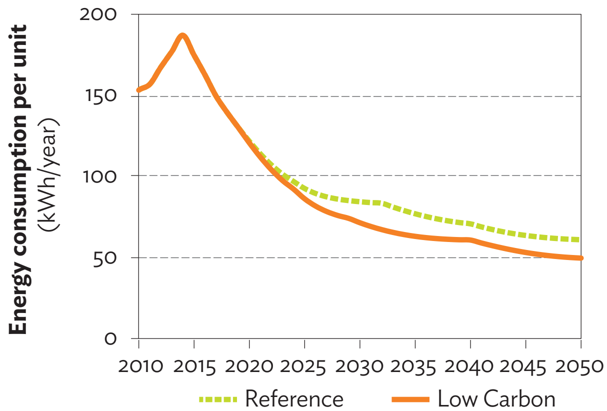
kWh = kilowatt-hour.
Source: Authors.

4.4.2 Efficient Television Sets

The current trend in television technology is expected to reduce the per-unit annual energy consumption from 154 kWh per year in 2010 to 84.4 kWh per year in 2030 and to 60.9 kWh per year in 2050 for the reference scenario. Under this option, aggressive penetration of high-efficiency television sets in the market (Figure 4.6) will reduce energy consumption further. By 2030, the annual energy consumption of TV sets is found to be reduced to 71.4 kWh per year, achieving 54% reduction from 2010 consumption.

Final electricity consumption in 2050 is modeled to be 49.6 kWh per year, which is 68% lower than the consumption in 2010. As a result, the mitigation potential and abatement cost for efficient television sets from 2010 to 2050 are 17.4 MtCO_2e and $2.8 per t$CO_2$e, respectively.

Figure 4.6: Annual per Unit Energy Consumption of Television Sets

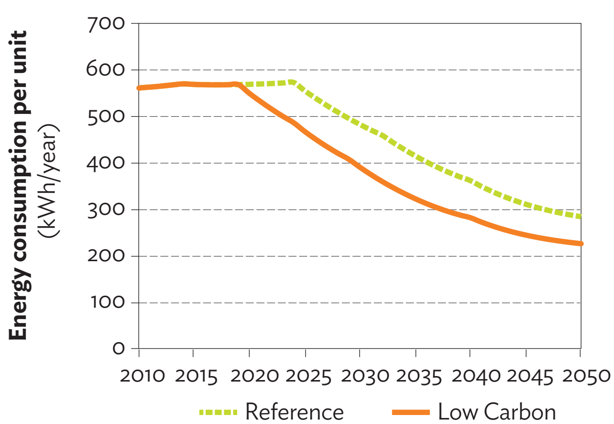


kWh = kilowatt-hour.
Source: Authors.

4.4.3 Efficient Refrigerators

Current trends in refrigerator characteristics are expected to reduce the per-unit energy consumption from 561 kWh per year in 2010 to 482 kWh per year in 2030 and to 284 kWh per year in 2050 (Figure 4.7). Adoption of efficient refrigerators is found to lead to reduced annual consumption of 390 kWh per year in 2030 and 226 kWh per year in 2050.

Figure 4.7: Annual per Unit Energy Consumption of Refrigerators



kWh = kilowatt-hour.
Source: Authors.

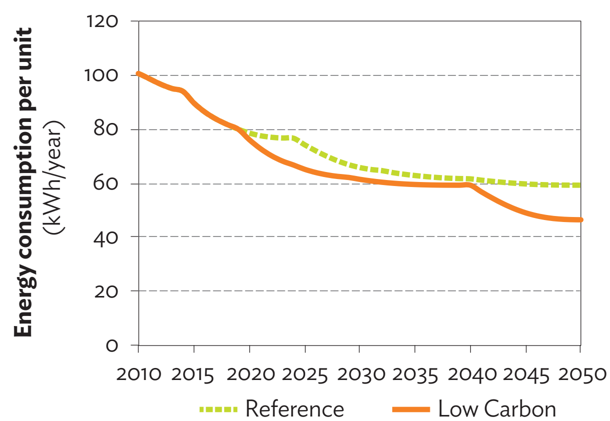
The overall reduction in energy consumption compared with the 2010 figures is 31% in 2030 and 60% in 2050. Accelerated adoption of high-efficiency refrigerators can mitigate 79.7 $MtCO_2e$ with an abatement cost of –$4.4 per tCO_2e for 2010–2050.

4.4.4 Efficient Fans

The average annual energy consumption of electric fans in 2010 is 101 kWh per year. Under the reference scenario, performance is expected to improve to 65.8 kWh per year in 2030 and 59.3 kWh per year in 2050 (Figure 4.8). With greater penetration of more efficient fans, energy consumption of electric fans will reduce annual consumption to 46.5 kWh per unit by 2050.

Compared with 2010 values, this translates to a 54% reduction in energy requirements. More efficient electric fans thereby mitigate 19.6 $MtCO_2e$ for 2010–2050 with an abatement cost of $1.5 per tCO_2e.

Figure 4.8: Annual per Unit Energy Consumption of Fans

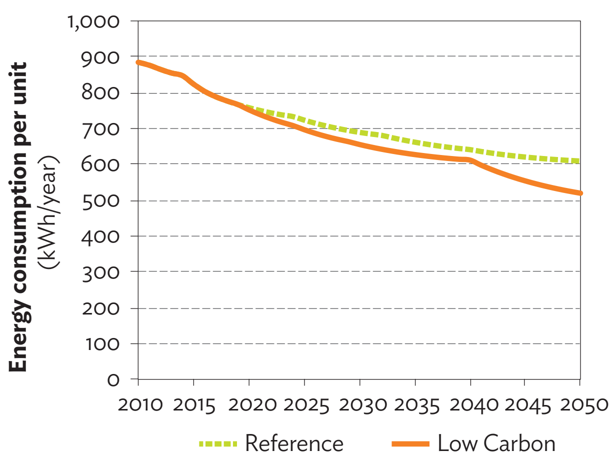


kWh = kilowatt-hour.
Source: Authors.

4.4.5 Efficient Air Conditioners

Air conditioners are the most energy-intensive appliances in residential electricity consumption. Air-conditioning units in 2010 consume an average of 885 kWh per year and by 2030 this is expected to fall to 689 kWh per year (Figure 4.9). In 2050, annual consumption is 609 kWh per year under the reference scenario, which can be reduced to 519 kWh per year by 2050 if efficient air conditioners were promoted.

Figure 4.9: Annual per Unit Energy Consumption of Air Conditioners



kWh = kilowatt-hour.
Source: Authors.

By 2050, this is found to equate to a 15% reduction in air-conditioning electricity use. High-efficiency air conditioners are found to mitigate a total of 39.9 $MtCO_2e$ for 2010–2050 at an abatement cost of –\$1.6 per tCO_2e.

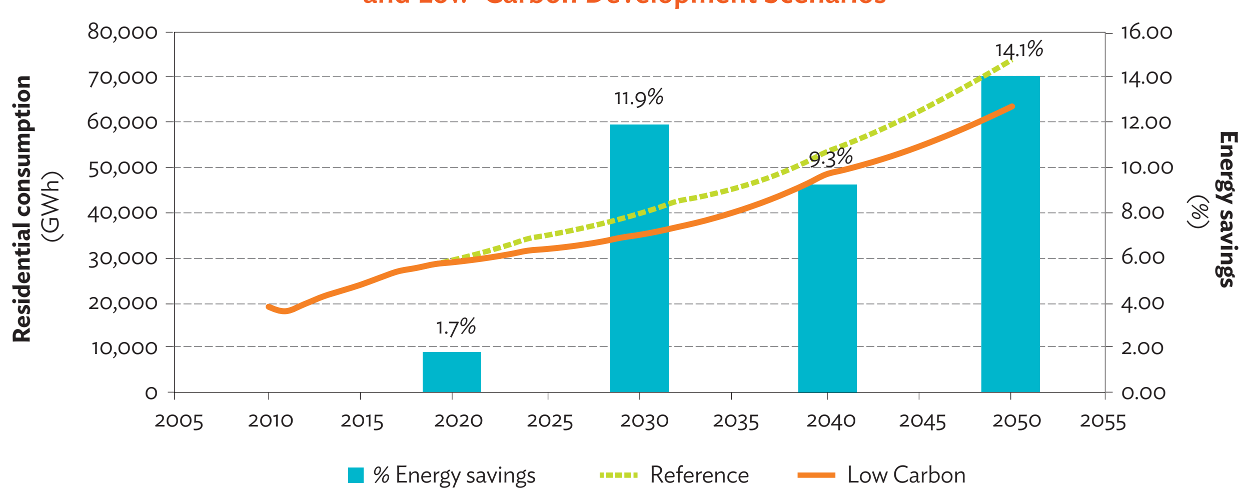
4.5 Marginal Abatement Cost Curve Analysis for the Household Appliance Sector

4.5.1 Reduction in Residential Electricity Demand

By implementing improvements to the efficiency of all five appliance types, residential electricity demand is reduced by up to 14% in 2050, with a total reduction in cumulative demand of 164 TWh from 2010 to 2050 (Figure 4.10). This suggests that the promotion of efficient appliances has potential to achieve the Government's 10% energy reduction target in the household sector.

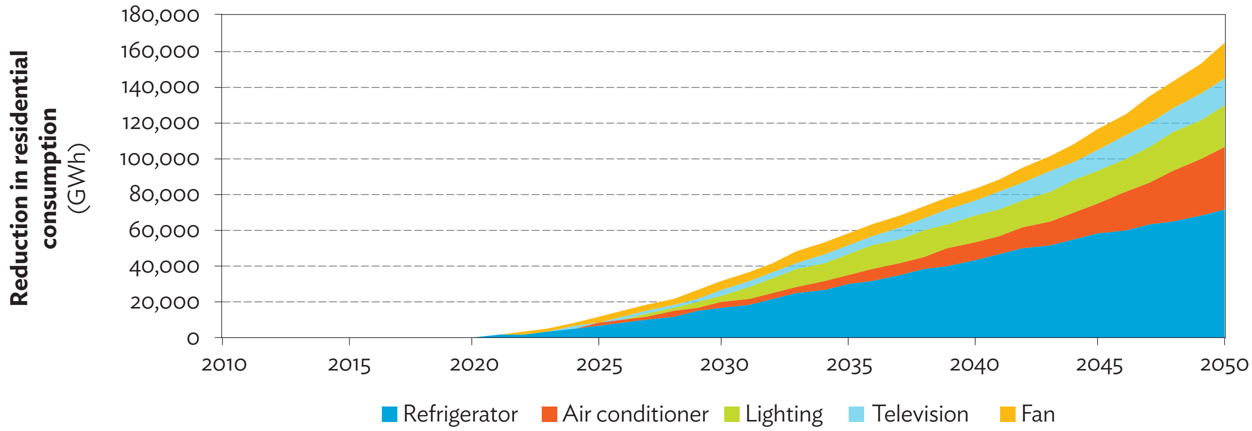
A majority of the 2015–2050 demand reduction is from the use of efficient refrigerators, followed by the use of efficient air conditioners (Figure 4.11). Most of the reduction takes place after 2030, due to adoption lags. The dominance of refrigerators is greatest earlier in the period.

Figure 4.10: Residential Electricity Consumption under Reference and Low-Carbon Development Scenarios



GWh = gigawatt-hour.
Source: Authors.

Figure 4.11: Cumulative Reduction in Residential Electricity Consumption

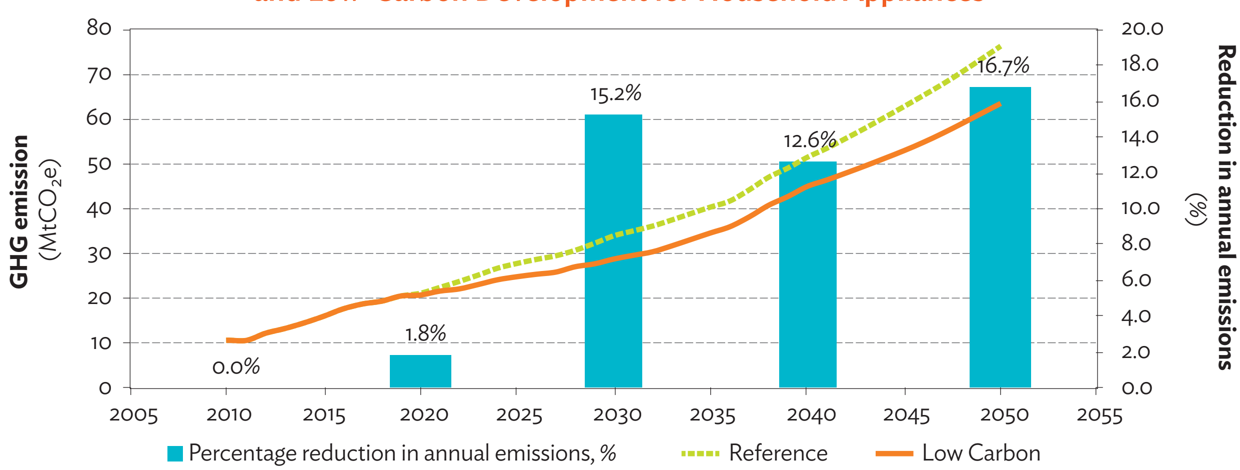


GWh = gigawatt-hour.
Note: The projections reflect the dynamics in appliance ownership when more efficient appliances are introduced in the market. The apparent drop of energy savings in 2040 is a result of the long delay assumed in introducing the fourth batch of more efficient appliances. Since appliance efficiencies are assumed to also improve in the reference scenario, this reference will eventually catch up with the appliance efficiency in the low-carbon development scenario if no stricter regulation is implemented soon.
Source: Authors.

4.5.2 Greenhouse Gas Emissions Reduction

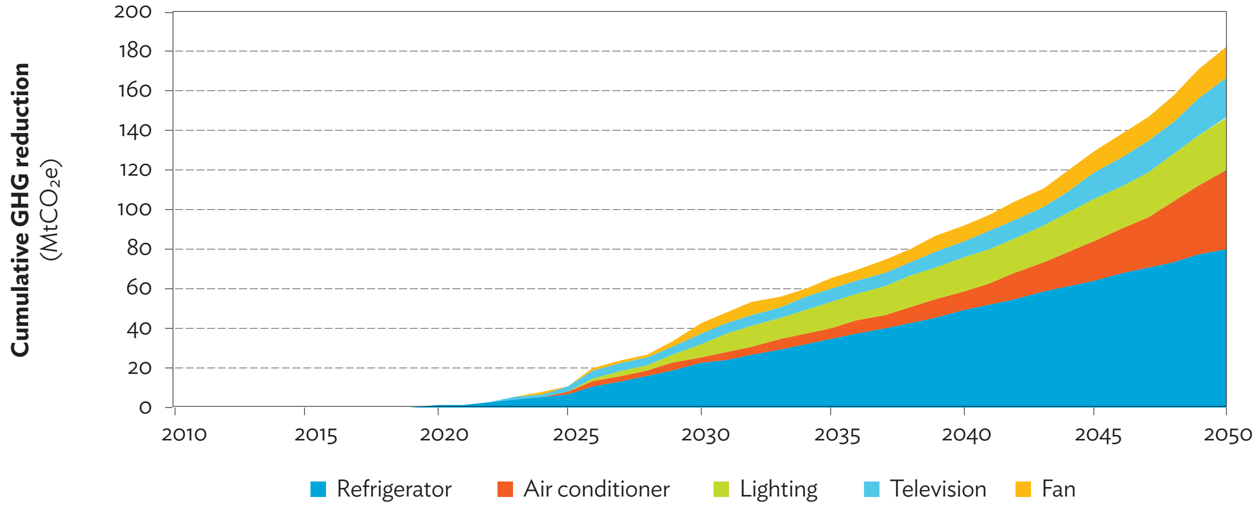
Annual emissions attributable to the household electricity sector can be reduced by up to 16.7% in 2050 (Figure 4.12). Implementing all five strategies will reduce the total cumulative GHG emissions by 182 $MtCO_2e$ as a result of the deferred use of fossil fuels in power generation by 2050 (Figure 4.13). The percentage emissions reduction is slightly larger than the percentage electricity reduction, due to the difference in installed generation capacity and generation dispatch between the reference and low-carbon scenarios.

Figure 4.12: Greenhouse Gas Emissions for Reference and Low-Carbon Development for Household Appliances



GHG = greenhouse gas, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Source: Authors.

Figure 4.13: Cumulative Greenhouse Gas Reduction Potential in the Household Appliance Sector



GHG = greenhouse gas, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Source: Authors.

4.5.3 Marginal Abatement Cost Curve for the Household Appliance Sector

Costs of avoided emissions reflect deferred fossil fuel use, deferred plant capacities,[10] incremental cost of more efficient appliances, and policy implementation cost to the public sector.[11] Table 4.3 shows the assumed incremental cost of more efficient appliances gathered from available literature. An annual cost of about ₱13.4 million or about $298,000 is the assumed policy implementation cost per standard per year.[12]

Co-benefits, such as market creation, new job opportunities, appliance life-cycle costs, and other externalities, are not considered in this study.

Table 4.3: Incremental Cost of More Efficient Appliances

Appliance	Incremental Cost per Unit ($)
Room air conditioner	35.0
Refrigerator	52.0
TV	12.1
Lighting unit	2.4
Electric fan	5.0

Source: Authors.

Simulations result in the marginal abatement cost curve shown in Table 4.4 and Figure 4.14. In order of increasing abatement cost, the mitigation options are (i) use of efficient refrigerators, (ii) use of efficient lighting, (iii) use of efficient air conditioners, (iv) use of efficient television sets, and (v) use of efficient electric fans.

10 Costs avoided from deferred fossil fuel use reflect the costs avoided due to the postponed use of fossil fuels in power plants when demand is reduced. Costs avoided from deferred plant capacity reflect the costs avoided as a result of the postponed installation of new power plants when electricity demand is reduced.

11 Refer to the power generation section for the fuel costs and power plant costs. Incremental costs of more efficient appliances were obtained from a review of related literature. Policy implementation cost was estimated from the Department of Trade and Industry (DTI)–Bureau of Product Standards (BPS) budget (see DTI–BPS [2015] and Legislative Budget Research and Monitoring Office [2014]).

12 Policy cost covers only additional manpower and operating expenses in the Government's enforcement of stricter monitoring activities. This value is estimated from the DTI–BPS budget for 2014, with significant additional budget allocated for the aforementioned expenses per standard per year.

Table 4.4: Mitigation Potential and Abatement Costs of Low-Carbon Development in the Household Appliance Sector

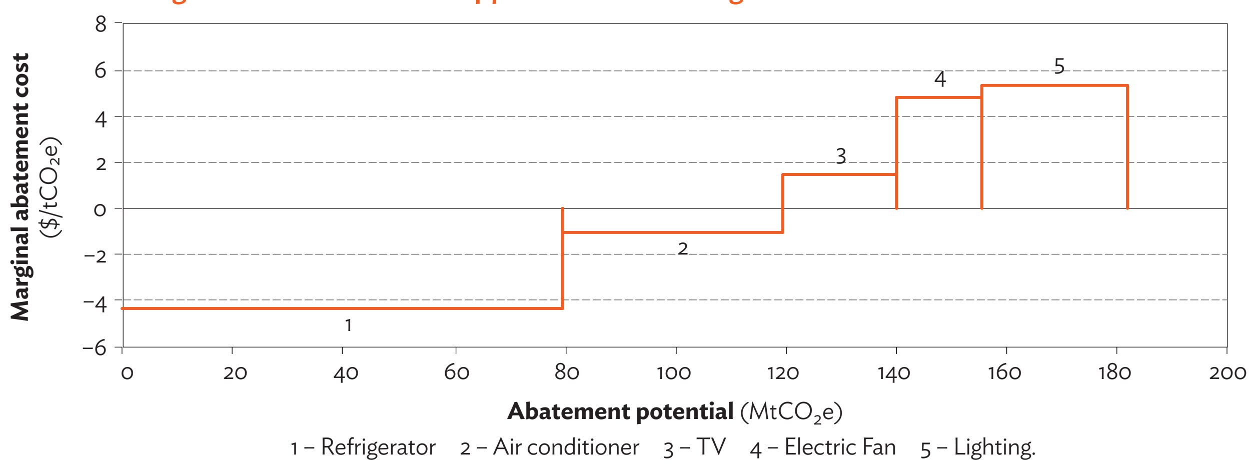
Low-Carbon Development Option	Mitigation Potential ($MtCO_2e$)	Abatement Cost ($/$tCO_2e$)
1 Efficient refrigerator	79.7	(4.41)
2 Efficient air conditioner	39.9	(1.60)
3 Efficient electric fan	19.6	1.47
4 Efficient TV	17.4	2.81
5 Efficient lighting	27.4	4.74

( ) = negative, $MtCO_2e$ = million metric tons of carbon dioxide equivalent, tCO_2e = metric ton of carbon dioxide equivalent.
Note: This table does not reflect interaction and substitution effects among measures when implemented simultaneously, which reduce overall mitigation levels.
Source: Authors.

Some mitigation options in the household sector yielded negative abatement costs for reducing CO_2e emissions. This means that pursuing these measures will yield net benefits to society in terms of deferred fuel costs and deferred power plant capacity despite incremental costs to end users and policy implementation cost to the public sector. Positive abatement cost implies that the benefits in terms of deferred fuel costs and power plant capacity may not recover the incremental costs to end users and policy implementation cost to the public sector. Given a suitable price of carbon, mitigation options with positive abatement cost can also become attractive.

Combining all strategies for low-carbon emission development yields a total mitigation potential of 181.7 $MtCO_2e$ with an abatement cost of −\$0.9 per tCO_2e (Table 4.5). More optimistic assumptions in the efficiency improvements of appliances in the future would result in higher estimates of carbon reduction potential for the household electricity sector.

Figure 4.14: Household Appliance Sector Marginal Abatement Cost Curve



$MtCO_2e$ = million metric tons of carbon dioxide equivalent, tCO_2e = metric ton of carbon dioxide equivalent.
Note: This figure does not reflect interaction and substitution effects among measures when implemented simultaneously, which reduce overall mitigation levels.
Source: Authors.

Table 4.5: Mitigation Potential of Combined Household Scenario and Average Mitigation Costs

Intervention	Composite Scenario	Mitigation Potential ($MtCO_2e$)	Abatement Cost ($/$tCO_2e$)
1 Market regulation of refrigerators	1	79.7	(4.41)
2 Plus market regulation of air conditioners	1 to 2	119.5	(3.39)
3 Plus market regulation of electric fans	1 to 3	137.6	(2.28)
4 Plus market regulation of TV sets	1 to 4	157.8	(1.74)
5 Plus market regulation of lighting units	1 to 5	181.7	(0.85)

( ) = negative, $MtCO_2e$ = million metric tons of carbon dioxide equivalent, tCO_2e = metric ton of carbon dioxide equivalent.
Source: Authors.

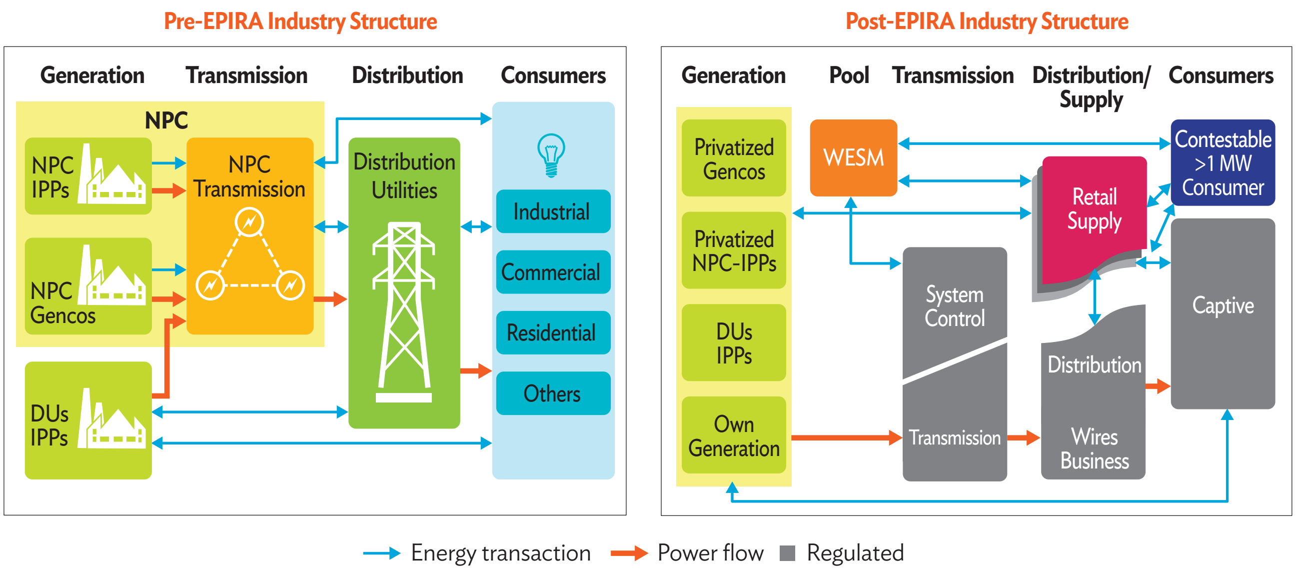
5. Power Generation Sector

5.1 The Power Industry of the Philippines

5.1.1 Power Industry Structure

The Philippines' electric power industry was restructured with the enactment of Republic Act No. 9136, also known as the Electric Power Industry Reform Act (EPIRA) of 2001. Figure 5.1 illustrates the structure of the industry before and after EPIRA. Before EPIRA was passed into law, the power industry was a monopoly with vertical separation for bulk power generation–transmission and distribution–supply to end users. The National Power Corporation (NPC) was the monopoly generation–transmission company with a portion of power generation owned and operated by independent power producers (IPPs) with bilateral contracts with either the NPC or private distribution utilities. The distribution utilities are composed of Meralco (the single largest distribution utility in Luzon supplying about three quarters of the demand in the Luzon grid), 18 small private distribution utilities, and about 120 small electric cooperatives.

Figure 5.1: Structure of the Philippines' Electric Power Industry



DU = distribution utility, EPIRA = Electric Power Industry Reform Act of 2001, Gencos = power generation companies, IPP = independent power producer, MW = megawatt, NPC = National Power Corporation, WESM =Wholesale Electricity Spot Market.
Source: KPMG Global Energy Institute. 2013. The Energy Report: Philippines—Growth and Opportunities in the Philippine Electric Power Sector (2013–2014 Edition).

EPIRA unbundled the business of (i) generation, (ii) transmission, (iii) distribution, and (iv) retail supply of electricity. Generation and supply are competitive sectors, while the transmission and distribution sectors remain as a regulated monopoly. The main structural reforms of EPIRA were (i) to divide and privatize the power generation and transmission assets owned by the NPC, and (ii) to create a market mechanism through the creation of a wholesale and retail market to optimize electricity rates in the liberalized market. As a result of the restructuring, new entry is allowed in power generation and retail supply. The NPC's generation and transmission assets were separated and privatized by the Power Sector Assets and Liabilities Management Corporation, which also assumed the NPC's debts. The NPC's power supply contracts (power purchase agreements) with the IPPs were also privatized through the IPP administrators in order to transfer control of the output of the IPP-owned and/or operated power plants to the private sector.

The National Transmission Corporation is the public agency that solely owns electric power transmission assets. The operation and maintenance of these facilities and the real-time grid operation and control by the system operator is privatized through a concession agreement that was awarded to the National Grid Corporation of the Philippines.

Distribution utilities remained as private investor-owned corporations (also called private distribution utilities), consumer-owned nonprofit electric cooperatives, or stock electric cooperatives. Distribution utilities were required to unbundle their business into distribution and supply through the separation of financial accounts.

The industry structure in the Philippines sets the context for low-carbon development in the power generation sector under this study since the market (i.e., private sector) will decide on the type, size, location, and fuel of power plants, unless specifically mandated to focus on particular technologies, such as renewables.

5.1.2 Electricity Grids

The electric power system in the Philippines consists of three main island grids—Luzon grid, Visayas grid, and Mindanao grid—and many isolated small island grids.

The Luzon grid in northern Philippines is the largest power system and serves about 74% of the country's total demand. It is interconnected to the Visayas grid in central Philippines by high-voltage direct-current-transmission submarine cables with a monopolar capacity of 440 megawatts (MW). The Visayas grid with five interconnected sub-grids (Cebu, Negros, Panay, Leyte–Samar, and Bohol) supplies the central part, while the Mindanao grid serves southern Philippines. There is no interconnection between the Mindanao grid and the other grids.

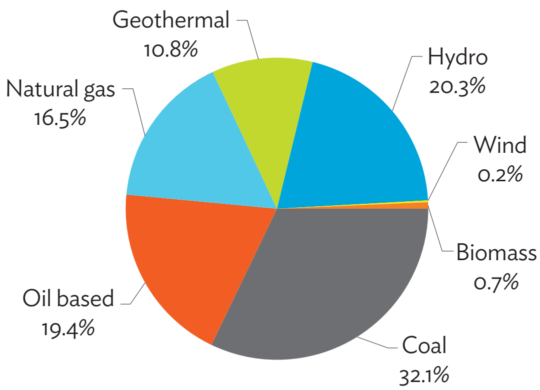
Small grids with predominantly diesel power plants supply the small and isolated islands. There are 87 small island grids operated by the NPC Small Utilities Group.

5.1.3 Installed Generating Capacity

The three main electric grids transmit and deliver a large portion of electricity to electric consumers in the Philippines. The Luzon grid transmits power across Luzon Island, where majority of the population and industries are located. A total of 12,790 MW generating capacity is connected to the Luzon grid, which supplied the 8,305 MW peak demand of 2013. The Visayas grid on the other hand, transmits power across five islands in the Visayas Region—Samar, Leyte, Cebu, Negros, and Panay. A total of 2,448 MW generating capacity is connected to the Visayas grid for the peak demand of 1,572 MW in 2013. The Mindanao grid transmits power across Mindanao Island with peak demand of 1,428 MW, and 2,087 MW of generating capacity is connected to this grid.

In total, 17,325 MW of generation capacity is connected to the Philippines' main grids. Figure 5.2 shows the capacity mix of the different plant types and indicates that the combined capacities of new renewable energy sources (solar, wind, and biomass) only account for about 1% of the total capacity. However, geothermal and hydropower account collectively for 31% of capacity, which is substantial. About 68% of capacity is fossil fuel based, with coal accounting for the largest share, followed by oil (DOE 2014).

Figure 5.2: Generation Capacity Mix in the Philippines, 2013

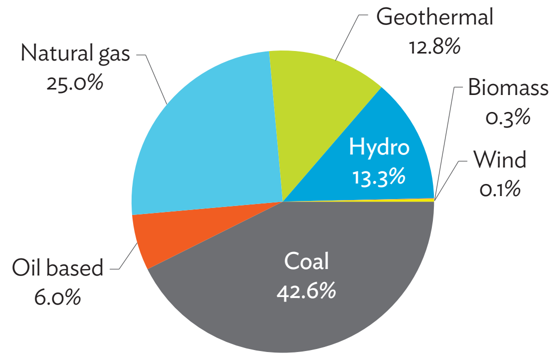


Source: Department of Energy. 2014. 2013 Philippine Power Statistics. https://www.doe.gov.ph/2013-philippine-power-statistics.

5.1.4 Electricity Generation Mix

Power generation was about 75 TWh of electricity in 2013. As shown in Figure 5.3, 74% of total generation was supplied through nonrenewable energy plants—with coal power plants taking the biggest share (43%) (DOE 2014). The remaining 26% of the total generation is supplied through the cleaner renewable energy plants (geothermal, hydro, wind, and solar). With increasing population and economic growth, electricity demand will continue to rise, and generation capacity must increase.

Figure 5.3: Electricity Generation Mix in the Philippines, 2013



Source: Department of Energy. 2014. 2013 Philippine Power Statistics. https://www.doe.gov.ph/2013-philippine-power-statistics.

5.2 Legal Framework for Renewable Energy Development

The Renewable Energy Act of 2008 (Republic Act No. 9513) seeks to accelerate the development of renewable energy sources by providing fiscal and nonfiscal incentives to private actors that will explore and develop renewable energy sources. This is necessary since the generation sector in the Philippines is liberalized under EPIRA. Without support under the Renewable Energy Act, coal power plants will dominate the generation mix because coal represents the lowest capital cost option for baseload plants. Diesel plants, on the other hand, are the most economical candidates for peaking power supply.

The Renewable Energy Act aims to reduce the cost of developing, building, and operating new renewable energy plants to make it attractive for private sector investments. It also aims to reduce greenhouse gas (GHG) emissions and minimize the country’s exposure to fossil fuel price volatility.

5.3 Reference Scenario for Power Generation Development

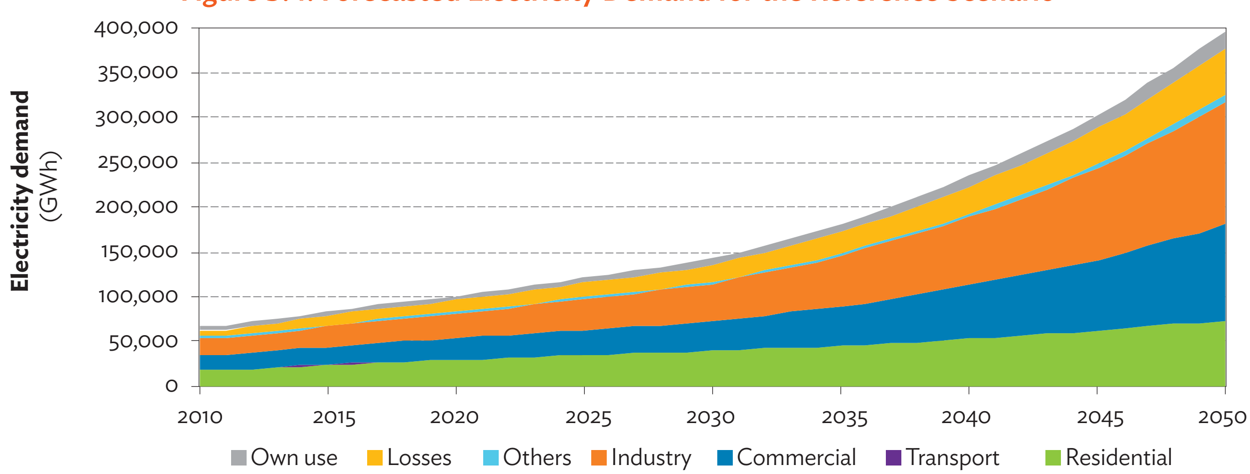
5.3.1 Electricity Demand Forecast

The bottom-up energy models described in Chapters 3 and 4 were used to forecast the electricity demand of the residential sector (for household appliances) and the land transport sector (for electric trains). The demand for commercial, industry, and other sectors up to 2050 were forecast using (i) annual sectoral growth rates from the DOE (2014 to 2030) with an average growth rate of 2.8% across sectors; and (ii) annual sector value-added growth rates from the PHILGEM Computable General Equilibrium Model (2031 to 2050) (Corong and Horridge 2012), with an average growth rate of 6% across sectors. The forecasts were made for the aggregate demand of the Philippines.[13]

The total electricity demand of the Philippines is expected to increase to around 400 TWh in 2050, about 5.9 times the demand in 2010, as a result of the increasing population as well as the growth in projected GDP.[14] Figure 5.4 shows the total electric energy demand of the Philippines that must be met from 2010 to 2050 for the reference scenario. It accounts for the demand of the household, transport, commercial, industry, and other sectors supplied through the grid. It also includes transmission and distribution system losses that are pegged at 13% of the total grid demand (based on 2013 power statistics), and another 5% is allocated for own use of power plants and substations of utilities.

From the annual energy demand (gigawatt-hour) forecasts, the peak demand (in MW) was determined using a system load factor of 71%, which was derived from the load curve of the Luzon grid.[15] The annual energy requirements of the country will translate to increase in peak demand from about 10 gigawatts in 2010 to 24 gigawatts in 2030. By 2050, the peak demand may be 64 gigawatts.

Figure 5.4: Forecasted Electricity Demand for the Reference Scenario



GWh = gigawatt-hour.
Source: Authors.

[13] Energy balance forecasts from the DOE's Energy Policy and Planning Bureau were used.

[14] Separately forecasting the demand on individual different grids is outside the scope of the study.

[15] The University of the Philippines National Engineering Center consolidated the 2009 data for the Luzon grid.

5.3.2 Generation Capacity Expansion and Production

The reference scenario for power generation assumes that the present preferences of investors, as demonstrated by the committed power plant projects reported by DOE will continue until 2050 (DOE 2015). These are dominated by coal power plants contracted competitively from the private sector under long-term power supply agreements. If renewable energy incentives and clear policy signals are not implemented, coal power plants will continue to be added as baseload plants, as the short-term returns are higher for such investments.

Existing natural gas power plants are being dispatched by Meralco as baseload plants on the basis of power purchase agreements. The installed capacity of gas plants is enough to meet the intermediate load requirements of the grid until the end of the economic life of the plants and the depletion of the Malampaya gas field. It is also assumed for the reference scenario that no LNG facilities will be constructed. Hence, no more natural gas power plants will be added after the existing plants are retired.

Renewable energy plants will be renewed after their useful life at a fraction of the plants' overnight cost to operate. However, under the reference scenario, new renewable energy plant investments are not made after 2016. It is also assumed that there will be no introduction of more efficient types of fossil fuel–based power plants, such as supercritical coal in the capacity mix.

The capacity addition in the reference scenario follows the optimal capacity and energy mix, assuming coal as baseload plant and diesel as peaking plant as shown in Table 5.1. The capacity and energy mix is based on the power plant screening curves that take into account capital costs, operation and maintenance costs (both fixed and variable costs), and fuel cost plotted against the annual load duration curve for electricity demand of the Luzon grid.

Table 5.1: Optimal Generation Mix for the Reference Scenario

Plant Type	Capacity (% of peak demand)	Energy (% of annual energy)
Baseload	87.4%	99.4%
Peaking	12.6%	0.6%

Source: Authors.

It is assumed that 100 MW diesel units are used for additional diesel peak load capacity. For baseload, 300 MW subcritical coal units are used for 80% of the additional coal capacities (for Luzon grid), while 150 MW subcritical coal units are used for the remaining 20% of the additional coal capacities (for Visayas and Mindanao). The Visayas and Mindanao grids will accommodate the smaller 150 MW coal units due to operative reserve constraints of a smaller grid.

On top of the peak demand, system capacity reserve is added to maintain a maximum of 1 day per year loss-of-load expectation. For 2010–2025, the reserve requirement used is 29% of the peak (Del Mundo and Espos 2011). Beyond 2025, the reserve requirements to maintain 1 day per year loss-of-load expectation were calculated for every 5-year interval using probabilistic methodology considering the forced and planned outage rates of the power plant technologies (Black and Veatech, Inc. 2012). Table 5.2 gives a summary of the reserve capacity requirements. Diesel power plants will also be used for the capacity reserve requirements for plant outage contingencies of the grid.

Table 5.2: Capacity Reserve Requirement

Year	Capacity Reserve
2010–2025	28.7%
2026–2030	26.0%
2031–2035	25.0%
2036–2040	22.0%
2041–2045	21.4%
2046–2050	21.3%

Source: Authors.

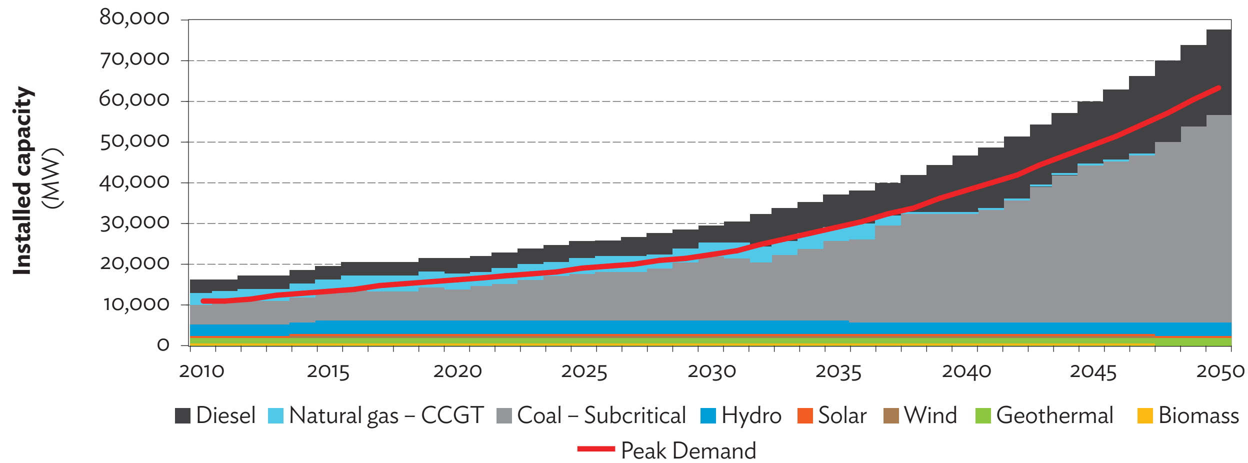
Renewable energy resources in the National Renewable Energy Program (NREP) until 2016 are already committed. Hence, they are included in the reference scenario. The resulting generation capacity expansion up to 2050 for each type of power plant is shown in Figure 5.5.

The total system installed capacity by 2050 will be 78 gigawatts, which is about 5 times the installed capacity in 2010. The share of coal power plants will increase from about 30% in 2010 to around 50% in 2030. This share will further increase to 65% by 2050 since the existing natural gas plants are retired in the future. Over 25% of 2050 capacity will be diesel.

It is also assumed that all of electricity demand will be supplied through electricity grids in which plants are dispatched to minimize variable costs. The energy generated by the different industry sectors for their own use (that is, energy that is consumed on-site and does not pass through the transmission grid) is not included in the study.

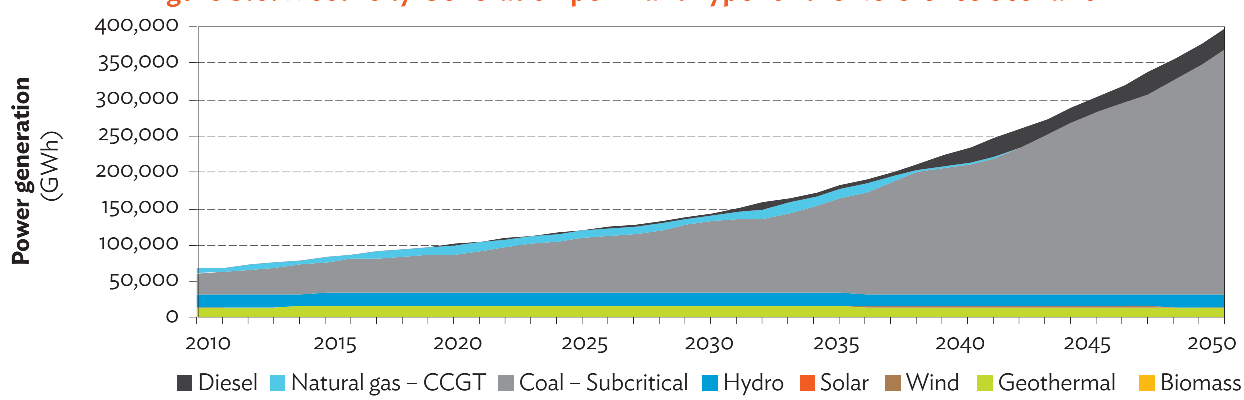
The resulting electricity production (energy generation) from the different plant types to meet the grid demand in the reference scenario is shown in Figure 5.6. The coal power generation share increases from 45% in 2010 to 70% in 2030. As natural gas plants are retired and replaced by coal

Figure 5.5: Generation Capacity Expansion per Plant Type for the Reference Scenario



CCGT = combined-cycle gas turbine, MW = megawatt.
Source: Authors.

Figure 5.6: Electricity Generation per Plant Type for the Reference Scenario



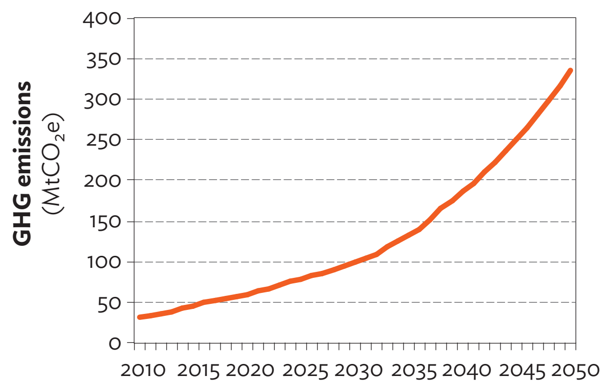
CCGT = combined-cycle gas turbine, GWh = gigawatt-hour.
Source: Authors.

power plants, the coal contribution to the power generation mix will rise to 85% by 2050.

5.3.3 Greenhouse Gas Emissions in the Reference Scenario

GHG emissions were estimated from the combustion of fossil fuels (coal, natural gas, and diesel) for generation. Figure 5.7 shows the annual GHG emissions from power generation in the reference scenario, under which GHG emissions from power generation will be 334 $MtCO_2e$ in 2050. This is about 10.5 times the GHG emissions in 2010 (32 $MtCO_2e$). [16]

Figure 5.7: Greenhouse Gas Emissions for the Power Sector Reference Scenario



GHG= greenhouse gas, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Source: Authors.

5.4 Low-Carbon Development Scenario for the Power Generation Sector

To explore the mitigation potential and estimate the corresponding abatement costs for reducing GHG emissions, seven low-carbon development options in the following four categories were simulated: (i) renewable energy development; (ii) clean fuel (natural gas power) development; (iii) high-efficiency fossil-based (supercritical coal power) plant development; and (iv) low-carbon backstop power development, such as nuclear. The options simulated in this study were identified and developed through a series of consultations with the national technical working group.

The renewable energy resources considered were those included in the NREP beyond 2016, which include geothermal, hydro, wind, and solar. Targets for biomass capacity extend only up to 2016; thus, no options for biomass were simulated in this study. For the renewable energy development options, four options were explored: (i) geothermal power capacity expansion, (ii) large and minihydropower development, (iii) wind power capacity expansion, and (iv) solar power addition. Capacity credits are also considered for solar and wind plants, as intermittent availability means that maximum generation is not provided at peak periods.

Table 5.3 shows the annual capacity additions used for renewable energy. The target additions from the NREP 2011–2030 were used as the basis for the capacity additions for the geothermal option from 2016 to 2030, and for the capacity additions for hydro and wind option from 2016 to 2025 (DOE 2011). After the NREP targets are achieved, the following assumptions are made:

(i) For the geothermal option, 100 MW of geothermal capacity is added to the system every 5 years after the NREP targets are achieved in 2028. This is a conservative assumption that considers the limited remaining exploitable geothermal resources in the country.

(ii) For the hydropower option, the capacity additions from 2026 to 2050 were calculated to maximize the exploitable 13,000 MW hydropower potential (DOE, Hydropower). This study assumes that 11,100 MW of the additional hydropower capacity from 2016 to 2044 will come from large hydropower plants while 1,780 MW will come from small hydropower plants.

[16] The GHG emissions results for reference power generation are consistent with those stated in the Philippines' Second National Communication (SNC) to the United Nations Framework Convention on Climate Change. Based on DOE data, the energy generation increased by about 50%, from 45,290 gigawatt-hours in 2000 to 67,743 gigawatt-hours in 2010. The Philippines' SNC lists GHG emissions of 21.21 $MtCO_2e$ from the energy industries subsector in 2000. The Philippines' EFFECT model results show GHG emissions from the power generation sector of 31.94 $MtCO_2e$, also an increase of 50% within the same time period.

Table 5.3: Annual Capacity Additions for the Geothermal, Hydro, Wind, and Solar Options (MW)

Year	Geothermal	Hydro (Large)	Hydro (Small)	Wind	Solar
2016	220	600	30	150	50
2017	220	600	30	150	50
2018	220	600	30	150	50
2019	220	600	35	200	50
2020	220	600	35	200	50
2021	0	300	30	100	50
2022	0	300	30	100	50
2023	100	600	20	100	50
2024	0	600	20	100	50
2025	0	300	20	50	50
2026	0	300	60	100	50
2027	0	300	60	100	50
2028	80	300	60	100	50
2029	0	300	60	100	50
2030	0	300	60	100	50
2031	0	300	60	100	50
2032	0	300	60	100	50
2033	100	300	60	100	50
2034	0	300	60	100	50
2035	0	300	60	100	50
2036	0	300	60	100	50
2037	0	300	60	100	50
2038	100	300	60	100	50
2039	0	300	60	100	50
2040	0	300	60	100	50
2041	0	300	60	100	50
2042	0	300	60	100	50
2043	100	300	60	100	50
2044	0	300	60	100	50
2045	0	300	60	100	50
2046	0	0	60	100	50
2047	0	0	60	100	50
2048	100	0	60	100	50
2049	0	0	60	100	50
2050	0	0	60	100	50
Total	**1,680**	**11,100**	**1,780**	**3,800**	**1,750**

MW = megawatt.
Source: Authors.

(iii) For the wind option, NREP targets were followed for 2021 to 2025. From 2026 to 2050, 100 MW of wind capacity is then added annually, resulting in a total addition of 3,800 MW by 2050, which is within the national exploitable wind capacity (WWF Philippines and UPSL 2003).

(iv) In the NREP 2011–2030, only 1 MW of solar power is added every year from 2016 to 2030. However, recent developments in solar technology suggest that more aggressive targets for solar are possible. Thus, for the solar power generation option, 50 MW annual solar power capacity additions are made, rather than the 1 MW annual additions listed in the NREP.

Without sufficient transport infrastructure, natural gas has a higher generation cost than coal. Thus, its development is considered only to meet intermediate load requirements, rather than as baseload. Supercritical coal plants are considered as an abatement opportunity, but lack economies of scale in the Philippines, which means that more efficient larger-scale ultra-supercritical plants were not considered feasible.

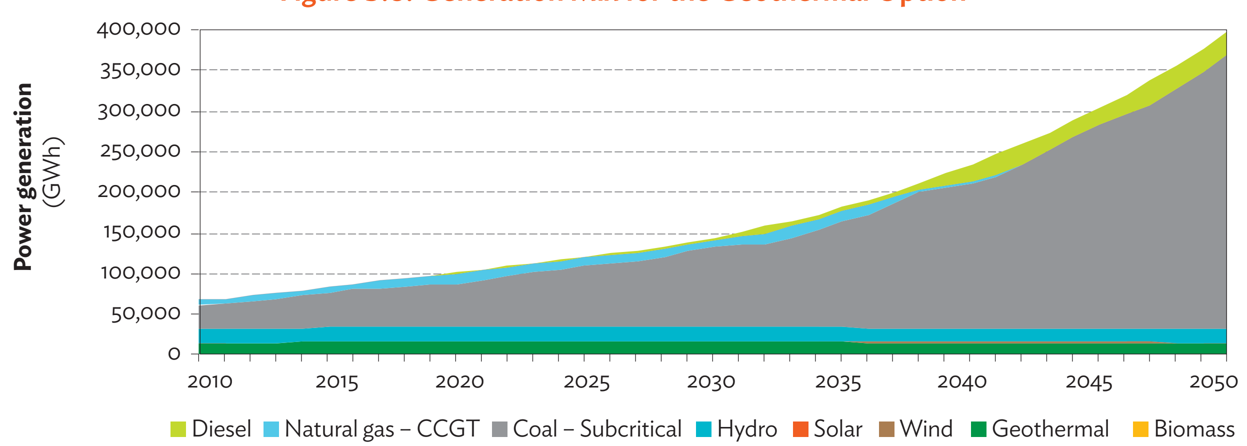
The introduction of advanced backstop, such as nuclear power plants, in the far future (2035), represents the potential of contributions of new technologies for which enabling conditions do not yet sufficiently exist. The different low-carbon options studied for the power sector are discussed in more detail in the following sections.

5.4.1 Geothermal Power

By following the NREP, a total of 1,280 MW of geothermal capacity is added from 2016 to 2030 for this option. In addition, a total of 400 MW is added beyond the NREP targets. Since the overall generation capacity rises more rapidly than geothermal capacity, the share of capacity and generation from geothermal still falls over time (Figure 5.8). The calculation for the marginal abatement costs includes the cost of building and operating geothermal plants and savings from the displaced subcritical coal plants. External costs were not included in the calculations. Regarding externalities, geothermal plants have little impact on land and water-use assuming that steam reinjections are regulated and enforced. Geothermal plants produce minimal and negligible solid waste.

These relatively small capacity additions are found to yield GHG mitigation of around 320 $MtCO_2e$, approximately 6% of the emissions in the reference scenario, with a marginal abatement cost of –$0.1 per tCO_2e.

Figure 5.8: Generation Mix for the Geothermal Option



CCGT = combined-cycle gas turbine, GWh = gigawatt-hour.
Source: Authors.

5.4.2 Hydropower

For this option, a total of 5,380 MW of hydropower capacity is added from 2016 to 2025 by following the NREP for 2011–2030. About 5,100 MW is assumed to be large hydro. In addition, 7,500 MW is added beyond the NREP targets from 2026 to 2050, of which 6,300 MW is large hydro. These additions utilize the 13,000 MW of exploitable hydropower potential in the country, as listed by the DOE, and yield the power generation mix in Figure 5.9.

The calculation for the marginal abatement costs includes the cost of building and operating hydropower plants plus savings from displaced subcritical coal plants. External costs of large hydro plants include the distortion of the natural ecosystem, displacement of communities, and use of water resources. These were not included.

The capacity additions for hydro yield GHG mitigation of around 1,276 $MtCO_2e$, approximately 24% of the emissions in the reference scenario, with a marginal abatement cost of –\$0.4 per tCO_2e. This is the highest mitigation potential among renewables and has the lowest marginal abatement cost.

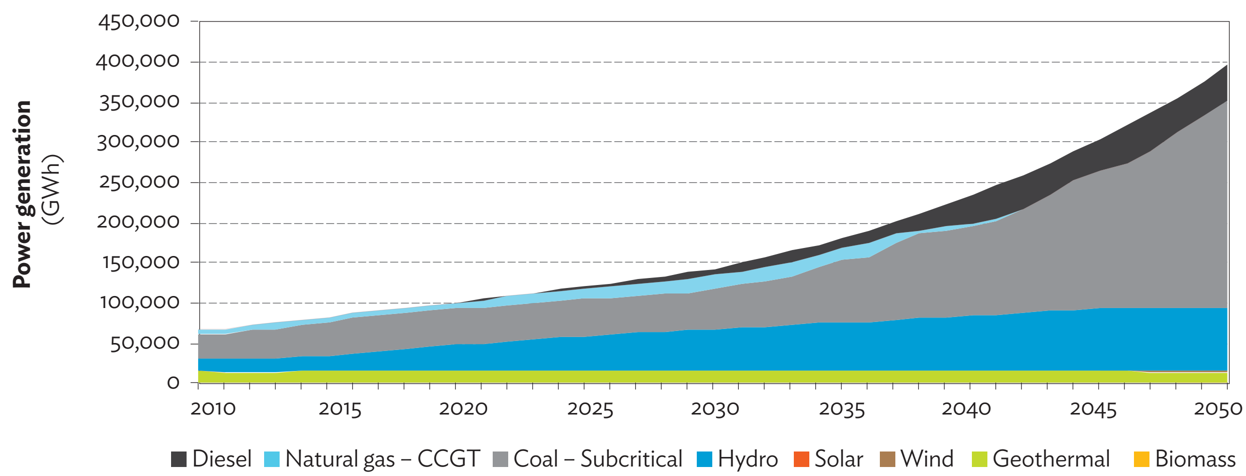
5.4.3 Wind Power

For this option, a total of 1,300 MW of wind capacity is added from 2016 to 2025 by following the NREP. Subsequently, a total of 2,500 MW is added beyond the NREP targets from 2026 to 2050. Although power generation from wind plants increases from 2013 to 2050, total generation increases faster than the generation from wind plants over time, resulting in a reduction of the share of wind generation in the power mix (Figure 5.10).

This analysis assumes that wind plants have an availability of 45%, as wind is not available for power plants much of the time. Because of the intermittency of the wind plants, this study also assumes that wind plants have a capacity credit of 29%—considering that wind plants cannot be relied on to deliver when peak demand occurs. The capacity credit of wind plants can be improved if bulk energy storage is available for the power system. If the technology for bulk energy storage for power systems falls in cost, wind plants can receive higher capacity credits.

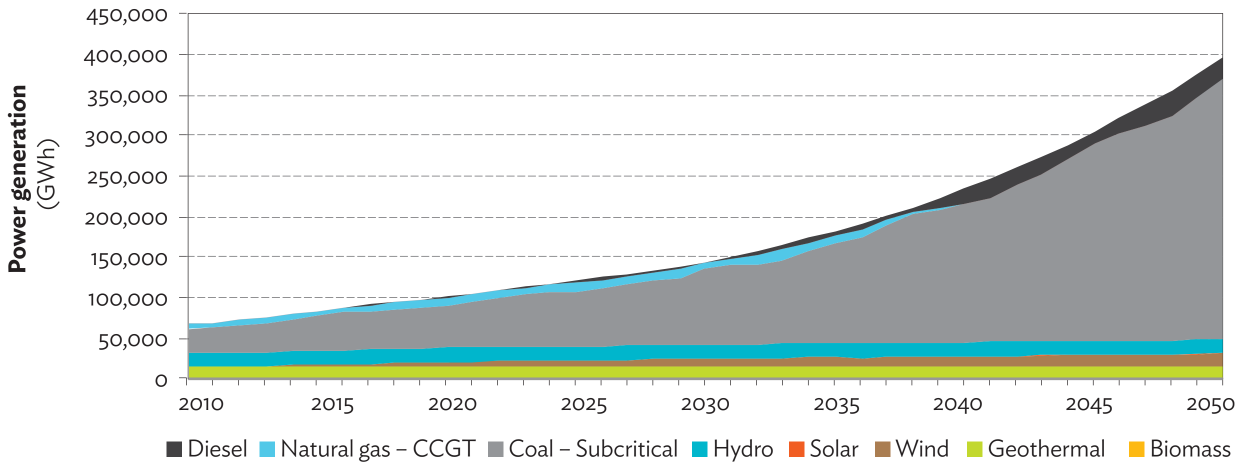
Under these assumptions, wind generation displaces some generation from coal, and mitigates the

Figure 5.9: Electricity Generation per Plant Type for the Hydropower Option



CCGT = combined-cycle gas turbine, GWh = gigawatt-hour.
Source: Authors.

Figure 5.10: Electricity Generation per Plant Type for the Wind Option



CCGT = combined-cycle gas turbine, GWh = gigawatt-hour.
Source: Authors.

reference GHG emissions by 253 $MtCO_2e$, or by approximately 4.8%, at a marginal abatement cost of \$0.4 per tCO_2e. Declining energy storage costs may reduce this cost further over time.

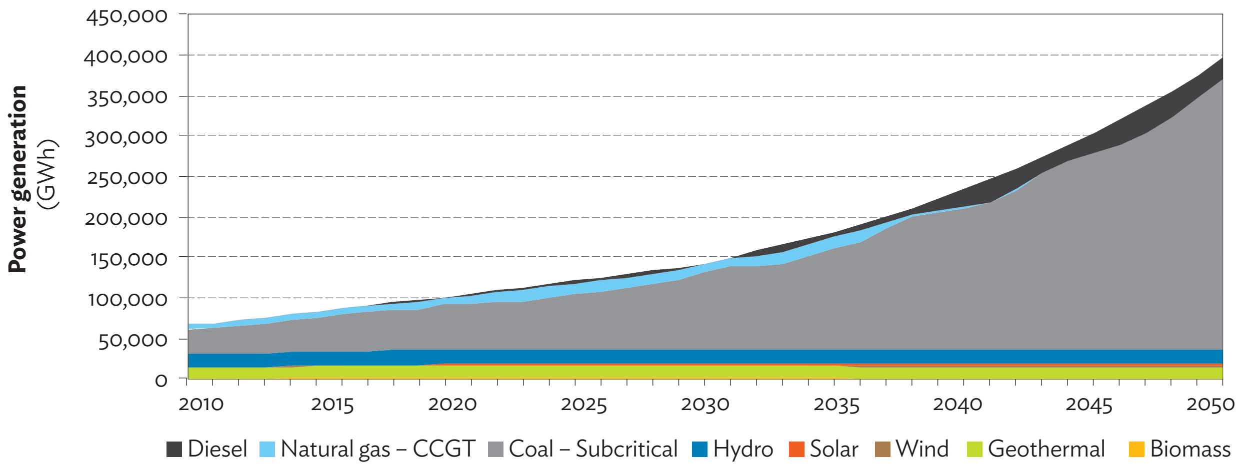
5.4.4 Solar Power

As noted earlier, 50 MW of solar capacity is added every year for this option. The solar power plants are assumed to have 23% availability and a 53% capacity credit, as a result of the intermittency of solar power.

Similar to the wind option, power generation from solar plants increases from 2013 to 2050, but overall generation increases faster than the generation from wind plants over time, resulting in a reduction of the share of solar in the generation mix. As shown in Figure 5.11, the contribution of solar plants to the mix remains small.

The results for this option show that solar generation can partially displace generation from coal, and mitigates the reference GHG emissions by

Figure 5.11: Electricity Generation per Plant Type for the Solar Option



CCGT = combined-cycle gas turbine, GWh = gigawatt-hour.
Source: Authors.

68 $MtCO_2e$, approximately 1.3% of the reference GHG emissions, at a marginal abatement cost of \$8.2 per tCO_2e. As is the case for wind, it is possible that improvements to energy storage technology may ultimately reduce this cost.

5.4.5 Natural Gas

This option explores the possibilities from development of natural gas (NatGas) power. Compared with coal plants, NatGas plants emit lower quantities of nitrous oxide and carbon dioxide, and produce minimal solid waste. However, the use of NatGas plants requires facilities to transport NatGas from sources to the plants.

The power plant screening curves indicate that single-cycle gas turbines (SCGTs) can act as peaking plants, while combined-cycle gas turbines (CCGTs) can act as intermediate plants. This option assumes that future peaking plants that will be added are 150 MW open or single-cycle NatGas (SCGT) plants and that combined-cycle NatGas (CCGT) plants will be added as intermediate plants to meet demand growth. NatGas CCGT plants have been used in the Philippines for power generation since the early 2000s, but no NatGas SCGT plant is installed in the country. The addition of subcritical coal, NatGas CCGTs, and NatGas SCGTs follows the mix shown in Table 5.4.

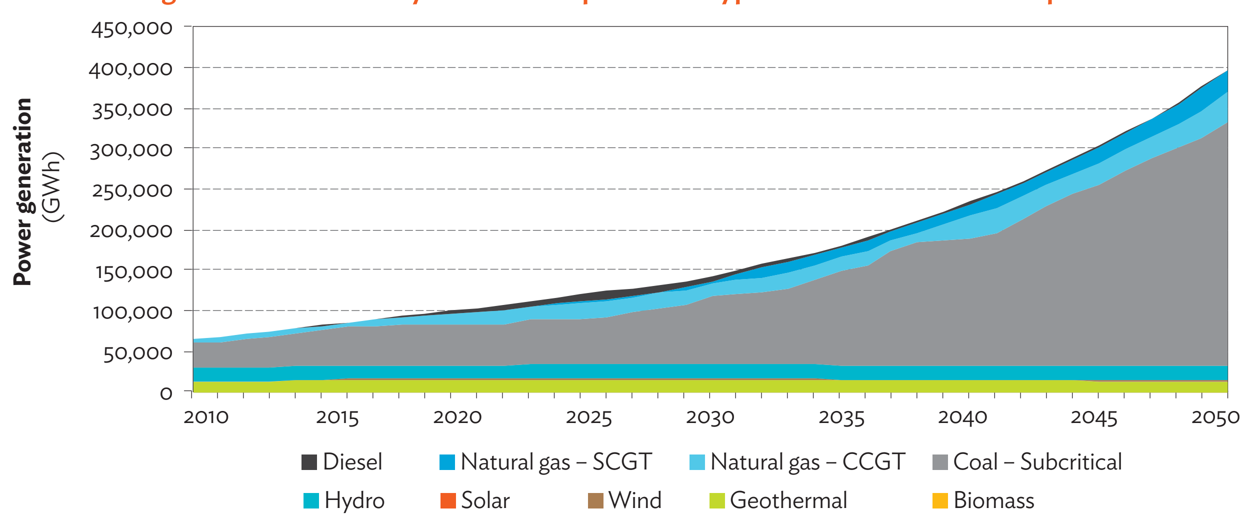
Table 5.4: Optimal Power Mix for the Natural Gas Option (%)

Load Type	Capacity	Energy Supplied
Base (coal subcritical)	76.27	95.22
Intermediate (NatGas CCGT)	11.89	4.29
Peaking (NatGas SCGT)	11.84	0.49

NatGas CCGT = natural gas combined-cycle gas turbine, NatGas SCGT = natural gas single-cycle gas turbine.
Source: Authors.

The implementation of this option decreases the power generation share of coal plants relative to the reference scenario, as shown in Figure 5.12. The figure also shows that power generation from diesel plants is negligible by 2040, as they are displaced by NatGas.[17]

Figure 5.12: Electricity Generation per Plant Type for the Natural Gas Option



GWh = gigawatt-hour, CCGT = combined-cycle gas turbine, SCGT = single-cycle gas turbine.
Source: Authors.

17 The power generation from the different plants is determined through a variable cost-based dispatch that considers variable operation and maintenance costs and fuel costs.

This option is found to yield a cumulative reduction of GHG emissions of 305 $MtCO_2e$, approximately 5.7% of the emissions in the reference scenario, with an abatement cost of $4.9 per tCO_2e. The calculation for marginal abatement cost includes the cost of building and operating the plants, but not the cost of building infrastructure for extracting and transporting natural gas.

5.4.6 Supercritical Coal

Supercritical coal plants operate at 5%–10% higher efficiency and use less coal compared with subcritical coal plants that produce the same amount of electricity. By burning less coal, building supercritical coal plants is expected to reduce GHG emissions and total fuel costs, compared with the subcritical plants in the reference scenario. However, supercritical coal plants have higher capital and operation and maintenance costs.

As of 2016, the existing coal plants in the Philippines are all subcritical. In the future, the Luzon grid, because of its size, can accommodate the installation of supercritical coal plants without sacrificing power system reliability. The present economy of scale for supercritical coal plants makes it an appropriate option for 600 MW capacity additions but not for 150 MW capacity additions.

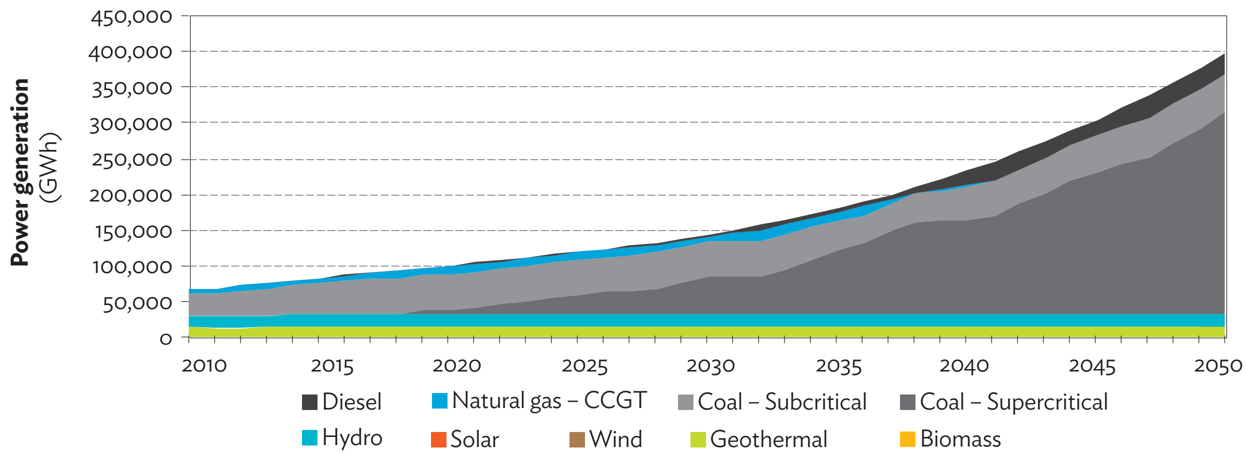
The supercritical coal option replaces 600 MW subcritical coal units with 600 MW supercritical coal units. The 150 MW subcritical coal units are maintained for the remaining 20% baseload capacity for the Visayas and Mindanao grids. A large portion of the energy produced from coal plants will be coming from the supercritical coal plants in this option (Figure 5.13).

This simulation shows that supercritical coal plants can reduce cumulative GHG emissions by 181 $MtCO_2e$, or by about 3.4% of the total GHG emissions in the reference scenario. The reduction comes with a marginal abatement cost of $3.1 per tCO_2e.

5.4.7 Backstop Power Development

This study considered nuclear power as one form of backstop power to determine the potential contribution of advanced energy sources to long-term GHG mitigation. Recent analysis (IEA 2013) suggests that nuclear power will increase as a share of electricity generation over the next 2 decades in Southeast Asia. The modeling of backstop/nuclear power however, should not be construed as an endorsement of nuclear

Figure 5.13: Electricity Generation per Plant Type for the Supercritical Coal Plants Option



GWh = gigawatt-hour, CCGT = combined-cycle gas turbine.
Source: Authors.

power development, and the role of nuclear may be considered principally as a proxy for other potential sources, such as advanced biomass.[18, 19]

This option adopts all assumptions of the reference scenario except that starting in 2035, 600 MW nuclear plants or from other potential sources will be added instead of the 600 MW coal plants. The resulting generation mix is shown in Figure 5.14.

The calculation for the marginal abatement costs includes the cost of building, decommissioning, operating the nuclear plants as well as the nuclear fuel cost. As for other modeled options, the external costs of nuclear plants are outside the scope of the study and were not included in calculating the marginal abatement cost. In addition, the GHG emissions generated when extracting the nuclear fuel from uranium ores are not included since these were emitted outside the power generation sector. Other externalities that are outside the scope of the study are the cost of nuclear waste management and cost of possible damages from nuclear hazards in a country that is prone to earthquakes.

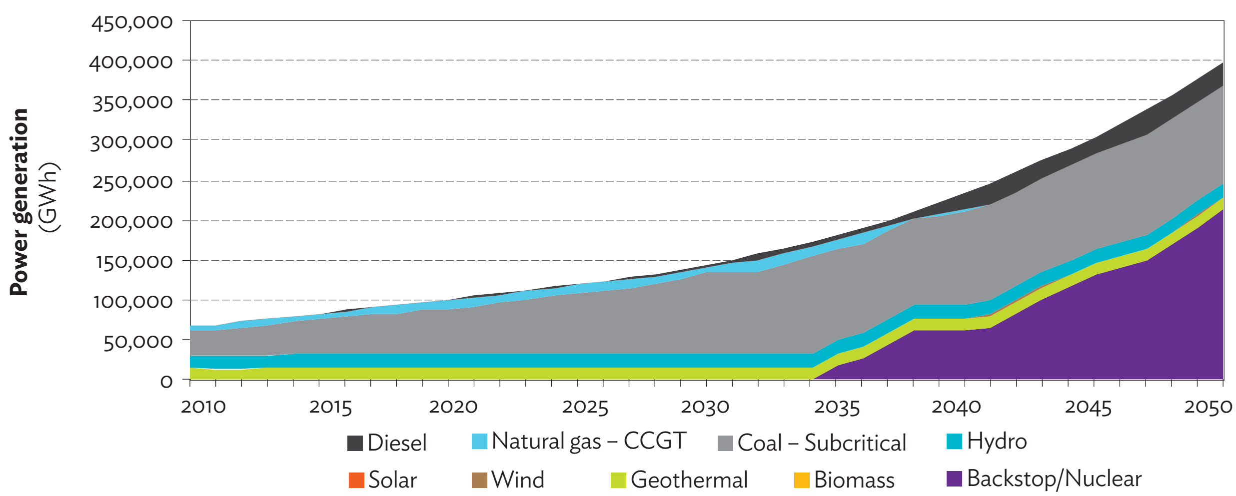
The results of simulations show that 1,586 $MtCO_2e$ can be mitigated with the backstop/nuclear power development option. This is approximately 30% of the emissions in the reference scenario, with a direct marginal abatement cost of –$0.6 per tCO_2e. However, it should be noted that full accounting of associated waste and other external costs would raise this abatement cost substantially.

5.5 Marginal Abatement Cost Curve Analysis for the Power Generation Sector

5.5.1 Capital Investment Requirements

To implement the different LCD options and keep up with the growing demand for electricity, investors must be encouraged to put up the

Figure 5.14: Electricity Generation per Plant Type for the Backstop Power Option



GWh = gigawatt-hour, CCGT = combined-cycle gas turbine.
Source: Authors.

18 ADB maintains a policy of noninvolvement in the financing of nuclear power projects. ADB notes the significant risk of locating nuclear power facilities, and particularly storing nuclear waste, in locations subject to seismic activity and the presence, or lack thereof, of suitable locations in the Philippines was not part of the analysis and may limit its viability.

19 Like nuclear power, biomass power can provide a stable low carbon baseload without the intermittency that affects wind or solar power, or the constraint of exploitable potential faced by hydropower or geothermal power. The levelized cost of electricity from biomass is similar to that of nuclear power according to studies collated by the U.S. National Renewable Energy Laboratory and U.S. Department of Energy (OpenEI Transparent Cost Database. http://en.openei.org/apps/TCDB/ [accessed 15 July 2017]).

investments needed to build and renovate power plants. The implementation of the different LCD options in the power sector requires the capital investment shown in Figure 5.15, which has a generally flat trend from 2014 to 2030 and an upward trend from 2031 onward.

Table 5.5 shows the 2011–2050 average capital investment requirements for the different LCD options in the power sector, except for the nuclear power option, which only starts at 2035. This table shows that only the natural gas option has a lower average capital requirement than the reference scenario.

Table 5.5: Average Annual Capital Investment Requirement for the Low-Carbon Development Options in Power (₱ billion)

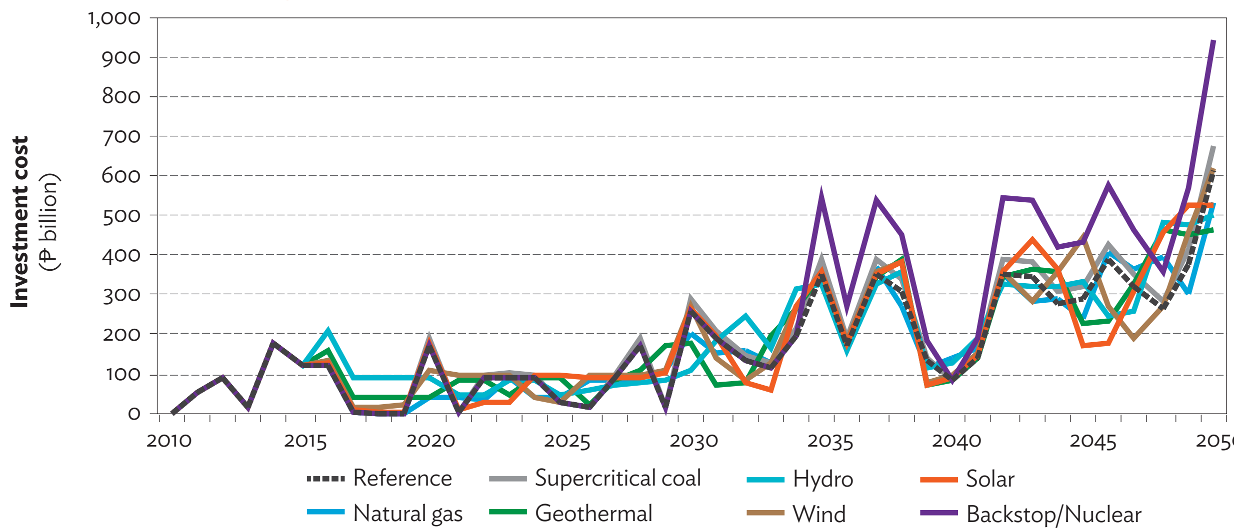
Option	2011–2050 Average
Reference	172.18
Natural gas	168.53
Supercritical coal	187.42
Geothermal	174.90
Hydro	183.82
Wind	177.26
Solar	175.93

Source: Authors.

5.5.2 Generation Costs of Reference and Low-Carbon Development Options

One co-benefit of implementing low-carbon development options in the power generation sector is reduction in generation cost. Table 5.6 and Figure 5.16 show the effect of the mitigation options on the annual average generation cost in pesos per kWh. The average generation cost from 2010 to 2050 is lower for the geothermal, hydro, and wind options than for the reference scenario. The average generation cost for solar and supercritical coal options are slightly higher than the average for the reference scenario. The NatGas option has the highest average generation cost. The generation costs if all LCD options are implemented are shown in Figure 5.17 and Table 5.7. It can be seen from the figure that implementing all LCD options will result in lower generation costs from 2026 until 2032 and from 2038 until 2050.

Figure 5.15: Capital Investment Requirement per Option



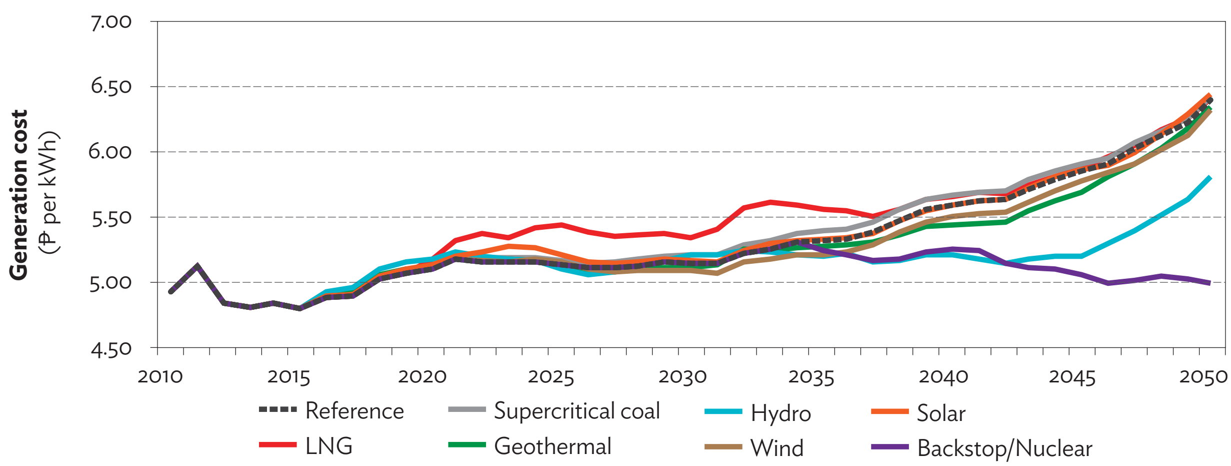
Source: Authors.

Table 5.6: Generation Cost per Option, 2010–2050
(₱ per kWh)

Option	2010–2050 Average	2010	2015	2020	2025	2030	2035	2040	2045	2050
Reference	5.33	4.93	4.80	5.10	5.14	5.15	5.32	5.60	5.85	6.39
Natural gas	5.45	4.93	4.80	5.18	5.44	5.34	5.56	5.66	5.88	6.40
Supercritical coal	5.37	4.93	4.80	5.12	5.17	5.21	5.40	5.67	5.91	6.41
Geothermal	5.29	4.93	4.80	5.12	5.11	5.11	5.28	5.44	5.69	6.34
Hydro	5.17	4.93	4.80	5.18	5.11	5.21	5.21	5.21	5.21	5.81
Wind	5.29	4.93	4.80	5.11	5.16	5.09	5.22	5.50	5.77	6.31
Solar	5.35	4.93	4.80	5.13	5.21	5.16	5.33	5.59	5.86	6.43
Backstop/Nuclear	5.09	4.93	4.80	5.10	5.14	5.15	5.24	5.26	5.07	5.00

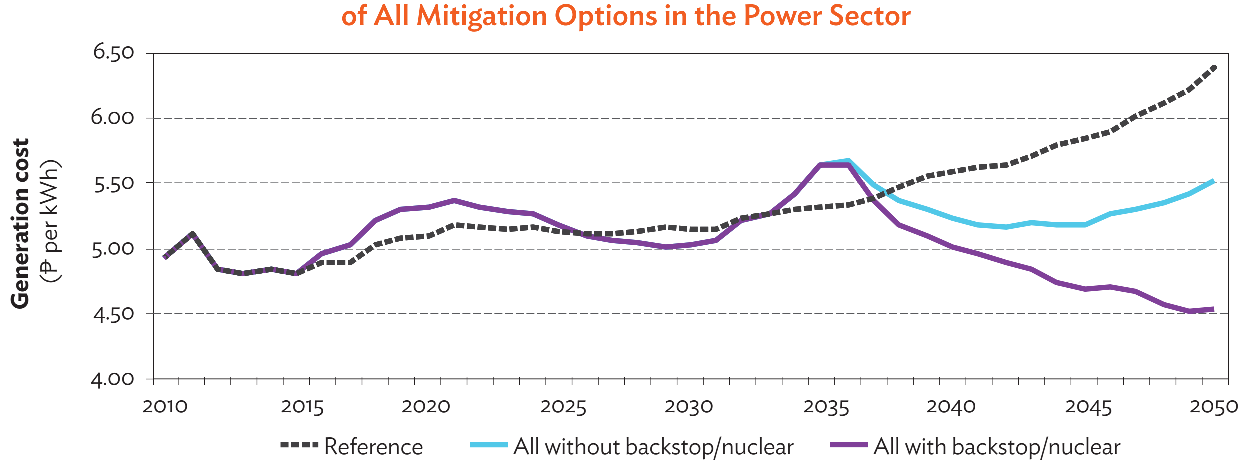
kWh = kilowatt-hour.
Source: Authors.

Figure 5.16: Generation Cost per Option



kWh = kilowatt-hour, LNG = liquefied natural gas.
Source: Authors.

Figure 5.17: Generation Cost of Simultaneous Implementation of All Mitigation Options in the Power Sector



kWh = kilowatt-hour.
Source: Authors.

Table 5.7: Generation Cost for the Combined Low-Carbon Options

Scenario	Average	2010	2015	2020	2025	2030	2035	2040	2045	2050
Reference (₱ per kWh)	5.33	4.93	4.80	5.10	5.14	5.15	5.32	5.60	5.85	6.39
All options without backstop/nuclear (₱ per kWh)	5.20	4.93	4.80	5.32	5.18	5.03	5.65	5.24	5.19	5.53
All options with backstop/nuclear (₱ per kWh)	5.05	4.93	4.80	5.32	5.18	5.03	5.65	5.02	4.70	4.54

kWh = kilowatt-hour.
Source: Authors.

5.5.3 Marginal Abatement Cost Curve for the Power Sector

The three low-carbon development options for the power sector with the highest mitigation potential are found to be (i) backstop power, (ii) hydropower, and (ii) geothermal power (Table 5.8).[20] Incidentally, these are also the three lowest-cost options when external costs are not considered (Figure 5.18). Incorporation of external costs may make nuclear power substantially more costly.

The solar and wind power options have higher abatement costs compared with the other renewable energy options since their intermittence gives them lower capacity credits. However, the wind power option still has lower abatement costs than the two options of cleaner use of fossil fuels through supercritical coal plants and NatGas plants, respectively.

Individually implementing each mitigation option is found to result in the annual GHG emissions shown in Figure 5.19. Given that plants have long life spans, even more GHG emission mitigation can be achieved if lower carbon options are built earlier.

Simultaneous implementation of all LCD options for power is found to result in the generation mix shown in Figure 5.20 and Figure 5.21. All LCD options implemented simultaneously will reduce carbon dioxide equivalent emissions by 3,140 $MtCO_2e$ cumulatively, or approximately 59% of the reference GHG emissions from 2010 through 2050, with a marginal abatement cost of \$0.3 per tCO_2e (Figure 5.22).

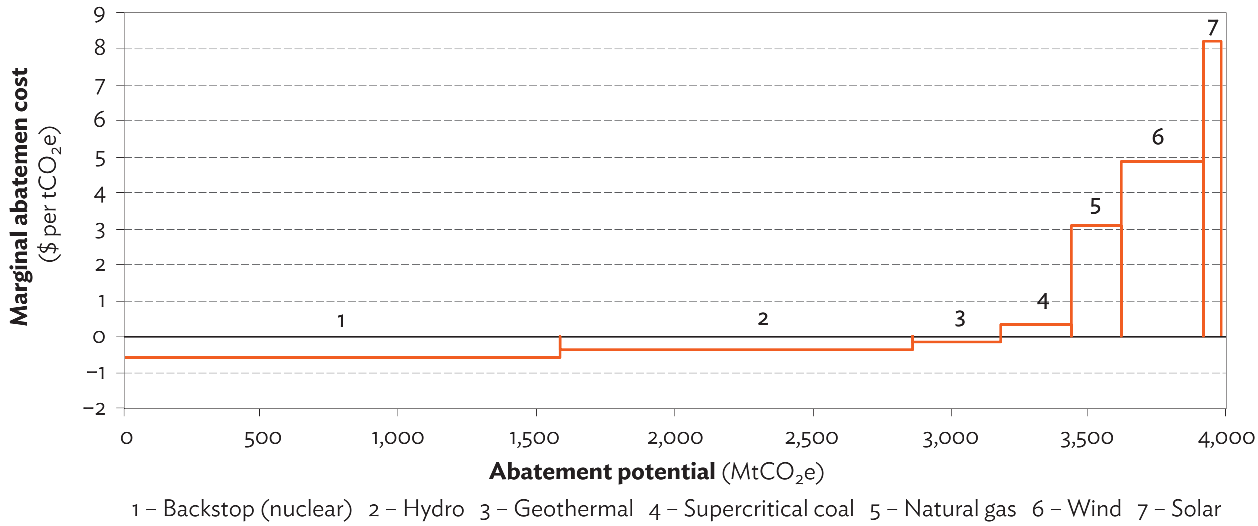
Table 5.8: Mitigation Potential and Costs for the Low-Carbon Development Options in Power Generation

Low-Carbon Development Option		Mitigation Potential ($MtCO_2e$)	Marginal Abatement Cost (\$/$MtCO_2e$)
1	Backstop power (nuclear power)	1,586	(0.59)
2	Renewable energy (hydropower)	1,276	(0.38)
3	Renewable energy (geothermal power)	320	(0.14)
4	Renewable energy (wind power)	253	0.35
5	High-efficiency (supercritical coal) thermal pant	181	3.07
6	Clean fuel (natural gas)	305	4.88
7	Renewable energy (solar power)	68	8.20

( ) = negative, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Note: This table does not reflect interaction and substitution effects among measures when implemented simultaneously, which reduce overall mitigation levels.
Source: Authors.

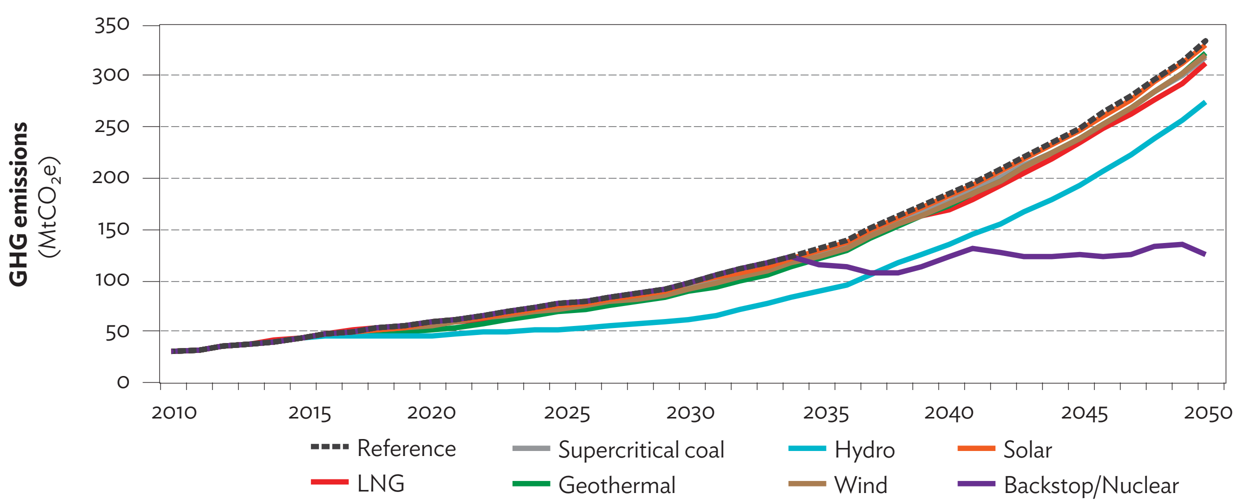
[20] This is based on an economic cost study and does not take into account the considerable and difficult to quantify risks associated with operating and, more so, disposal and storage of nuclear waste in seismically active locations.

Figure 5.18: Marginal Abatement Cost Curve for the Low-Carbon Development Options in Power Generation



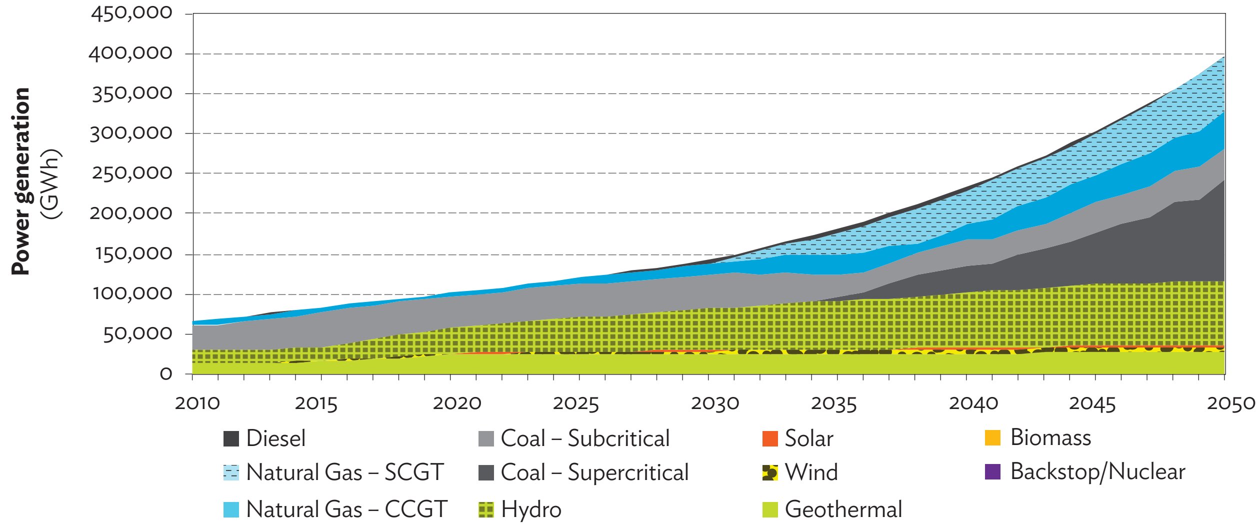
$MtCO_2e$ = million metric tons of carbon dioxide equivalent, tCO_2e = metric ton of carbon dioxide equivalent.
Note: This figure does not reflect interaction and substitution effects among measures when implemented simultaneously, which reduce overall mitigation levels.
Source: Authors.

Figure 5.19: Annual Greenhouse Gas Emissions under Each Individual Option in the Power Generation Sector



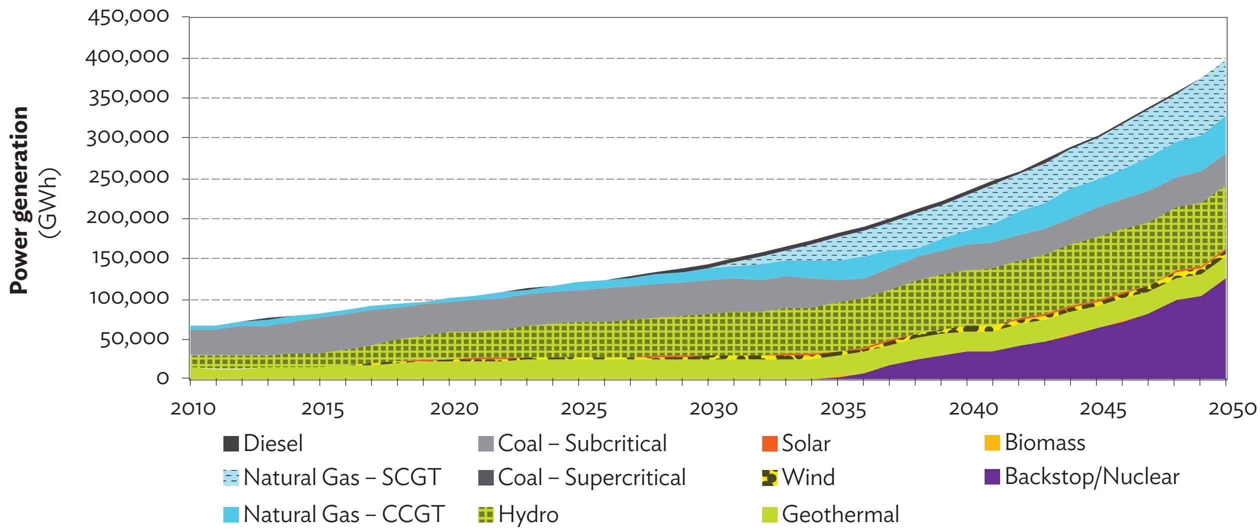
LNG = liquefied natural gas, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Note: This figure does not reflect interaction and substitution effects among measures when implemented simultaneously, which reduce overall mitigation levels.
Source: Authors.

Figure 5.20: Electricity Generation per Plant Type for the Combined Scenario without the Backstop Option



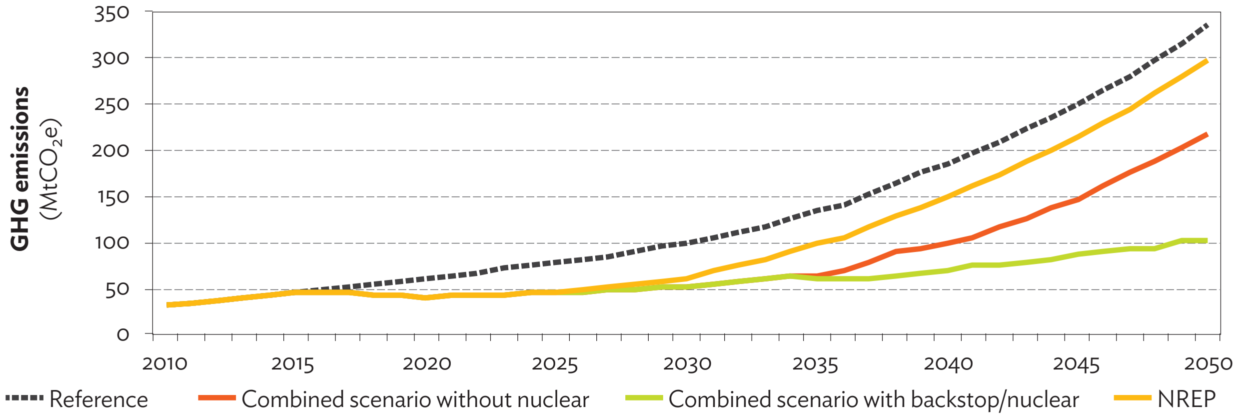
CCGT = combined-cycle gas turbine, GWh = gigawatt-hour, SCGT = single-cycle gas turbine.
Source: Authors.

Figure 5.21: Electricity Generation per Plant Type for the Combined Scenario with the Backstop Option



CCGT = combined-cycle gas turbine, GWh = gigawatt-hour, SCGT = single-cycle gas turbine.
Source: Authors.

Figure 5.22: Greenhouse Gas Emissions of Combined Scenarios in the Power Sector



$MtCO_2e$ = million metric tons of carbon dioxide equivalent, NREP = National Renewable Energy Program.
Source: Authors.

Figure 5.22 also shows GHG emissions if only the NREP's 2015–2030 targets used in the renewable energy options in this study were met (DOE 2011), which yields a reduction of 372 $MtCO_2e$, or approximately 28.3% of the cumulative emissions from 2010 to 2030. The direct marginal costs of simultaneously implementing the options are listed in Table 5.9.

Table 5.9: Mitigation Potential of Combined Power Generation Options and Average Mitigation Costs

Option	Composite Scenario	Mitigation Potential ($MtCO_2e$)	Marginal Abatement Cost ($/$MtCO_2e$)
Hydropower	2	1,275.6	(0.38)
Plus geothermal power	2 to 3	1,573.7	(0.20)
Plus wind power	2 to 4	1,808.3	(0.09)
Plus supercritical coal	2 to 5	1,891.5	0.02
Plus natural gas	2 to 6	2,203.2	0.43
Plus solar power	2 to 7	2,266.6	0.63
Plus nuclear/Backstop power	1 to 7	3,137.4	0.25

( ) = negative, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Source: Authors.

6. Policies to Realize Low-Carbon Potential

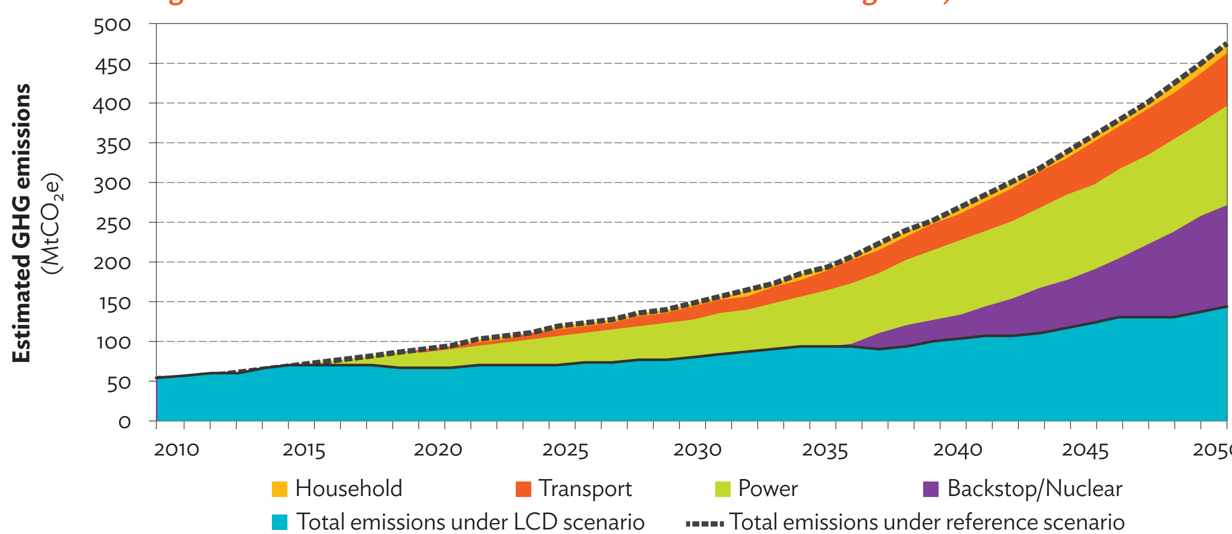
6.1 Low-Carbon Development in the Philippines Can Achieve Substantial Mitigation at Low Cost

Although the Philippines has low per capita GHG emissions, these emissions will rise rapidly without concerted efforts toward low-carbon development. Accordingly, this study finds substantial mitigation potential from a limited array of mitigation measures.

Implementing all assessed LCD options in the household, transport, and power generation sectors—excluding the backstop option—could reduce GHG emissions in 2050 by 42.5% of the reference scenario. The total cumulative emissions reduction over 2015–2050 is 3,270 $MtCO_2e$ (Figure 6.1). Were a backstop energy source to be added to the mix after 2035, the mitigation in 2050 would be 69.8% of the reference, with a total cumulative emissions reduction of 4,160 $MtCO_2e$ over 2015–2050, and a negative abatement cost of –$0.1 per ton, considering interaction and substitution effects among measures.

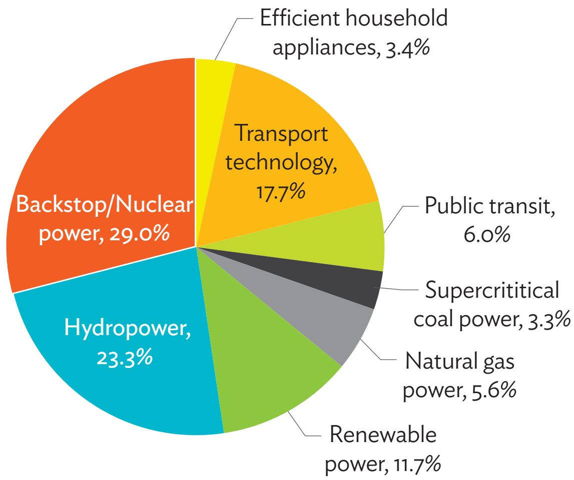
The power generation sector can contribute 72.9% of GHG reduction as shown in Figure 6.2. Collectively, renewable energy and hydropower have the highest potential at 35.0%. This is followed by backstop energy (29.0%), transport technology (17.7%), natural gas power (5.6%), and household appliance efficiency considered collectively (3.4%).

Figure 6.1: Sector Contributions to Greenhouse Gas Mitigation, 2010–2050



GHG= greenhouse gas, LCD = low-carbon development, $MtCO_2e$ = million metric tons of carbon dioxide equivalent.
Source: Authors.

Figure 6.2: Contribution of Low-Carbon Development Options to Mitigation Potential



Source: Authors.

An important reason for the low relative share of household efficiency is that residential consumption is only a small share (under 30%) of total power. Were similar efficiency improvements possible across industrial and commercial users, the share would be much higher.

Table 6.1 and Figure 6.3 summarize the mitigation potential and marginal abatement costs for 2010–2050 of the low-carbon development options considered under the study.[21] The land transport sector provides the pathway to reduce GHG emissions at lowest cost per tCO_2e. Promotion of buses, vehicle carbon emissions standards, electric motorcycles, hybrid buses, and electric tricycles have the most negative marginal abatement costs from –$24.4 per tCO_2e to $5.6 per tCO_2e. These are followed by refrigerators and air conditioners of the household appliance sector with –$4.4 per tCO_2e to –$1.6 per

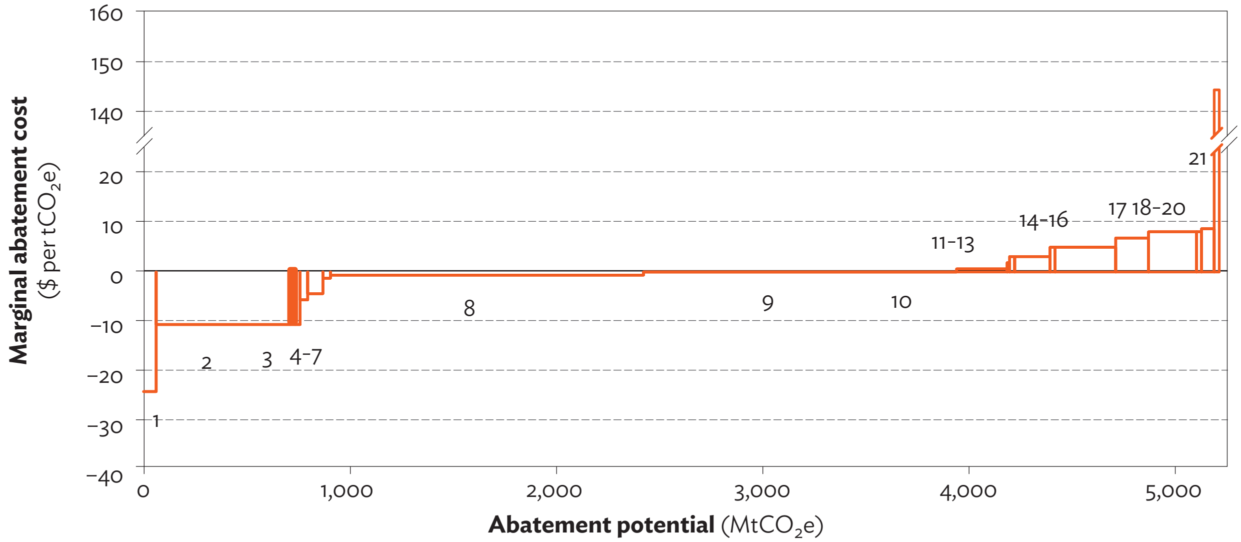
Table 6.1: Mitigation Potential and Costs of Low-Carbon Development Options

Options		Mitigation Potential ($MtCO_2e$)	Marginal Abatement Cost ($/$MtCO_2e$)
1	Buses and BRT system	63.2	(24.40)
2	Vehicle carbon standards	681.2	(11.10)
3	Electric motorcycles	19.5	(10.90)
4	Hybrid buses	26.1	(10.80)
5	Electric tricycles	36.6	(5.60)
6	Efficient refrigerators	79.7	(4.41)
7	Efficient air conditioners	39.9	(1.60)
8	Backstop power (nuclear power)	1,586.0	(0.59)
9	RE (hydropower)	1,275.6	(0.38)
10	RE (geothermal power)	319.6	(0.14)
11	RE (wind power)	252.6	0.35
12	Efficient electric fans	19.6	1.47
13	Efficient television sets	17.4	2.81
14	High-efficiency (supercritical coal) thermal plant	180.6	3.07
15	Efficient lighting	27.4	4.74
16	Clean fuel (natural gas)	304.8	4.88
17	Electric jeepneys	168.7	6.40
18	Biofuels blending	244.8	7.80
19	Motor vehicle inspection	20.3	8.10
20	RE (solar power)	67.6	8.20
21	LRT infrastructure	34.7	144.30

( ) = negative, BRT = bus rapid transit, LRT = light rail transit, MtCO2e = million metric tons of carbon dioxide equivalent, RE = renewable electricity.
Note: This table does not reflect interaction and substitution effects among measures when implemented simultaneously, which reduce overall mitigation levels.
Source: Authors.

[21] The mitigation potential and abatement costs are based on the individual contributions of each low-carbon option relative to the reference scenario.

Figure 6.3: Marginal Abatement Cost Curve for the Combined Household Appliance, Land Transport, and Power Generation Sectors, 2010–2050



1 – Promotion of buses 2 – Vehicle carbon standards 3 – Electric motorcycles 4 – Hybrid buses 5 – Electric tricycles 6 – Efficient refrigerators 7 – Efficient air conditioners 8 – Backstop (nuclear) 9 – Hydropower 10 – Geothermal power 11 – Wind power 12 – Efficient fans 13 – Efficient TV sets 14 – Supercritical coal 15 – Efficient lighting 16 – Gas power 17 – Electric jeepneys 18 = Biofuel blending 19 – Motor vehicle inspection 20 – Solar power 21 – Light rail infrastructure

LNG = liquefied natural gas, $MtCO_2e$ = million metric tons of carbon dioxide equivalent, tCO_2e = metric ton of carbon dioxide equivalent.
Note: This figure does not reflect interaction and substitution effects among measures when implemented simultaneously, which reduce overall mitigation levels.
Source: Authors.

tCO_2e and the backstop/nuclear, hydropower plants, and geothermal plants of the power generation sector with –$0.6 per tCO_2e to –$0.1 per tCO_2e.

Nearly all options have abatement costs under $10 per tCO_2e. These include wind, supercritical coal, and natural gas options for power development; more efficient electric fans, TVs, and lighting appliances for households; and electric jeepneys, biofuel blending, motor vehicle inspection options for transport; and solar power.

Light rail infrastructure is the most expensive option at $144.3 per tCO_2e. However, rail infrastructure may have additional abatement potential to what is modeled through effects on congestion, as well as synergies with bus systems , which would lower the abatement cost substantially if included.

All of these costs reflect only direct costs of infrastructure and facilities for the low-carbon options. In addition, these options have important external benefits and costs, including reduced air pollution from less coal combustion in power plants and lower vehicular emissions, especially in urban areas. Such reductions may have important benefits in terms of reduction in the costs of disease (Raitzer et al. 2015). Low-carbon transport options involving modal shifts to public transit also reduce congestion and save travel times, and are likely to reduce the costs associated with vehicular accidents. Including these external benefits would result in even lower abatement costs.

There is close alignment between the results of this study and strategies and actions outlined in the Philippine Development Plan (PDP) 2017–2022 (NEDA 2017) and priority "flagship infrastructure projects" identified by the Infrastructure Committee of the National Economic Development Authority (NEDA). PDP 2017–2022 recognizes the threats posed by climate change to the Philippines, and emphasizes measures in line with an avoid-shift-improve approach to transit, actions to enhance demand side energy efficiency, and policies that can help to decarbonize power generation.

6.2 Realizing the Mitigation Potential of the Land Transport Sector

6.2.1 Low-carbon transport depends on a multifaceted approach

Low-carbon development of the transport sector is not only important as a source of mitigation potential. It also is the area where co-benefits are likely to be largest, in terms of reduced local air pollution, as well as congestion and travel accident reduction. However, achieving mitigation potential in this area is also arguably the most complex of the sectors assessed. Some of the challenges pertain to establishing supply chains for biofuel blending, infrastructure needs for modal shifts, supporting facilities for electric vehicles, and regulatory needs for vehicle standard implementation.

6.2.2 Infrastructure is critical to shift passengers to low-carbon transport modes

Modal shifts from private to public transit are critical to the overall effectiveness of low carbon transport measures , as they allow improved technologies to be more effective under lower congestion. Shift measures are strongly emphasized in PDP 2017–2022, with a focus on “ensuring the accessibility, availability, affordability, adequacy, convenience, and reliability of rail transport and bus rapid transit (BRT) systems”. Similarly, “flagship infrastructure projects” approved as of late 2017 include two BRTs (along Quezon Avenue and EDSA in Metro Manila), a commuter rail line and a long haul rail line. Five more rail projects, one more BRT, and the first 22 km phase of a Metro Manila subway are under consideration.

In addition, the Light Rail Transit (LRT 1) extension to Niog, Cavite, LRT 2 extension to Antipolo, and metro rail transit (MRT) 7 from North Avenue, Quezon City to San Jose del Monte, Bulacan are also currently being constructed. There is scope to further expand public transit by establishing secondary lines to complement these projects. For example, the Mega Manila Dream Plan study (JICA and NEDA 2014) proposed an even broader array of investments, including additional LRT and MRT segments, as well as a network of secondary monorail lines. Additional BRTs could also serve as feeder routes to rail transit projects.

Accelerating efficient infrastructure from modal shifts requires a higher level of investment from the public sector, as well as from private sources through public–private partnerships. It also requires that urban planning processes be improved, along with land acquisition procedures for public projects.

In so doing, the development of more efficient bus routes, bus rapid transit systems, and light rail infrastructure is a natural starting point for reducing both the fuel consumed by passengers switching transport modes and the efficiency of remaining road transport. Aside from building the infrastructure, facilitating shifts may be enhanced by strategies that aim to improve convenience and make mass transport accessible, shorten travel periods and connectivity of routes within and among the different transport routes, and make fares more affordable.

6.2.3 Electric vehicle adoption may be accelerated

Electric motorcycles are already on the Philippine market and are being increasingly adopted because of their competitive costs. Shifts toward electric motorcycles from gasoline models may be further promoted through tax and registration incentives, as well as favorable treatment in congestion regulations.

Adoption of larger electric vehicles is progressing more slowly. An important barrier to adoption is cost, as the cost differential between electric and petrol units increases as vehicle size increases. In addition, differences in recharging range become more important for larger vehicles. High electricity costs in the Philippines also tend to offset operating cost reductions from electric vehicles and discourage adoption. Many of the cost disadvantages for larger electric vehicles are likely to decline over time, as storage technology falls in cost. However, adoption of electric vehicles can still be incentivized through favorable tax and congestion treatment.

Electric vehicles for public transport need recharging or battery swapping stations. This may be addressed by tapping private sector distribution utilities and retail electricity suppliers to put up charging-for-fee stations.

6.2.4 Advanced biofuels may help to reduce emissions

The current approach to biofuel blending has rested on first generation biofuels, which rely on food crops as feedstock. This creates supply-chain problems and causes competition with food security and agricultural development objectives.

Biofuels are currently promoted by the 2006 Biofuels Act, which aims to reduce the dependence on imported oil, while contributing to economic growth and protecting public health and the environment. The act mandates a target of 2% biofuel blending in diesel and 10% ethanol blending in gasoline. In the Philippines, sugarcane and coconut oil are the preferred biofuels feedstock.

The country has nine registered biodiesel producers with an aggregate annual capacity of 393 million liters. Being the world's top coconut oil producer, the 2% blending requirement has been achieved with ease. The coconut industry even lobbied for a higher blending requirement of 5% (USDA Foreign Agricultural Service 2013).

The target blending of ethanol, however, has not been achieved because of low productivity and high production costs. The total capacity of local sugarcane distilleries was not entirely utilized, as refineries only produced 16 million liters of ethanol in 2012 when their combined capacity was 133 million liters (USDA Foreign Agricultural Service 2013) (Table 6.2).

While higher biofuel blending percentages may be achieved by encouraging investments in bioethanol plants, and by implementing programs and adopting technologies and practices that decrease sugarcane production cost and increase yields, first generation biofuels are likely to continue to have domestic supply challenges. In contrast, second generation bioethanol production can use agricultural waste and residues as feedstock, which does not compete with other agricultural production. The production cost for second generation biofuel is projected to decrease substantially over time from levels that are already competitive with fossil fuels (ATKearney 2014). Furthermore, the Philippines already has abundant waste feedstock for second generation biofuels such as grass, corn stover, rice husk, and wood fuel, which is potentially sufficient to produce 1,100 million liters of ethanol from rice husks, 20 million liters from empty fruit bunches, and 350 million liters using wood fuels (ATKearney 2014).

The main challenge to utilize this potential is to develop a reliable supply chain of residues from agricultural production undertaken by millions of farm households and scattered across vast areas. This requires substantial piloting to identify appropriate collection, distribution, and processing arrangements. In addition, vehicle technology may need to be adapted to higher blending percentages (ATKearney 2014).

Table 6.2: Market Penetration of Ethanol and Biodiesel in the Land Transport Sector, 2006–2014
(million liters)

	2006	2007	2008	2009	2010	2011	2012	2013	2014
Biodiesel, on-road use	3	49	64	130	123	123	125	185	350
Diesel, on-road use	5,832	5,924	6,017	6,109	6,202	6,295	6,388	6,480	6,573
Blend rate (%)	0.1	0.8	1.1	2.1	2.0	2.0	2.0	2.9	5.3
Fuel ethanol	0	3	14	88	151	219	264	298	321
Gasoline	3,819	3,921	4,023	4,125	4,227	4,329	4,431	4,533	4,635
Blend rate (%)	0.0	0.1	0.3	2.1	3.6	5.1	6.0	6.6	6.9

Source: USDA Foreign Agricultural Service. 2013. Philippines: Biofuels Annual. *Global Agricultural Information Network (GAIN) Report.* 10 July. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Manila_Philippines_7-10-2013.pdf.

6.2.5 Vehicle standards can play an important role

Vehicle GHG emissions standards offer large emissions mitigation potential at a negative to minimal cost. The cost of more efficient and less-emitting vehicle technology decreases with time, and is often outweighed by reduced fuel costs. As a small market, the Philippines can take advantage of standards elsewhere to stipulate that cleaner vehicles sold in other markets are available domestically. To minimize regulatory costs, standards can follow those of other larger markets, such as the European Union. PDP 2017–2022 reinforces plans to implement a Motor Vehicle Type Approval System. Such a system is a necessary precursor for enforcing standards for greenhouse gas and other pollutant emissions.

Public awareness campaigns are necessary for vehicle manufacturers, suppliers, and end users to prepare eventually adopting stricter rules and for implementing standards. Systems for testing and monitoring of fleet performance would need implementation, along with penalties for manufacturer noncompliance. This may build upon the proposed motor vehicle inspection system.

6.3 Realizing the Mitigation Potential of the Residential Electricity Sector

6.3.1 An array of measures can incentivize household energy efficiency

Results of the simulations show that a 14% reduction in electricity demand in the household sector is achievable by adopting efficient appliances more rapidly. At the same time, realizing this potential requires changes in the purchasing patterns of consumers, who are conditioned both by regulations and economic incentives. This is recognized in PDP 2017–2022, which emphasizes the need to focus on increasing demand side electricity efficiency through increased promotion of efficient technologies.

Several strategies are available to address the challenges in energy demand reduction in the household electricity sector: regulatory approaches regarding energy efficiency, enhanced information for consumers, electricity pricing approaches, markets for energy-efficiency services, and information for monitoring efficiency outcomes.

6.3.2 Energy performance standards and labeling may be expanded

The Government of the Philippines has been actively promoting energy efficiency and conservation. Approaches include information awareness, promotion of efficient lighting, standards for air conditioners and labeling, through the following initiatives:

(a) **National Energy Efficiency and Conservation Program.** The program aims "to make energy efficiency and conservation as a way of life." In the household sector, energy efficiency and conservation programs include various information, education, and communication campaigns and energy standards and labeling. Information dissemination websites, such as "wattmatters", were also launched to help people compare appliance consumption rates.

(b) **The SWITCH Project of the Department of Energy.** A "social mobilization movement" of the DOE, the project calls for different sectors to switch to more energy-efficient alternatives.

(c) **Standards and Labeling Program.** Through this program, appliance manufacturers are required to comply with minimum efficiency standards and to label their products subject to approval with the objective of empowering consumers to make informed decisions on choosing more efficient electricity appliances. Currently, there are minimum efficiency requirements for room air conditioners and labeling requirements for refrigerators, compact fluorescent lamps (CFLs), and fluorescent ballasts.

(d) **The Philippine Energy Efficiency Project.** Supported by a loan from the Asian Development Bank, the DOE implemented several projects on reducing energy demand through the use of energy-efficient lighting. Of particular importance in relation to household electric consumption are the distribution of more than 8.6 million CFLs in exchange for incandescent bulbs and the distribution of LED lamps in off-grid areas (Lites. Asia n.d.).

(e) **The Philippine Efficient Lighting Market Transformation Project.** Under Global Environment Facility support since 2005, activities are centered on local capacity building and public awareness to expand the use of energy-efficient lighting in the country.

(f) **The Efficient Lighting Initiative Program (Philippines).** Major accomplishments include public awareness campaigns and the launching of the CFL Energy Labeling Program in 2002.

However, there is still scope to improve these efforts. Regular review and revision of the standards can help them to keep pace with advances in energy-efficient technologies. In addition, existing measures could be complemented, as follows:

(a) **Expansion of the Standards and Labeling Program to other appliances**. There are plans to upgrade the labeling program of CFLs, magnetic ballasts, and refrigerators to the adoption of minimum energy-efficiency standards. The minimum energy-efficiency standards for room air conditioners may further be updated to adopt more stringent efficiency cutoff. Furthermore, the program can cover other high-impact appliances like electric fans and television sets. These combined measures will help force less efficient appliances out of the market and thus help reduce the country's electricity demand and carbon footprint. Building codes can also embed efficiency requirements and expand the effects of standards.

(b) **Technology transfer partnerships with advanced countries.** Since minimum energy performance standards (MEPS) for appliances are already well established in other countries, the Philippines could greatly benefit from deferred costs in testing appliances and establishing its own set of standards. As a first step, local capacity in crafting and enforcing MEPS can be developed further in light of ongoing plans to integrate MEPS for appliances in members of the Association of Southeast Asian Nations. Appliance standards in other countries can also be evaluated for applicability to the local setting. Assessment can be conducted on how local appliance suppliers and retailers can meet current global trends in MEPS. Technical cooperation may be established to help local industries to embed energy efficient technologies in their products.

(c) **Information dissemination campaigns and legislation.** Consumer awareness is also crucial in successful implementation of MEPS. Survey results from the Household Energy Consumption Survey 2004 showed that of the total number of households aware of energy labeling programs, 83.3% used this information to choose the appropriate appliance for their needs (NSO and DOE 2004). Existing information dissemination campaigns of the DOE can be further strengthened to reach a larger consumer base, focusing its efforts on emerging and heavy consumers of electricity, e.g., buyers of new appliances and middle-income families.

6.3.3 Tiered electricity pricing can help induce efficiency

Tiered electricity pricing can help to set incentives for energy efficiency. Under this pricing approach, tariffs rise as the volume of electricity consumed increases. This amplifies incentives for energy efficiency, as the marginal cost of extra consumption can increase progressively. Current utilities have very limited use of this pricing approach.

6.3.4 Energy service companies can facilitate efficiency solutions

Energy service companies (ESCOs) can offer innovative solutions related to energy efficiency and can often be funded sustainably on the basis of saved energy expenditure. The ESCO model often works on the basis of the company providing initial capital investments and plans for energy efficiency, with the client reimbursing the ESCO with a portion of the saved energy cost. In the Philippines, the ESCO market has yet to mature, but is rapidly developing, as the number of accredited ESCOs rose from four in 2015 to 26 in 2017 (DOE 2017). ESCO development could be further supported through information availability and attention to reporting and verification procedures that enhance investor confidence.

6.3.4 Improved data can underpin better efficiency programs

The Philippines has relatively little data on electricity consumption patterns by households or by other sectors. The Household Energy Consumption Survey is conducted intermittently, and the Family Income and Expenditure Survey (FIES) data do not contain many electricity details. Greater monitoring can help to ascertain the effectiveness of efficiency improvement programs and identify mechanisms that best promote efficiency.

6.4 Realizing the Potential for Clean Power

6.4.1 Clean energy deployment depends on appropriate policies

Most of the mitigation potential identified in this study comes from a dramatic transformation of the power sector, in which subcritical coal is progressively replaced by an array of low-carbon sources. Achieving such transformation requires concerted effort to realign incentives for private sector investment toward cleaner and renewable power generation, even if the direct long-term abatement costs can be modest.

Wind and solar power are intermittent and depend on the adoption of storage for high capacity credits in the power system. While the attractiveness of these investments is likely to increase over time, current incentives may be insufficient for large-scale adoption. On the other hand, geothermal and hydropower have much less intermittency and could be more amenable to nearer-term expansion.

A principal constraint to wider adoption of natural gas–fueled generation is dependency on a single source of natural gas fuel (i.e., Malampaya gas) with limited reserves. Investments for the transport of LNG have been insufficient for wider use of imported gas.

Large mitigation potential is identified for backstop/nuclear power. This should be principally interpreted as suggesting a need for more clean energy deployment than is currently targeted by the NREP, as the renewable power options modeled in this study are derived from NREP targets. Put another way, the backstop power option is a gap that could be filled by various clean energy technologies to boost mitigation beyond the NREP.

Nuclear power has substantial risks that must be adequately addressed before it could be considered a feasible option for emissions reduction. Disposal of nuclear waste is a challenge even in advanced economies, and may be particularly problematic in a country where standard solid waste disposal remains limited. The Philippines faces substantial seismic risk, as well as a high frequency of natural disasters, such as typhoons, which must be adequately considered in any plant design. Such technology is also met with substantial social resistance. By 2035, it is likely that alternative backstop low-carbon options may be adoptable in lieu of nuclear power to offer the mitigation identified by this option.

While this study illustrates the large potential of renewable and low-carbon power to reduce emissions by following the NREP targets, more can be done than is targeted under the NREP. Higher target capacity additions for geothermal, hydro, and wind listed in the NREP (DOE 2011) are achievable in terms of the available potential, as shown in Table 6.3. However, such additions can only be realized in the context of conducive policies.

Table 6.3: National Renewable Energy Program Targets and the Renewable Energy Potential in the Philippines

Technology	Total NREP Target 2016–2030 (MW)	Untapped Potential (MW)
Geothermal	1,275	2,600
Hydro	5,053	13,097
Wind	1,297	7,404

MW = megawatt, NREP = National Renewable Energy Program.
Sources: NREP targets: Department of Energy (DOE). National Renewable Energy Program. Renewable Energy Plans and Programs (2011–2030). https://www.doe.gov.ph/sites/default/files/pdf/nrep/nrep_books_021-087_re_plans_programs.pdf; Untapped potential for geothermal and hydropower: DOE. Geothermal Statistics. https://www.doe.gov.ph/geothermal-statistics, and DOE. Hydropower. https://www.doe.gov.ph/hydropower; and Untapped potential for wind power: University of the Philippines Solar Laboratory. 2003. Power Switch! Scenarios and Strategies for Clean Power Development in the Philippines. Report prepared for the Kabang-Kalikasan ng Pilipinas (WWF Philippines). http://assets.panda.org/downloads/wwf_powerswitch_scenario_philippines.pdf.

6.4.2 The Renewable Energy Act may be more fully implemented

A range of ambitious targets for renewable energy have been approved under the NREP. The Renewable Energy Act also created the Renewable Energy Management Bureau of the DOE to lead the implementation of the following policy and incentive mechanisms:

(a) Feed-in Tariffs, or stable guaranteed tariffs for electricity from renewable sources, often at above market prices;

(b) Renewable Portfolio Standards (RPS), which create demand for renewables by specifying minimum renewable shares of power supply that must be procured by distribution utilities and electricity suppliers;

(c) Net Metering, which allows end users that generate electricity using renewable energy generation to sell surplus power back to the grid; and

(d) Green Energy Option, which allows end users (customers) to select renewables as their source of energy.

In addition, there are fiscal and nonfiscal incentives such as tax holidays and exemption from import duties for renewable energy, and regulations such as priority connection and dispatch to accelerate the development of renewable energy.

Although a range of supportive measures has been established, their implementation may be expanded. For example, the capacity covered by feed-in tariffs is currently limited. While the RPS policy prescribes for each grid the minimum percentage of generation from eligible renewable energy resources that electricity suppliers must source, it may be further enforced and escalated. In line with this, PDP 2017–2022 identifies the need to "expedite the implementation of remaining policy mechanisms under the Renewable Energy Act of 2008 (e.g., renewable energy market, renewable portfolio standards) to further encourage development." It also notes that the Government will more "strictly monitor compliance to the DOE Department Circular DC2015-07-014, 'Guidelines for Maintaining the Share of Renewable Energy in the Country'."

6.4.3 Infrastructure for transmission, distribution, and transport needs to complement clean power

Adoption of cleaner fuels depends not only on direct investment in new generation technologies, but also on other infrastructure necessary for substitution of fuel supplies. For example, expanded use of LNG depends on having appropriate gas transport infrastructure and import facilities in place. Greater generation from hydropower may mean more investment in transmission lines, as much hydropower potential is far from population centers. Possible long-term use of nuclear depends on infrastructure for safe transport and disposal of fuels and waste, among other measures. All of this means much need for intersectoral and long-term planning for a low-carbon transition.

6.4.4 Power supply procurement needs adjustment to accommodate clean energy

The current practice for power supply procurement is to undertake a negotiation process between the distribution utility and the generation company. The DOE has issued Department Circular No. DC2015-06-0008, which mandates aggregation of demand of distribution utilities and a competitive selection process for power supply contracting. Smaller distribution utilities have also begun to aggregate demand and jointly competitively select power generators (Energy Regulatory Commission 2014; Energy Regulatory Commission 2015). Aggregation of demand may make it possible for easier stipulation of more efficient generation technologies, such as supercritical coal, or for enforcement of the RPS at the level of individual contracts. It may also be worthwhile to intentionally specify the development of specific hydro and geothermal projects through competitive selection processes within the distribution utilities' power supply agreements to guarantee off-takes. Such an approach is starting to be reflected in the designation of two hydropower projects as "flagship infrastructure" under consideration by NEDA. Expanded adoption of competitive processes, such as auctioning, for the selection of renewable projects may help to attract larger-scale and more competitive options for renewable generation.

Additional flexibility in incentives for renewable energy deployment may be afforded by the use of renewable energy certificates as the basis of the RPS and "green energy options." These certificates may be sold by an entity undertaking renewable power supply as a credit for the unit of power being renewable. Buyers can then use the renewable credit to comply with RPS requirements or pass along the credits to consumers as sales of renewable power. Such certificates have not yet been issued in the Philippines.

7. Conclusions

The Philippines is on the front line of climate change. It is among the most vulnerable countries in the world to climate disasters, and it is likely to be strongly affected by continued global warming. At the same time, although historical GHG emissions have been low, the country is poised to have dramatic increases in emissions unless a proactive approach to mitigation is taken.

The current study investigates likely emissions pathways and mitigation potential in three sectors of the Philippines' economy—transportation, household electricity, and power generation. In the absence of climate action, emissions from these sectors may rise nearly 500% between 2015 and 2050.

In contrast, a limited number of options in these sectors have the potential to dramatically reduce emissions, with nearly a 70% reduction by 2050, relative to business as usual. Moreover, most of that reduction comes at a direct cost that is negative or negligible. When the fact that many of these options have substantial co-benefits is considered, this suggests that the Philippines has much to gain from a low-carbon path. It also suggests that the country may be an efficient object of carbon finance were international carbon markets to emerge from the Paris Agreement or as an object of international assistance.

Most of the mitigation potential identified emanates from low-carbon electricity generation by the power sector. In the medium term, this study finds substantial potential for abatement from renewables using current technologies, while in the longer term, more advanced technologies are likely to be needed to continue low-carbon growth of the energy mix. In this sector, current policies provide many of the elements necessary to promote increased generation from renewables and other low-carbon sources. However, implementation can be extended and augmented with a greater array of complementary measures, such as facilitative infrastructure and altered contracting arrangements.

Greater household electricity efficiency is found to make a relatively minor mitigation contribution, largely because the residential share of electricity consumption is relatively small. Although it comes out as having direct marginal abatement costs that are in the midst of other estimates, accounting indirect costs would likely make this a lower-cost option than low-carbon power generation.

Transportation mitigation potential from vehicle emissions standards is substantial, along with effects of expanded use of low-carbon energy for transport. Individual measures to facilitate modal shifts come out with both high and low direct costs, depending on their infrastructure intensiveness. However, modal shifts are likely to generate the greatest co-benefits in terms of congestion, which if accounted, would likely make a larger range of these measures among the lowest costs.

More broadly, there are interaction effects across individual options, as well as sectors, which may pose challenges to traditional sector-based planning approaches. For example, increased use of electric vehicles alters electricity demand, while energy efficiency may reduce it. Moreover, changes to energy technologies, which are rapidly evolving, may mean that the mitigation potential and costs are likely to change over time. These all suggest a need for cross-sectoral low-carbon planning and analysis as a continuing process.

References

A.T. Kearney. 2014. Will Biofuels Revolutionize the Southeast Asian Energy Industry?. Chicago. https://www.atkearney.com/documents/10192/5185824/Will+Biofuels+Revolutionize+the+Southeast+Asian+Energy+Industry.pdf/aec9d620-6cd8-47d3-8ce0-44a2ff4a8553.

Black and Veatch, Inc. 2012. Cost and Performance Data for Power Generation Technologies. Cost Report. Overland Park, Kansas. https://www.bv.com/docs/reports-studies/nrel-cost-report.pdf.

Bossello, F., F. Eboli, and R. Pierfederici. 2012. Assessing the economic impacts of climate change. *Review of Environment, Energy and Economics*. http://dx.doi.org/10.7711/feemre3.2012.02.002.

Climate Change Commission. 2011. National Climate Change Action Plan 2011–2028. Manila. http://extwprlegs1.fao.org/docs/pdf/phi152934.pdf.

Congress of the Philippines. Republic Act No. 7156. An Act Granting Incentives to Mini-Hydroelectric Power Developers and for Other Purposes (the “Mini-hydroelectric Power Incentive Act”). 12 September 1991. Manila. https://www.doe.gov.ph/laws-and-issuances/republic-act-no-7156.

_____. Republic Act No. 9136. An Act Ordaining Reforms in the Electric Power Industry, Amending for the Purpose Certain Laws and for Other Purposes (the “Electric Power Industry Reform Act of 2001”). 8 June 2001. Manila. http://www.gov.ph/2001/06/08/republic-act-no-9136/.

_____. Republic Act No. 9367. An Act to Direct the Use of Biofuels, Establishing for this Purpose the Biofuel Program, Appropriating Funds Therefor, and for Other Purposes. 24 July 2006. Manila. https://www.senate.gov.ph/republic_acts/ra%209367.pdf.

_____. Republic Act No. 9513. An Act Promoting the Development, Utilization and Commercialization of Renewable Energy Resources and for Other Purposes. 28 July 2008. Manila. https://www.doe.gov.ph/laws-and-issuances/republic-act-no-9513.

_____. Republic Act No. 9729. An Act Mainstreaming Climate Change into Government Policy Formulations, Establishing the Framework Strategy and Program on Climate Change, Creating for this Purpose the Climate Change Commission, and for Other Purposes. 23 October 2009. Manila. http://www.gov.ph/2009/10/23/republic-act-no-9729/.

Corong, E. and J. M. Horridge. 2012. PHILGEM: A SAM-based Computable General Equilibrium of the Philippines. Melbourne: The Centre of Policy Studies. https://ideas.repec.org/p/cop/wpaper/g-227.html.

Del Mundo, R. 2015. Understanding and Reducing Power Rates in the Philippines. Presentation for the University of the Philippines–Center for Integrative and Development Studies. 16 April. Manila. http://cids.up.edu.ph/lecture-2015.

Del Mundo, R. D. and E. A. Espos. 2011. Philippine Electric Power Industry Market and Policy Assessment and Analysis of International Markets. Final Report. Manila: University of the Philippines–National Engineering Center.

Department of Budget Management. 2012. 2013 Budget Message of President Aquino. Manila. http://www.dbm.gov.ph/?page_id=3692.

Department of Energy (DOE). n. d. *Philippine Energy Plan 2011–2030*. Manila. https://www.doe.gov.ph/sites/default/files/pdf/pep/2012-2030_pep.pdf.

_____. 2011. National Renewable Energy Plan. Renewable Energy Plans and Programs (2011–2030). Manila. https://www.doe.gov.ph/sites/default/files/pdf/nrep/nrep_books_021-087_re_plans_programs.pdf.

_____. 2014. 2013 Philippine Power Statistics. https://www.doe.gov.ph/2013-philippine-power-statistics.

_____. 2015. 25th Electric Power Industry Reform Act (EPIRA) Implementation Status Report. Manila. https://www.doe.gov.ph/sites/default/files/pdf/electric_power/power_industry_reforms/25th_epira_report_final.pdf.

_____. 2015. Department Circular No. DC2015-06-0008. Mandating All Distribution Utilities to Undergo Competitive Selection Process (CSP) in Securing Power Supply Agreements (PSA). Manila. https://www.doe.gov.ph/sites/default/files/pdf/issuances/dc_2015-06-0008.pdf.

_____. Hydropower. https://www.doe.gov.ph/hydropower.

_____. 2017. List of DOE Accredited ESCOS as of May 2017. Manila. https://www.doe.gov.ph/list-doe-accredited-energy-service-companies-escos.

Department of Trade and Industry–Bureau of Product Standards (DTI–BPS). 2015. BPS Memorandum Circular No. 1503: List of Products under Mandatory Certification. 10 July. Manila. http://www.bps.dti.gov.ph/index.php?option=com_docman&task=doc_download&gid=5809&Itemid=77.

Energy Regulatory Commission. 2014. ERC Case No. 2014-011 RC. Manila. http://www.erc.gov.ph/ContentPage/29443.

_____. 2015. ERC Case No. 2015-024 RC. Manila. http://www.erc.gov.ph/ContentPage/29664.

European Parliament and Council of the European Union. 2009. Regulation (EC) No. 443/2009. Setting Emission Performance Standards for New Passenger Cars as Part of the Community's Integrated Approach to Reduce CO_2 Emissions from Light-Duty Vehicles. Strasbourg. http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=celex:32009R0443.

Hallmark, S. L., B. Wang, Y. Qiu, and B. Sperry. 2012. Assessing the Costs for Hybrid Buses versus Regular Transit Buses. Tech Brief. Ames, Iowa: Center for Transportation Research and Education. http://www.intrans.iastate.edu/publications/_documents/t2summaries/hybrid_transit_bus_tech_brief1.pdf.

International Council on Clean Transportation (ICCT). 2014. EU CO_2 Emission Standards for Passenger Cars and Light-Commercial Vehicles. *ICCT Policy Update*. January. http://www.theicct.org/sites/default/files/publications/ICCTupdate_EU-95gram_jan2014.pdf.

International Energy Agency (IEA). 2013. Southeast Asia Energy Outlook. World Energy Outlook Special Report. Paris.

Japan International Cooperation Agency (JICA) and National Economic Development Authority (NEDA). 2014. Roadmap for Transport Infrastructure Development for Metro Manila and Its Surrounding Areas (Region III & Region IV-A). Final Report Summary. Manila. http://www.neda.gov.ph/wp-content/uploads/2015/03/FR-SUMMARY.-12149597.pdf.

Kabang Kalikasan ng Pilipinas (WWF Philippines) and University of the Philippines Solar Laboratory (UPSL). 2003. Power Switch! Scenarios and Strategies for Clean Power Development in the Philippines. Manila. assets.panda.org/downloads/wwf_powerswitch_scenario_philippines.pdf.

Kjellstrom, T., B. Lemke, M. Otto, O. Hyatt, D. Briggs, and C. Freyberg. 2015. Climate Change and Increasing Heat Impacts on Labor Productivity. Text contribution to the Climate Vulnerable Forum. 25 April. Mapua, New Zealand: Ruby Coast Research Centre.

Kreft, S., D. Eckstein, L. Junghans, C. Kerestan, and U. Hagen. 2014. Global Climate Risk Index 2015. Bonn: Germanwatch. http://germanwatch.org/en/download/10333.pdf.

Legislative Budget Research and Monitoring Office. 2014. FY 2014 Budget of the Department of Trade and Industry. Budget Facts & Figures. 2 (1). January–March. Manila. http://www.senate.gov.ph/publications/LBRMO%20DTI%20and%20SUCs%20FY%202014%20Budget%28final%29.pdf.

Lites.Asia. National Standards and Labels–Country Profile: Philippines. http://www.lites.asia/files/otherfiles/0000/0193/National_Standards_and_Labels_-_Philippines_25_January_2013.pdf.

National Economic Development Authority (NEDA). 2013. NEDA Board Approves 7 Infra, Health Projects. http://www.neda.gov.ph/2013/11/21/neda-board-approves-7-infra-health-projects/.

______. 2017. Philippine Development Plan 2017–22. Manila. http://pdp.neda.gov.ph/wp-content/uploads/2017/01/PDP%202017-2022-06-06-2017.pdf.

National Statistics Office (NSO) and Department of Energy (DOE). 2004. October 2004 Household Energy Consumption Survey. Manila: Philippine Statistics Authority. https://psa.gov.ph/content/october-2004-household-energy-consumption-survey.

______. 2014. 2011 Household Energy Consumption Survey. Manila: Philippine Statistics Authority. https://psa.gov.ph/content/electricity-most-common-source-energy-used-households.

Ntziachristos L., D. Gkatzoflias, C. Kouridis, and Z. Samaras. 2009. COPERT: A European Road Transport Emission Inventory Model. In: Athanasiadis I.N., Rizzoli A.E., Mitkas P.A., Gómez J.M. (eds) *Information Technologies in Environmental Engineering*. Berlin, Heidelberg: Springer.

Peng, S. B., J. L. Huang, J. E. Sheehy, R. C. Laza, R. M. Visperas, X. M. Zhong, G. S. Centeno, G. S. Khush, and K. G. Cassman. 2004. Rice Yields Decline with Higher Night Temperature from Global Warming. Proceedings of the National Academy of Sciences. 101 (27): 9971–75.

Philippine Statistics Authority. 2012. Household Population of the Philippines Reaches 92.1 Million. 30 August. https://psa.gov.ph/content/household-population-philippines-reaches-921-million.

______. 2014. Family Income and Expenditure Survey (FIES) 2012. https://psa.gov.ph/fies-index.

Raitzer, D. A., F. Bosello, M. Tavoni, C. Orecchia, G. Marangoni, and J. N. G. Samson. 2015. *Southeast Asia and the Economics of Global Climate Stabilization.* Manila: ADB.

Regidor, J. R., and S. F. D. Javier. n. d. The Philippines: A Study of Long-Term Transport Action Plan for ASEAN. Tokyo: Institute for Transport Studies. http://cleanairasia.org/wp-content/uploads/portal/files/philippines_0.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). 2014. Second National Communication to the United Nations Framework Convention on Climate Change: Philippines. Geneva. http://unfccc.int/resource/docs/natc/phlnc2.pdf.

______. 2015. Intended Nationally Determined Contributions. October. Geneva. http://www4.unfccc.int/submissions/INDC/Published%20Documents/Philippines/1/Philippines%20-%20Final%20INDC%20submission.pdf.

United Nations Population Division. 2014. World Urbanization Prospects, the 2014 revision. http://esa.un.org/unpd/wup/ (accessed 19 October 2015).

USDA Foreign Agricultural Service. 2013. Philippines: Biofuels Annual. Global Agricultural Information Network (GAIN) Report. 10 July. Manila. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Manila_Philippines_7-10-2013.pdf.

World Bank. 2010. A Strategic Approach to Climate Change in the Philippines: An Assessment of Low-Carbon Interventions in the Transport and Power Sectors. Final Report. Washington, DC. http://siteresources.worldbank.org/INTPHILIPPINES/Resources/PH_Low_Carbon_Transport_and_Power.pdf.

World Bank. 2011. Energy Intensive Sectors of the Indian Economy: Path to Low Carbon Development. Energy Sector Management Assistance Program Briefing Note 006/10. Washington, DC. https://openknowledge.worldbank.org/bitstream/handle/10986/17944/771530ESM0P1010L0LCD0India0BN006010.pdf;sequence=1.

Pathways to Low-Carbon Development for the Philippines

The Philippines currently has a low level of per capita greenhouse gas emissions. However, emission levels are growing at an increasing rate, with 4% annual growth between 2006 and 2012. The country's energy system is becoming more carbon intensive to satisfy escalating energy demand caused by strong economic growth. This study assesses how the Philippines can take a low-carbon pathway by drawing on detailed modeling of the power, residential, and transport sectors. It identifies low-carbon development options that can be deployed at approximately zero net cost to reduce energy sector greenhouse gas emissions by 70% by 2050. With energy use levels still low, the country has an opportunity to follow a low-carbon development trajectory—if action is taken soon.

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