DIRECTIONS IN DEVELOPMENT
Environment and Sustainable Development

Exploring a Low-Carbon Development Path for Vietnam

Pierre Audinet, Bipul Singh, Duane T. Kexel, Suphachol Suphachalasai, Pedzi Makumbe, and Kristy Mayer

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Foreword

Can Vietnam pursue a path of continued economic growth without a proportional expansion of carbon emissions, reflecting an unabated consumption of natural resources? Will the goals set in Vietnam's Green Growth Strategy to reduce carbon emissions in the next 15 years be easy to achieve? Won't reducing carbon emissions in Vietnam hamper economic development? Will reducing carbon emissions require more expensive investments? How can Vietnam schedule its efforts to reduce carbon emissions in the large emitting sectors of electricity production, industry, residential, or transport? Which measures bring the most cost-effective benefits? Won't investing in more capital-intensive electricity production push the price of electricity further upward? Are there really significant measures that can be taken to reduce carbon emissions in the transport sector? Will reducing carbon emissions help improve energy security?

This report provides elements to help respond to all these questions. Bringing together a large set of data and building upon two years of consultations in Vietnam with Government counterparts, research organizations, state-owned enterprises, the private sector, and Vietnam's international development partners, the report formulates two scenarios to explore and analyze Vietnam's options up to the year 2030: a business-as-usual and a low-carbon development scenario. On the basis of a thorough data modeling effort for the key carbon-emitting sectors of Vietnam, the report also provides some policy guidance for the Government's consideration. This report is also unique as it brings together and presents data on multiple sectors of Vietnam's economy, making this information available for future reference.

This effort is the result of two years of collaboration with the Government of Vietnam as part of the Vietnam Low Carbon Options Assessment technical assistance. By highlighting several economic opportunities and clarifying the issues at hand, this work constitutes a milestone in this complex debate and I believe will help responsible stakeholders to design the policies and measures to address those challenges.

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Country Director, Vietnam
The World Bank

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The World Bank team performed all modeling and analysis, with input from the CIEM (macroeconomic assumptions and analysis), the TDSI (data for transport sector), the IEVN (data for the five industries, household, and power sectors), and Ernst and Young (data on energy efficiency and marginal abatement cost [MAC] calculations for industry and household sectors). The World Bank team closely cooperated with the ADB and UNDP to harmonize assumptions and baseline datasets.

The authors remain fully responsible for any errors or omissions in the contents of this report, and for the minor differences across scenarios that may arise as a result of modeling and assumptions that have not been fully reconciled.

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Executive Summary

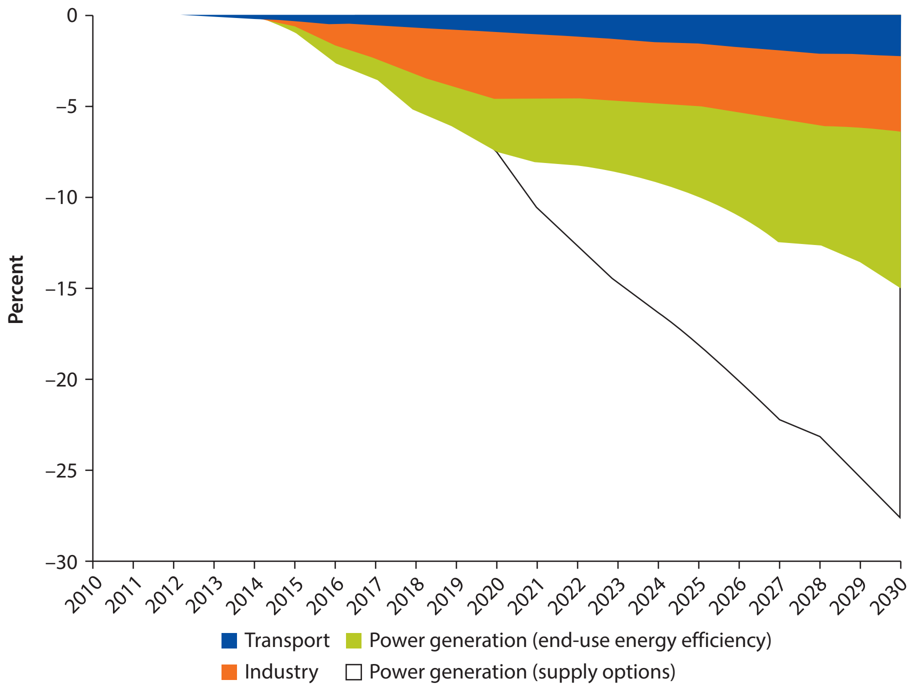
Low-cost energy and other natural resources have played a key role in driving the Vietnamese economy over the past decades. But current consumption and production patterns, accompanied by urbanization at an unprecedented pace, are placing enormous pressure on these resources. The resulting environmental deterioration has the potential to undermine human productivity and limit the country's future growth potential.

Emissions from the largest emitting sectors of energy, industry, and transport, if they continue at the current pace, are projected to rise to 279 million tons of carbon dioxide ($MtCO_2$) in 2020 and reach 495 $MtCO_2$ in 2030. Vietnam's carbon dioxide (CO_2) emissions from those sectors—estimated at 110 $MtCO_2$ in 2010—would increase 4.5-fold under a business-as-usual (BAU) scenario in 2010–30. These include emissions from (i) electricity generation; (ii) energy use in road, rail, and water transport; (iii) energy use in, and process emissions from, industrial production; and (iv) energy use in the nonresidential sector. The BAU scenario assumes no further investments or policy reforms beyond those committed to or approved by 2012. This is compared against the low-carbon development (LCD) scenario, which encompasses a distinct set of priority actions toward the targets of the Vietnam Green Growth Strategy (VGGS).

Under the BAU scenario, per capita emissions increase fourfold, and the carbon intensity of gross domestic product (GDP) rises by 20 percent between 2010 and 2030. Over the past decade Vietnam's CO_2 emissions tripled, growing at the fastest rate in the region. Future increases projected in the BAU scenario are driven primarily by growth in the use of coal for power generation. The share of coal in the power generation mix would increase from 17 percent in 2010 to 58 percent in 2030. Four-fifths of the coal used by Vietnam in 2030 would be imported, considerably increasing the country's energy dependence and the risks associated with reliance on a single dominant fuel for power generation.

Under the LCD scenario, Vietnam can achieve its VGGS (Vietnam Green Growth Strategy) targets. The analysis demonstrates the feasibility of achieving a cumulative 845 million tons of CO_2 emissions reductions by 2030. Annual CO_2 emissions are projected at 258 $MtCO_2$ in 2020 (7.5 percent less than under the BAU scenario), and at 358 $MtCO_2$ in 2030 (27.7 percent less than the BAU) (figure ES.1). The Government of Vietnam underscored its commitment to pursuing an LCD path through the approval of the VGGS in 2012. This report,

Figure ES.1 CO_2 Emissions Reductions Proposed, Relative to Business as Usual



Source: World Bank estimates.

based on a comprehensive review of the VGGS targets, proposes several low-carbon options that yield both CO_2 emissions reductions and net economic gains to Vietnam through lower energy and input costs. The report finds that the VGGS sets ambitious but achievable targets for emissions reductions but will require early actions and significant policy commitment, design, and implementation across key sectors.

The LCD scenario is not expected to adversely affect economic growth in Vietnam and may even boost growth, building on the evidence that growth and a clean environment can be realized simultaneously and can be mutually reinforcing. Vietnam needs to act early to avoid investment in technology and infrastructure that will "lock in" carbon-intensive economic structures. Positive spillover effects from LCD are expected in terms of economic growth, productivity, and avoided health costs. The LCD scenario promises to accelerate the development of the service sector in Vietnam and boost greener sectors of the economy. Beyond national-level benefits, Vietnam can also contribute toward limiting the rise in global average surface temperatures.

Switching to a low-carbon investment strategy is cost-effective but requires significant initial investment. The annual incremental investment of implementing the LCD scenario in the 2014–20 period ($3 billion per year) is three times as high as the investment required over the 2021–30 period ($1 billion per year), highlighting the importance of resource mobilization during the course of the next Socio-economic Development Plan. Investment in the LCD scenario is estimated to be $2 billion more (about 1 percent of the country's GDP) than in BAU scenarios, per year on average, during 2010–30.

Measures to save electricity by 2017 are critical to avoid coal plant additions planned for 2021. Energy savings (both fuel and electricity) promise to boost emissions reductions. Under the LCD scenario a proposed 11 percent decrease in electricity demand would, in effect, avoid 11.7 gigawatts (GW) of power generation capacity over 2010–30. More than 60 percent of reduced demand for grid electricity in big industry would be due to waste-heat recovery power generation at large iron and steel and cement production facilities. Such recovery provides a highly focused target, yielding large energy-efficiency gains.

Implementing the LCD scenario would significantly lower capital and fuel expenditures in the electricity sector, relative to the BAU scenario. Reducing total electricity consumption and diversifying the electricity supply to include more natural gas and renewable energy (RE) power would lead to a projected savings of $8.1 billion in capital expenditures and $17.6 billion in fuel over 2015–30, when compared with the BAU scenario. These savings are estimated using the very conservative assumption of one-to-one natural gas–fueled electricity generation capacity as backup for all variable, renewable additions to electricity generation capacity. If that assumption is relaxed, the capital savings would be 75 percent greater. The proposed LCD electricity supply mix would translate into displacing 40 percent, or 13.7 GW, of the planned coal-fired power plant additions in 2021–30, at a marginal abatement cost (MAC) of $2.50 per tCO_2.

The combined energy-efficiency and clean-technology impacts of the LCD scenario would reduce the cost of imported fuels by $2.5 billion in 2030, or a cumulative $7.9 billion over 2015–30. LCD would improve Vietnam's energy security by diversifying energy supply and increasing renewable energy. In the LCD scenario, electricity supply from RE (hydroelectricity, wind, solar, and biomass only) would reach 7.9 percent of electricity generation by 2030.

Investing in LCD itself would not prompt a projected rise in the price of electricity. Rapid growth in electricity costs—above inflation levels—is unavoidable in Vietnam because the country is projected to depend more and more on higher-cost fuel imports (natural gas and coal). But under the LCD scenario electricity prices grow only marginally faster than in the BAU scenario—just 5 percent above that of the BAU scenario by 2030.

The implementation of industrial energy-efficiency measures could generate $10 billion in economic savings by 2030 (compared with BAU). Implementation of fuel-saving measures in the transport sector could provide another cumulative $22 billion. All together, the potential for direct savings through efficiency gains in Vietnam is expected to be at least $55 billion by 2030, if the full technical and economic potential of these no-regret options can be realized. In addition, "cobenefits"—relating to improved air quality and reduced health impacts from the power sector over the life of the power plants added between 2021 and 2030—are estimated to be $48 billion.

Increasing the use of public transportation and electric bicycles (e-bikes) is fundamental to Vietnam's sustainable mobility and economic growth, given the country's high population density and the structure of its cities. To this end, the government needs to promote the use of buses, rail, or mass rapid transit (MRT) systems. In the LCD scenario e-bikes contribute to over half of all CO_2 emissions reductions in the transport sector. Regulations requiring manufacturers to sell a certain proportion of e-bikes relative to gasoline motorcycles would help jump-start the market for this alternative mode of transport.

As Vietnam's cities expand, considerable attention to intelligent urban planning and the promotion of occupational density is critical to reducing CO_2 emissions from the transport and building sectors. Mixed-use urban planning and proper road planning would significantly improve mobility and lower CO_2 emissions.

In the immediate future LCD will require moderate incremental capital investment and significant political commitment to the design and coordinated implementation of a number of policy reforms, including the following:

- Continue to reform pricing mechanisms for fossil fuels, and do not delay adjusting energy prices to cover costs, most notably for coal and electricity. This will help kick-start the transformation of traditional sectors, reduce environmental externalities, and mainstream long-term sustainability goals.
- Make aggressive efforts to improve energy efficiency in the household and industry sectors. While the economic and green growth benefits of energy-efficiency measures promise to be significant, the achievement of meaningful energy savings in these target areas and other economic sectors will not happen on its own. The Ministry of Industry and Technology's (MOIT's) Energy Efficiency and Conservation Office (EECO) should be strengthened or a separate energy-efficiency institution set up to effectively support relevant efforts. The institution would likely need more resources, independent decision-making powers, and relatively high-ranking leadership so that it can coordinate action across ministries. It is also essential that demand-side potential be fully recognized in a transparent way in all future power supply plans.
- Aggressively replace coal-fired generation with gas-fired combined-cycle gas turbines (CCGTs), both on a stand-alone basis and paired with hydro (mainly run-of-river [ROR]), wind, and solar photovoltaic (PV).
- Actively pursue policies to facilitate investment in RE (biomass, hydro, wind, and solar PV) to meet Vietnam's growing energy needs. Advance utility planning and operational capabilities to fully integrate renewables with CCGT generation, and draw on lessons learned for the design of dynamic feed-in tariffs.
- Consider mandating the adoption of cleaner coal technology (such as supercritical coal technologies) to accelerate gains in emissions reductions.
- Promote low-carbon cities with compact urban design, public transport, green buildings, and clean-fuel vehicles. Encourage the use of e-bikes; strictly enforce automobile fuel-quality norms and emissions standards; switch to compressed

Table ES.1 Summary of Policy Recommendations

Cross-Cutting	*Power Sector*	*Energy Efficiency (End Use and Industry)*	*Transport and Urban*
(Percent reduction by 2030, relative to business as usual [BAU] and following the low-carbon development [LCD] scenario)	**(12.5%)**	**(12.2%)**	**(2.2%)**
Mainstream LCD in the Socio-economic Development Plan process through adoption of mechanisms such as the Multi-criteria Decision Analysis (MCDA).	Update Vietnam's power development plan to be consistent with the LCD scenario; explicitly incorporate economic costs of externalities in power system planning.	Significantly strengthen the Ministry of Industry and Technology's (MOIT's) Energy Efficiency and Conservation Office (EECO), or consider establishing a separate energy-efficiency institution to scale up energy-efficiency gains.	Prepare and implement a road map to increase the penetration of electric bicycles (e-bikes).
Implement a monitoring, reporting, and verification (MRV) system in coordination with the national greenhouse gas (GHG) inventory.	Complete potential, location, and grid integration studies for the renewable and combined-cycle gas turbine (CCGT) using liquefied natural gas plants by 2017.	Establish and enforce mandatory performance-based energy-efficiency targets for industries and provinces.	Implement a comprehensive policy for inland waterway improvement, including replacement of smaller with larger vessels and self-propelled with pushed barges.
Prepare a strategy to cover the incremental financing required for LCD.	Advance utility planning and operational capabilities to fully integrate renewables with CCGT generation.	Provide financing and incentives for energy efficiency through mechanisms such as guarantees, credit lines, grants, subsidies, rebates, tax relief, and so on.	Ensure stricter enforcement of auto fuel-quality norms and emissions standards.
Consider market, economic, and fiscal instruments to support low-carbon investments and provide the right incentives for private sector actions.	Prepare a road map for adoption of supercritical coal combustion technology.	Establish and enforce efficiency standards for residential refrigerators, air conditioners, and lighting at the point of sale starting by 2015.	Introduce and enforce vehicle fuel-efficiency standards.
Build consensus on the BAU scenario and institute processes for periodic updates.	Carry out an analysis of Vietnam's health costs, reduced productivity, and other damages related to emissions of SO_2, NO_x, and particulate matters.	Coordinate the waste-heat recovery and new turbine generation for large iron and steel and cement producers with grid planning.	Encourage compact urban development and mixed land use for all new cities.

Source: World Bank.
Note: SO_2 = sulfur dioxide; NO_x = nitrous oxide.

natural gas (CNG) as fuel for buses; encourage mixed land-use policy for new cities; and promote shared transport on school buses, factory buses, and so on.

- Consider market, economic, and fiscal instruments to support low-carbon investments and provide the right incentives for private sector actions. This in turn requires the proposal of various policy designs and in-depth analysis of their impacts, trade-offs, and interactions with other measures and policy options.

- Take concrete steps to mainstream low-carbon and green growth considerations into the planning process by building capacity in key institutions and through the effective implementation of a monitoring, reporting, and verification (MRV) system coordinated with the national greenhouse gas (GHG) inventory. Feedback loops between MRV and a low-carbon policy formulation should be identified and strengthened.
- Explore how to promote the low-carbon measures that have been studied in this report. The policy and technical potential for Vietnam to go beyond even the LCD scenario is undoubtedly significant and warrants an examination.

The window of opportunity is limited; immediate action is needed to capture the full potential of clean technologies and to avoid inefficient infrastructure lock-ins. Over the next 20 years and beyond, the cities of Vietnam are expected to expand tremendously. As millions of Vietnamese switch to an urban lifestyle and seek the convenience and comfort of modern modes of transport for better connectivity, the number of motor vehicles is expected to grow rapidly. The country will continue to build new power and industrial plants, new infrastructure, and new commercial and residential buildings. The time to act is now to move Vietnam onto a clear and sustainable LCD path.

Abbreviations

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BAU	business as usual
BF	blast furnace
CAGR	compound annual growth rate
CAPEX	capital expenditure
CCGT	combined-cycle gas turbine
CCS	carbon sequestration
CES	constant elasticity of substitution
CET	constant elasticity of transformation function
CFL	compact fluorescent lamp
CGE	computable general equilibrium
CIEM	Central Institute for Economic Management
CNG	compressed natural gas
CO_2	carbon dioxide
DFID	Department for International Development (U.K.)
EAP	East Asia and Pacific
EE	energy efficiency
EE&C	energy efficiency and conservation
EECO	Energy Efficiency and Conservation Office
EFFECT	Energy Forecasting Framework and Emissions Consensus Tool
EIA	Energy Information Administration
ESCOs	energy service companies
ESMAP	Energy Sector Management Assistance Program
ETSAP	Energy Technology Systems Analysis Program
EVN	Electricity Vietnam
FIT	feed-in tariff
FUELEX	fuel expenses
GAMS	General Algebraic Modeling System

GDP	gross domestic product
GGAP	Green Growth Action Plan
GHG	greenhouse gas
GoV	Government of Vietnam
HCMC	Ho Chi Minh City
I&S	iron and steel
IEA	International Energy Agency
IEVN	Institute of Energy Vietnam
IFC	International Finance Corporation
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
LCD	low-carbon development
LCO	low-carbon option
LCOE	levelized cost of energy
LED	light-emitting diode
LNG	liquefied natural gas
MAC	marginal abatement cost
MACC	marginal abatement cost curve
MCDA	Multi-Criteria Decision Analysis
MCP	Mixed Complementary Problem
MOF	Ministry of Finance
MOIT	Ministry of Industry and Technology
MONRE	Ministry of Natural Resources and Environment
MOT	Ministry of Transport
MPI	Ministry of Planning and Investment
MRT	mass rapid transit
MRV	monitoring, reporting, and verification
NCCS	National Climate Change Strategy
NLDC	National Load Dispatch Center
NO_x	nitrous oxide
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
OMEX	operation and maintenance expenditures
PDPVII	Power Development Plan VII
PECSME	Promoting Energy Conservation in Small and Medium Scale Enterprises
PM	particulate matter
PRGF	Partial Risk Guarantee Fund
PV	photovoltaic

RE	renewable energy
ROR	run-of-river
S&L	standards and labeling
SAM	social accounting matrix
SMEs	small and medium enterprises
SO_2	sulfur dioxide
SOE	state-owned enterprise
SSP	small steel producer
T&D	transmission and distribution
TDSI	Transport Development Strategy Institute
TFP	total factor productivity
UNDP	United Nations Development Programme
VFD	variable frequency drive
VGGS	Vietnam Green Growth Strategy
VHLSS	Vietnam Household Living Standards Survey
VNCLIP	Vietnam Climate Partnership
VNEEP	Vietnam's National Energy-Efficiency Program
WIDER	World Institute for Development Economics Research

Units of Measurement

cal/kg	calorie per kilogram
CO_2e	carbon dioxide equivalent
GJ	gigajoule
GJ/t	gigajoule/ton
GW	gigawatt
GWh	gigawatt-hour
GWh/a	gigawatt-hour per annum
GWhe	gigawatt-hour equivalent
km	kilometer
km/h	kilometers per hour
ktoe	kilotonne of oil equivalent
kWh	kilowatt-hour
m	meter
MMBTUs	million British thermal units
Mt	million tons
$MtCO_2$	million tons of carbon dioxide
$MtCO_2e$	million tons of carbon dioxide equivalent
Mtpa	million tons per annum
MW	megawatt

MWhe	megawatt hour equivalent
tCO_2	tons of carbon dioxide
tCO_2e	tons of carbon dioxide equivalent
toe	ton of oil equivalent
TWh	terawatt-hour

ton/tonne = metric ton (international system)
$ = 2010 U.S. dollars unless otherwise indicated

CHAPTER 1

The Case for Low-Carbon Development

Overview

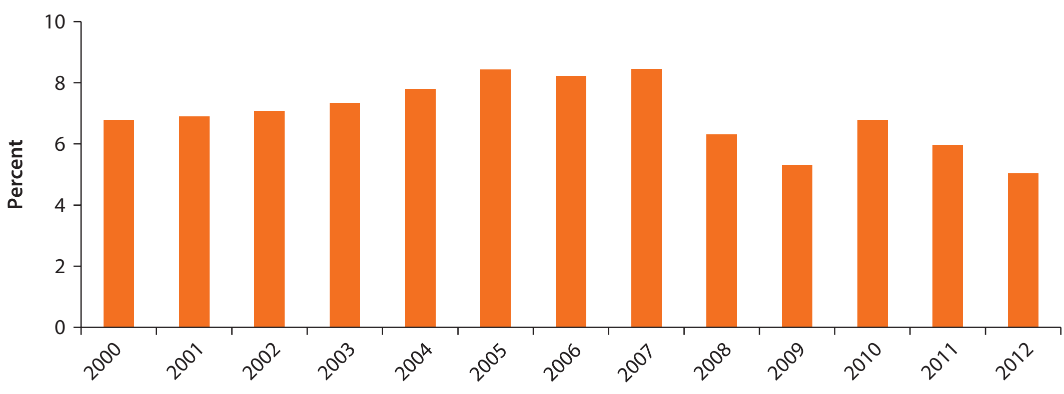
- Over the past decade, Vietnam's carbon dioxide (CO_2) emissions tripled, growing at the fastest rate in the region. The carbon intensity of the country's gross domestic product (GDP) increased by 48 percent in the same period, a sign that Vietnam's current economic growth model is not sustainable over time. Under the business-as-usual (BAU) scenario, Vietnam's overall emissions would increase fivefold, per capita emissions fourfold, and the carbon intensity of GDP by 20 percent between 2010 and 2030.
- These increases are projected to be driven primarily by growth in the use of coal for power generation; the share of coal in the power generation mix would triple from 17 percent in 2010 to 58 percent in 2030 under the BAU scenario. Four-fifths of the coal used by Vietnam in 2030 would be imported, which would increase the nation's dependence on external energy sources.
- Under the BAU scenario, local environmental and health costs in the power sector would be $48 billion more than under the low-carbon development (LCD) scenario.
- Although LCD has a small economic cost, it can offer a significant number of new growth opportunities for Vietnam in multiple sectors, depending on how effectively the government pursues green growth policies and investments.
- The low-carbon measures identified in this report can help the country meet the Vietnam Green Growth Strategy (VGGS) targets, increase energy security at affordable costs, and pursue a more sustainable growth path.

Vietnam's Economic and Emissions Performance

Vietnam is widely seen as a development success in terms of its economic performance over the past 20 years. Vietnam was one of the poorest countries in the world in 1986, when it launched a political and economic renewal campaign that marked the beginning of its transition from a centrally planned economy to a socialist-oriented market economy. Since then, Vietnam has made an impressive economic turnaround. Between 1990 and 2010, Vietnam's economy grew at an annual average rate of 7.3 percent, and the per capita income almost quintupled. The share of the population living below the poverty line fell by nearly half over the past decade—from 28.9 percent in 2002 to 14.5 percent by 2010. The rapid expansion of the economy has been accompanied by high levels of growth in international trade; large-scale inflows of foreign direct investment; a dramatic reduction in poverty; and almost universal access to primary education, health care, and life-sustaining infrastructure such as paved roads, electricity, piped water, and housing.

There have been signs, however, of an economic slowdown in recent years (figure 1.1). The country has been experiencing the longest spell of relatively slow growth since the onset of economic reforms in the late 1980s. Bouts of macroeconomic turbulence in recent years—double-digit inflation, depreciating currency, capital flight, and loss of international reserves—have eroded investor confidence. Real GDP grew by 5 percent in 2012, the lowest level since 1998. These weaknesses point to a number of structural problems. The quality and sustainability of Vietnam's growth remain sources of concern, given the resource-intensive nature of this growth, high levels of pollution, lack of diversification and value addition in exports, and the declining contribution of productivity. Vietnam's industrial competitiveness is under threat: power generation has not kept pace with demand, logistical costs and real estate prices have climbed, and skill shortages are becoming prevalent. The country also faces many new social challenges: vulnerability is increasing, poverty is concentrated among ethnic minorities, rural-urban disparity is growing, and the pace of job creation is slowing. These problems, taken together, pose a serious threat to Vietnam's medium-term socioeconomic aspirations.

Figure 1.1 Vietnam's Annual GDP Growth, 2000–12



Source: World Development Indicators 2012.
Note: GDP = gross domestic product.

The performance of state-owned enterprises (SOEs) has significantly contributed to the slowdown. Vietnam's SOEs, which control all the critical sectors in Vietnam, are among the least efficient users of capital, and are at the same time the largest owners. SOEs use several times more capital than the industry average to produce one unit of output. This is not entirely unexpected, since SOEs specialize in more capital-intensive products. But the difference is becoming excessive: in 2000, an average SOE required nine times the amount of capital to produce a unit of output; by 2009, this had increased to almost 20 times. In other words, while the enterprise sector as a whole was getting better at optimizing the use of capital, the SOEs were using it more extravagantly. SOEs are also very inefficient consumers of energy and have generally been slow to adopt energy-efficiency measures to reduce energy consumption.

Vietnam needs to sustain and improve the quality of its growth in the coming decades to meet its development goals. According to its Socio-economic Development Strategy for 2011–20, Vietnam aspires to achieve a per capita income level of $3,000 by 2020. This translates into nearly 10 percent annual growth in per capita income from 2010—requiring the country to replicate and sustain the economic success it achieved in the previous decade. To achieve these goals, Vietnam will have to move from resource-driven growth that is dependent on cheap labor and capital to growth driven by innovation and supported by medium- and high-value added production. SOE reforms and restructuring will need to be part of such an effort. The Socio-economic Development Strategy identifies the country's key priorities for achieving this: stabilize the economy, build world-class infrastructure, create a skilled labor force, and strengthen market-based institutions.

The growth model that has delivered economic growth in recent years is unlikely to deliver the same performance over the next two decades. There are three main reasons for this:

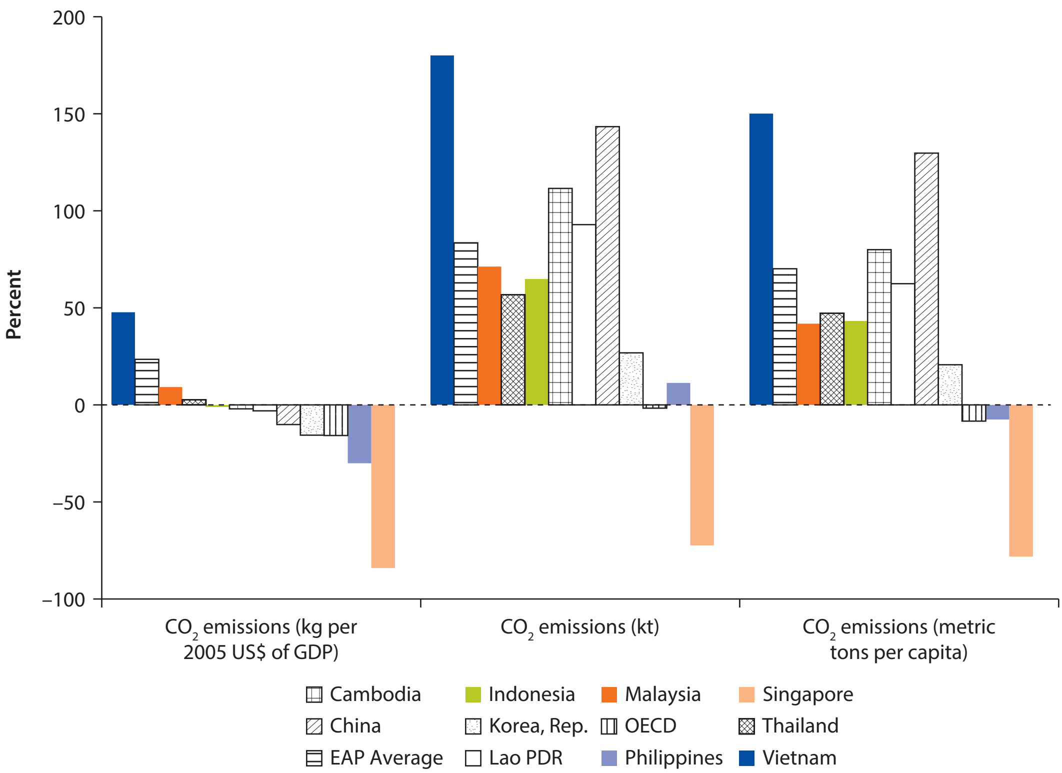
- First, there are clear indications that the relationship between factor accumulation, particularly investment, and growth is weakening in Vietnam, even as improvement in productivity is necessary to keep the country on a fast economic growth path. Vietnam's economic performance has been increasingly dependent on factor accumulation[1] over improvements in productivity. Nearly 40 to 60 percent of growth during the 1990s came through productivity growth and the rest through factor accumulation. But the situation changed during the 2000s, a period when Vietnam received a record inflow of external capital. During this period, productivity accounted for only 15 percent of growth, with the remainder due to the accumulation of physical and human capital. And in 2007–10 almost all growth came from factor accumulation.

- Second, Vietnam historically has had an abundance of cheap domestic energy (primarily hydro). But going forward it will increasingly have to rely on more expensive imported energy, which will adversely affect Vietnam's economic growth by increasing the cost of producing goods and services in the economy and stifling supply and demand.

- Third, Vietnam will be unable to repeat its high-growth performance over the next two decades without incurring substantial environmental pollution. Vietnam's current growth model, which is highly energy and fossil-fuel intensive, places a heavy burden on the environment. The overall growth of the economy, population, urbanization, and industrialization over the past two decades has combined to increase water pollution, urban air pollution, and the extraction of natural resources.

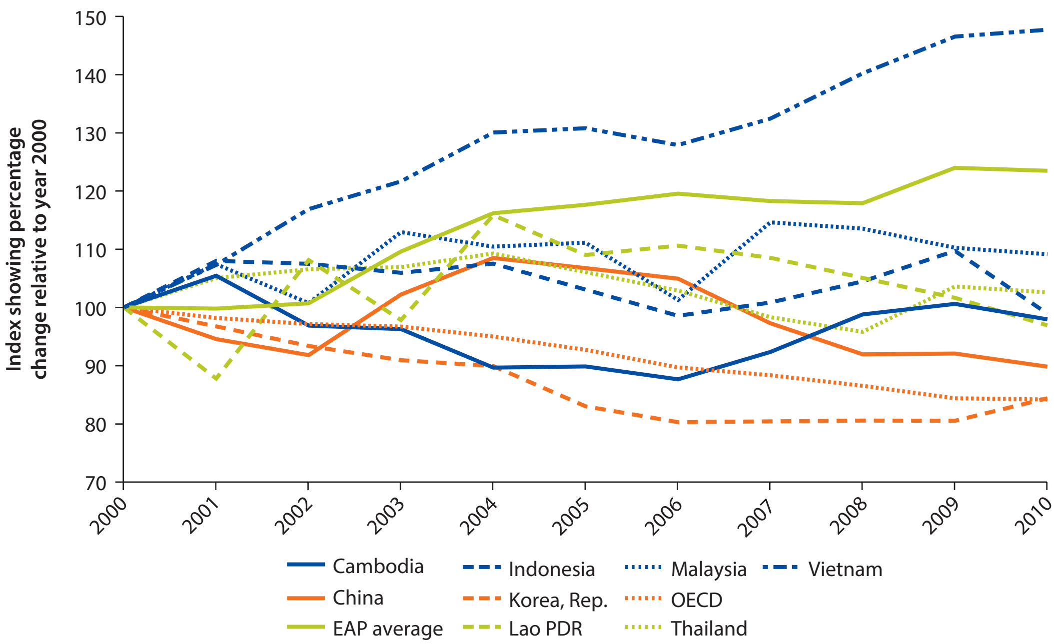
Over 2000–10 Vietnam achieved the fastest growth in CO_2 emissions in the region. Both Vietnam's total emissions and per capita emissions almost tripled in the 10-year period, while the carbon intensity of GDP increased by 48 percent. On all three measures, the increases observed in Vietnam were among the highest in the world—significantly higher than regional comparators such as Cambodia, China, Indonesia, Malaysia, the Philippines, and Thailand (figure 1.2).

Figure 1.2 Changes in Carbon Dioxide Emissions in Select Nations and Regions, 2000–10



Source: World Development Indicators.
Note: CO_2 = carbon dioxide; EAP = East Asia and Pacific; kg = kilogram; kt = kilotonne; OECD = Organisation for Economic Co-operation and Development; PDR = People's Democratic Republic.

Figure 1.3 Vietnam's Change in CO_2 Emissions per GDP Compared with Select Nations and Regions, 2000–10



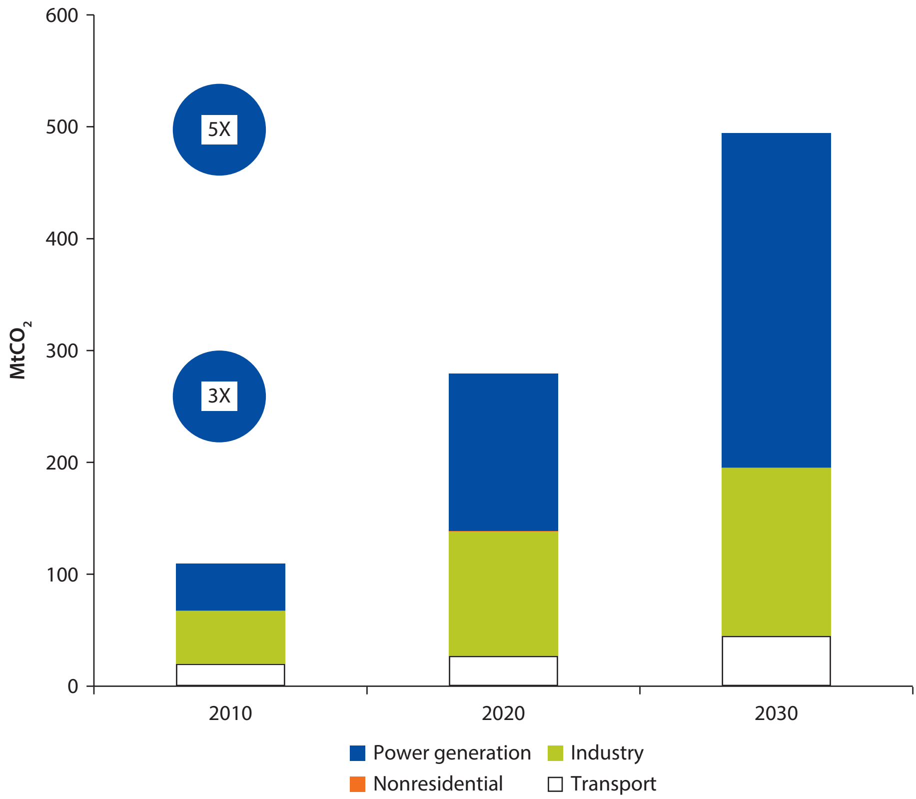
Source: World Development Indicators.
Note: On y axis the year 2000 = 100. EAP = East Asia and the Pacific; GDP = gross domestic product; OECD = Organisation for Economic Co-operation and Development; PDR = People's Democratic Republic.

Of particular importance is the increasing carbon intensity of Vietnam's GDP, which is now the second highest in the region after China. Furthermore, while the carbon intensity of China's GDP is on a declining trend (having fallen by 10 percent in 2000–10), the figure for Vietnam is still increasing (figure 1.3). Vietnam started the decade from a relatively low base, but at current rates of growth it will soon become one of the major emitters of CO_2 in the region.

Business as Usual versus Low-Carbon Development

Under the BAU scenario[2] Vietnam's emissions are expected to increase dramatically by 2030. Vietnam's overall emissions will increase fivefold (figure 1.4), per capita emissions fourfold, and the carbon intensity of GDP by 20 percent between 2010 and 2030. While CO_2 emissions from industry and transport are expected to increase by a factor of 2.8 between 2010 and 2030, CO_2 emissions from the power sector will increase by a factor of 9.9, driven primarily by growth in the use of coal for power generation and a decrease in the power generation mix from hydro. The share of coal in the power generation mix is expected to triple from 17 percent in 2010 to 58 percent in 2030. The share of hydro, by contrast, is projected to fall from 30 percent in 2010

Figure 1.4 Carbon Dioxide Emissions under the Business-as-Usual Scenario



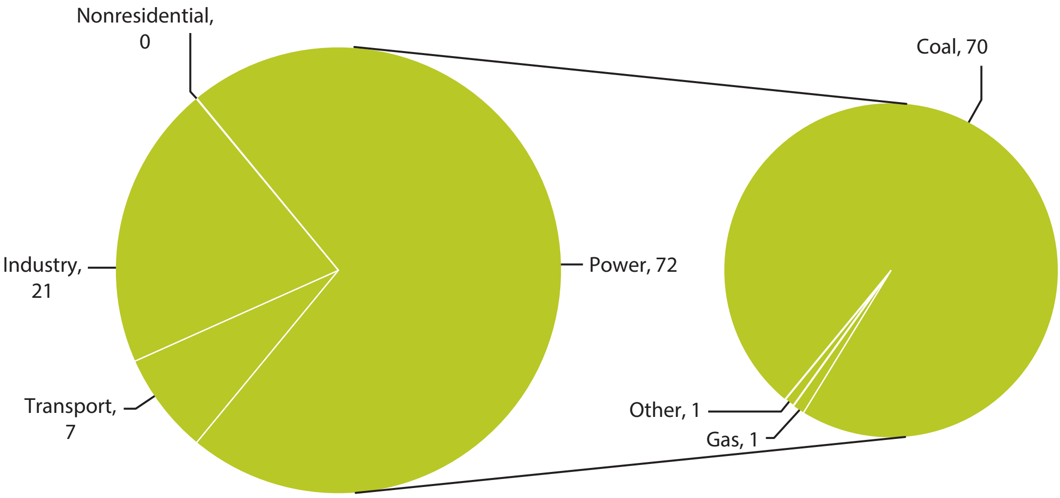
Source: World Bank estimates.
Note: CAGR percentages correspond to the type of emissions, for example, 8% = annual growth rate of total CO_2 emissions over the period 2010–2030 and 10% = annual growth of emissions from power generation over the same period. CAGR = compound annual growth rate; $MtCO_2$ = million tons of carbon dioxide.

to 18 percent in 2030. The increased use of coal for power generation is expected to account for two-thirds of the increase in Vietnam's overall CO_2 emissions over the 2010–30 period.

Changes to the power generation mix are expected to occur even as Vietnam turns into a net energy importer (figure 1.5). Under the BAU scenario, the ratio of imported coal to the total coal demand for power generation is expected to increase rapidly, from 12.7 percent in 2019 to 78.3 percent in 2030. The price of imported coal is likely to be highly volatile, and imported coal will cost power generators at least twice as much as domestic coal. Reducing energy supply diversity and increasing import dependence is likely to have adverse implications for Vietnam's energy security and also, as discussed in chapter 6, to contribute to rising electricity generation costs.

Vietnam is highly vulnerable to the impacts of climate change, which makes addressing this global concern a matter of national interest. As mentioned earlier, because of rapid economic expansion and Vietnam's reliance on a traditional

Figure 1.5 Share of Increase in CO_2 Emissions under BAU Scenario, 2010–30
Percent



Source: World Bank estimates.
Note: BAU = business as usual; CO_2 = carbon dioxide.

model of development, Vietnam's emissions increased at a high rate over 2000–10 and are projected to increase dramatically in the next two decades under the BAU scenario. Although Vietnam is starting from a low base in CO_2 emissions, it is on course to become one of the largest contributors to CO_2 emissions in the region. By pursuing LCD, Vietnam can help limit a rise in global average surface temperatures to 2°C.

The approval of the National Climate Change Strategy (NCCS) in 2011 and the VGGS in 2012 underscores the Government of Vietnam's (GoV's) commitment to LCD. The NCCS and VGGS aim to establish a clear structure and identify specific tasks to be accomplished to achieve LCD objectives. The VGGS in particular establishes renewable energy and energy efficiency as important elements of sustainable development. The VGGS proposes more efficient use of natural capital, reduction of CO_2 emissions, and an improvement in environmental quality. The Green Growth Action Plan (GGAP), developed in 2013 and approved in March 2014 to implement the VGGS, categorizes activities into four main areas: (i) awareness raising; (ii) institutional improvement; (iii) economic restructuring in sectors, localities, and enterprises; and (iv) technology innovation. The GGAP further divides a total of 66 activities into 12 groups. The priority activities for 2013–15 include organizing the Inter-ministerial Coordinating Board for the VGGS, completing an institutional framework to enhance the economic restructuring process in accordance with the VGGS, and formulating a green growth financial-policy framework.

Furthermore, there is growing evidence that growth and a clean environment can be realized not only simultaneously, but may also be mutually reinforcing. The experience of Japan shows that stringent environmental policies do not interfere with economic growth. In fact, they may even catalyze growth (World Bank and Development Research Center 2012). There is support for this proposition from new literature (for example, Acemoglu and others 2014; Jaeger and others 2011), which suggests that it is possible to significantly reduce emissions without reducing long-term growth. Health risks and other related damage associated with coal combustion would also economically justify cleaner power supply alternatives. By contrast, a strategy of "grow now and clean up later" can be counterproductive. Even after discounting future costs and benefits, it is more economical to reduce or prevent pollution at an early stage of growth than to incur higher clean-up costs at later stages. Acting early to avoid investment in technology and infrastructure that will "lock in" carbon-intensive economic structures is particularly important for developing countries such as Vietnam, which are still in the process of building much of their long-term infrastructure (Fay 2012).

This report provides a framework and supporting analysis to assess the targets and actions proposed in these government strategies. In particular the report carries out a comprehensive review of the targets in the VGGS and proposes a list of those actions that will yield the greatest CO_2 emissions reductions—and also net economic gains for Vietnam through lower energy and input costs.

The report argues that LCD offers an opportunity for sustained growth in Vietnam. As presented in chapter 6, a computer-generated equilibrium (CGE) model analysis undertaken by the Central Institute for Economic Management (CIEM) for this study suggests that the LCD scenario could have short-term implications for economic growth but would not alter the economy's long-term growth trend. Meanwhile, low-carbon investments generate positive externalities to other sectors of the economy and contribute to value added and employment. The LCD scenario is seen to accelerate the development of the service sector in Vietnam, leading to a shift to greener sectors of the economy. This is a common feature found in emerging economies, in which LCD can end up being more an economic opportunity than a cost.

According to study estimates, the implementation of industrial energy-efficiency measures could generate $10 billion in financial savings by 2030 compared with BAU. Implementation of fuel-saving measures in the transport sector could provide another $22 billion. Altogether, the potential for direct savings through efficiency gains in Vietnam is expected to be at least $55 billion over the period 2014–30, if the full technical and economic potential of these no-regret options can be realized. Similarly, there are many other options that have very low marginal abatement costs (MACs) and promise large CO_2 emissions reductions. Such options include (i) increased use of gas in the power sector, (ii) use of more efficient coal-combustion technology, and (iii) renewable energy. In addition to the direct benefits, implementation of low-carbon policy and investment options will also bring additional "cobenefits" to the economy by improving local air quality and thus reducing the health impacts of air pollution. According to the estimates of this study, the value of these cobenefits in the power sector over the life of Vietnam's power plants is estimated to be $48 billion—on top of the direct savings of $55 billion—by 2030.

Notes

1. Factor accumulation refers to the basic factors used to produce goods and services in the economy: labor, capital, and land.
2. See "Methodology: The BAU and LCD Scenarios" in chapter 2 for the description of the BAU scenario in this study.

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CHAPTER 2

Low-Carbon Development Scenario

Overview

- Vietnam's Green Growth Strategy (VGGS) sets an ambitious but realistically achievable goal to reduce carbon dioxide (CO_2) emissions by 20 percent compared with the business-as-usual (BAU) scenario by 2030. Low-carbon development (LCD) options assessed in this study show that it is possible for Vietnam to cut back its annual emissions by 7.5 percent by 2020—and 10.6 percent by 2021 (compared with the BAU scenario). This represents a year's delay in meeting the VGGS target of a 10 percent reduction by 2020 but exceeds the target of a 20 percent reduction by 2030.

- Achieving LCD will require an aggressive, all-encompassing drive to implement numerous measures across several sectors (electricity demand in industry and residential sectors, fuel demand in industry and transport, electricity generation, and supply of transport services). Analysis of the marginal abatement cost (MAC) demonstrates the economic viability of a wide range of options that would allow emissions to be reduced beyond the VGGS targets.

- By 2030, CO_2 emissions in the LCD scenario would be 28 percent below the level reached in the BAU scenario.

- Emissions reductions are equally shared between demand-side and supply-side options. Most of the initial reduction is through efficiency improvement and energy conservation in the industry and residential sectors.

- Thirty percent of emissions reductions arise from end-use energy efficiency in household appliances and industry technologies. The resulting lower electricity demand helps lower power capacity requirement by an equivalent of 11.7 gigawatts (GW) during the modeling period. Other demand-side gains are found in fossil-fuel savings in the industry sector (21 percent of emissions reductions).

- The transport sector is responsible for 9 percent of emissions reductions. Supply-side changes in the electricity supply mix displace a total of 13.7 GW of coal capacity (9.8 GW of supercritical coal plants and 3.9 GW of subcritical coal plants).

- A low-carbon investment strategy is needed to switch from the BAU portfolio; the incremental investment required is a modest 1 percent of gross domestic product (GDP) during 2010–30. The incremental cost is projected to be $3 billion per year between 2010 and 2020, and estimated to decline to $1 billion per year during 2021–30.

Introduction

Low-cost energy and other natural resources have played a key role in driving the Vietnamese economy over the past decades. But current consumption and production patterns, accompanied by urbanization at an unprecedented pace, are placing enormous pressure on these resources. The resulting environmental deterioration could undermine human productivity and the quality of the resource base, and limit the country's future growth potential.[1]

Vietnam is also vulnerable to the multifaceted impacts of global climate change, and will be increasingly prone to environmental risks (MONRE 2010). Densely populated coastal cities are exposed to rising sea levels and intensifying tropical cyclones, while inland areas will have to cope with greater climate variability that results in droughts and floods (World Bank 2013). The rising temperature will increase economic burdens, ranging from health risks to higher electricity bills.

Vietnam is already convinced that development as usual has put the country on an unsustainable path. Green growth—a growth path that prioritizes long-term developmental and environmental sustainability—has emerged as a new and desirable economic model in Vietnam, and has moved into the mainstream of the country's policy discourse over the recent years. The VGGS recognizes that green growth is essential for the country's long-term economic development.[2]

The remainder of this chapter is organized as follows. "Methodology" provides a brief description of the methodology used. "Toward Low-Carbon Development" presents the LCD scenario—a possible low-carbon pathway for Vietnam developed in the process of this study—and compares it against BAU. It also analyzes technology and policy levers within the LCD scenario. "Achieving Green Growth Targets" evaluates the LCD scenario against the VGGS targets for CO_2 emissions reductions. "The Economics of Low-Carbon Development" discusses the economic implications of the LCD scenario, focusing on the cost-effectiveness of mitigation options, and overall investment requirements. The final section provides key recommendations. The analysis focuses on energy-related sectors including power generation, industry, transport, and residential sectors between 2010 and 2030.

Methodology: The BAU and LCD Scenarios

This study considers two development and emissions trajectories, namely the BAU and the LCD scenarios. The BAU scenario provides a reference path against which the LCD scenario is assessed in terms of greenhouse gas (GHG) mitigation and economic impacts. The BAU scenario estimates Vietnam's emissions, assuming the country makes no further investments or policy reforms beyond those already committed or approved by 2012. The LCD scenario encompasses a distinct set of actions that are consistent with the targets set in the VGGS.

The key drivers across both the BAU and the LCD scenarios are the following:

- *GDP growth per year:* 6.99 percent (2011–15), 7.05 percent (2016–20), and 7.18 percent (2021–30)—consistent with the low case demand projection of Power Development Plan VII (PDPVII)
- *Population growth per year:* 1 percent (2011–20) and 0.7 percent (2021–30) (ADB 2013; Dung and Sawdon 2012)
- *Urbanization rate per year:* from 25.5 percent of the total population in 2010 to 34.3 percent in 2020 and to 44.1 percent in 2030 (ADB 2013; Dung and Sawdon 2012)
- *Fuel prices:* at full cost-recovery levels by 2015, with distinct prices for domestic and imported fuels (as projected by the Institute of Energy Vietnam, IEVN)

An extensive consultation process concluded that these assumptions represent a plausible macro- and socioeconomic trajectory in Vietnam, considering historical and current trends (see appendix E for specific data on these assumptions).

Both scenarios are for the time period 2010–30, matching the time horizon of the concrete targets for the energy sector stipulated in the VGGS. The CO_2 accounting/modeling framework covers energy-related sectors that include power generation, transport (electricity and fuel consumption in road, rail, and water-borne transport),[3] industry (electricity and fuel consumption in iron and steel, cement, fertilizer, pulp and paper, and refinery), generic analysis of electric use by "all other" industries, residential (electricity consumption from lighting and the use of appliances), and nonresidential (use of electricity and liquefied petroleum gas).

The Business-as-Usual Scenario

The development of the BAU scenario for the power generation sector involves the following four basic steps:

1. An inventory of the installed capacity and the actual electricity generation in 2010, calibrated at the plant level to the National Load Dispatch Center (NLDC) report, which was published by Electricity Vietnam (EVN) in 2010.

2. The addition of planned capacity between 2011 and 2030, based on the plant-level capacity expansion plan provided in the PDPVII, which defines the supply response to the base case demand projection.
3. The reduction of planned capacity additions from the PDPVII base case to the low case demand projection, representing this study's BAU scenario. The capacity reduction is guided by the least-cost approach, which prioritizes those technology options with lower levelized costs of energy (LCOEs). This study also assumes that investment decisions to adopt the low demand case begin in 2013, and assumes construction periods (four years for coal, 2.5 years for gas, and two years for wind) for those plants that are already committed. All electricity import is assumed to be hydro, while plant retirements follow the IEVN's's identifications.
4. The development of electricity generation and dispatch profile are in accordance with the generation mix in PDPVII, taking into account take-or-pay arrangements in domestic gas supply, and the domestic coal and gas production constraints following the projections from Vinacomin.

The demands from end-use sectors are primarily driven by the macro- and socioeconomic assumptions described above. The transport sector's BAU scenario is developed by the Transport Development Strategy Institute (TDSI) and includes projects currently in development, while the BAU construction for the industry's sector is undertaken by the IEVN according to sectoral master plans. The modeling of the ownership of appliances and private motor vehicles is built on the household-level econometric analysis of the Vietnam Household Living Standards Survey (VHLSS), published in 2010.

The Low-Carbon Development Scenario

The LCD scenario analyzes low-carbon options that are considered technically and economically feasible for Vietnam.[4] As many as 66 specific low-carbon measures are selected from the various sectors and are included in the LCD scenario modeling. Beyond the 66 options, the scenario also includes electricity savings due to generic energy-efficiency improvements in "all other" industry subsectors (assuming 1 percent improvement per year based on international experience) and for other household appliances that are not explicitly evaluated.[5]

MAC analysis is conducted for 68 measures (see appendix B for a full list), including the abovementioned 66 specific options, electricity savings due to generic energy-efficiency improvements in other industry subsectors, and supercritical coal-fired power generation. Note that the LCD scenario does not include the supercritical coal option, as investments in this technology are considered part of the BAU scenario. In the LCD scenario supercritical coal is among the coal-combustion technologies to be possibly replaced by other, cleaner options.

The development of the LCD scenario for the power sector begins with cost-effective, demand-side measures that reduce generation requirements starting in 2015. The displacement of planned coal plant additions begins in 2021, allowing time for energy-efficiency improvements to displace new plant additions and for needed renewable-energy plant location and grid integration studies. This translates into the following analytical steps:

1. The reduction of the planned capacity addition from the power sectors' BAU to match the lower level of electricity demand resulting from end-use efficiency measures implemented in the industry and the residential sectors (net of electricity demand increase from greater penetration of electric bicycles, or e-bikes, in the transport sector). This intermediate step is referred to as the EE$10 Scenario.[6] Again, this is based on the least-cost approach using the LCOE as a guiding indicator, and takes into account construction lead times for different plant types.
2. The next step to complete the LCD scenario is the displacement of some planned coal-fired capacity (both subcritical coal plants using domestic anthracite and supercritical coal plants using imported bituminous coal) remaining from the preceding step in the 2021–30 period.
3. The addition of cleaner capacity from biomass, nuclear, combined-cycle gas turbines (CGGTs) using imported liquefied natural gas (LNG), and CCGTs paired with solar photovoltaic (PV), wind, and hydro, to generate the equivalent of the coal-based electricity displaced.

All modeling and analysis are performed by the World Bank team, with inputs from the Central Institute for Economic Management or CIEM (macroeconomic assumptions and analysis), TDSI (data for transport sector), IEVN (data for the five industries, household, and power sectors), and Ernst and Young (data on energy efficiency and MAC calculations for industry and household sectors). The World Bank team closely cooperated with the Asian Development Bank (ADB) and the United Nations Development Programme (UNDP) to harmonize assumptions and baseline datasets.

Similar analytical exercises have been undertaken. These include, for example, the analysis undertaken by the Ministry of Natural Resources and Environment or MONRE (2010) as part of Vietnam's National Communications to the United Nations Framework Convention on Climate Change; an ADB (2013) Technical Working Paper on GHG Emissions, Scenarios, and Mitigation Potentials in the Energy and Transport Sectors of Vietnam (draft); and the UNDP-MPI (2012) Background Analysis of Marginal Abatement Costs for the Green Growth Strategy (unpublished). A comparative analysis between these and the World Bank's study suggests (i) a divergence of results in terms of mitigation potential, largely explained by the difference in scope of analysis and assumptions in critical parameters (such as discount rates), that does not mask a broad convergence of results—pointing to a consistent set of low-carbon actions—and (ii) the complementarity of the studies, which can be viewed as sensitivity analyses of one another. A snapshot of the key features and outcomes of the three studies is provided in table 2.1.

Table 2.1 Comparisons across Vietnam's Recent Low-Carbon Studies

Study	*Coverage*	*Model*	*CO_2 Emissions in 2010 ($MtCO_2$)*	*CO_2 Emissions in 2030 under BAU($MtCO_2$)*	*Mitigation potential during 2010–30 ($MtCO_2$)*	*Number of low-carbon options analyzed*	*Reaching VGGS target in 2030*
MONRE (2010)	Energy end use in transport, industry, agriculture, residential, and commercial + energy production	LEAP	113	471	192	15	Unlikely
ADB (2013)	Energy end use in transport, industry, agriculture, residential, and commercial + power generation and energy transformation	LEAP & EFFECT	~150	~640	1,200	35	Likely
UNDP-MPI (2012)	Energy end use and power generation	MACC Builder Pro + IPCC guidelines	129	615	227	35	Unlikely
World Bank (2014)	Energy end use in transport, industry, residential, and commercial + power generation	EFFECT	110	495	845	66 + additional energy-efficiency improvements	Likely

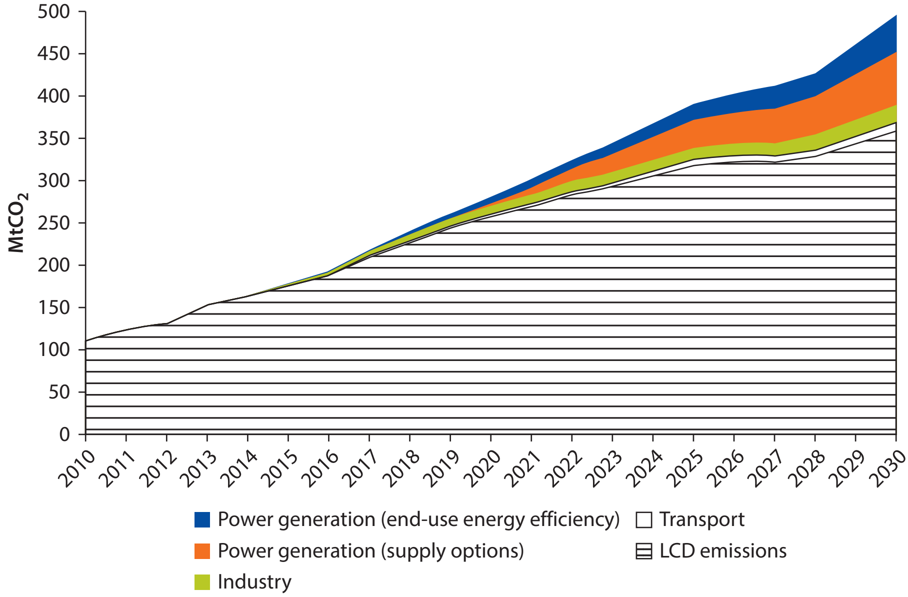
Source: ADB (Asian Development Bank) 2013; MONRE (Ministry of Natural Resources and Environment (MONRE) 2010; UNDP (United Nations Development Programme)–MPI (Migration Policy Institute) 2012; World Bank 2014. MONRE (2010) and UNDP-MPI (2012) also cover GHG emissions in agriculture and land use, land-use change, and forestry sectors. But results from only the energy sector are used here for comparison across the studies.
Note: BAU = business as usual; CO_2 = carbon dioxide; EFFECT = Energy Forecasting Framework and Emissions Consensus Tool; IPCC = Intergovernmental Panel on Climate Change; LEAP = Low-range Energy Alternatives Planning system; MACC = marginal abatement cost curve; $MtCO_2$ = million tons of carbon dioxide; VGGS = Vietnam Green Growth Strategy.

Toward Low-Carbon Development

Vietnam's CO_2 emissions will increase 4.5-fold under the BAU scenario during 2010–30. The CO_2 emissions from the largest emitting sectors of energy, industry, and transport are calculated to be 110 million tons of carbon dioxide ($MtCO_2$) in 2010. These include emissions from (i) electricity generation; (ii) energy use in road, rail, and water transport; (iii) energy use and process emissions in the industry sector; and (iv) energy use in the nonresidential sector. Those emissions under the BAU are projected to rise to 279 $MtCO_2$ in 2020, and reach 495 $MtCO_2$ in 2030—4.5 times the emissions in 2010. In transitioning to an LCD scenario, a range of emissions-reduction measures is evaluated. This study focuses on low-carbon options (LCOs) that are technically and economically feasible today for Vietnam.

A number of economically viable options are available to help Vietnam transform its usual practices into a low-carbon investment strategy. Figure 2.1 shows

Figure 2.1 CO_2 Emissions: Business as Usual vs. Low-Carbon Strategy, 2010–30

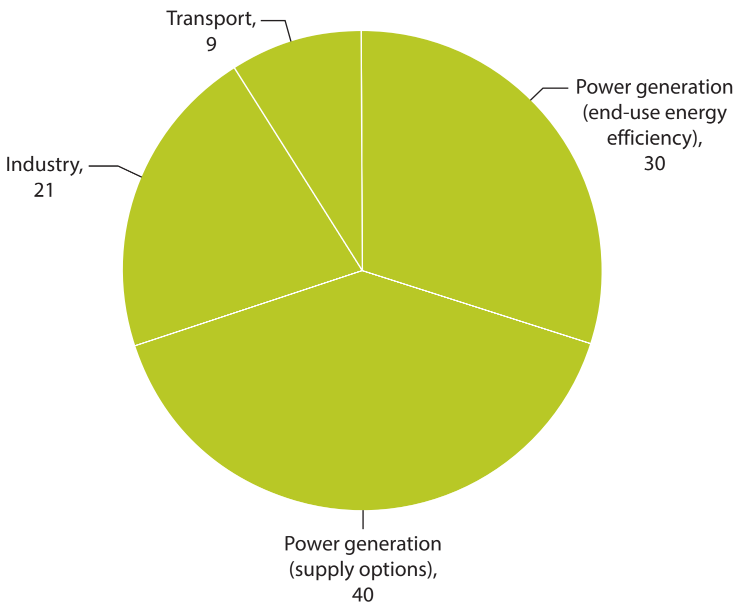


Source: World Bank estimates.
Note: The upper contour represents total BAU emissions, while the areas between the BAU emissions and LCD emissions show emissions reduction wedges. BAU = business as usual; LCD = low-carbon development; $MtCO_2$ = million tons of carbon dioxide.

CO_2 mitigation potential in the power generation, industry, and transport sectors. The reduction potential in the power sector is a result of (i) energy-efficiency improvements in electrical appliances in the residential sector, (ii) electricity savings from industrial energy-efficiency measures, and (iii) fuel switching in electricity generation, from coal to natural gas, nuclear, and renewable energy sources including hydropower, wind, solar, and biomass. Although the modeling base year is 2010, the LCD scenario assumes that policy and investment decisions to move from BAU to LCD will happen in 2015, taking into account lead time and prior commitment to infrastructure development and plant construction. Further sector-specific details and assumptions associated with individual mitigation options are provided in respective sections of this report.

The impacts of low-carbon investments will grow over time, with cumulative emissions reductions amounting to 845 $MtCO_2$ by 2030.[7] Under the LCD scenario Vietnam's annual CO_2 emissions are projected at 258 $MtCO_2$ in 2020 (a 7.5 percent reduction relative to the BAU scenario), and at 358 $MtCO_2$ in 2030 (a 27.7 percent reduction). In cumulative terms, total CO_2 mitigation for the sectors under consideration amounts to 845 $MtCO_2$ between 2010 and 2030, with over two-thirds of the overall reduction coming from the power generation sector (figure 2.2).[8] CO_2 reductions from the transport and industry sectors constitute about 30 percent of the total reduction—that is, 253 $MtCO_2$

Figure 2.2 Share of Cumulative Emissions Reductions: LCD Scenario, 2010–30
Percent



Source: World Bank estimates.
Note: LCD = low-carbon development.

avoided during 2010–30—and are more than double the amount of CO_2 emitted over the entire year in 2010.

Both demand- and supply-side measures are key elements of the LCD scenario. Electricity savings from demand-side measures in the end-use sectors and supply-side clean technology options are estimated to result in the abatement of 592 $MtCO_2$ by 2030. Energy-efficiency improvements in industry and household sectors (that reduce electricity demand) alone would help lower the power capacity requirement of 11.7 GW during the modeling period. Consequently, the demand-side energy-efficiency measures mitigate 251 $MtCO_2$ by 2030—42 percent of total emissions reductions from electricity generation.

Natural gas and renewable energy together play a critical role. Supply-side options contribute another 58 percent of total emissions reductions within the electricity generation sector (341 $MtCO_2$) by 2030. These options include replacing subcritical coal-fired power plants (using domestic anthracite) and supercritical coal-fired power plants (using imported bituminous coal) with biomass, nuclear, and CCGTs using imported LNG alone and then pairing with solar PV, wind, and hydro. All supply-side options displace the total of 13.7 GW of coal capacity (9.8 GW of supercritical coal plants, and 3.9 GW of subcritical coal plants). Table 2.2 compares the power capacity mix of the BAU and LCD scenarios developed in this study and data from the PDPVII Prime Minister's Decision document.

Table 2.2 Installed Capacity Mix in BAU, LCD, and PDPVII Base, 2020 and 2030
Percentage share

	2020			*2030*		
	BAU	*LCD*	*PDP7 Base*	*BAU*	*LCD*	*PDP7 Base*
Coal	46	44	47	62	42	49
Natural Gas	16	17	16	8	18	11
Hydroelectricity	32	33	25	20	21	15
Nuclear	2	2	1	8	9	6
Renewable	3	3	5	1	9	9

Source: World Bank estimates based on PDPVII PM Decision (July 2011).
Note: All numbers are percentage shares. Includes domestic grid capacity, and excludes captives and import. BAU = business as usual; LCD = low-carbon development; PDPVII = Power Development Plan VII.

Achieving Green Growth Targets

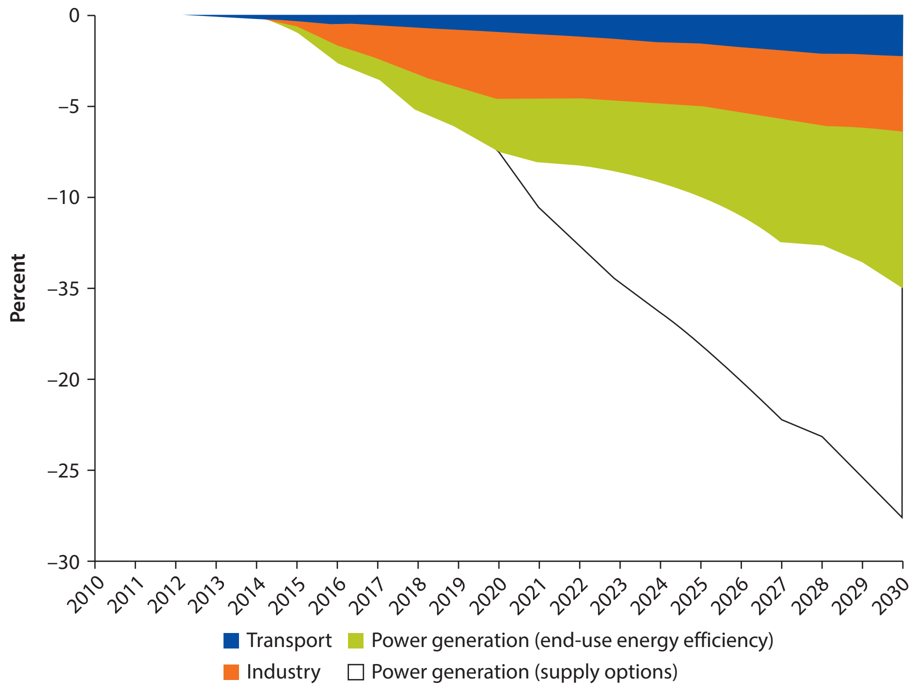
The VGGS aims to (i) reduce GHG emissions from energy activities by 10 to 20 percent compared with the BAU case during the 2011–20 period and (ii) reduce the same by 20 to 30 percent compared with the BAU by 2030. The lower targets are formulated as Vietnam's voluntary reduction, but levels of effort beyond these will require additional international support. Because the targets are tied to BAU, the absolute emissions reductions necessary to achieve the VGGS targets depend critically on how the BAU's emissions level is officially developed. The VGGS document does not establish the BAU's emissions levels, nor does it specify how the BAU scenario would be updated over time.

The VGGS sets ambitious but realistically achievable goals. This study illustrates a way in which Vietnam could transition to an LCD path that is consistent with the emissions-reduction targets envisaged in the VGGS. Figure 2.3 shows that the LCD scenario developed under this study would help Vietnam cut back its annual emissions by 7.5 percent by 2020, and 10.6 percent by 2021—a year's delay in meeting the VGGS 2020 targets. Most of the initial reduction would be realized through efficiency improvements and energy conservation in the industry and residential sectors. Efforts to switch from coal to cleaner fuels in electricity generation would significantly accelerate Vietnam's CO_2 mitigation after 2020. Annual emissions reductions would hit the 20 percent target by 2026, and reach 27.7 percent compared with the BAU scenario in 2030.

The LCD scenario is projected to mitigate 845 $MtCO_2$ between 2011 and 2030, with 62 $MtCO_2$ saved during 2011–20 (3.2 percent of cumulative BAU emissions) and 761 $MtCO_2$ saved during 2021–30 (19.4 percent of cumulative BAU emissions).[9] Such results depend on the implementation schedule of the mitigation options, and should be updated and revisited as VGGS efforts progress. All in all, this study demonstrates that the objectives (pertaining to emissions reductions from energy activities) set out in the VGGS are realistically achievable.

The carbon intensity of the Vietnamese economy and per capita emissions will improve significantly with the LCD measures. Low-carbon growth

Figure 2.3 Emissions Reductions under LCD Scenario, 2010–30, Relative to BAU

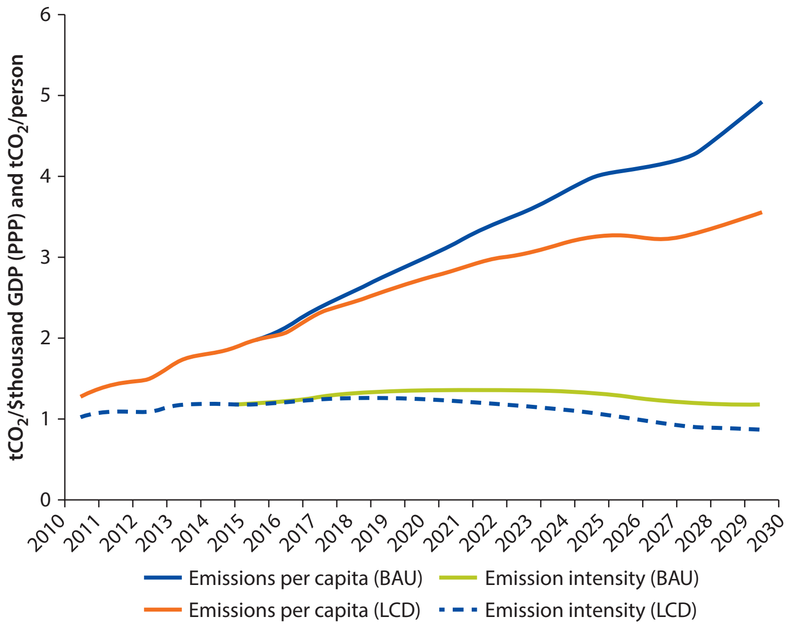


Source: World Bank estimates.
Note: BAU = business as usual; LCD = low-carbon development.

performance can be assessed through various dimensions. Measured on a per capita basis, the LCD scenario is projected to substantially improve Vietnam's carbon footprint per capita, without jeopardizing people's energy access and use. The CO_2 emissions under the LCD scenario would be 0.22 and 1.36 tons per person lower than those under the BAU scenario, in 2020 and 2030, respectively (figure 2.4). The CO_2 emissions per unit of GDP under the BAU scenario are projected to increase slightly and peak at approximately 1.36 tCO_2 per thousand GDP (at purchasing power parity) by 2022. Beyond this point, CO_2 intensity would drop to around 1.19 tCO_2 per thousand GDP by 2030. As expected, CO_2 intensity is lower under the LCD scenario, peaking earlier than under the BAU scenario at 1.26 tCO_2 per thousand GDP in 2019, then declining 0.86 tCO_2 per thousand GDP in 2030.

Energy pricing reforms and efforts to remove fossil-fuel subsidies are gaining momentum in Vietnam and have potentially significant environmental benefits. This is evident in the plan to move to cost-recovery electricity pricing in the PDPVII, as well as in the road map to market-based pricing in the coal sector (resolution number 10/11/QH13). In fact, the price transition is already under way, and coal prices and electricity tariffs have been increasing in recent years (announcement 244/TB/VPVP and Prime Minister's Decision 24).

Figure 2.4 Emissions Intensity and Emissions per Capita, 2010–30, BAU vs. LCD Scenarios



Source: World Bank estimates.
Note: tCO_2/$thousand GDP (PPP), tCO_2/person. BAU = business as usual; GDP = gross domestic product; LCD = low-carbon development; PPP = purchasing power parity; tCO_2 = tons of carbon dioxide.

In the context of the VGGS, it is important that Vietnam establish a mechanism to evaluate how such policies perform and to track the resulting emissions reductions over time.[10]

Per unit electricity costs under the LCD scenario are projected to be slightly higher than those in the BAU scenario, as discussed in detail in chapter 6. Although any prediction of the impact is highly uncertain, historical observation suggests that consumers would likely respond to the higher electricity prices by curbing their electricity demand.[11] Based on a conservative estimate of the price elasticity of electricity demand, the higher prices would reduce electricity demand in 2030 by about 2,850 gigawatt-hours (GWh) (1 percent) relative to the LCD demand. Assuming the median elasticity estimate, demand reduction in 2030 would be approximately 9,930 GWh (2 percent).[12] This reduction in electricity demand would have a meaningful impact on CO_2 emissions, ranging from 2.3 $MtCO_2$ to 8.1 $MtCO_2$ in 2030 alone.[13]

The Economics of Low-Carbon Development

What does it take to restructure the economy as envisaged in the VGGS? Taming the growth of CO_2 emissions requires a comprehensive policy package that provides the right incentives, removes barriers and market failures, and generates substantial investment by both public and private sectors in green infrastructure and technologies. It is also important to steer the low-carbon transformation in an economically efficient manner by exploiting cost-effective solutions today.

Despite its limitations and inherent uncertainty,[14] the marginal abatement cost curve (MACC) offers an overview of the cost and abatement potential of a set of mitigation options across relevant sectors. It should be noted that while the MACCs rank emissions reductions from the cheapest to the most expensive, they are not prescriptive of any particular implementation schedule.[15] Sixty-eight mitigation measures are evaluated in this study, and may be useful to the policy dialogue and consensus-building process.[16]

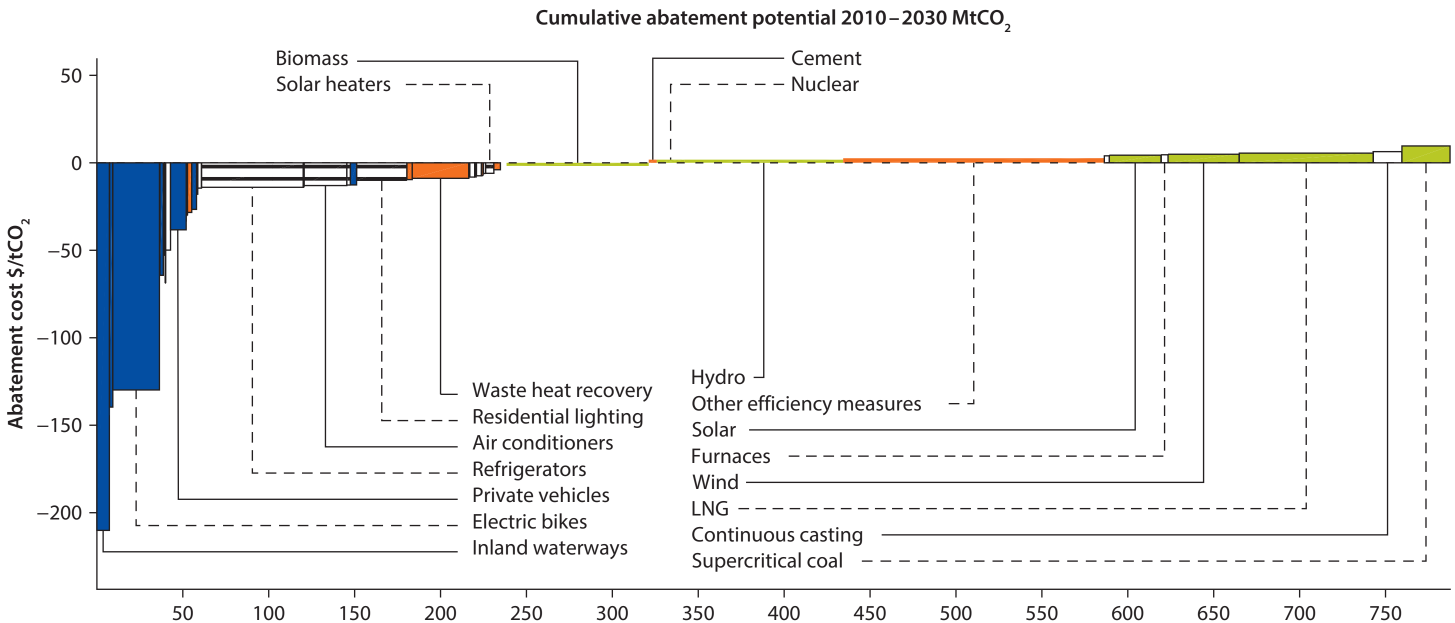
Figure 2.5 presents Vietnam's MACC during 2010–30.[17] The mitigation potential is presented as a sum of annual emissions reductions over a certain period. Potential power supply options are measured throughout the lifetime of power plants; options in the end-use sectors are measured up to 2030 and are based on assumed penetration rates for the cleaner technologies considered. For the latter, the total mitigation potential over the lifetime would be much larger, as many of these investments have lifetimes that extend beyond the modeling time horizon.

About 40 percent of the total mitigation potential during 2010–30 is "win-win" with net negative costs. The MAC analysis shows that 40 percent of the cumulative mitigation potential not only reduces CO_2 emissions but also results in net cost and energy savings. These win-win options are in end-use sectors such as industry, transport, and residential buildings. Another 58 percent of total MAC potential has incremental costs lower than \$10/tCO_2e (tons of carbon dioxide equivalent), indicating their economic viability given the general trend of the international carbon market.[18]

As Vietnam's economy continues to grow significantly over the 2010–30 period, substantial capital investments are required in both the BAU and the LCD scenarios. But the investment profiles differ significantly between the two. Table 2.3 lists the total capital costs associated with BAU and specific MAC options, as evaluated in this study. Costs are concentrated in the power generation and transport sectors. For power generation, capital costs include investment in the construction of new power plants and the renovation of existing plants; in transport, costs include capital expenditure on new vehicles or vessels and rail or metro infrastructure (the latter constituting investment of around 10 percent of the transport total). Total capital costs during 2021–30 are nearly double those of 2010–20 in both the BAU and the LCD case; cumulative costs throughout the modeling period exceed \$700 billion.

The additional cost of moving from the BAU to the LCD scenario is estimated at \$2 billion per year on average during 2010–30—approximately 1 percent of the projected annual GDP. The incremental cost is projected to be \$3 billion per year between 2010 and 2020, declining to \$1 billion per year during 2021–30. The change of investment profile from the BAU to LCD would avoid 804 MtCO_2 over the 20-year period (95 percent of the total reduction potential under the LCD scenario). Although there are positive MACs associated with

Figure 2.5 Vietnam's Marginal Abatement Cost Curve, 2010–30



Source: World Bank estimates.

Note: The figure depicts marginal abatement costs (MACs) and potential emissions reduction up to \$10/tCO_2 for visualization purposes. The entire range of MACs (with those over \$10/tCO_2) can be found in appendix B. Because of limited space, the option legends do not show all the mitigation options analyzed. LNG = liquefied natural gas.

MAC is defined as the ratio of the difference between the costs of the low carbon and baseline option (in present values) to the difference between the emissions from the low carbon and baseline option. Costs include capital expenditures (CAPEX), operating and maintenance expenditures (OMEX), and fuel expenses (FUELEX). All costs are expressed in 2010 U.S. dollars and discounted using a social discount rate of 10 percent. Emissions in power supply options are measured through the lifetime of power plants. Emissions associated with options in end-use sectors are measured up to 2030 on the basis of assumed penetration rates of the cleaner technologies.

MtCO_2 = million tons of carbon dioxide.

Table 2.3 Total Investment in the BAU and LCD Scenarios, 2010–30

2010 $ billion	*2010–20*	*2021–30*	*2010–30*
BAU			
Power generation	69	98	166
Transport	187	370	556
Industry	0	0	0.09
Residential	6	13	20
Total	262	480	742
LCD			
Power generation	67	91	158
Transport	190	382	571
Industry	1	3	4
Residential	7	14	21
Total	264	490	754
Incremental cost			
Subtotal*	2	9	12
All other industry**	33	4	37
Total	35	14	49
Average annual	3	1	2
% of projected GDP	2.1	0.4	1.0

Source: World Bank estimates.
Note: The costs in this table represent economic capital costs and are not discounted. Metropolitan transport, or metro, is excluded from the marginal abatement cost (MAC) (figure 2.5) because it does not yield net emissions reduction within the 2030 time horizon. But metro is included in table 2.3 because its investment under the BAU and LCD scenarios is made during 2010–30 with significant mitigation impacts expected beyond 2030. In industry the cost includes capital costs of low-carbon technologies and equipment only and does not include construction of new industrial plants; it includes all MAC options evaluated in this study in iron and steel, cement, fertilizer, pulp and paper, and refinery; the cost under BAU reflects indigenous efficiency improvement only. In residential, the cost includes capital costs of new appliances and includes all (five) MAC options evaluated in this study and excludes the generic energy-efficiency improvement assumed in the overall LCD scenario for other appliances.
* Subtotal incremental cost includes power generation, transport, industry (MAC options only), and residential sectors; ** "All other" industry represents incremental costs associated with the generic energy-efficiency improvement of 1 percent per year assumed in the overall LCD scenario beyond the industries (iron and steel, cement, fertilizer, pulp and paper, and refinery) whose MAC options are specifically evaluated.
BAU = business as usual; GDP = gross domestic product; LCD = low-carbon development.

switching to new technologies in the power generation sector, the LCD scenario lowers costs (that is, it yields net negative incremental costs) in the sector through significant energy savings from end-use sectors and thus lower capacity requirements.

The VGGS, together with the National Action Plan on Green Growth, provides a crucial first step. But more aggressive efforts beyond the VGGS are likely needed to put Vietnam on a low-carbon and sustainable development pathway in the long term. Substantial investment will be required not only to improve efficiency and reduce emissions but also to make those investments resilient and robust against future climate risks. A synergy between public and private financial flows is essential for the magnitude of investment requirements: the key is to use limited public sector funds, incentive frameworks, and price signals to leverage private capital.

Over the next 20 years and beyond, the cities throughout Vietnam are expected to expand tremendously. As millions of Vietnamese switch to an urban lifestyle and seek the convenience and comfort of modern modes of transport for better connectivity, the number of motor vehicles is expected to grow rapidly. The country will continue to build new power and industrial plants, new infrastructure, and new commercial and residential buildings. The window of opportunity is limited: immediate action is needed to capture the full potential of clean technologies, and to avoid inefficient infrastructure lock-ins.

Key Recommendations

- Build consensus on the definition of Vietnam's BAU scenario at the national and sectoral levels, and develop guidelines and institutional processes for the periodic update of the BAU scenario for national and international purposes.
- Building on the National Action Plan on Green Growth, conduct a comprehensive policy and technological mapping across sectors; revisit sector master plans and recommend revisions on additional actions and investment required to meet VGGS targets.
- Consider market, economic, and fiscal instruments to support low-carbon investments and provide the right incentives for private sector actions. This in turn requires the proposal of various policy designs and in-depth analysis of their impacts, trade-offs, and interactions with other measures and policy options.
- Develop a national-scale measurement, reporting, and verification (MRV) system to track the progress of LCD policies and to account for emissions reductions associated with the VGGS targets and beyond. Such an MRV system should provide a common framework for project-, program-, and policy-level mitigation activities, and be coordinated with the national GHG inventory.

Notes

1. http://www.worldbank.org/vn/environment.
2. Vietnam National Green Growth Strategy (Prime Minister's Decision No. 1393/QD-TTg, September 25, 2012, Hanoi).
3. International transport is not included.
4. The study initially used $10/t$CO_2$ as a screening threshold for the selection of low-carbon measures to be included in the MAC analysis. But the analysis later suggests that the level of emission reductions in line with the VGGS target could be reached with a much lower MAC.
5. Preliminary assessment suggests that such energy-efficiency improvements in Vietnam involve reasonable MACs (less than $3/t$CO_2$).
6. EE$10 represents the scenario that includes electric demand saving measures with the MAC of up to $10/t$CO_2$.
7. This study evaluated an extensive set of low carbon options. Effective pursuit of all possible low carbon options may produce a reduction of 845 MtCO_2. The Government

of Vietnam may wish to select a subset of low carbon options that produce the most significant reductions with the greatest likelihood of success. One illustrative subset of 31 low carbon options could produce 751 $MtCO_2$ reduction and yield a net benefit of $7.0 billion. This subset would still easily meet Vietnam Green Growth Strategy goals for 2030.

8. The distribution of emission reductions for an 845 $MtCO_2$ reduction program also differs from a more focused 751 $MtCO_2$ reduction program. The less aggressive subset would have less emphasis on transport and industry and increased focus on power sector demand reductions.
9. As previously noted, this study offers an extensive menu of possible low carbon options for the Government of Vietnam's and other stakeholders' consideration and plausible ranges from 750 to 845 $MtCO_2$. The all-inclusive set of measures has been used throughout the study to provide a full range of options.
10. Vietnam will benefit from activities that support the measurement, reporting, and verification (MRV) of energy pricing reform policies. Policy-based MRV would likely complement other MRV approaches being developed. The policy MRV tool would also provide relevant ministries and agencies with useful information for further implementation of energy price reform, as well as lay a needed foundation toward attracting additional finance. Such revenues could be utilized to facilitate the price adjustment process or buy down the costs associated with putting in place measures to minimize any undesirable social and economic impacts of the policy.
11. See, for example, Dahl (2011).
12. The conservative estimate uses –0.04 price elasticity of demand based on the 3rd quartile of 1,450 price elasticity estimates. The median price elasticity is –0.14 (Dahl 2011).
13. This assumes the demand reductions avoid 983 tCO_2/GWh during 2010–18 and 811 tCO_2/GWh during 2019–30, due to displacement of subcritical and supercritical coal-fired power plants at the margin in power sector modeling, respectively.
14. MAC analysis is highly sensitive to underlying assumptions such as scenario design, time horizon, baseline, cost parameters, discount rate, and so on. A major limitation is MAC's limited definition of cost that includes only capital, operational, and fuel expenditures, and typically excludes hidden costs or barriers and transaction costs.
15. An underlying assumption when building MACCs is that action to promote each emissions-reduction option starts as soon as possible. Implementing only the cheapest options in the short term would lead to underinvesting in high-potential but expensive and long-to-implement options, such as clean transportation infrastructure, possibly locking the economy in a carbon-intensive pathway (Vogt-Schilb and Hallegatte 2014; Vogt-Schilb, Hallegatte, and Gouvello 2014).
16. Total mitigation potential from the specific measures considered for MAC analysis is a subset (95 percent) of the total emission reduction in the LCD scenario. See also the section in this chapter on methodology.
17. Figure 2.5 compares MACs for 19 labeled low carbon options plus a number of additional LCOs with small individual emission reduction impacts. Total reductions from 2015 to 2030 are about 760 $MtCO_2$ compared to 845 $MtCO_2$ from all measures that were evaluated. Emission reductions and MACs for individual measures by sector are provided in table B.1.
18. Only 2 percent of the total emissions reduction potential evaluated for MAC has a net incremental cost of over $10/$tCO_2$.

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CHAPTER 3

Energy Efficiency in Industrial and Household Sectors

Overview

- Implementing the energy-efficiency measures identified in this report would reduce required power capacity additions in 2015–30 by 11.7 GWe (7 percent), reduce 2030 generation requirements by 11 percent, reduce capital expenditure (CAPEX) for power plants by $19.1 billion, and reduce imported coal requirements by 24 million tons per year.
- Energy efficiency in the low-carbon development (LCD) scenario also contributes 35 percent of carbon dioxide (CO_2) emissions reductions (314 million tons of carbon dioxide equivalent [MtCO_2e]), and lowers energy consumption by 350,000 gigawatt-hour equivalent (GWhe) compared with the business-as-usual (BAU) scenario.
- Dominant industrial and household sector energy-efficiency programs can reduce cumulative CO_2 emissions at a composite marginal abatement cost (MAC) of –$4.24, or $1.4 billion below BAU levels.
- Enforcing the Energy Efficiency and Conservation Law, combined with accessing financial resources, will improve the implementation of energy-efficiency programs in Vietnam. In light of available opportunities, there is a need to strengthen energy-efficiency institutional capacity, as well as to review the adequacy of public and private investments in energy efficiency.
- Energy-efficiency opportunities quantified in the report can be considered elements of an investment pipeline and used to encourage banks to finance energy efficiency, given the magnitude of the opportunities available. They can also be used to define targets for specific industries in a national energy-efficiency program.

Introduction

Energy efficiency promises to be one of the most significant contributors to Vietnam's goal of improving economic competitiveness while lowering CO_2 emissions. Energy-efficiency measures described in the LCD scenario have the potential to reduce electricity demand by a cumulative 350,000 GWhe between 2015 and 2030, without detrimental effects on the end services or products provided. They would potentially lower power capacity requirements by 11.7 GW during the modeling period, and subsequently contribute 35 percent of the CO_2 emissions reduction projected in the LCD scenario. Most of the energy-efficiency measures outlined have negative MACs—that is, the low-carbon options (LCOs) are less costly than the baseline alternatives. Many countries integrate energy efficiency in their strategic energy programs. China has an energy-efficiency program whose goal is to reduce energy intensity by 16 percent between 2011 and 2015; Brazil's goal is to save 106 terawatt-hours (TWh) by 2030—25 percent of total consumption in 2010, and is expected to be 10 percent of consumption by 2030.

Decoupling economic growth from energy demand growth offers a significant opportunity to increase economic competitiveness. Vietnam's energy demand has been growing in tandem with its economic growth rate. While the economy is projected to grow by 7.14 percent per year until 2030, energy demand is expected to grow by 9.3 percent under the BAU scenario. Decoupling the growth in energy demand from economic growth—that is, reducing their correlation—would lead to lower energy costs per unit of output, and thus make Vietnamese products more competitive. China successfully weakened the correlation between its economic growth and primary energy consumption.

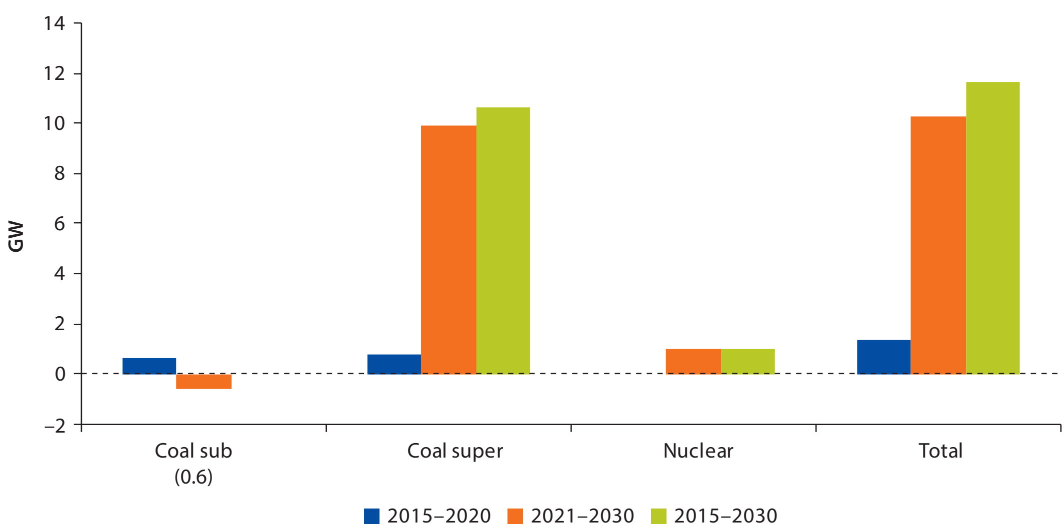
Vietnam's energy intensity is the highest among major East Asian economies. Vietnam's industrial sector plays a crucial role in the nation's economy. It generated around 42 percent of the gross domestic product (GDP)(ILO 2011) and provided employment to nearly 21 percent of the workforce in 2011.[1] Industrial energy use grew from 3.6 million tons of oil equivalent (toe) in 1998 to 13.9 million toe in 2007—almost fourfold in just nine years. In 1998 the industrial sector accounted for one-third of final energy use; by 2007 it accounted for 46 percent. The significant influence of the industrial sector is partly responsible for Vietnam's energy intensity being about 10 times larger than that of Japan, where the service sector plays a more significant role. Vietnam's industry is also generally more energy intensive than the global energy intensity benchmark. Vietnam's iron and steel (I&S) plants use twice as much energy as similar plants around the world to produce the same amount of steel. This is because this and many other sectors, such as cement and textiles, use relatively old technologies.[2] Investing in energy efficiency in this sector would not only improve the competitiveness of the sector but also reduce CO_2 emissions. For instance, investing in energy-efficient measures in I&S plants would result in about 45,000 GWhe reduction in energy consumption (that is, cost reduction) between 2015 and 2030.

Domestic power sources will not be able to meet energy demand at current economic growth rates. Between 2000 and 2010 Vietnam's electricity demand grew by about 14 percent per year, and electricity generation reached 100,189 gigawatt-hours (GWh) in 2011, which was roughly four times the 25,694 GWh generated in 2000.[3] Vietnam's industrial power demand is expected to grow by 7 percent between 2010 and 2030 in the BAU scenario,[4] and Electricity Vietnam (EVN) forecasts 9 percent growth in total electricity demand during the same period. Thus Vietnam might have to start relying on imported coal or liquefied natural gas (LNG) starting as early as 2019 to feed its power plants. This would imply significant risks for energy security and further industrial sector import dependence.

The successful implementation of energy-efficiency measures identified in this study would reduce grid capacity additions by 1,400 megawatts (MW) in 2015–20 and by 10,300 MW in 2021–30. Energy-efficiency measures can defer 600 MW of subcritical coal plants and eliminate the need for 800 MW of supercritical coal plants using imported coal through 2020.[5] The major revision to the BAU capacity expansion plan occurs between 2021 and 2030, with the elimination of 10,300 MW (figure 3.1).[6] Thus the combined impact of all energy-efficiency measures considered in this study reduces total generation requirements in 2015–30 by 7 percent and 2030 generation requirements by 11 percent. The total reduction of 11,700 GW of capacity additions reduces CAPEX by $19.1 billion. It is also important to note that the energy-efficiency measures considered here have impacts that extend well beyond the 2030 end date considered in this study. The major industrial measures considered involve investment in technologies with lives of at least 20 years. Household refrigerators have expected lives of at least 15 years. Efficient units added in 2030 would continue to produce savings for another 15–20 years. While this study logically focuses on efforts to reach the Vietnam Green Growth Strategy (VGGS) targets through 2030, beneficial emissions reductions would extend well beyond that year.

From the demand side, 19.3 percent of grid electric demand reductions during 2015–30 could come from I&S, cement, fertilizer, and pulp and paper industries (table 3.1; see also figure 3.2). Refineries were also included in the large industry

Figure 3.1 Reduced Electricity Generation Capacity Additions: EE$10 vs. Business as Usual



Source: World Bank estimates.
Note: BAU = business as usual; EE = energy efficiency; GW = gigawatts.

Table 3.1 Grid Electricity Reductions Due to Increased Energy Efficiency

Grid electric demand reductions from energy efficiency											
Sector	*MACs calculated*	*Ref point*	*Units*	*2015*	*2020*	*2025*	*2030*	*Total 2015–30*	*% Shares*	*2015–30 % of BAU*	*2030 % of BAU*
Six large industries (1)	Yes	At User	GWhe	666	1,721	4,749	12,684	68,077	19.3	17.2	40.0
All other industries	No	At User	GWhe	364	3,337	13,299	31,091	170,296	48.2	7.4	13.0
Total industry	Partial	At User	GWhe	1,030	5,058	18,048	43,775	238,373	67.4	8.9	16.1
Households top 5 (2)	Yes	At User	GWhe	757	4,100	9,602	17,120	120,035	34.0	19.6	26.9
Households next 8 (3)	No	At User	GWhe	52	482	1,446	2,764	17,717	5.0	10.6	22.0
Household 13 end uses	No	At User	GWhe	809	4,581	11,049	19,884	137,753	39.0	17.7	24.2
Transport (4)	Yes	At User	GWhe	−201	−814	−1,850	−2,985	−22,653	−6.4	−59.0	−85.5
Total	Partial	At User	GWhe	1,638	8,825	27,247	60,674	353,473	100.0	10.1	17.0
Trans distn losses				9.48%	9.11%	8.75%	8.40%	8.67%			
Total (5)	Partial	Total supply	GWhe	1,810	9,709	29,858	66,239	387,022	109.5		
Total	Partial	Dom grid gen	GWhe	1,709	8,629	26,774	59,981	348,325	90.0		

(1) Large i&s; small i&s, cement, fertilizer, refinery, pulp&paper

(2) Lighting; refrigerator, air conditioner, water heaters, fans

(3) Radio, stereo, cd player, tv, dvd/vcr, computer, washing machine, thermo pot

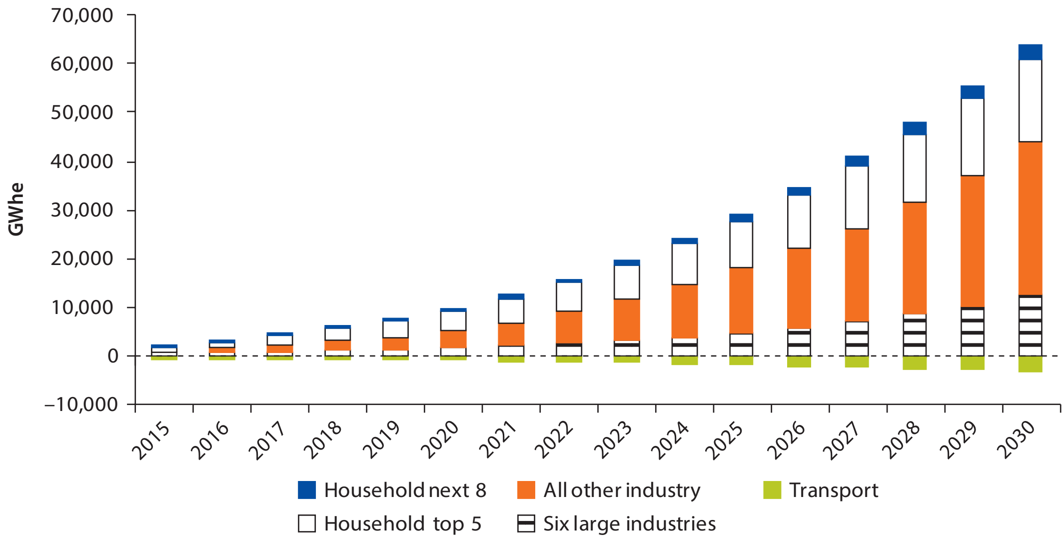
(4) Increased use in transport due to electric bikes replacing gas bikes

(5) Includes imports and captive generation

Source: World Bank estimates.

Note: GWhe = gigawatt-hour electric; MAC = marginal abatement cost; Trans Distn Losses = transmission and distribution losses.

Figure 3.2 Electric Demand Reductions at the Consumer Level



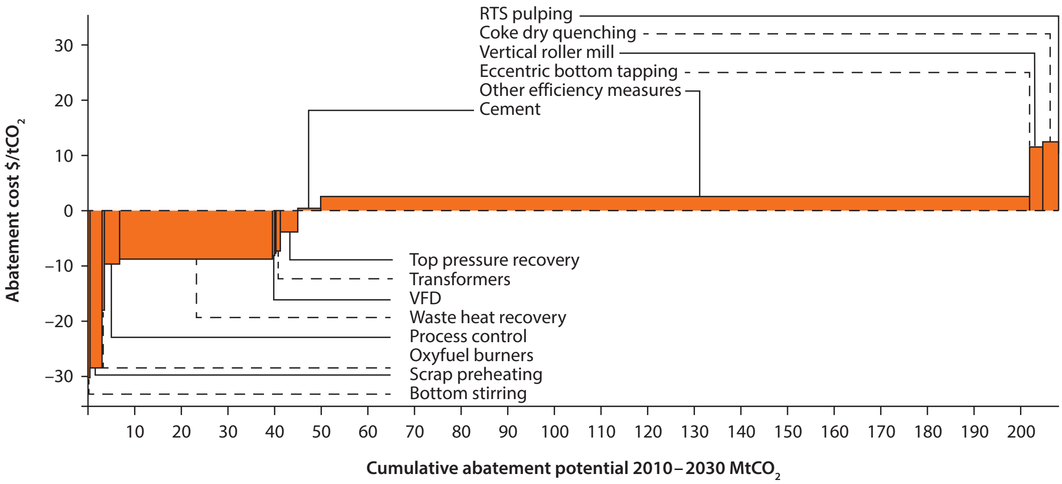
Source: World Bank estimates.
Note: GWhe = gigawatt-hour electric.

category, but reduced emissions from energy efficiency there did not include reduced electricity demands. Efficiency standards for five household uses account for 34 percent of grid electric demand reductions by 2030. The combined grid demand reductions from energy efficiency in the industry and household sectors are offset to a limited extent by the 6.4 percent share of demand increases from the conversion of gas to electric bicycles (e-bikes) in the transport sector. Clearly, the 48.2 percent share of grid electric demand reductions for "all other" industry requires intensive additional research to establish a more comprehensive set of energy-efficiency measures with specific estimates of MACs and related emissions reduction potential. Reductions of 40 percent for large industry and 26.9 percent for five household end uses in 2030 are impressive, but the lack of sufficient data for other industries leaves substantial untapped potential for further research.[7]

Energy Efficiency and Financial Competitiveness

As a means of reducing CO_2 emissions and improving economic competitiveness, energy-efficiency measures in Vietnam are found to generally have negative MAC curves (MACCs) (figure 3.3). A MACC consists of a number of columns, each of which represents an opportunity to reduce CO_2 emissions. The width of the column denotes the amount of CO_2 that could be potentially abated, and the height denotes the present cost of avoiding one ton of CO_2 (tCO_2) with this opportunity. Hence, negative costs (bars below the horizontal axis) indicate net

Figure 3.3 Marginal Abatement Cost Curve for Industrial Sector Energy Saving (Electricity and Fossil Fuels)



Source: World Bank estimates.
Note: $MtCO_2$ = million tons of carbon dioxide; RTS = lower Retention time, higher Temperature, higher refiner Speed; tCO_2 = tons of carbon dioxide; VFD = variable frequency drive.

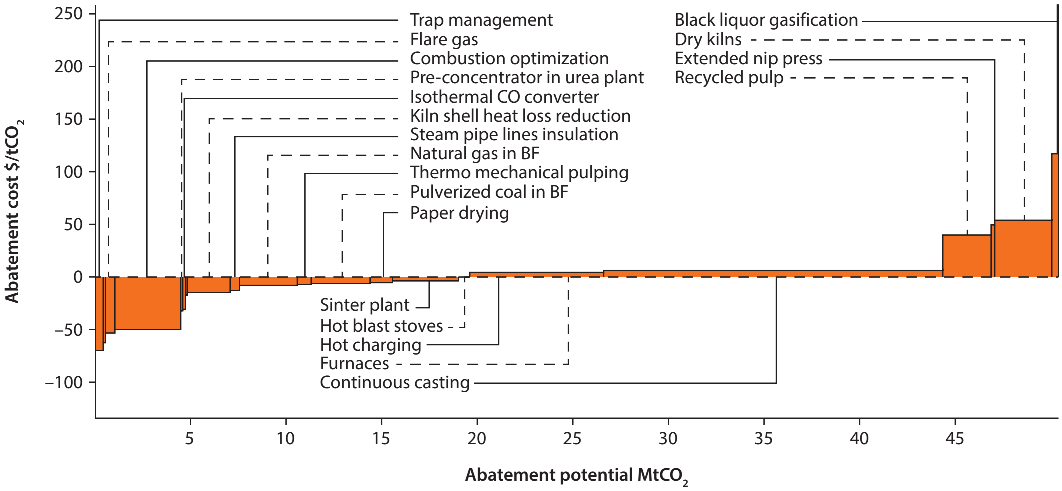
economic benefit to the economy over the life cycle of the abatement opportunity, while positive costs (bars above horizontal axis) indicate incremental costs compared to the BAU case. Thus the role of the MACC is to help policy makers identify opportunities for cost-effective CO_2 reduction. (Appendix B explains the methodology and main assumptions used to create the MAC curves.)

Emission reductions from "other efficiency measures" in industry are quite significant, and can only be estimated at indicative levels due to the lack of sufficient data for Vietnam. Electricity demand reductions reported in "other efficiency measures" are estimates based on typical results achieved in other countries that have established industrial energy-efficiency programs. Recent studies by the American Council for an Energy Efficient Economy of extensive sets of industrial energy-efficiency measures document a levelized cost of energy (LCOE) of $30 per MWhe (megawatt-hour equivalent). This would imply total incremental CAPEX in the range of $37 billion with an estimated MAC in the range of $2.62 per ton of CO_2 equivalent (tCO_2e) for Vietnam.

Industrial energy efficiency reduces both electricity and fuel consumption; the MACC for industrial measures that directly affect electricity consumption is shown in figure 3.4.

More than 60 percent of emissions reductions from reduced grid electricity demands by the large industry sector come from waste-heat recovery power generation at large I&S and cement production facilities. The importance of sound feasibility assessments and adequate financing mechanisms for efficient power generation for large I&S and cement producers is clear (see table 3.2).

Figure 3.4 Marginal Abatement Cost Curve for Industrial Sector Electric and Energy Savings Options



Source: World Bank estimates.
Note: BF = blast furnace; CO = carbon monoxide; $MtCO_2$ = million tons of carbon dioxide; tCO_2 = tons of carbon dioxide.

Table 3.2 Summary of Select Industrial Marginal Abatement Costs that Affect Electricity Demand

Industry sector	*EE measure*	*2015–30 $MtCO_2$ Redn (1)*	*% Shares*	*MAC $/tCO_2$*	*2015–30 CAPEX MUSD (2)*
Small I&S	Improved process control	3.10	5.9	(9.59)	5.1
Small I&S	Transformer efficiency	0.97	1.8	(7.33)	9.1
Large I&S	Installation of VFD	32.93	62.6	(8.88)	56.2
Large I&S	Variable frequency drives	0.09	0.2	(7.81)	0.6
Large I&S	NG injection	3.82	7.3	(3.96)	52.2
Large I&S	Heat recuperation from hot blast stoves	3.26	6.2	12.49	204.3
Cement	Variable frequency drives	0.58	1.1	(8.17)	2.7
Cement	Waste heat recovery power	4.76	9.0	0.46	232.1
Cement	Vertical roller mill	2.85	5.4	11.46	174.6
Fertilizer	Variable frequency drives	0.02	0.0	(7.63)	0.0
Pulp & Paper	RTS pulping	0.28	0.5	33.74	50.1
Total		52.64	100.0		787.0
Weighted Average				(5.03)	

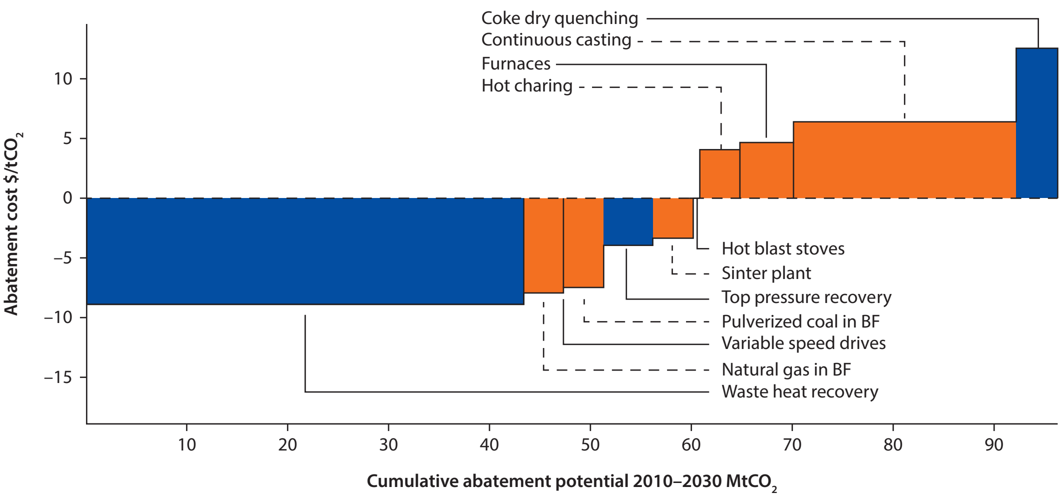
(1) Million Metric Tons Emission Reductions
(2) CAPEX equals incremental investment vs the BAU Baseline in Million USD

Source: World Bank estimates.
Note: CAPEX = capital expenditure; EE = energy efficiency; I&S = iron and steel; MAC = marginal abatement cost; $MtCO_2$ = million tons of carbon dioxide; MUSD = millions of U.S. dollars; Redn = reduction; RTS = lower Retention time, higher Temperature, higher refiner Speed; tCO_2 = tons of carbon dioxide.

With a weighted average MAC of –$5.03, these industrial energy-efficiency measures are clearly high-priority, cost-effective emissions reduction alternatives with modest incremental CAPEX requirements.

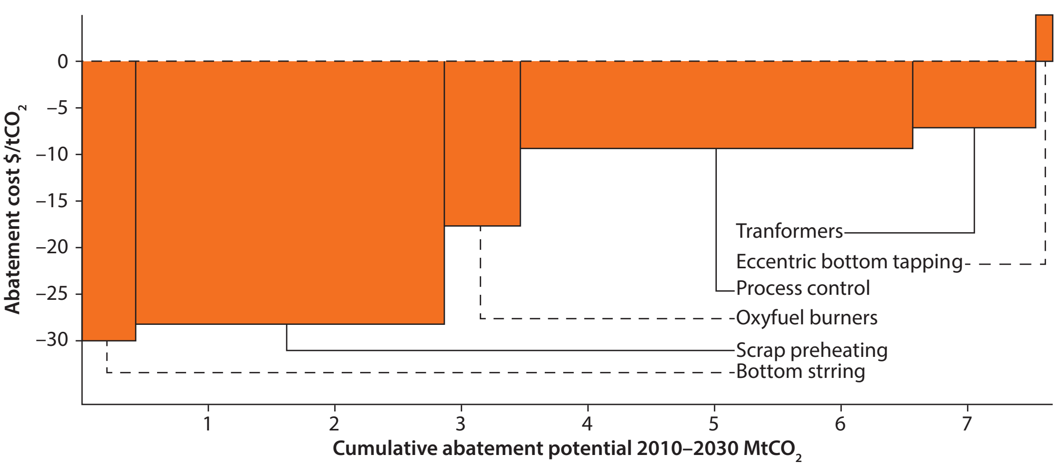
Figures 3.5, 3.6, and 3.7 show the MACCs of the I&S producers, small-scale steel producers, and cement producers, respectively (see appendix B for relevant details).

Figure 3.5 Iron and Steel Producers: Marginal Abatement Cost Curves



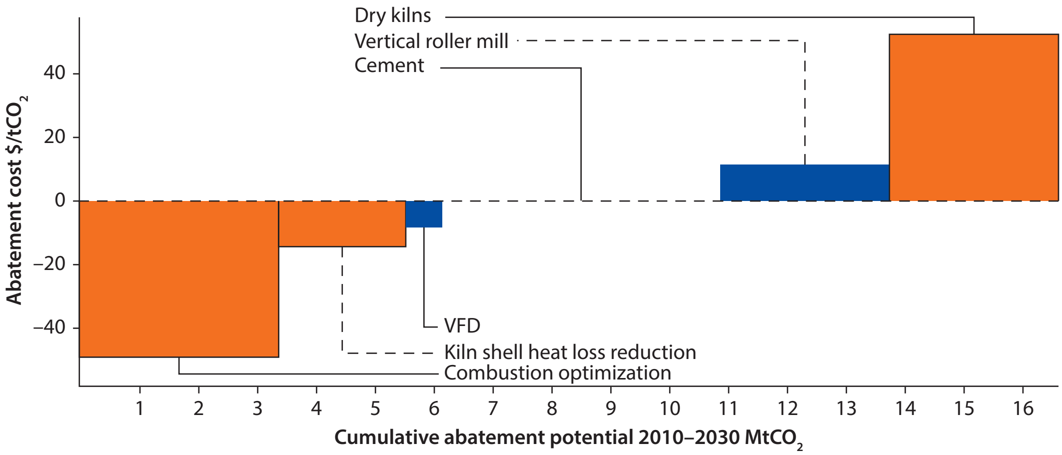
Source: World Bank estimates.
Note: BF = blast furnace; $MtCo_2$ = million tons of carbon dioxide; tCO_2 = tons of carbon dioxide.

Figure 3.6 Small Steel Producers: Marginal Abatement Cost Curves



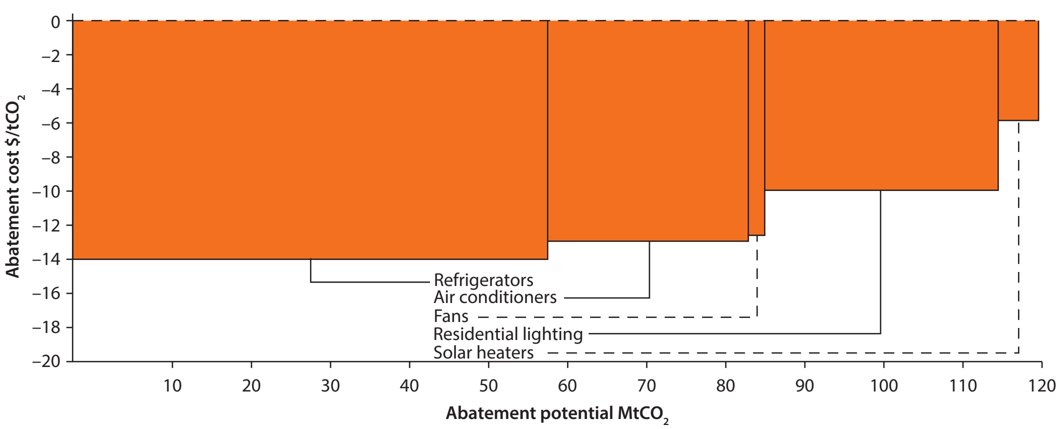
Source: World Bank estimates.
Note: $MtCO_2$ = million tons of carbon dioxide; tCO_2 = tons of carbon dioxide.

Figure 3.7 Cement Sector: Marginal Abatement Cost Curves



Source: World Bank estimates.
Note: $MtCO_2$ = million tons of carbon dioxide; tCO_2 = tons of carbon dioxide; VFD = variable frequency drive.

Figure 3.8 Household Sector: Marginal Abatement Cost Curves



Source: World Bank estimates.
Note: $MtCO_2$ = million tons of carbon dioxide; tCO_2 = tons of carbon dioxide.

Energy Efficiency at the Household Level

Supporting energy efficiency in the five main household end uses reduces cumulative CO_2 emissions by 120 million tons of CO_2 equivalent (CO_2e) by 2030, with negative MACs. Well-developed efficiency standards enforced at the point of sale can provide the emissions reductions summarized in figure 3.8 based on estimated replacements and new purchases. Efficiency improvements for refrigerators and air conditioners can be achieved with no incremental investment. Although new, more efficient refrigerators tend to have higher sticker prices, the increases are principally due to added size and features rather than to the inclusion of energy-efficient technology. The lighting improvements shown are limited to compact fluorescent lamp (CFL) replacement of incandescent bulbs. Much greater efficiency gains are possible at somewhat higher cost if light-emitting diodes (LEDs) are introduced in addition to or in lieu of CFLs. The item "solar heaters" refers to the modest substitution of solar for electric water heating. This would require education and promotion programs. It should be noted that administrative and enforcement costs have not been included in the MAC estimates shown for either the industrial or household sectors.

Energy Efficiency: An Implementation Gap Assessment

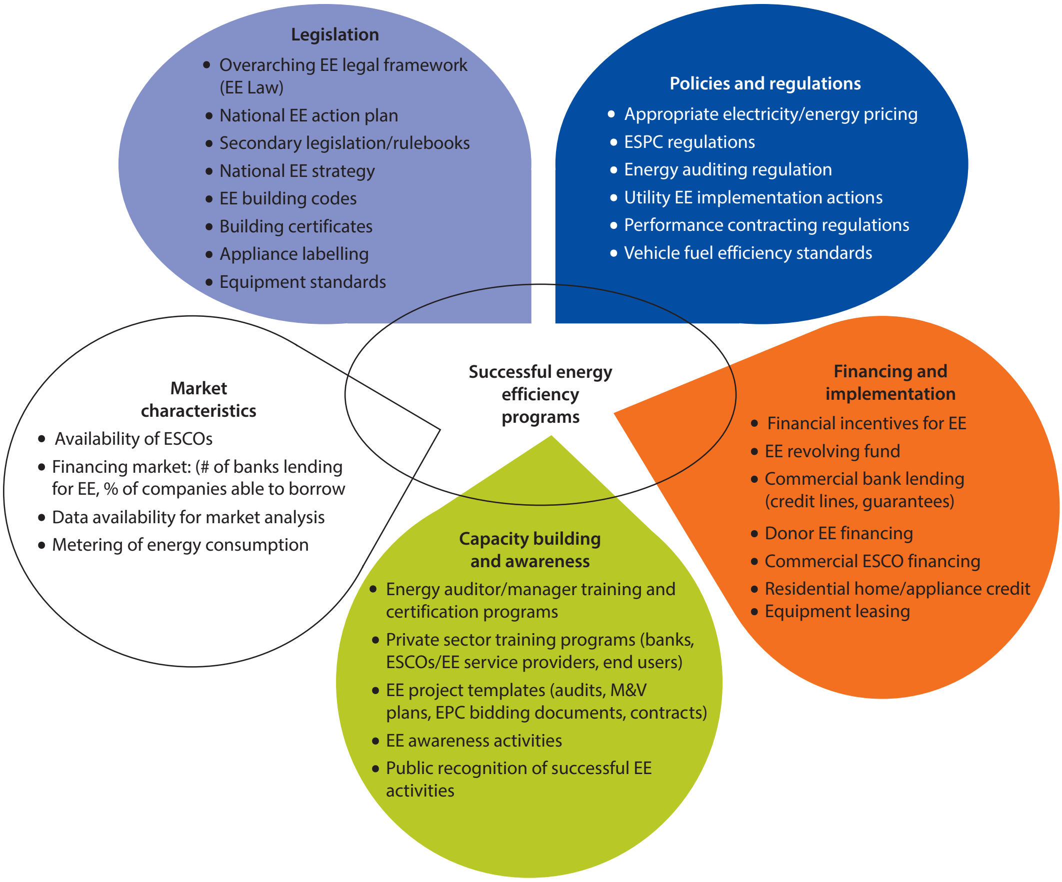
Despite having energy-efficiency laws and programs in place, Vietnam's energy consumption quadrupled in the decade leading up to 2011 and its energy elasticity reached 1.8. This section evaluates Vietnam's programs against a framework of typically successful energy-efficiency programs based on the World Bank's international experience. Successful programs typically consist of the right combination of legislation, policies and regulations, financing and implementation mechanisms, capacity-building and awareness programs, and market characteristics. Each of these is described in figure 3.9.

Energy-efficiency legislation is generally in place, but the government would need to ensure that enforcement is at a level commensurate with the policy goals. The Energy Efficiency and Conservation (EE&C) Law (2010) is the cornerstone of the legal energy-efficiency framework. The government issued 10 decisions, decrees, and circulars as secondary legislation to support the law, but the law is barely *enforced* and has had limited success.

Many policies and regulations are in place, but the implementing institutions could be strengthened with additional resources. The Energy Efficiency and Conservation Office (EECO) was established through Decision No. 79/2006/QD-TTG dated April 14, 2006, and Vietnam's National Energy-Efficiency Program (VNEEP I) was established in the same year. The program had saved 4,900 kilotonnes of oil equivalent (ktoe) of energy when it ended in 2010, and VNEEP II was launched in 2011. Additional programs include Standards and Labeling (S&L), Promoting Energy Conservation in Small and Medium Scale Enterprises in Vietnam (PECSME), and the building codes program run through Vietnam Building Energy Efficiency Codes. The government also set a target of 5–8 percent energy savings between 2012 and 2015, allocated across provinces. All these programs have had limited success because the responsible institutions need to be strengthened. The EECO is temporary, and it is uncertain what will happen to the office when the VNEEP II ends. Moreover, the energy-efficiency targets and agreements with large energy consumers are voluntary, and electricity prices are subsidized; hence there are no incentives to implement energy-efficiency measures.

Energy-efficiency financing and implementation capacity are limited. Development institutions such as the International Finance Corporation (IFC)

Figure 3.9 Framework of a Typically Successful Energy Efficiency Program



Source: World Bank.
Note: EE = energy efficiency; EPC = engineer procure and construct; ESCOs = energy service companies; ESPC = Energy Savings Performance Contracts; M&V = monitor and evaluate.

and the World Bank have provided some energy-efficiency financing. The Ministry of Industry and Technology (MOIT) has a $1 million subsidy fund that offers up to 30 percent of a project's cost with a cap of $250,000 per project. The government also funds energy audits, technical assistance, and training, and promotes energy efficiency. But the incentives are limited and complex to use, and banks are hesitant to lend for energy efficiency because they do not understand the sector well. Additionally, the interest rates are high, and there is virtually no project finance for energy efficiency in Vietnam.

Existing capacity-building and awareness programs can be strengthened. The Vietnam Industry Association holds awareness-building workshops and provides energy-efficiency training to its members. The government and universities also provide training for energy managers. But there is limited energy-efficiency awareness among small and medium enterprises (SMEs), and there is an energy-efficiency capacity gap among workers, engineers, and managers. In an attempt to raise awareness, the government publishes energy-efficiency success stories. The distribution of these success stories could be widened. Many firms lack focus on improving efficiency in existing production systems, but focus instead on maximizing "production" by adding machinery. Banks are also more comfortable lending for additional machinery.

The industrial sector is dominated by state-owned enterprises (SOEs), which makes it harder for SMEs to thrive. Economic liberalization would encourage the competition that drives firms to be efficient. The current energy prices in Vietnam are generally lower than in other Association of Southeast Asian Nations (ASEAN) countries. This largely discourages energy efficiency, and the lack of market data makes it difficult to analyze the market. Energy service companies (ESCOs) are at a nascent stage—there are a couple of well-established ESCOs such as Ho Chi Minh City Energy Conservation. Additionally, there is limited investment (in terms of both fiscal and other resources) in developing energy-efficiency research facilities and testing laboratories. Sixty percent of lending is tied to SOEs, and this creates a barrier for private enterprises that would otherwise use energy efficiency as a competitive instrument.

Key Recommendations

It is critical that energy-efficiency measures be implemented rapidly, not only because of the cost-effectiveness of these measures but also to allow time to estimate the revised supply options for displacing coal-based generation in the electricity sector. Based on the findings of this study, energy-efficiency programs can be implemented as early as 2015 to reduce grid electric demand through 2030 and beyond. While this is an aggressive schedule, it avoids unnecessary costs. Every year Vietnamese firms acquire substantial amounts of electrical equipment and appliances. Failure to identify and promote efficient technologies represents lost opportunities for cost-effective emissions reductions. This is particularly critical for energy-efficiency measures designed to reduce grid electricity demands: many power plants coming on line in 2021 will close financing in 2016 and begin construction in 2017.

EE&C law enforcement and the strengthening of relevant institutions would jump-start energy efficiency in Vietnam. While Article 33 of the EE&C law mandates that major energy consumers develop five-year energy-efficiency plans, and Article 34 mandates that they engage energy auditors certified by the Government of Vietnam (GoV) to conduct energy audits every three years, there are no *mandatory performance-based* targets. As a result, there are virtually no incentives to implement energy-efficiency investments. International best practices indicate that mandatory performance-based targets would be very effective in spurring energy-efficiency investments compared to voluntary input-based targets. The GoV would need to break the national energy-efficiency targets down into province- or enterprise-specific targets, and hold officials responsible through penalties and incentives for meeting the targets. The EECO would need to be strengthened or a separate energy-efficiency institution set up to effectively support the program. The institution would need more resources, independent decision-making power, and a relatively high rank to coordinate across ministries. Lastly, the program would need an effective delivery model (such as in Ho Chi Minh City, mentioned above). China offers an example of a successful, mandatory energy-efficiency target program. The Chinese government set targets to reduce energy intensity per unit GDP by 20 percent in 2005–10 and 16 percent in 2011–15. The national target was allocated to each province, and the provincial leaders were held accountable. The government also signed specific energy-efficiency targets with the nation's top 10,000 energy consumers, which accounted for two-thirds of China's energy use.

Coupling financing with EE&C law enforcement and institutional strengthening would significantly improve the implementation of energy-efficiency programs. Energy-efficiency targets without financial incentives would not succeed. The GoV could provide financial support using different mechanisms: guarantees, credit lines, grants, subsidies, rebates, and tax relief. Partial Risk Guarantee Funds could be developed so as to support the nascent ESCO industry. There is a need to raise the current energy-efficiency subsidy program and make it fairly simple for enterprises to utilize available resources. The government could also provide incentives for the public to purchase more energy-efficient appliances such as refrigerators, air conditioners, and televisions where needed. The Chinese government spent $25 billion between 2006 and 2010 to support energy efficiency, and the Turkish government provided $2 billion worth of guarantees to finance energy efficiency in the five years leading up to 2013. Raising the needed resources from levies on energy tends to be the most financially stable way to raise energy-efficiency finance. This could be supplemented by donor financing.

There would need to be a differentiated approach, taking into account the challenges in each sector. For instance, investments in the industry sector are fairly sizable and concentrated among a few stakeholders, while investments in the residential sectors are fairly small and dispersed. Depending on the goals of the implementing entity, the government might lean toward one sector more than the other. The capabilities of the entity and financiers involved would influence some of the implementation decisions as well.

At the implementation level, there are some specific recommendations that tie in closely to the Green Growth Action Plan (GGAP) approved on March 20, 2014. As applicable, the GGAP activities are cross-referenced in endnotes to the following list of recommendations:

- Almost 80 percent of the emissions reductions from energy-efficiency measures for large industry come from waste-heat recovery and new turbine generation for large I&S and cement producers. The GoV should ensure that the planning of potential generation by such producers is closely coordinated with grid planning, that interconnection policies and possible sales to the grid are clearly defined, and that the economics of such projects are sufficiently documented to allow for commercial financing.[8]

- Variable frequency drives and transformer efficiency programs constitute the other major programs for large industry. The GoV should develop specific policies for these programs and provide regular reporting of reliable electric rate forecasts to support such analyses by interested industrial facilities.[9]
- The most significant gap in industrial energy-efficiency program development lies in the compilation of reliable survey and energy audit data to support evaluation and implementation of electricity demand reductions by SMEs. Commitments to reduce electric demand by 1 percent per year for "all other" industries should be established.[10]
- Efficiency standards should be established for residential refrigerators, air conditioners, and lighting, and enforced at the point of sale starting in 2015.[11]
- Energy-efficiency resource plans should be separately identified and included in all future power sector development plans. (The GGAP focuses on the 2014–20 period; longer-term integration of energy efficiency with power sector planning for 2021–30 is also needed based on near-term energy-efficiency program development.)

Notes

1. World Bank data indicators.
2. http://tietkiemnangluong.com.vn/en/activity-news/cement-industry-strives-to-reduce-energy-consumption-31003-11224.html.
3. http://www.eia.gov/countries/country-data.cfm?fips=VM#elec.
4. IEVN estimates.
5. Assuming that the eliminated supercritical coal plants operate at 42 percent efficiency with annual capacity factors of 75 percent, the total reduction of 10,700 MW of such plants would reduce coal imports by 24 million tons per year.
6. Implementation of the energy efficiency programs is not expected to influence capacity additions of hydro, gas, or renewable energy generation plants in 2015–30.
7. All grid electric demand reductions related to energy efficiency are logically estimated initially at the consumer level as 9.5 percent (transmission and distribution [T&D] losses) then summed to arrive at reduced grid generation requirements.
8. This corresponds to the Green Growth Action Plan (GGAP) activities 3, 14, 16, 37.
9. This corresponds to GGAP activities 3, 14, 16, 37.
10. This corresponds to GGAP activities 15, 16, 37.
11. This corresponds to GGAP activities 4, 6, 11, 12, 13, 62.

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CHAPTER 4

Decarbonizing the Power Sector

Overview

- The low-carbon development (LCD) electricity generation supply plan replaces 3,900 megawatts (MW) of subcritical coal and 9,800 MW of supercritical coal with 8,100 MW of renewables, 9,700 MW of CCGT-LNG (combined-cycle gas turbines using liquefied natural gas), and 2,000 MW of nuclear capacity additions from 2021 to 2030.
- The renewable mix includes 2,000 MW of biomass, 2,800 MW of run-of-river (ROR) hydro, 1,800 MW of wind, and 1,500 MW of utility-scale solar photovoltaic (PV). The approach taken in this report is conservative only to demonstrate the feasibility of those additions. Vietnam could also consider tapping into a largely unexploited potential for other sources of renewable energy (RE): two prominent examples are rooftop solar for individual commercial and residential installations and geothermal power.
- Capital expenditures for new power plants are $8.1 billion less for the LCD power sector plan than for the business-as-usual (BAU) plan. In addition fuel costs for power generation in 2015–30 are $17.6 billion less for the LCD power sector plan than for the BAU plan. Significant LCD fuel savings beyond 2030 are anticipated but have not been quantified except as part of the marginal abatement cost (MAC) calculations.
- The costs of imported generation fuels for the combined demand- and supply-side modifications of the BAU power supply plan are reduced by $7.9 billion from 2015 through 2030.
- The LCD capacity expansion plan fits comfortably within the limits envisioned in the approved Power Development Plan VII (PDPVII) base plan and within the capacity limits of a 6.0 million tons per annum (mtpa) LNG import terminal.
- Composite MACs for the LCD plan are modest at $2.50 per ton of carbon dioxide equivalent (tCO_2e) without externalities, and $0.74 per ton including externalities.

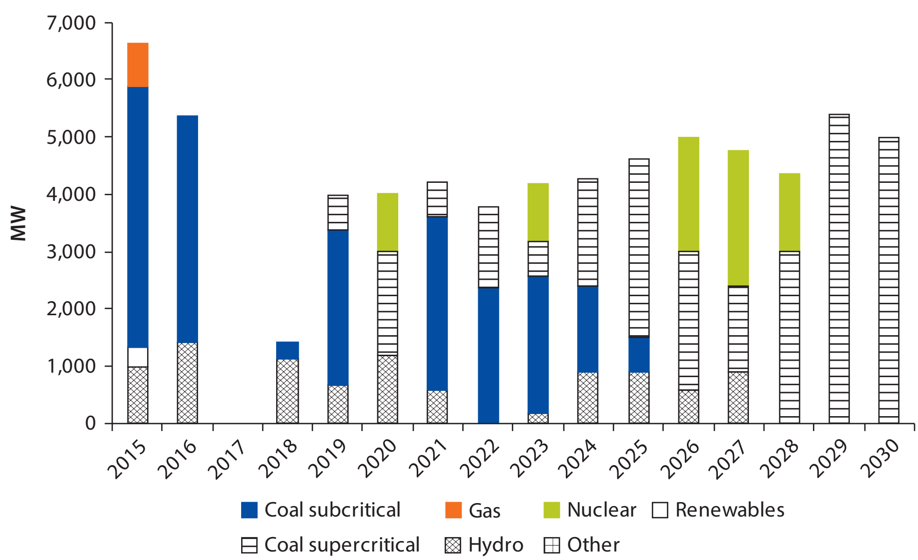
- Cumulative CO_2 equivalent (CO_2e) emissions reductions through 2030 for the LCD plan are 341 million tons. Over the lifetime of the power plants included in the LCD scenario, emissions reductions are nearly two billion tons.
- Over the lifetime of the LCD power plants, avoided health costs and other environmental damages are estimated at $48.1 billion.

Displacing CO_2-Emitting Coal-Fueled Power Plants to Achieve Low-Carbon Development

The LCD scenario is developed by modifying the EE$10 power sector capacity expansion plan to replace carbon-intensive generation with cleaner technologies. Chapter 3 documented cost-effective energy-efficiency (EE) measures that trimmed 11.7 gigawatts (GW) of power plant additions and 387 terawatt-hours (TWh) from the BAU requirements for 2015–30.[1] The resulting capacity expansion plan for that period is summarized in figure 4.1 and table 4.1.[2]

Most plant additions through 2018 are already under construction. Additions through 2020 will be reaching final commitment points before the full set of recommended EE measures from this study for that period are implemented. Thus, power supply modifications have been conservatively limited to the 2021–30 period. As documented in table 4.1, the targets of opportunity in that period consist of 45,520 MW of additions. The large hydro additions will remain unchanged for the LCD scenario. Thus, the key supply-side LCD questions relate to how many coal plants can be replaced with cleaner alternatives and whether the nuclear share can reasonably be increased.

Figure 4.1 Electricity Generation Capacity Added Net of Energy Efficiency Gains



Source: World Bank estimates.
Note: EE= energy efficiency; MW = megawatts.

Table 4.1 Electricity Generation Capacity Added Net of Energy Efficiency Gains, MW and %

	EE$10 MW addition summary					
Technology	*2015–20 (MW)*	*% Shares*	*2021–30*	*% Shares*	*2015–30 (MW)*	*% Shares*
Hydro	5,411	25.3	4,080	9.0	9,491	14.2
Renewables	350	1.6	0	0.0	350	0.5
Coal Subcritical	11,500	53.7	9,870	21.7	21,370	31.9
Coal Supercritical	2,400	11.2	24,870	54.6	27,270	40.7
Nuclear	1,000	4.7	6,700	14.7	7,700	11.5
Gas	750	3.5	0	0.0	750	1.1
Other	0	0.0	0	0.0	0	0.0
Total	**21,411**	**100.0**	**45,520**	**100.0**	**66,931**	**100.0**

Source: World Bank estimates.
Note: EE = energy efficiency; MW = megawatts.

The LCD power supply challenge is to identify an attractive mix of renewables, new combined-cycle generation using imported LNG[3], and nuclear additions to meet the Government of Vietnam's (GoV's) security, affordability, and sustainability objectives. Renewable generation considered in this study includes biomass, ROR hydro, wind, and solar PV. Generic cost and potential data for renewable resources can be used to outline the LCD power supply plan for 2021–30. But systematic potential and site-selection studies will need to be developed over the next three to four years to confirm the preferred mix of renewable generation with site-specific costs and production estimates. Power plant investment decisions can then be finalized to allow completion of new generation by 2021. While domestic proven natural gas reserves are sizeable, future development of those resources remains highly uncertain. To assure that the LCD plan identified here can be implemented, all new CCGTs added from 2021 have been assumed to use imported LNG.

The EE$10 power supply plan includes 7,700 MW of nuclear plant additions by 2030. With aggressive international competition to introduce nuclear generation to Vietnam, the exact size and timing of nuclear plant completions is not firm. The simplifying assumption for this study is that any expansion beyond 7,700 MW would be limited to 1,000 MW in 2029 and 1,000 MW in 2030.

Initial LCD generation resource limits reflect already approved PDPVII base plan targets and plans already being discussed for an LNG terminal with 6 mtpa capacity. Multiple criteria have been used to establish the LCD test coal displacement plan summarized in table 4.2. The capacity additions shown represent increments above the 2021–30 additions shown in table 4.1.

Nuclear. The approved PDPVII plan includes 9,700 MW by 2030 compared to 8,700 MW included in the BAU scenario. EE improvements lower nuclear additions to 7,700 MW. The LCD plan outlined above restores nuclear to the 9,700 MW envisaged in PDPVII.

Biomass. The approved PDPVII plan calls for development of 2,000 MW of power generation fueled by crop residues by 2030. This target has set the biomass limit in the LCD scenario. Biomass fuels could include rice husks, bagasse,

Table 4.2 Incremental Capacity Additions and Generation, the LCD Scenario

Clean technology	*Test MW*	*Capacity factor %*	*Test GWh/a*	*LNG use mtpa (1)*
Nuclear	2,000	85.0	14,892	0
Biomass	2,000	75.0	13,140	0
ROR hydro (2)	2,800	50.0	12,264	0
Wind	1,800	25.0	3,942	0
Solar PV (3)	1,500	15.0	1,971	0
CCGT LNG solo (4)	3,600	75.0	23,652	2.8
CCGT LNG paired	6,100	41.0	21,900	2.6
CCGT LNG total	9,700	53.6	45,552	5.4
Total renewables	8,100	44.1	31,317	0
Total CCGT LNG	9,700	53.6	45,552	5.4
Nuclear	2,000	85.0	14,892	0
Total	**19,800**	**52.9**	**91,761**	**5.4**
Coal displacements	13,700	76.5	91,761	0

(1) Million tons per annum
(2) Run-of-river hydro
(3) Solar photovoltaic
(4) Combined-cycle gas turbine fueled by imported liquefied natural gas

Source: World Bank estimates.
Note: GWh/a = gigawatt-hours per annum; LCD = low-carbon development; LNG = liquefied natural gas; MW = megawatts.

and waste wood. Rice husks have been assumed as the illustrative biomass fuel for this study.

Small hydro. ROR hydro will be the most familiar renewable resource and may be located in Vietnam or at neighboring sites in Cambodia or Lao People's Democratic Republic. It is anticipated that at least 700 MW may come from foreign hydro sites that can operate at 50 percent capacity factors. An additional 1,100 MW with similar capacity factors would then be sought from domestic sites.

Wind. The PDPVII anticipates aggressive pursuit of wind power reaching installed capacity of 6,200 MW by 2030. Both the BAU and EE$10 scenarios include 90 MW of wind coming on line in 2015 but none thereafter. The LCD plan outlined above averages 180 MW of onshore wind additions per year from 2021 through 2030, which is comfortably within the PDPVII targets. Based on continuing dramatic cost reductions, it is expected that solar PV may replace some of the wind power that was anticipated in the PDPVII.

Solar PV. Solar irradiance maps indicate resources in southern Vietnam are as strong as those in most of the southwest United States and far superior to resources in Germany.[4] Thus, the assumed capacity factor of 15 percent is believed to be very conservative. Solar PV costs continue to plummet with expectations that $1 per watt capital expenditure (CAPEX) for utility-scale plants will be reached by 2020. Solar PV also offers the greatest potential for domestic manufacture of power generation components. The most effective kick-start for solar PV will likely be for some utility-scale plants located strategically on the grid near substations to minimize transmission and delivery losses. This approach would provide domestic proof of concept and grid integration efforts that would in turn pave the way for improved feed-in-tariff (FIT) design and grid connection policies that stimulate additional private rooftop development. As more site-specific data are compiled, the solar PV and wind components of the LCD plan may change but their combined contribution should be readily achievable.

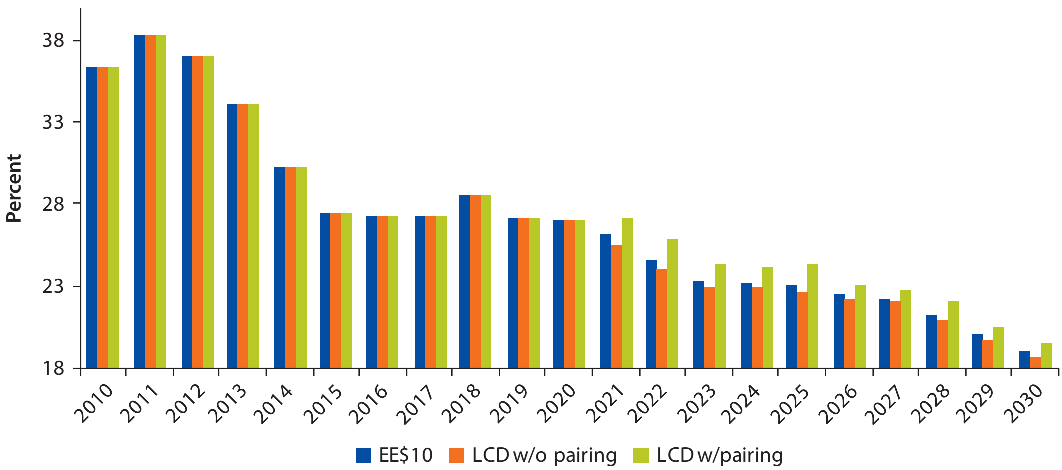
CCGT-LNG. Finally, a major component of the LCD plan would be provided by new CCGTs fueled by imported LNG. Based on take-or-pay fuel contracts, it is expected that these plants would operate as base load units in separable operation or as complementary units in combination with ROR hydro, wind, and solar PV generators. In either case the generation resource would be fully dispatchable and capable of displacing base-load coal plants that would operate at 75 percent annual capacity factors. In total, the amount of CCGT-LNG generation in the LCD plan has been limited to use less than 6 mtpa of imported LNG, based on the terminal sizes that are already being planned.

Generally, none of the capacity additions in the LCD power plan are believed to exceed the targets identified in the approved PDPVII base plan or the LNG terminal plans. The test LCD supply plan outlined here can be scaled up or down as needed to meet or exceed the Green Growth Strategy 2030 emissions reduction targets.

The need for peaking generation to firm up variable renewable resources poses a critical question in evaluating CAPEX requirements for the LCD scenario. The variable output of renewable generation resources is well known and can provide a grid integration constraint in systems without adequate peaking generation, sufficiently developed grid management data systems, and liquid ancillary services markets. At one extreme, countries such as Spain have installed substantial solar PV without specific requirements to back up such resources. They can do this, however, because PV owners are required to firm up their resources—and can do so easily because there are ample peaking resources to provide ancillary support in transparent markets at predictable prices. The opposite extreme would require additions of peaking capacity fully equal to the capacity of the renewable energy resources added. In practice, such a high requirement is never needed. This is obviously a very conservative approach that tends to underestimate the potential for variable electricity generation from renewable sources. This potential would likely be revised upward when such an assumption is lifted at the time more detailed power system planning is undertaken. Figure 4.2 provides the rationale for this assumption.

The EE$10 capacity expansion plan concentrates intensively on additions of base load generation resources with the share of peaking resources thus falling significantly between 2010 and 2020.[5] These declines continue through 2030 in the EE$10 scenario. The optimum share of peaking resources requires detailed analysis of load shapes and response times for power plants. From 2021 to 2030 failure to add peaking resources paired with renewable energy additions would accentuate the decline in the share of peaking resources. The safe, simplifying assumption used here is that CCGTs using LNG will back up all nondispatchable resources 100 percent. Thus, 19,800 MW of LCD resources are used to displace

Figure 4.2 Peaking Share of Total Installed Capacity, by Scenario, 2010–30, MW



Source: World Bank estimates.
Note: EE = energy efficiency; LCD = low-carbon development; MW = megawatts.

13,700 MW of coal. This inclusion of 6,100 MW of CCGT to firm up the renewable generation adds $6.3 billion to the CAPEX requirements for the LCD scenario. As Vietnam develops site-specific assessments of renewable energy production at the time of system peak, this requirement can certainly be relaxed, and LCD CAPEX requirements can be reduced proportionately.

MAC calculations provide the basis for evaluating the incremental economic costs and emissions reductions of the LCD coal displacement plan outlined in table 4.2. Clear documentation of MAC calculations would provide the GoV with needed support to implement this LCD plan or to explore more aggressive displacement efforts, if necessary, to achieve green growth targets.

The PDPVII decision document of July 2011 includes a power sector commitment to charge the full and fair costs of environmental externalities in investment costs as an environmental safeguard. Studies of health costs related to coal and gas combustion for power generation are not yet available for Vietnam. But detailed studies of all major coal and gas generation stations in the United States have been reported in Hidden Costs of Energy, Unpriced Consequences of Energy Production and Use, National Research Council of The National Academies, 2010. Adjusting U.S. externality estimates for differences in gross domestic product (GDP) per capita and population density provides indicative estimates of $20 per megawatt-hour (MWh) for subcritical coal-fired and $1 per MWh for gas-fired generation as health-related external costs. The external cost for supercritical coal plants is estimated at $17.14 per MWh based on the relative efficiency of subcritical and supercritical plants. Power-supply MACs have been calculated both with and without these externality cost adders to guide the GoV's power supply decisions in accordance with PDPVII commitments.

Key inputs for power supply MAC calculations have been provided by the Institute of Energy Vietnam (IEVN), by the International Energy Agency's (IEA's)

Energy Technology Systems Analysis Program (ETSAP), and by U.S. Energy Information Administration (EIA) sources. Basic power supply technologies have similar cost characteristics around the world, as major plant components are subject to international bidding. Thus, international data sources are a useful supplement to data on Vietnam, especially for technologies (such as nuclear and renewables) without significant local data histories. Beyond plant characteristics, the most important and uncertain determinants of MACs are projected fuel prices. Domestic and international coal prices, nuclear fuel, and biomass prices have been projected by the IEVN. Domestic coal prices have been projected at full cost-covering levels from 2015 forward. Table 4.3 summarizes the key power supply cost data used for this report. Such data should be updated regularly to reflect the Vietnamese experience as part of the IEVN's power supply planning efforts.

LNG price projections have significant impacts on key MACs and on the total costs of the LCD coal displacement plan, and merit specific documentation. Prices for LNG delivered to Asia have historically been indexed to oil prices, but this structure is now in flux due to the relative abundance of gas produced by fracking and the emergence of new LNG sources. Most expect a shift to LNG contracts indexed to the Henry Hub gas price in the United States, as the United States approves conversion of more LNG import terminals to export. Landed prices in Vietnam are expected to be about $6 per Million British Thermal Units (MMBTU) above the Henry Hub price, which averaged $3.73 in 2013 and averaged $5.06 for the first four months of 2014. Following extremely heavy use for grain drying in the fall of 2013 and an extremely cold winter, projected landed prices have been fixed at $12 per MMBTU. Delivered costs to new CCGT plants have been estimated to include regasification costs of $0.40 per MMBTU and cost recovery for required investments in an LNG terminal (or terminals) with

Table 4.3 Summary of New Power Plants' Main Parameters

Technology	Life years	CAPEX 2010 $/kW	Variable OMEX 2010 $/MWh	Fixed OMEX 2010 $/kw-yr	Fuel efficiency %	FUELEX 2010 $/MWh 2021	FUELEX 2010 $/MWh 2025	FUELEX 2010 $/MWh 2030	Annual escalation %
Subcritical coal	30	1,432	1.20	30.40	36.0	21.91	23.71	26.18	2.0
Supercritical coal	30	1,432	1.20	30.40	42.0	36.56	39.60	43.69	2.0
Nuclear	40	3,792	2.30	89.00	35.0	22.53	24.37	26.91	2.0
CCGT	30	1,040	3.14	14.77	60.0	85.56	85.56	85.56	0.0
Biomass	30	1,698	9.05	21.26	33.0	21.60	23.38	25.81	2.0
ROR hydro	30	1,798	0	13.35	NA	NA	NA	NA	NA
Wind	25	1,785	0	38.01	NA	NA	NA	NA	NA
Solar PV	30	861	8.04	13.95	NA	NA	NA	NA	NA

OMEX: Operating and Maintenance Expenditures

FUELEX: Fuel expenses (from IEVN Fuel Price Forecasts)

CAPEX is as of the online date (BOY) including allowance for funds used during construction.

Source: World Bank estimates.
Note: CCGT = combined-cycle gas turbine; KW = kilowatts; MW = megawatts; ROR = run-of-river.

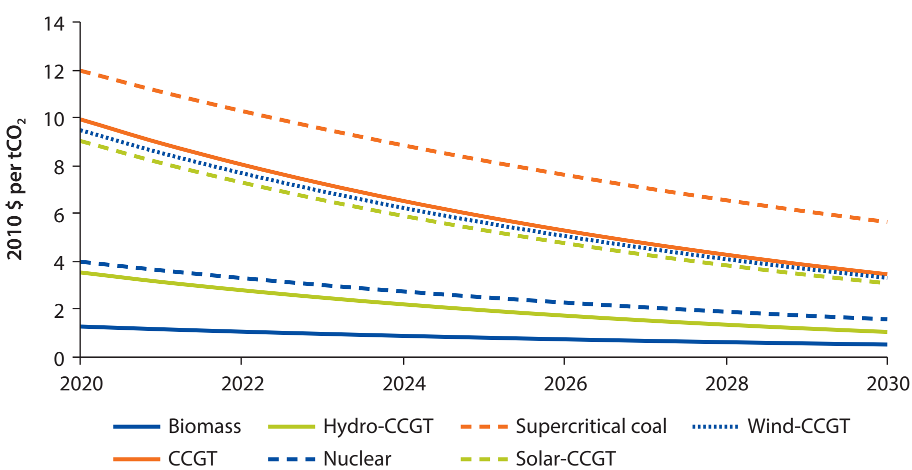
6 mtpa capacity and new gas pipelines connecting the terminal to the new CCGTs. The LNG terminal investment has been estimated at $600 million per mtpa of capacity based on the new terminal just completed in Singapore, although India has recently completed several terminals at about half of that unit cost. Pipeline costs will depend on the terminal and plant locations, but the IEVN estimates an additional $500 per KW for the CCGT CAPEX to cover connecting pipelines. Since high-end estimates have been used for all LNG components, the projected delivered price is left constant at $15.05 per MMBTU for all future years.

MACs are time dependent and obviously related to whether the coal plants displaced are using subcritical technology with domestic anthracite or supercritical technology with imported bituminous coal. Table 4.1 identified 9.9 GW of subcritical and 24.9 GW of supercritical coal plant additions as candidates for displacement in 2021–30.

Figures 4.3 and 4.4 compare MACs for low-carbon options replacing each type of coal plant as functions of the years in which the displaced plants would have come online. Notably in figure 4.3, replacement of subcritical with supercritical coal costs about $2 more per ton of CO_2 emissions reduction than any other option. The efficiency gain for supercritical coal units is simply insufficient to offset the differential costs of domestic and international coal. Pairing wind or solar PV with CCGTs is slightly less costly than solo GTs as gas cost savings from renewables more than offset the incremental capital investment even with 100 percent gas backup. Paired ROR hydro with CCGT and nuclear are lower-cost options, with biomass costing the least among low-carbon options.

All MACs decline as the displacement year is deferred because cost differences are discounted to 2010 while lifetime emission differences are unchanged. However, deferral also reduces the cumulative emissions reductions achieved by

Figure 4.3 Marginal Abatement Costs for Subcritical Coal Displacement by Online Year



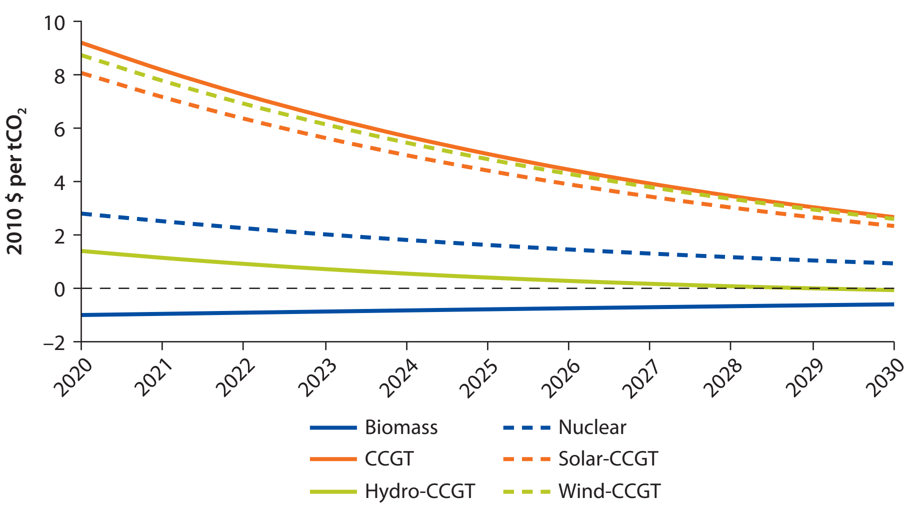
Source: World Bank estimates.
Note: CCGT = combined-cycle gas turbine; tCO_2 = tons of carbon dioxide.

2030, which has been chosen as a key metric for Vietnam's green growth strategy. The trade-off between deferring displacements to lower MACs or accelerating displacements to increase emissions reductions by 2030 is critical in shaping the choice and timing of the low carbon options included in the LCD scenario.

Figure 4.4 shows all alternatives with MACs below $9 for a supercritical coal replacement regardless of the displacement year. By 2025, all alternatives have MACs below $5. The three lowest-cost low-carbon options have MACs below the $2.62 level estimated for energy-efficiency measures for "all other" industry sectors.

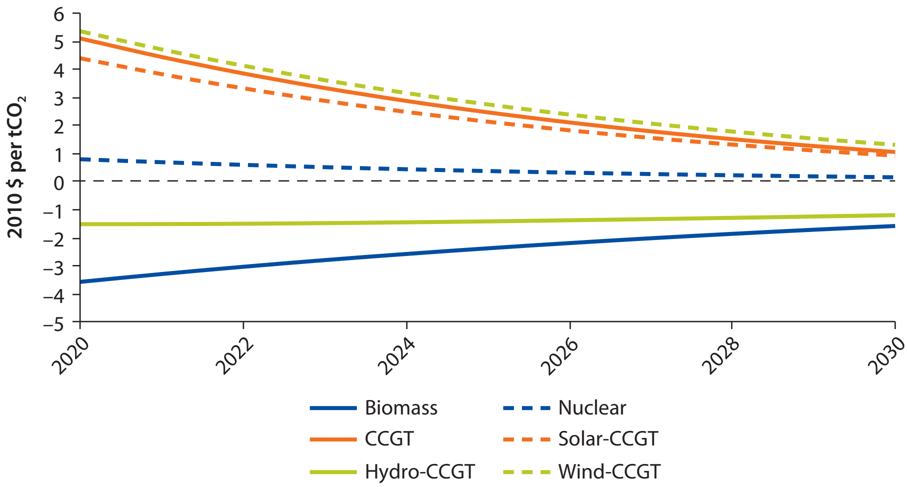
As shown in figure 4.5, including externalities in the MAC estimates, in accordance with PDPVII guidance, dramatically reduces the incremental cost of clean power supply alternatives. With externalities included, all low-carbon supply options after 2025 compare favorably with energy-efficient, low-carbon options; biomass and hydro-CCGT low-carbon options have negative MACs for all online years. If unlimited biomass and ROR hydro resources were available and there were no constraints on nuclear, negative composite power supply low-carbon options might well be possible. Under realistic constraints, however, choices must be made regarding which coal plants to displace on what schedule with which low-carbon options. The objective is to find the least-cost combination of low-carbon options that produces sufficient emissions reductions by 2030 to meet the GoV's green growth targets. Sophisticated modeling might provide an optimal solution. But the uncertainties associated with the data being used limit the analysis at this stage to trial-and-error methods. The immediate challenge is to develop composite MACs (with and without externalities) and emissions reduction estimates for the coal displacement plan outlined in table 4.2 to guide GoV design of a low-carbon power supply plan.

Figure 4.4 Marginal Abatement Costs for Supercritical Coal Displacement by Online Year



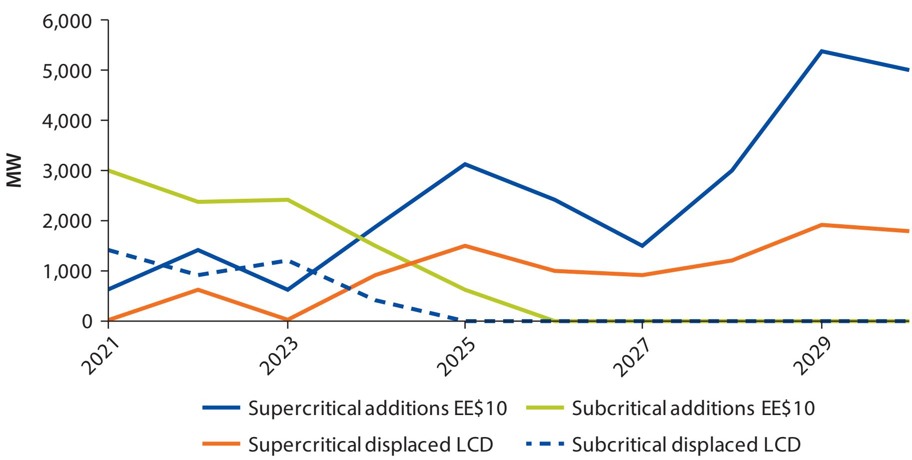
Source: World Bank estimates.
Note: CCGT = combined-cycle gas turbine; tCO_2 = tons of carbon dioxide.

Figure 4.5 Marginal Abatement Costs for Supercritical Coal Displacement, with Externalities by Online Year



Source: World Bank estimates.
Note: CCGT = combined-cycle gas turbine; tCO_2 = tons of carbon dioxide.

Figure 4.6 Coal Capacity Displaced in LCD and EE$10 Scenarios, by Type, 2021–30



Source: World Bank estimates.
Note: EE = energy efficiency; LCD = low-carbon development; MW = megawatts.

MAC and emissions reduction estimates for any low-carbon coal displacement plan for the power sector must specify the online year of the replacement and whether the coal plant being replaced uses subcritical or supercritical technology. While total supercritical coal displacement opportunities (24,780 MW) are much larger than for subcritical coal (9,870 MW), these rankings are reversed in early years through 2023 as shown in figure 4.6. Displacement percentages over the total period approach 40 percent for each technology, with the time pattern logically tracking opportunities.

The LCD power supply plan specifies the clean technology used to displace each of the coal plants in each year. The complete LCD power capacity expansion plan tested in this study is defined in table 4.4 with clear trajectories for the addition of RE, CCGT-LNG, and nuclear plants in lieu of each type of coal plant. By 2030, 9,800 MW of supercritical coal and 3,900 MW of subcritical coal have been displaced in the LCD scenario. This mix avoids complete elimination of new power plant demands for domestic anthracite and also concentrates on reducing reliance on imported coal. The displacement mix also recognizes the lower MACs for supercritical coal displacement.

At this time, the greatest uncertainty in this plan may lie in identifying the specific sites for the planned wind and solar PV plants combined with supportive regulatory policies to allow sound commercial investment in these technologies.

Table 4.4 Total Capacity Additions and Coal Displacement in LCD Scenario, 2021–30 (MW)

	LCD MW Coal Displacements										
Supercritical	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*Total*
Biomass	0	200	0	200	200	200	200	200	0	0	1,200
Nuclear	0	0	0	0	0	0	0	0	1,000	1,000	2,000
Hydro-CCGT	0	0	0	200	600	200	100	300	200	100	1,700
Wind-CCGT	0	0	0	100	200	200	200	200	200	200	1,300
Solar-CCGT	0	100	0	100	200	100	100	200	200	200	1,200
LNG-CCGT solo	0	300	0	300	300	300	300	300	300	300	2,400
Total	**0**	**600**	**0**	**900**	**1,500**	**1,000**	**900**	**1,200**	**1,900**	**1,800**	**9,800**
Repl percent	0.0	42.6	0.0	48.4	48.1	41.7	60.0	40.0	35.3	36.0	39.4
Subcritical	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*Total*
Biomass	400	100	200	100	0	0	0	0	0	0	800
Nuclear	0	0	0	0	0	0	0	0	0	0	0
Hydro-CCGT	400	300	400	0	0	0	0	0	0	0	1,100
Wind-CCGT	200	100	200	0	0	0	0	0	0	0	500
Solar-CCGT	100	100	100	0	0	0	0	0	0	0	300
LNG-CCGT solo	300	300	300	300	0	0	0	0	0	0	1,200
Total	**1,400**	**900**	**1,200**	**400**	**0**	**0**	**0**	**0**	**0**	**0**	**3,900**
Repl percent	46.7	38.0	50.0	26.7	0.0	0.0	0.0	0.0	0.0	0.0	39.5
Total	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*Total*
Biomass	400	300	200	300	200	200	200	200	0	0	2,000
Nuclear	0	0	0	0	0	0	0	0	1,000	1,000	2,000
Hydro-CCGT	400	300	400	200	600	200	100	300	200	100	2,800
Wind-CCGT	200	100	200	100	200	200	200	200	200	200	1,800
Solar-CCGT	100	200	100	100	200	100	100	200	200	200	1,500
LNG-CCGT solo	300	600	300	600	300	300	300	300	300	300	3,600
Total	**1,400**	**1,500**	**1,200**	**1,300**	**1,500**	**1,000**	**900**	**1,200**	**1,900**	**1,800**	**13,700**
Repl percent	38.9	39.7	40.0	38.7	40.3	41.7	60.0	40.0	35.3	36.0	39.4

Source: World Bank estimates.
Note: CCGT = combined-cycle gas turbine; LCD = low-carbon development; LNG = liquefied natural gas; MW = megawatts.

Land requirements for utility-scale wind and solar plants are significant, and full grid integration would require advanced planning efforts.

The substantial addition of 9,700 MW of CCGT-LNG plants with synchronized investment in LNG terminal facilities and connecting gas pipelines must also be carefully planned to implement the LCD plan being recommended here.

LCD economic evaluation will balance both internal and external costs of power generation against reduced carbon and other pollutant emissions achieved through 2030 and over the lifetime of the power plants. Table 4.5 details annual emissions reductions from each low-carbon option and highlights the most interesting evaluation metrics for the recommended LCD power supply plan. Compared to the EE$10 scenario, the LCD plan would:

- Reduce cumulative emissions through 2030 by 341 million tons of carbon dioxide equivalent ($MtCO_2e$).
- Reduce cumulative emissions over the life of the LCD plants by almost 2.0 billion tons of CO_2e.
- Reduce environmental damages over the life of the LCD plants by $48.5 billion (the 2010 present value of those noncarbon benefits is $3.5 billion using a real discount rate of 10.0 percent). Achieve these emission reductions at a modest composite MAC of $2.50 per tCO_2e without recognition of external costs and $.74 per tCO_2e when external costs are acknowledged.

The economic value of these reduced carbon and other pollutant emissions could be established if the damages to Vietnam from those emissions could be projected. If the present value of carbon-related damage exceeds $2.50 per ton, the LCD plan would produce net economic benefits. Avoided health costs would add another $3.5 billion to those net benefits. A common criterion for cost-effective carbon reduction is $10 per ton. Using that estimate of economic value, the LCD power supply plan would have economic benefits of about $23.5 billion compared to economic costs of about $5 billion expressed in 2010 present values. Net benefits expressed in 2014 present value would be about $27.1 billion.

Perhaps the most compelling economic comparisons of the LCD and BAU power sector scenarios are provided in appendix G, which documents reductions of $8.1 billion in CAPEX and $17.6 billion in generation fuel costs.[6] Of course, fuel cost savings would be even greater over the entire life of the power plants and if the external costs of coal combustion were recognized.

Marginal abatement cost curves provide a convenient summary that shows the tons of CO_2 reduction that can be achieved by 2030 compared to the cost per ton of reduction as shown in figure 4.7, which excludes externalities, and in table 4.5 both with and without externalities.

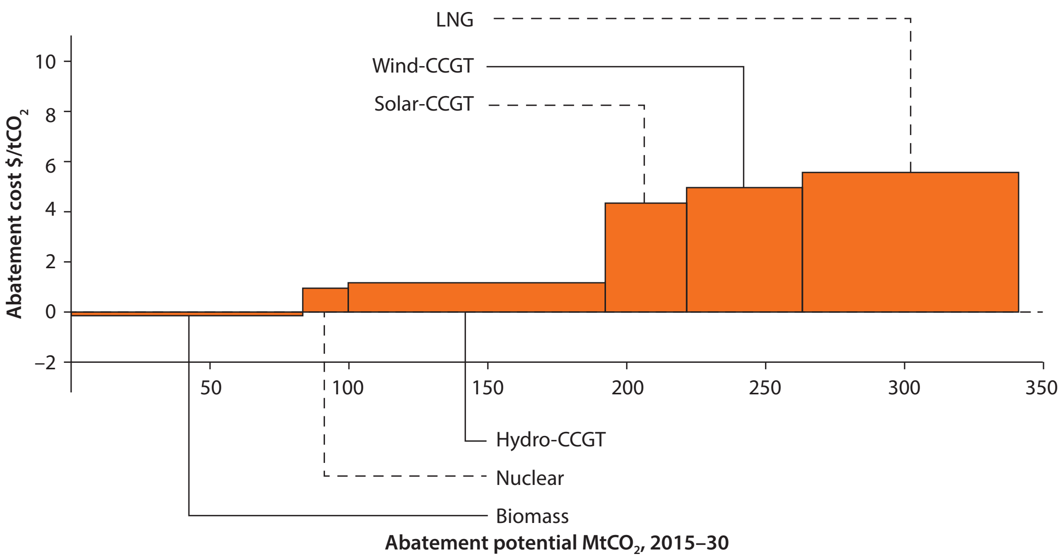
In figure 4.7, the highest option considered is the introduction of supercritical coal-fueled power plants. Leaving aside the introduction of supercritical coal-fueled power plants, all other sources of cleaner electricity production would

Table 4.5 Power Supply Emissions Reductions and Composite Marginal Abatement Costs: LCD Scenario, 2021–30

	$MtCO_2e$												*\$/tCO_2e*	
Supercritical displacement	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*Total*	*Lifetime*	*MAC w/o externalities*	*MAC w/ externalities*
Biomass	0	1.1	1.1	2.1	3.2	4.3	5.3	6.4	6.4	6.4	36.2	191.8	\$ (0.78)	\$ (2.35)
Nuclear	0	0	0	0	0	0	0	0	5.3	10.7	16.0	483.0	\$ 0.96	\$ 0.15
Hydro-CCGT	0	0	0	0.9	3.7	4.6	5.0	6.4	7.3	7.8	35.8	234.1	\$ 0.25	\$ (1.35)
Wind-CCGT	0	0	0	0.4	1.2	1.9	2.7	3.5	4.2	5.0	18.9	125.2	\$ 3.80	\$ 2.07
Solar PV-CCGT	0	0.4	0.4	0.7	1.4	1.8	2.1	2.8	3.6	4.3	17.4	128.1	\$ 3.61	\$ 1.67
CCGT-LNG solo	0	0.9	0.9	1.9	2.8	3.7	4.7	5.6	6.5	7.5	34.6	224.3	\$ 4.44	\$ 2.12
Total	**0**	**2.4**	**2.4**	**6.0**	**12.3**	**16.3**	**19.9**	**24.7**	**33.4**	**41.6**	**158.9**	**1,386.6**	**\$ 1.66**	**\$ 0.19**
Subcritical displacement	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*Total*	*Lifetime*	*MAC w/o externalities*	*MAC w/ externalities*
Biomass	2.6	3.2	4.5	5.2	5.2	5.2	5.2	5.2	5.2	5.2	46.5	155.0	\$ 1.06	\$ (0.99)
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	\$ 0	\$ 0
Hydro-CCGT	2.3	4.0	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	56.6	188.8	\$ 2.79	\$ 0.52
Wind-CCGT	1.0	1.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	22.4	62.3	\$ 7.74	\$ 5.18
Solar PV-CCGT	0.5	0.9	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	12.7	42.2	\$ 7.34	\$ 4.64
CCGT-LNG solo	1.3	2.5	3.8	5.1	5.1	5.1	5.1	5.1	5.1	5.1	43.3	152.9	\$ 7.73	\$ 4.91
Total	**7.6**	**12.2**	**18.5**	**20.5**	**20.5**	**20.5**	**20.5**	**20.5**	**20.5**	**20.5**	**181.5**	**601.2**	**\$ 4.43**	**\$ 2.02**
Total	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*	*Total*	*Lifetime*	*MAC w/o externalities*	*MAC w/ externalities*
Biomass	2.6	4.3	5.6	7.3	8.4	9.4	10.5	11.6	11.6	11.6	82.7	346.8	\$ (0.04)	\$ (1.80)
Nuclear	0	0	0	0	0	0	0	0	5.3	10.7	16.0	483.0	\$ 0.96	\$ 0.15
Hydro-CCGT	2.3	4.0	6.3	7.2	10.0	10.9	11.3	12.7	13.6	14.1	92.4	422.9	\$ 1.25	\$ (0.62)
Wind-CCGT	1.0	1.5	2.5	2.9	3.6	4.4	5.2	6.0	6.7	7.5	41.3	187.5	\$ 4.90	\$ 2.93
Solar PV-CCGT	0.5	1.3	1.8	2.1	2.8	3.2	3.5	4.3	5.0	5.7	30.1	170.3	\$ 4.36	\$ 2.26
CCGT-LNG solo	1.3	3.5	4.8	7.0	7.9	8.8	9.8	10.7	11.6	12.6	77.9	377.2	\$ 5.53	\$ 3.05
Total	**7.6**	**14.6**	**20.9**	**26.5**	**32.7**	**36.8**	**40.3**	**45.2**	**53.9**	**62.1**	**340.5**	**1,987.7**	**\$ 2.50**	**\$ 0.74**

Source: World Bank estimates.
Note: CCGT = combined-cycle gas turbine; LCD = low-carbon development; LNG = liquefied natural gas; MAC = marginal abatement cost; $MtCO_2$ = million tons of carbon dioxide; PV = photovoltaic; tCO_2 = tons of carbon dioxide.

Figure 4.7 Marginal Abatement Cost Curves for the Power Sector



Source: World Bank estimates.
Note: CCGT = combined-cycle gas turbine; LNG = liquefied natural gas; $MtCO_2$ = million tons of carbon dioxide; tCO_2 = tons of carbon dioxide. MACs and abatement potential reflects data provided in table 4.5.

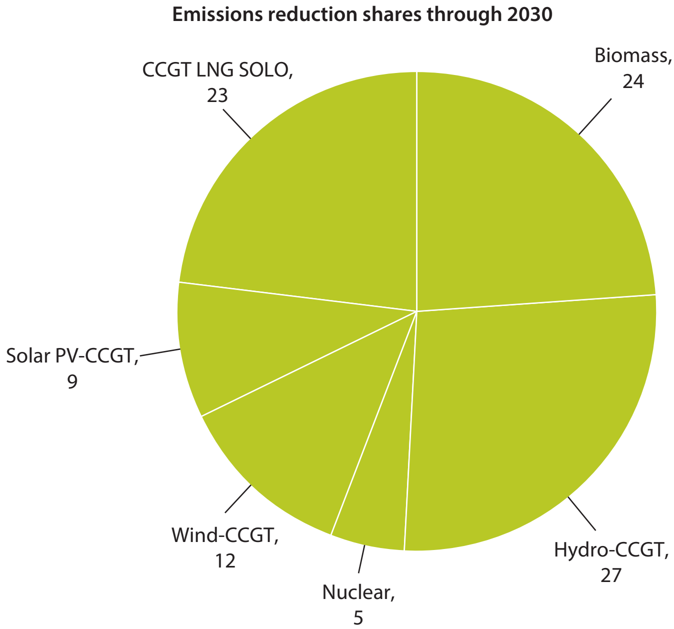
enable Vietnam to abate 341 million ton of CO_2 at a composite cost of $2.50, even without accounting for externalities. If externalities were accounted for, then this composite cost would reduce to $0.74 per ton.

Low-Carbon Development and Energy Security

Both the security and adaptability of the LCD power supply plan are enhanced by the diversity of the generation resources used. The mix of resources included in the LCD power supply plan recommended in this study is indicated in figure 4.8. Substituting gas, four types of renewable energy, and nuclear generation for coal substantially enhances the diversity of fuel supply compared to singular reliance on coal. Such diversity would allow refinement of the mix of LCD renewable sources used—as needed potential, site location, and grid integration studies are completed—and provides some hedging against the uncertainties inherent in fuel price projections.

The total cost of imported power generation fuels would be significantly lower in the LCD scenario than in the BAU scenario. With more than 70 percent of the displaced coal plants using imported coal, increased reliance on renewable domestic fuels enhances the security of power supply and eventually lowers the cost of imported fuels. Assuming a high-end LNG landed price of $12 per MMBTU and no incremental nuclear capacity before 2029, the incremental cost of imported generation fuels compared to the EE$10 scenario is $420 million in

Figure 4.8 Cumulative Emissions Reductions from Power Supply Low-Carbon Options
Percent



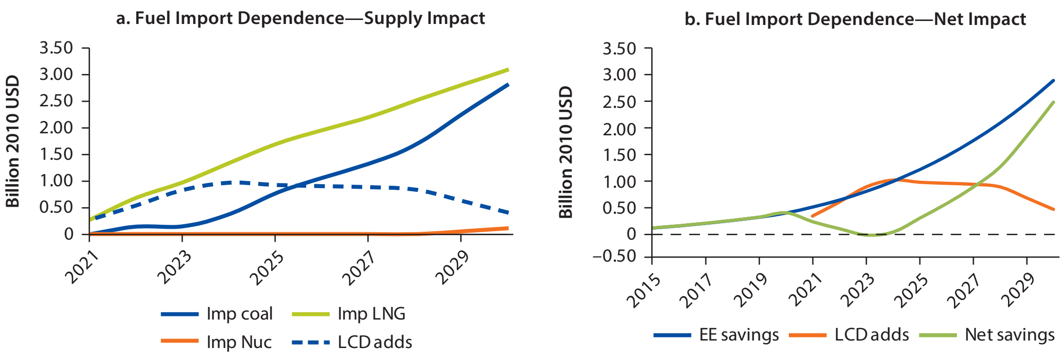
Source: World Bank estimates.
Note: CCGT = combined-cycle gas turbine; LNG = liquefied natural gas; PV = photovoltaic. Based on emission reductions reported in table 4.5.

2030 (figure 4.9, panel a). Shortly after 2030, the LCD fuel import bill would fall below the EE$10 import bill for the remaining lives of the LCD plants. The combined EE and clean technology impacts of the LCD plan would reduce the 2030 cost of imported fuels by $2.5 billion (figure 4.9, panel b) and by a total of $7.9 billion over the 2015–30 period.[7]

While LCD net economic benefits are substantial, the GoV would need to consider financing requirements to implement this power supply plan. Chapter 3 estimated that reductions of 11.7 GW of power plant additions would be possible in 2015–30 with the successful implementation of the cost-effective energy-efficiency measures here considered. With 100 percent CCGT backup for ROR hydro, wind, and solar PV resources, the LCD scenario requires 6.1 GW of capacity additions above the EE$10 scenario. Figure 4.10 tracks the power plant CAPEX requirements for each scenario. CAPEX for both the EE$10 and LCD scenarios are below BAU levels in most years. The cumulative CAPEX reduction from BAU levels for the LCD plan reaches $8.1 billion by 2030.[8]

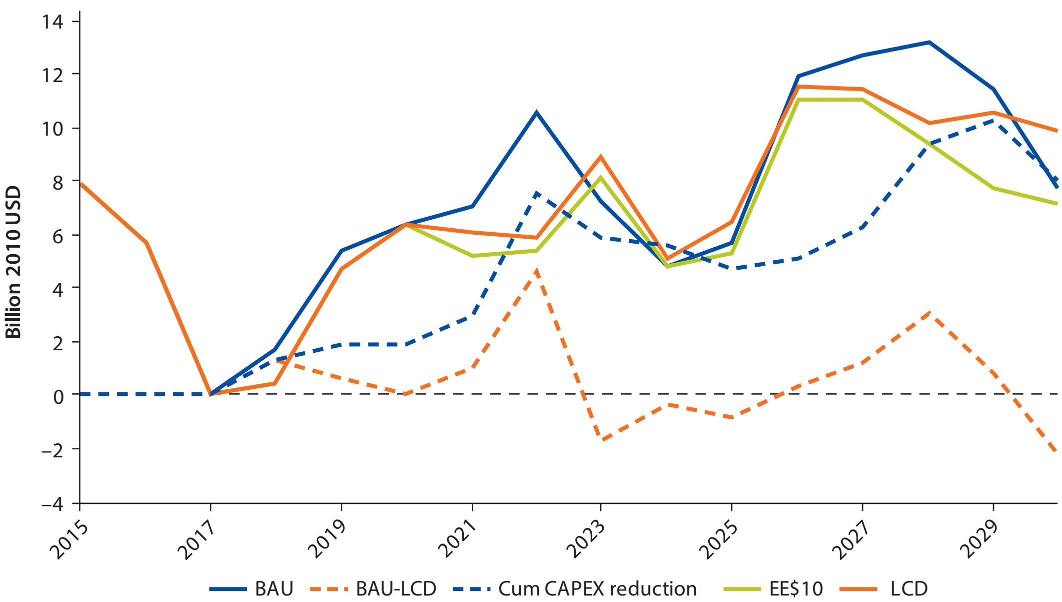
The LCD plan presented here is proposed for adoption by the GoV as a basis for revising the currently approved PDPVII and confirming the targets of the Vietnam Green Growth Strategy (VGGS) for cumulative CO_2 emissions

Figure 4.9 Fuel Import Dependence Changes from Low-Carbon Development



Source: World Bank estimates.
Note: EE = energy efficiency; LCD = low-carbon development; LNG = liquefied natural gas; Nuc = nuclear.

Figure 4.10 Total Power Plants Investments, by Scenario, 2015–30



Source: World Bank estimates.
Note: BAU = business as usual; CAPEX = capital expenditure; EE = energy efficiency; LCD = low-carbon development.

reductions through 2030. As such, it should be seen as a living document subject to continuing refinement as conditions and forecasts evolve. Continuing research in the following areas may reinforce or suggest revisions to the LCD scenario.

Cleaner coal. As shown in table 4.6 the LCD proposed here eliminates 20.45 GW of supercritical coal and 3.90 GW of subcritical coal plant additions from the BAU capacity expansion plan, but 34.94 GW of coal additions still remain in

Table 4.6 Electricity Generation Capacity Additions, by Scenario, MW

	2015–2030					
MW additions	*BAU*	*EE$10*	*LCD*	*BAU-EE$10*	*LCD-EE$10*	*BAU-LCD*
Big hydro	9,491	9,491	9,491	0	0	0
Subcritical coal	21,370	21,370	17,470	0	(3,900)	3,900
Supercritical coal	37,920	27,270	17,470	10,650	(9,800)	20,450
Nuclear	8,700	7,700	9,700	1,000	2,000	(1,000)
CCGT	750	750	10,450	0	9,700	(9,700)
Renewables	350	350	8,450	0	8,100	(8,100)
Total	**78,581**	**66,931**	**73,031**	**11,650**	**6,100**	**5,550**

Source: World Bank estimates.
Note: BAU = business as usual; CCGT = combined-cycle gas turbine; EE = energy efficiency; LCD = low-carbon development; MW = megawatts.

the LCD capacity expansion plan. Thus, it may be possible to further reduce emissions from these plants. Carbon sequestration continues to attract significant research and demonstration efforts. At this time, however, it appears that neither the technologies nor the costs are sufficiently firm to justify large-scale commitments prior to 2030. As new coal plants are designed for Vietnam, consideration should be given to subsequent conversion to sequestration if that becomes technically and economically viable.

The 17.45 GW of subcritical coal plant additions provide additional opportunities for improvement through replacement with supercritical technology that increases efficiency from 36 percent to 42 percent. The limiting factor to increasing such substitutions is the relatively high MAC for this low-carbon option based on the much higher price forecast for imported coal compared to domestic coal. If domestic and international coal price differences were to narrow in the future, this MAC barrier would diminish. This study also assumes that supercritical technology operates much better using more volatile bituminous coal than it can on domestic anthracite. If supercritical technology could be effectively used with less expensive domestic coal, it would obviously be beneficial to displace all future subcritical plants with supercritical units.

Beyond carbon considerations, the external costs of coal combustion could also be reduced significantly by establishing and enforcing tighter standards for new plant emissions of sulfur dioxide (SO_2), nitrous oxide (NO_x), and particulate matter (PM). The best available technology can increase the CAPEX for coal plants by as much as 50 percent, but that cost premium may be economically justified by the reduced health costs associated with emissions from coal plants that have more effective control systems.

Increased use of renewables. In the absence of systematic potential and site location studies for renewable power plants, this study has set modest targets well within the general expectations of the PDPVII. Certainly, the assumed wind generation is substantially below the PDPVII expectations by 2030. The binding constraint here has been the assumed need for 100 percent backup by new

CCGTs fueled with imported LNG, supplied through a new terminal with up to 6 mtpa capacity. Since all costs of LNG supply have been covered in the delivered price to power plants, there is no apparent reason that terminal capacity could not be expanded beyond the 6 mtpa limit. But the phased development of terminals and pipelines must be synchronized with the addition of new CCGTs and the grid integration of renewables. If take-or-pay contracts are used to sell LNG to new power plants, contract volumes must be synchronized with the intended use of the CCGT plants.

The MAC analysis has shown significant economic advantages for ROR hydro and biomass plants. ROR hydro should be the first candidate for expanded consideration, both because of the attractive MAC but also because this technology is well known in Vietnam. Biomass generation is technically proven and cost-effective; but reliable fuel supply, drying, and storage at predictable long-term prices will require policy, organizational, and infrastructure support. Locational studies that identify sufficient fuel densities within an economic radius and fuel procurement strategies need to be developed.

Fuel pricing. The relative price of generation fuels is one of the most decisive determinants of electric grid capacity expansion and utilization strategies. For this study, generation fuel prices have been projected by the IEVN at full cost-recovery levels following subsidy removals to be completed by 2015. But differentials between domestic and international sources both of gas and coal are still open policy questions to be resolved. For this study, the delivered price of LNG has been fixed at $6 per MMBTU above the Henry Hub price, plus cost adders for regasification and debt service on new terminal and pipeline capacity. Domestic coal use is limited more by production constraints than by cost. Changes in generation fuel pricing policy could have significant impacts on the MAC estimates that have guided the low-carbon strategy recommended here.

Electric pricing. From an economic policy perspective, this study firmly concludes that full cost pricing of electricity is essential as a guide to efficient resource utilization. Even though the LCD plan developed here has lower total electric costs than the BAU plan, the increases in electric prices compared with subsidized histories will need to be carefully managed to assure their political viability. Increased electric prices will increase the attractiveness of EE measures, but transitions are often contentious.

Key Recommendations

The LCD strategy recommended here is a power sector road map to a cleaner energy future for Vietnam. As such, it provides options for *what* the GoV may wish to accomplish. Once the road map is established, the remaining questions address *how* that LCD scenario may best be realized. A revised PDPVII that includes both clear demand- and supply-side components with cumulative emissions reduction targets through 2030 would be sufficient to establish the approved road map. Energy-efficiency program development and monitoring in accordance with the recommendations outlined in chapter 3 of this study should be sufficient to cover the needed demand-side adjustments to arrive at the EE$10 power sector scenario. Migration from EE$10 to the LCD scenario would require additional planning and policy development, including the initiatives listed below.

The Green Growth Action Plan (GGAP) approved on March 20, 2014, focuses directly on activities for the 2014–20 period, while the power sector supply-side low-carbon options detailed in this chapter are designed to displace coal-fired power plants with online dates from 2021 to 2030. But the long lead times for power plants require that necessary research on renewable energy potential, siting, grid integration, and biomass and LNG fuel supply be initiated as soon as possible. The GGAP aligns, in part, with the recommendations below (as indicated in endnotes), but this alignment can be strengthened by prerequisite activities to enable the implementation of an LCD power sector plan including both demand- and supply-side components.

- Update and revise Vietnam's power development plan by 2015 to reflect clear EE programs and targeted electric demand reductions for the industrial, household, and transport sectors and the GoV version of table 4.4.[9]
- The LCD scenario recommended here displaces 1,400 MW of coal plants with online dates of 2021. Construction periods and financial closure on such investments typically require five years. Thus, potential, location, and grid integration studies for the renewable and CCGT-LNG replacement plants should be completed by 2017.[10]
- The LCD scenario recommended here requires the increased import of LNG, as follows:

LNG	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
mtpa	0.50	1.22	1.73	2.36	2.98	3.43	3.85	4.39	4.91	5.39

  Thus, terminal and pipeline connections, supply contracts, and pricing must be synchronized to meet these demands unless the LCD scenario is modified. Of course, new sources of domestic gas, if available, could displace some LNG.
- Alternative renewable technologies could replace or supplement those considered here. Possibilities include biomass cofiring with coal, solar thermal to preheat boiler feed water for coal plants, geothermal, and anaerobic digesters for power generation. The LCD scenario should be updated on an annual basis through 2020 and every other year thereafter to provide evergreen power sector development plans in all years.[11]
- Power sector development of renewable generation may be controlled through plant permitting or induced by FITs designed to attract private investment. Vietnam's work on FITs should be expanded to assure a mix of renewable generation that aligns with the LCD scenario, that fully recognizes external costs associated with coal-fired generation, and that clearly establishes the responsibilities for establishing variable energy sources to allow the planned displacement of coal-fired alternatives.
- As demonstrated by the indicative estimates used in this study, externalities relating to health costs associated with coal-fired generation have substantial

influence on the MACs of cleaner technologies. Research to establish Vietnamese health costs, reduced productivity, and other damages related to emissions of SO_2, NO_x, and PM should be initiated as soon as possible. Economic evaluation of establishing and enforcing tighter limits on coal and gas plant emissions can then be established and reflected in the LCD scenario.[12]

- The Vietnamese appetite for nuclear power will have significant impact on the LCD scenario. The range of acceptable nuclear additions prior to 2030 should be established (not directly addressed in the GGAP).

Electric price forecasts for any LCD scenario must be compared to forecasts for the BAU power sector plan to assess macroeconomic impacts and the need for social safety net programs to moderate transitions to full cost-recovery pricing (not directly addressed in the GGAP).

Notes

1. This figure includes end-user electricity savings from increased efficiency in the industry, residential, and transport sectors, as well as transmission and distribution losses.
2. The 1,000 MW nuclear addition shown in 2020 was included as part of the PDPVII base plan. That schedule no longer appears feasible, but has not been revised pending receipt of new information regarding the nuclear capacity addition plan.
3. This study assumes that gas-fired generation added prior to 2016 will be supplied from domestic natural gas based on take-or-pay contracts. All new CCGTs added in the post-2015 period will burn imported LNG. If some new CCGTs added after 2015 can be supplied with domestic gas, the costs of the LCD scenario could be reduced significantly from those estimated in this report.
4. Ho Chi Minh City's solar irradiance at 5.2 $KWh/m^2/day$ translates to 1,900 $KWh/m^2/year$, which is comparable to the southern two-thirds of Spain and about 50 percent above the German average.
5. Peaking resources on the Vietnamese grid consist of some small oil- and diesel-fueled peakers, plus storage hydro, plus pumped storage hydro.
6. These amounts are expressed in 2010 $.
7. Imported fuel cost comparisons primarily reflect projected costs for imported coal and imported LNG. LNG landed costs have been estimated at $12.00 per MMBTU for 2015–30 based on a Henry Hub price of $6.00. Current (2015) landed costs for LNG in Asia are about $8.00 per MMBTU.
8. The CAPEX analysis here focuses solely on comparative investments in power plants. The sizeable CAPEX required for an LNG terminal and for new gas pipelines has not been included here since those costs have been fully reflected in the delivered price of LNG to the new CCGT plants in the LCD.
9. This corresponds to GGAP activities 14, 15, 16, 37.
10. See GGAP activities 26, 27, 28, 36, 41.
11. See GGAP activities 21, 26, 27.
12. See GGAP activities 2 and 9.

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CHAPTER 5

Sustainable Transportation and Urban Planning

Overview

- Transport interventions with a marginal abatement cost (MAC) less than $10/t$CO_2$ (tons of carbon dioxide) contribute 10 percent of the CO_2 emissions reductions projected in the low-carbon development (LCD) scenario.
- Considerable attention to spatial urban planning will be critical for reducing CO_2 emissions from the transport and building sectors as cities in Vietnam expand. Mixed-use urban planning would significantly reduce the need to travel and, thus, lower CO_2 emissions.
- Electric bicycles (e-bikes) contribute 52 percent of all CO_2 emission reductions in the transport sector in the LCD scenario.
- Improvement to inland waterways is the initiative with the lowest MAC—it results in a benefit of over $200 per ton of CO_2 (tCO_2) avoided.

Low-Carbon Development in the Transport Sector

Transportation needs have grown significantly as the Vietnamese economy has grown. Freight increased by over 12 percent per year between 1995 and 2006 in terms of volume (tons) and distance traveled (kilometers, km). Passenger traffic grew by slightly less than 10 percent per year during the same period. Vehicle ownership increased as well—Vietnam had approximately one million cars and 20 million motorcycles at the end of 2010, which represented an increase from 450,000 cars and six million motorcycles at the end of 2000. Transport energy demand is projected to grow by 7.6 percent per year, and emissions from the sector are projected to rise likewise. Transport plays an important role in reducing CO_2 emissions while sustaining economic growth. Since urban spatial planning is closely related to transportation needs, spatial urban development is equally important for sustaining economic growth.

The economic cost of poorly planned transportation is significant; hence improved transportation planning is needed to sustain economic growth. A recent study of the existing traffic congestion in Ho Chi Minh City (HCMC) indicates that congestion is already having serious economic consequences. The average delay at peak times was 45 minutes. The study shows that this is largely because of reckless driving, high overall traffic volumes, and a low share of public transport. The socioeconomic cost of traffic congestion is about VND 14,000 billion a year (equivalent to $0.8 billion), which is 6.25 percent of the total gross domestic product (GDP) of HCMC. Traffic congestion in Hanoi has yet to reach the levels in HCMC, but there is need for sustainable modes of urban transportation that provide efficient mobility within and between the cities. Without efficient transportation, the economic potential of urban centers will be constrained; competitiveness and safety will be compromised; congestion and air pollution will abound; and there will be consequential negative effects on economic growth, household incomes, the urban environment, and quality of life.

Under the business-as-usual (BAU) scenario, emissions from the transport sector are expected to rise by 140 percent. The BAU scenario was constructed by summing up emissions from vehicle activity in the country, and projecting this into the future. Only road, water, and rail transportation are included in the analysis. Aviation and other aspects of the transportation value chain are not included. Thus emissions from airports, railway stations, and the bus-building industry are not included.

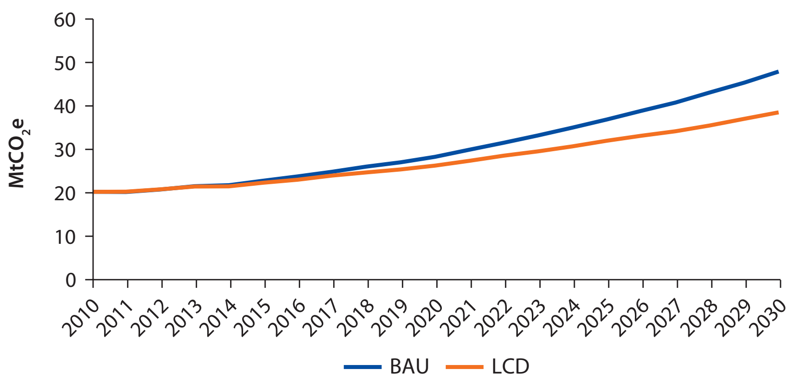
Measures incorporated in the LCD scenario promise a 20 percent reduction in emissions in the transport sector by 2030. The specific measures that would accomplish this are summarized in table 5.1. The resulting potential reduction in CO_2 emissions is about 60 $MtCO_2$ (million tons of carbon dioxide). Figure 5.1 provides a comparison of potential reductions under the BAU and LCD scenarios.

Table 5.1 Summary of Transport Measures Incorporated in the BAU and LCD Scenarios

	Measures
1	Improve inland waterways—replace smaller with larger vessels at the rate of 2 percent per year and replace self-propelled with pushed barges at the rate of 15% per year; BAU assumes current fleet
2	Coastal freight—replace smaller with larger ships or vessels at the rate of 2% per year
3	Freight modal shift from road to coastal: BAU has 17%, LCD has −22%
4	Motorcycles—40% of new sales in BAU are electric by 2030, in LCD 90% of new sales are electric
5	Freight modal shift from road to rail: in BAU rail represents 12% of total freight and passenger kilometers; in LCD this increases to 14%
6	Private vehicles move from EURO III standard in BAU to EURO VI standard by 2030
7	In the LCD 9.36% shift from two wheelers to public transport and 3.57% shift from cars to buses
8	Switch bus fuel to CNG (from 20% in BAU to 60% by 2030 in LCD)
9	Increase the use of biofuel (from 2.75% to 4.2% in 2030)
10	Passenger modal shift from road to rail: BAU has 10.3%, LCD has 12%
11	Add BRT in Hanoi (1 line) and HCMC (2 lines)

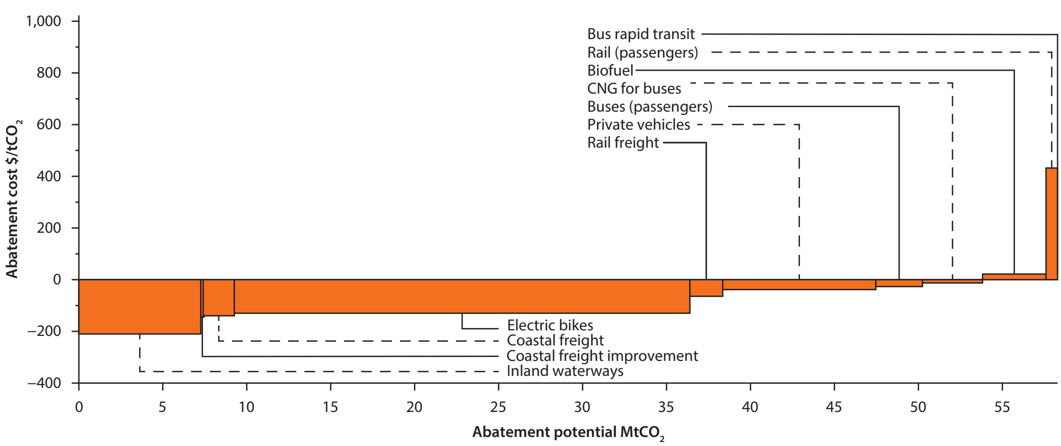
Source: World Bank estimates.
Note: BAU = business as usual; BRT = bus rapid transit; CNG = compressed natural gas; HCMC = Ho Chi Minh City; LCD = low-carbon development.

Figure 5.1 Transport: The BAU vs. LCD Scenarios, 2010–30



Source: World Bank estimates.
Note: BAU = business-as-usual; LCD = low-carbon development; $MtCO_2e$ = million tons of carbon dioxide equivalent.

Figure 5.2 Transport Sector: Marginal Abatement Cost Curves



Source: World Bank estimates.
Note: CNG = compressed natural gas; $/$tCO_2$ = U.S. dollars per tons of carbon dioxide; $MtCO_2$ = million tons of carbon dioxide.

The interventions incorporated in the BAU scenario are in line with the National Climate Change Strategy (NCCS), Vietnam's Green Growth Strategy (VGGS), transport sector master plans, and relevant decrees and decisions. The effect of each political decision is included in either the BAU or LCD scenario, as summarized in figure 5.2. Of the interventions, integrated land-use and transportation planning, support for electric vehicles, and enhanced public transportation are described.

The MACs in the transport sector are summarized in figure 5.2; the majority of the measures selected have negative MACs.

The increased use of e-bikes has the highest mitigation potential, at 27.13 million tons of carbon dioxide equivalent ($MtCO_2e$), and a negative MAC of \$130/tCO_2e. The number of motorcycles in Vietnam grew by

17.6 percent per year between 1990 and 2006; the country had 20 million motorcycles by 2010. Switching the population of gasoline motorcycles to e-bikes would result in a net economic gain of $3.5 billion to the Vietnamese economy. Decision No. 49/2011/QD-TTg, dated September 1, 2011, by the prime minister, stipulated a road map for applying emissions standards to manufactured, assembled, and newly imported cars and two-wheeled motor vehicles. Electric mobility could be added to this decision. Within the framework of the Green Growth Action Plan (GGAP), this would fit under activities 10 and 14.

Passing regulations requiring that manufacturers sell a certain proportion of e-bikes relative to gasoline motorcycles would help jumpstart the market for e-bikes. Considering restricting access of gasoline-powered two-wheelers to certain areas has also proved effective in other countries. The government would also have to set standards for e-bikes, and motorcycle manufacturers would have to invest to comply with the regulations. Alternatively, the government could provide incentives that encourage people to purchase e-bikes.

Increasing the use of public transportation is fundamental to Vietnam's sustainable mobility and economic growth, given its cities' high population density and structure. The benefits of public transportation projects stem not only from associated savings in energy and operational costs, but from broader benefits to social welfare. Public transport was neither a central government nor a municipal priority in the initial years after the Doi Moi Reform in the 1980s, and by the end of the 1990s, bus travel accounted for only about 2 percent of all trips. This has changed significantly in the past few years, with buses accounting for about 8 percent of trips by vehicles in 2006. Despite a 20-fold increase in bus ridership, from 1.2 million monthly trips in 2001 to over 24 million monthly trips in 2006, public transport accounts for only 10 percent of total trips. In Decision No -71/2004/QD-TTg, the prime minister established priorities to promote public transport with mode-share goals for 2010 and 2020 (30 percent in 2010 and 50 percent in 2030) and to encourage the participation of the private sector in the provision of bus services. The analysis undertaken for this study indicates that public transportation projects reduce congestion (time-saving benefits), lower accident rates (health and value-of-life benefits), and lower the burden of disease as they improve air quality (health benefits). This fits within Decision No. 403/QD-TTG activities 17, 18, and 19.

To improve public transport, the government needs to encourage passengers to shift to buses, rail, or mass rapid transit (MRT). A shift to buses is the only way of supporting public transportation that has a negative MAC of –$27/t$CO_2$e. The transport sector master plan specifies a provision to introduce bus rapid transit (BRT) in Hanoi, HCMC, and several other cities. Decision No. 403/QD-TTG Activity 32 encourages the Ministry of Transport (MOT) to consider the role of sustainable development in the transport master plan. But comprehensive transport system planning—and not only the construction of stand-alone BRT corridors—is needed to increase the demand for public transport and optimize investment costs for large infrastructure.

In addition to the BRT, the Government of Vietnam (GoV) could also support community vehicles, such as school buses, factory buses, or any other schemes offering a public or commercial transportation service to a group of commuters. The GoV should promote systems allowing seamless travel between one mode and another, and among systems managed by different operators. Such seamless interchange is possible if proper interchange infrastructure is available and users are able to use a single ticket across systems. The central government's financial support could be contingent on setting up the appropriate authorities or entities to ensure that a coordinated and integrated public transport system becomes available.

Integrated Land-Use Planning

Developing policies and institutions that enable integrated land-use and transportation planning is critical for sustainable economic growth. There are inherent links among urban structure, transport, and mobility. For example, in Hanoi the high population density and sparse road networks are not compatible with the widespread use of private cars. At the current average density in Hanoi (188 people per hectare), a car ownership ratio of 250 cars per 1,000 people (similar to the average in Malaysia but much less than in Kuala Lumpur) would require a vehicular street area that comprises 19 percent of the total built area—practically the entire street area of Hanoi. This would allow just half of the cars owned to run at 30 kilometers per hour (km/h). As the centrally located districts have densities close to 400 people per hectare, a car ownership ratio of 250/1,000 would lead to total gridlock in the central business district. Thus city planners must discourage car use in this district and carefully consider the relationship between transportation and spatial growth as the city expands. Hanoi has an ambitious growth plan based on leading investments in urban road infrastructure. The major directions of this planned growth are to the west of the existing urban area (that is, to the west of West Lake) and to the north (beyond the Red River). Necessary prerequisites are the development of the primary road network serving these areas and mixed-use planning. Hanoi currently has few high-standard urban arterial roads as the recent expansion of the city has occurred around an evolving network of ring and radial routes. The expansion and extension of the Second Ring Road, in the west and toward the north of the city, is perceived by many as the key facilitator of the proposed urban growth. Within Decision No. 403/QD-TTG, this effort is largely supported by activity number 48.

One way to enable integrated land-use and transport planning is to support pilot studies in a few cities, connected to Decision No. 403/QD-TTG (activities 32, 35, and 36). The newly developed areas would tend to adopt mixed land-use policies and road planning that supports two or more modes of transport: for example, sidewalks for pedestrians and bicycle lanes for cyclists. Implementing these measures would require the strengthening and capacity building, notably of the Ministry of Construction (MOC), to regulate and constrain urban sprawl. The government could also support integrated planning by offering incentives for the construction of bicycle paths, pedestrian walkways, and midsize streets to connect local networks of small lanes to the larger roads of the city. The new streets being created are generally too wide: many are 40 meters (m) wide with lanes of 4 m width. A ten-fold jump in width between the many small local lanes and the higher-level system does not provide the transition needed to ensure efficient street pattern integration.[1]

Note

1. For the sake of comparison, 60 percent of Parisian streets are less than 12 meters (m) wide; the urban boulevards of Paris are like the avenues and streets in Manhattan—most are 20 m wide and some are 30 m wide.

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CHAPTER 6

Macroeconomic and Electricity Pricing Implications

Overview

- At first, gross domestic product (GDP) growth would be modestly reduced by the additional investments that low-carbon development (LCD) entails, but in the medium and long term the additional efficiency of the economy would benefit economic growth and exports.
- Unit electricity costs in the LCD scenario would be only slightly higher than under the business-as-usual (BAU) scenario.
- Investing in low-carbon options, however, would not be responsible for the bulk of the projected growth in the price of electricity in Vietnam. This increase is mainly due to the growth in consumption of fossil fuels, independent of a low-carbon strategy.

Introduction

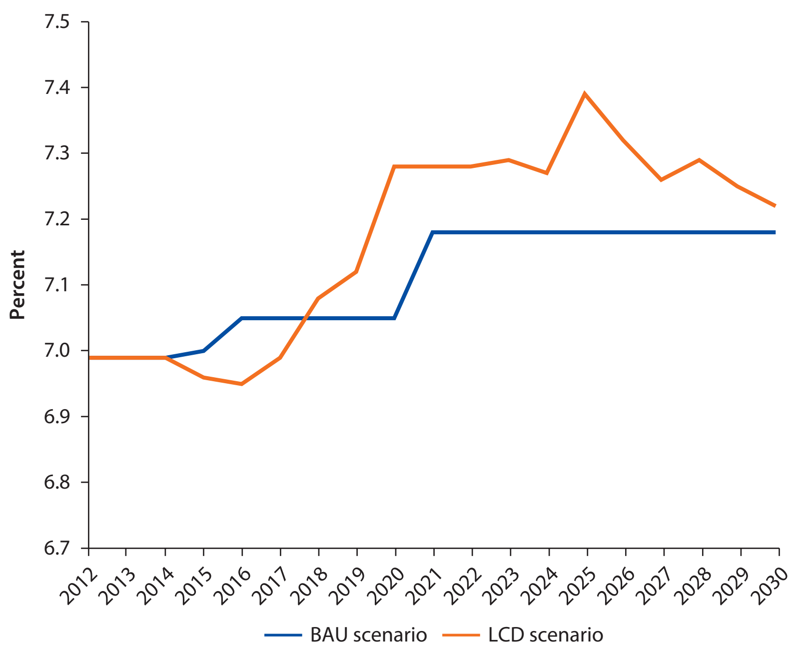
This chapter assesses the macroeconomic and electricity pricing implications of LCD in Vietnam. Since Vietnam is a low-income country and is likely to remain so in the near future, robust economic growth is required to reduce poverty and meet the economic goals of the country. The macroeconomic and electricity pricing implications of the LCD scenario are, hence, an important consideration in the implementation of LCD options. How would the LCD scenario impact Vietnam's economic growth? How would the structure of the economy evolve? How would Vietnam's external competitiveness be affected? What about inflation and employment? How would the implementation of low-carbon options affect electricity pricing? Two models—a computable general equilibrium (CGE) model[1] and a revenue requirement model[2]—are used to evaluate the implications of the LCD scenario, developed based on bottom-up modeling using the Energy Forecasting Framework and Emissions Consensus Tool (EFFECT).

Macroeconomic Implications

The LCD scenario would have a positive impact on economic growth after a brief initial adjustment period (figure 6.1). The results of the CGE analysis suggest that beyond 2019 GDP growth would be slightly higher under the LCD scenario than under the BAU scenario. Before 2019, a slight reduction in growth is anticipated: the large up-front investments required under the LCD scenario would not yield immediate net economic benefits. But both the gains and losses estimated from the CGE model are relatively small. This is consistent with the results of modeling carried out by the Intergovernmental Panel on Climate Change (IPCC) at the global level, which indicate that policies for climate change mitigation, such as those proposed in this report, are likely to have a minor impact on global economic growth—on average less than around +0.08 to –0.12 percent of GDP growth (IPCC 2007). Furthermore, investments in the green economy are also expected to reduce the downside risks of adverse events associated with climate change, energy shocks, water scarcity, and loss of ecosystem services.

The implementation of low-carbon options is expected to accelerate a shift to services. The share of industry is expected to maintain a similar level. Low-carbon options identified in this report represent long-term

Figure 6.1 Vietnam's Economic Growth under the BAU and LCD Scenarios, 2012–30



Source: World Bank estimates.
Note: BAU = business-as-usual; LCD = low-carbon development.

benefits through reduced fuel costs and improved performance (beginning with "no-regrets" mitigation options) but short-term costs to those who pay for them.

Vietnam's exports can be expected to be marginally lower in 2015–17 under the LCD scenario due to an increase in energy costs and production costs. Beyond 2017, once firms respond by restructuring their production and improving their energy efficiency, exports should be higher and more than make up for the losses incurred in the initial years. By 2030, exports under the LCD scenario are projected to be 8 percent higher than under the BAU scenario.

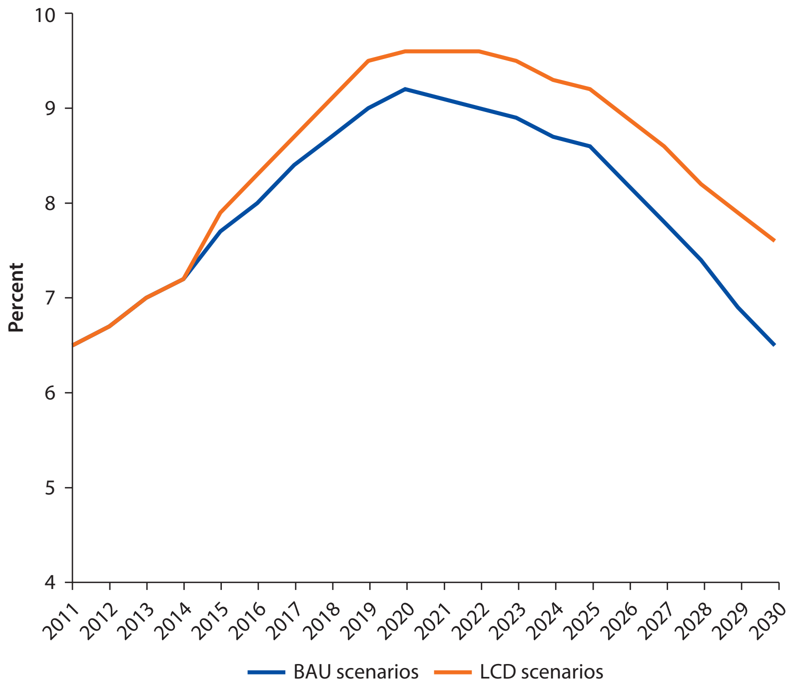
As Vietnam undergoes the structural changes inherent in the move toward a low-carbon economy, new export opportunities are likely to open up. The strongest potential for growth in Vietnam is likely to be in low-carbon technologies and renewable energy technologies and services. A number of developing country firms have already gained significant market share in new technologies. China is now the largest solar panel exporter in the world, with a two-thirds share of the global market. It has captured close to 80 percent of the European market for solar panels, with exports that reached $27 billion in 2011. India's Suzlon Energy is now a global supplier of wind turbines, with a 6.3 percent share of the global market in 2013. Both China's and India's sizable domestic markets have been springboards for export success, driven—as in the Organisation for Economic Co-operation and Development (OECD) countries—by ambitious domestic targets for renewable energy generation.

The LCD scenario is projected to result in a modest increase in consumer prices over 2014–30 (figure 6.2). This is mainly a reflection of higher electricity costs and prices on account of the adoption of low-carbon electricity options such as renewable energy, combined-cycle gas turbine (CCGT), nuclear, and liquefied natural gas (LNG), which are projected to be more expensive than coal generation.

Implementation of LCD options is anticipated to have a minor overall impact on employment. Gains in employment in low-carbon sectors of the economy are expected to even out the losses in carbon-intensive sectors (such as coal mining). Employment opportunities in the green sectors of the economy are expected to increase. New occupations will be created in alternative energy technology and building retrofitting: for example, energy auditors, wind technicians and engineers, and solar installers and technicians.

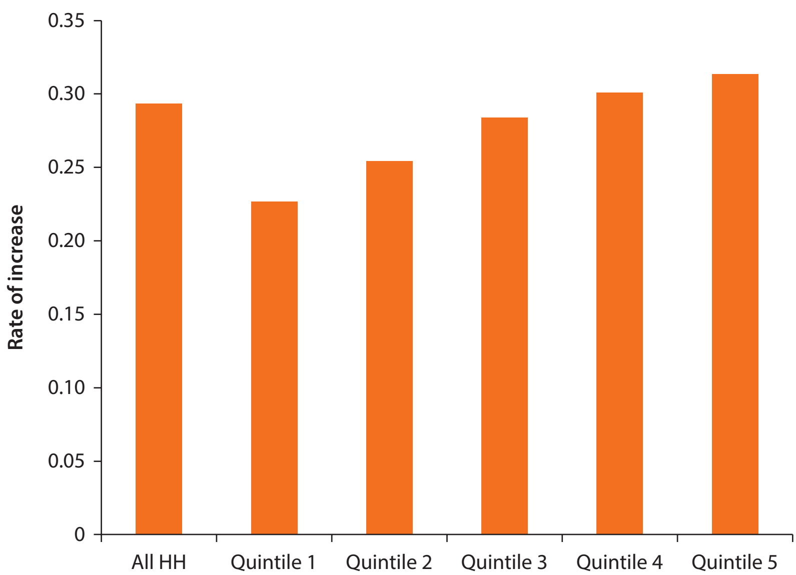
People in higher-income quintiles are likely to benefit more than people in lower-income quintiles in the LCD scenario. The results of the CGE model indicate that household consumption is expected to be higher across all income quintiles in the LCD scenario than the BAU scenario. But the rate of increase is expected to be higher in the upper-income quintiles than in the lower-income quintiles (figure 6.3).

Figure 6.2 Inflation under the BAU and LCD Scenarios, 2011–30



Source: World Bank estimates.
Note: BAU = business-as-usual; LCD = low-carbon development.

Figure 6.3 Difference in the Rate of Increase in Household Consumption over 2014–30 between the LCD and BAU Scenarios, by Income Quintile



Source: World Bank estimates.
Note: BAU = business-as-usual; HH = households; LCD = low-carbon development.

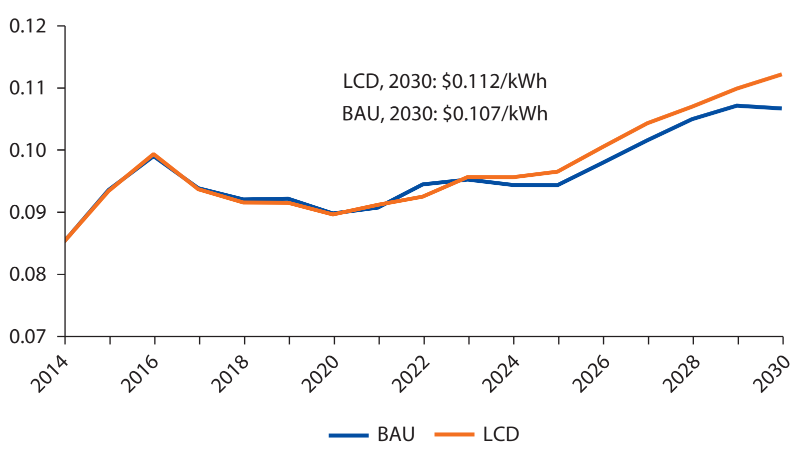
Electricity Pricing Implications

The unit cost of electricity supply is projected to increase under both the BAU and LCD scenarios developed in this report.[3] Under the BAU, they would rise from (in real 2010 terms) 8.5 cents to 10 cents by 2016, fall to 9 cents by 2020, and then rise gradually to almost 11 cents (figure 6.4).[4] From 2015 through 2030, this represents an average 1.4 percent annual increase above inflation. This cost includes all utility costs of generating and supplying electricity; it does not include the costs of externalities.[5]

Under the LCD scenario, unit electricity costs would be only slightly higher than under BAU, reaching just over 11 cents (in real 2010 terms) by 2030 (figure 6.4). As in the BAU scenario, they would initially peak at 10 cents in 2016, then fall and not surpass the 2016 peak until 2026. From 2015 through 2030, they would increase by an annual average of about 1.7 percent above inflation. Because there is significantly less electricity produced under the LCD scenario than under the BAU scenario, however, total electricity costs (the per unit cost, multiplied by electricity sales) are significantly lower under the LCD scenario—6.4 percent lower by 2030—than under the BAU scenario.

The unit cost of electricity, meanwhile, would be *lower* under the LCD scenario than under the BAU scenario if the economic cost of carbon and local pollutant emissions were included in the electricity cost. As described in chapter 2, the LCD scenario emits significantly less carbon dioxide (CO_2) and local pollutants (particularly from coal combustion). Using conservative assumptions for the cost of these pollutants[6] brings the unit cost of electricity under the BAU just

Figure 6.4 Unit Electricity Costs, 2014–30
2010 $/kWh



Source: World Bank estimates.
Note: Vietnam's electricity costs are expected spike in 2014–16 due to an anticipated over-investment in generation capacity in this period.
BAU = business as usual; kWh = kilowatt-hour; LCD = low-carbon development.

above the cost under the LCD by 2030 and well above the LCD cost over the lifetime of plants built under each scenario. It is critical to be aware of the costs of conducting BAU, as the country will ultimately pay them, even though they are not paid by an individual utility.

The increase in the cost of electricity in both scenarios is driven primarily by the scarcity of domestic fuels and growing electricity consumption. This manifests in an increase in fuel costs and increased generation investment. Vietnam is projected to rely more heavily on coal and gas as new hydro will become unavailable, which will deplete its domestic sources (thus raising their prices) and require new reliance on costly imports. It is also projected to remove coal subsidies, further increasing domestic coal costs. Last, the country will add significant generation capacity, requiring large capital expenditures (CAPEXs) and increased operation and maintenance (O&M) costs (see appendix C for details).

The further increase in per-unit electricity costs under the LCD scenario results from electricity demand falling by more than electricity costs. Energy-efficiency (EE) measures reduce demand under the LCD scenario. This lowers generation capacity investment needs and operating costs. The low-carbon generation options (renewable energy, CCGT, nuclear plants, and greater use of LNG) negate this initial cost reduction somewhat; however, they are necessary for Vietnam to come close to achieving its green growth targets. In addition, if the economic costs of pollutants are included, the generation options presented in the LCD scenario are cheaper than those in the BAU scenario over their lifetime (which is why the unit electricity cost, including the economic cost of pollutants, is lower under the LCD than under the BAU).

The electricity demand impact of pricing policies has implications for CO_2 emissions. If cost-recovery pricing is not pursued, CO_2 emissions would be higher—by between 2.3 and 8.1 million tons, depending on whether consumers are less or more responsive to price increases.

Mitigating Adverse Impacts

The government will need to balance the wider social benefits of reforms with the losses of those adversely affected. Safety net policies for those likely to be negatively affected may include an expansion of lifeline electricity tariffs; income support; and access to alternative employment, retraining opportunities, and relocation assistance. Energy-intensive businesses—particularly small and medium enterprises (SMEs)—may also be at risk. Vietnam can strengthen support to them by expanding the reach of the National Target Program on Energy Efficiency and developing the capacity of energy service companies to assist in implementing energy-efficiency measures. Such policies will go a long way toward mobilizing political and workplace-based support for the changes that are needed.

The political economy of low-carbon reforms promises to be challenging; concerted communication efforts are required to build support for reforms.

Energy-intensive state-owned enterprises (SOEs), for instance, may lobby for subsidies to maintain their competitiveness. A strong communication strategy would help ensure that the public appreciates and understands how to access benefits of the various mitigation measures. Information about energy-efficiency improvements and other steps consumers can take to protect themselves from the impact of price increases; the high health, environmental, and other costs of underpricing and overconsuming electricity; and the benefits that cost-recovery pricing will have in promoting green growth is key. Along with information on the underlying rationale, the benefits of price increases (those discussed above, as well as alternative uses for avoided subsidy expenditures) may be stressed, as well as the negative side effects of subsidies. At the same time, the government can ease the transition to higher prices by offering low-cost and easy-access financing to industries changing their processes to be more efficient—and to produce more-efficient products.

Notes

1. To carry out the analysis, the Central Institute for Economic Management (CIEM) made extensions and modifications to a computable general equilibrium (CGE) model that had been prepared by CIEM for an earlier study by (i) adding a production function to allow substitution among energy types and energy and production factors and (ii) changing the closure rules to have the model cover the 2011–40 period. The model is based on the 2011 social accounting matrix (SAM) for Vietnam, which was constructed by CIEM in collaboration with the World Institute for Development Economics Research (WIDER, United Nations University). The model uses the General Algebraic Modeling System (GAMS) software and is formulated as a Mixed Complementary Problem (MCP) with a system of simultaneous linear and nonlinear equations.
2. To project electricity costs, a revenue requirements model has been used. The model assumes that a utility requires revenue to cover the entirety of its fuel expenditures, operating and maintenance costs, and capital expenditure (CAPEX) financing costs (figure 6.1). It then derives a per unit electricity cost by dividing the total utility revenue requirement by final electricity sales.
3. Both the business-as-usual (BAU) and low-carbon development (LCD) scenarios assume a two-tier fuel pricing policy with domestic fuels priced to cover production and delivery costs and imported fuels priced at projected international prices. Domestic coal prices move from subsidized prices in 2010 (approximately 70 percent of production costs) to full cost-recovery levels by 2015 and thereafter. Domestic gas prices represent long-term contract prices for specific power plants that cover all costs for production, pipeline, and delivery services.
4. We can compare this to the long-term electricity price goal in Power Development Plan VII (PDPVII), of between 8 and 9 cents per kilowatt-hour (kWh) by 2020. This projected path leads to an electricity price of about 9 cents (in real 2010 terms) in 2020.
5. This includes fuel costs, operating expenditures on generation and transmission and distribution (T&D), and the cost of capital investments in generation capacity and T&D infrastructure (financed at the social discount rate of 10 percent).

6. \$5 per ton of CO_2, \$20 per gigawatt-hours (GWh) from a subcritical coal plant and \$17 per GWh from a supercritical coal plant.

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CHAPTER 7

Policy and Institutional Measures

Introduction

The policy areas described in this report will have a profound effect on the pattern of Vietnam's development. The demands on government to set Vietnam on a low-carbon development (LCD) path are significant. Whether Vietnam can capture strategic green opportunities over the next two decades will depend on its willingness to implement reforms in a large number of areas. Through the Vietnam Green Growth Strategy (VGGS) and the Green Growth Action Plan (GGAP), the government has already made a strong commitment to reforms. The policy recommendations offered in this chapter are aligned with GGAP but at the same time are more specific, prioritized in areas with the most impact, and take a longer view of reforms.

Area 1: Energy Price Reform

Energy price reform is necessary to provide the basic market conditions for green development in Vietnam. Reforming pricing mechanisms for fossil fuels, most notably coal and electricity, can help kick-start the transformation of traditional sectors, start reducing environmental externalities, and mainstream long-term sustainability goals. To ensure that prices reflect market scarcity, direct and indirect subsidies for traditional energy and resource commodities must be removed, and state-owned enterprises (SOEs) must be required to pay the full market price for their resource inputs. Vietnam has already put in place some components that would enable a commitment to market-based pricing, but these need to be strengthened and accelerated.

A transition to market-based pricing would provide a strong impetus for LCD but would need to be well managed to avoid adverse economic, social, and political impacts. To strengthen capacity to implement a transition to market-based pricing, Vietnam can draw upon best practices suggested from broad international experience in subsidy reform (Vagliasindi 2013): (i) develop a comprehensive reform plan; (ii) develop a strong communication strategy; (iii) appropriately phase price increases; (iv) improve the efficiency of SOEs; (v) promote consumer energy efficiency; (vi) provide targeted mitigation measures; and (vii) manage the political economy of energy pricing. Fuel pricing policies for domestic and international coal and gas resources drive technology investments in industry and power sectors and must be synchronized with public investment and planning programs for those sectors.

Area 2: Increasing the Energy Efficiency of Households and Industry

Vietnam needs to make aggressive efforts to improve energy efficiency in both the consumer and industry sectors. In 2006 Vietnam has rolled out the Vietnam Energy Efficiency Program (VNEEP) to promote energy efficiency and achieve an overall reduction of energy consumption by 3 percent over the period 2006–10. But these goals fall short of Vietnam's overall energy efficiency potential as well as its economic and green growth imperatives. Reducing electricity demand by 1 percent a year would not be unrealistic for Vietnam.

Notwithstanding recent progress, Vietnam's energy intensity is the highest among major East Asian economies. Starting from a high base, the energy intensity of Vietnam's gross domestic product (GDP) increased by 39 percent between 2000 and 2010. Industrial energy use in particular has grown fourfold since 1998. The availability of relatively cheap and subsidized energy to industries, a large share of which are SOEs, continues to serve as a disincentive for investment in new and more energy-efficient equipment. As a result, Vietnam's industries are highly inefficient users of energy. For example, the energy consumption in Vietnam's cement and steel sectors is significantly higher than global benchmarks.[1] Continued profligate use of energy in the industrial sector may well compromise the competitiveness of Vietnamese production in many areas.

While the economic and green growth imperatives of energy-efficiency measures (as demonstrated by negative marginal abatement costs, MACs) are convincing, the achievement of meaningful energy savings in these target areas and other economic sectors is not likely to happen on its own. Barriers to the adoption of energy-efficient measures in Vietnam include lack of information, lack of readily available expertise, pricing issues, insufficient cost consciousness in some sectors, assignment of a lower priority to cost savings compared to expansion in investment, transaction costs, perceived high investment risks, and market failures in some sectors.

Efforts must target issues relevant to both energy-price reform and SOE reform (both of them critical to energy efficiency) and also

- Strengthen current energy auditing and reporting mechanisms for major energy-using industries.
- Set energy-efficient targets for key energy-intensive sectors.
- Accelerate the adoption of energy-efficiency standards and labels, particularly for residential refrigerators, air conditioners, and lighting.
- Promote outreach, education, and training.
- Promote energy performance contracting for energy-efficient projects.

- Strengthen credit lines for promoting energy-efficient investment in small and medium enterprises (SMEs).
- Develop provisions for performance contracts through a Partial Risk Guarantee Fund (PRGF) for Energy Efficiency.
- Expand the capacity of the Energy Efficiency and Conservation Office (EECO).
- Design the potential generation of large industries with grid planning.
- Include energy-efficient resource plans in all future power sector development plans.

Area 3: Promotion of Gas in the Power Sector

The government should consider aggressively replacing coal-fired generation with gas-fired combined-cycle gas turbines (CCGTs) both on a stand-alone basis and paired with run-of-river (ROR) hydro, wind, and solar photovoltaic (PV). The LCD scenario in this study includes 9,700 megawatts (MW) of new CCGT capacity additions between 2021 and 2030—without exceeding the liquefied natural gas (LNG) import demands already being considered for a second LNG terminal with import capacity up to 6 million tons per annum (mtpa). The entire LCD proposed here can be achieved at a modest MAC of $2.50 per ton when the external costs of coal combustion are ignored. Notable advantages of CCGTs over coal-fired generation include (i) lower capital expenditure (CAPEX) requirements; (ii) dramatically higher efficiencies; (iii) better compatibility with nondispatchable renewable technologies such as ROR hydro, wind, and solar PV; (iv) significantly lower health and environmental costs; and (v) significantly lower greenhouse gas (GHG) emissions.

These shifts present a number of risks and challenges. Despite large proven natural gas reserves in Vietnam, the future availability and cost of gas remains highly uncertain. Import prices for gas are forecast to be higher than coal prices, which may have adverse implications for Vietnam's trade balance. The Government of Vietnam (GoV) can facilitate the shift to natural gas in the power sector by (i) updating and revising the country's power development plan to reflect the electricity generation mix in the LCD scenario by 2015; (ii) completing potential, location, and grid integration studies for the renewable and CCGT-LNG replacement plants by 2017; (iii) promoting foreign investment to develop natural gas reserves through take-or-pay contracts; and (iv) coordinating gas and power sector investments in LNG terminals and gas pipeline connections to new CCGT plants.

Area 4: Use of Supercritical Coal Combustion Technology

Adoption of supercritical coal combustion technology promises substantial emissions reductions. Reductions are primarily from the substitution of subcritical coal technologies with supercritical coal technologies. Supercritical new plant efficiencies of 42 percent are typical, compared with 36 percent for new subcritical plants. Supercritical designs can be chosen with negligible differences in CAPEX or operating and maintenance expenditure (OMEX) parameters. Vietnam's domestic coal resource is anthracite, while supercritical power plants may require bituminous or subbituminous coal that must be imported. Historically, this has served as an obstacle to the adoption of supercritical technology. The LCD scenario defined in this study replaces 3.9 gigawatts (GW) of subcritical coal plants with gas, renewables, and nuclear generation. But another 6 GW of subcritical capacity could be displaced with supercritical plants between 2021 and 2025 to further reduce cumulative CO_2 emissions by 58 million tons (Mt) by 2030.

There may be potential for gains from rehabilitation and enhanced maintenance of older plants as well, although these will provide a much smaller low-carbon opportunity. Historically, Vietnam has been able to supply relatively low-cost domestic coal for power generation and has even subsidized coal prices to keep electric prices low. Thus, incentives to maximize generation efficiency have not been as strong as they will be in the future. Vietnam is now committed to setting the price of domestic coal used for power generation at full cost-recovery levels by 2015. This could generate interest in the rehabilitation and enhanced maintenance of older plants to improve efficiency.

Ultimately, dramatic reductions in carbon emissions from coal-fired power plants can only be achieved through carbon sequestration technologies currently under development worldwide. Unfortunately, the time horizon for practical, large-scale deployment of such technologies at a predictable and affordable cost currently extends beyond 2030. That said, it would be advantageous to construct new coal plants in such a way as to be ready for the later adaptation of carbon sequestration technologies.

In addition to updating and revising the power development plan to incorporate the power generation mix outlined in the LCD scenario, the government should (i) prepare a road map for the adoption of supercritical coal combustion technology, (ii) carry out an analysis of the health costs, reduced productivity, and other damages related to emissions of sulfur dioxide, nitrous oxide, and particle matter—to be initiated as soon as possible; (iii) explicitly incorporate the economic costs of externalities in the power development plan; and (iv) ensure that new coal plants are constructed to be ready for carbon sequestration.

Area 5: Renewable Energy

Renewable energy (RE) will play an increasingly important role in meeting Vietnam's electricity needs in the coming decades. Even with the active promotion of energy efficiency in the industrial and consumer sectors, capacity requirements are expected to increase by 4.8 times and energy requirements by 5.7 times by 2030. At the same time, Vietnam is anticipated to face upward pressures on electricity costs and a major shift toward the use of imported fuels, which will impact the balance of payments and heighten awareness of energy security issues.

In light of these developmental constraints, RE offers clear benefits to Vietnam by (i) reducing the reliance on imported fuels—and thus mitigating impacts on both the balance of payments and security concerns; (ii) providing low- or zero-cost generation fuels; and (iii) substantially reducing environmental and health-related costs (when compared with fossil fuel generation). Despite the obvious benefits, there are likely to be notable challenges in identifying and developing the local potential for renewable energy, including (i) higher levelized costs, (ii) relatively low capacity factors, and (iii) additional infrastructure needs for integrating renewable energy into the grid (or changes in dispatching infrastructure to accommodate more distributed generation like roof-top solar).

Renewable energy presents itself as an attractive option for Vietnam, in particular paired with CCGTs fueled with LNG, which provide fully dispatchable, equivalent service to the base-load coal-fired plants that they displace. This study finds that Vietnam should consider replacing at least 8,100 MW of its coal-based electricity plants with renewable energy plants over 2021–30. Of this, 6,100 MW of RE capacity (2,800 MW hydro, 1,800 MW wind, and 1,500 MW solar) could be paired with CCGTS and another 2,000 MW provided by biomass-fired generation without gas.

To make this happen, the GoV would have to (i) actively pursue policies to facilitate these investments; (ii) complete potential and location studies for biomass and additional ROR hydro, wind, and solar PV; (iii) advance utility planning and operational capabilities to fully integrate renewables with CCGT generation; and (iv) draw on lessons learned in the development of utility-scale RE projects to design dynamic feed-in-tariffs (FITs) and encourage the private development of renewable technologies.

Area 6: Sustainable Transport

The speed and scale of urbanization in Vietnam presents an unrivaled opportunity to build low-carbon cities with compact urban designs, public transport, green buildings, and clean vehicles. Between 2000 and 2010, the country's urban population increased from 18.1 million to 25.4 million, and is projected to reach 45 million (50 percent of the population) by 2025. Vietnam must act today to "lock in" low-carbon policies and investments that will have long-lasting implications for efficiency, lifestyles, the environment, and carbon emissions over the next two decades. For example, if Vietnam can invest adequately in public transit facilities, it will be able to reduce excessive reliance on private vehicles—thus reducing congestion and environmental pollution, including emissions of CO_2. Similarly, low-carbon commercial and residential building design largely locks in lower energy needs for the life of the building, even if future price and other policy incentives change dramatically.

Specific steps the GoV can undertake to facilitate the development of low-carbon cities include the following:

- Promote the use of electric bicycles (e-bikes) or those fitted with solar panels.
- Enforce vehicle fuel–quality norms and emissions standards.
- Introduce vehicle fuel–efficiency standards.

- Improve inland waterways, including by replacing smaller with larger vessels and replacing self-propelled with pushed barges.
- Switch bus fuel to compressed natural gas (CNG).
- Adopt compact city designs at the planning stage of all new cities.
- Establish a mixed land-use policy for new cities.
- Promote "community vehicles" such as school buses, factory buses, or any other schemes offering public or commercial transportation to commuters.

Area 7: Cross-Cutting Reforms to Promote LCD

The institutional environment for LCD in Vietnam is characterized by (i) inadequate coordination between ministries and different levels of government; (ii) weak monitoring and enforcement of environmental standards, especially at the local level; (iii) weak institutional and administrative capacity, and (iv) limited availability of statistical information to plan and design policies as well as to monitor emissions. These contribute toward limiting the effectiveness of the government's low-carbon policies and regulations.

Vietnam can improve the institutional environment for LCD by taking concrete steps to mainstream low-carbon and green growth considerations into the planning process. One such step is to use a Multi-criteria Decision Analysis (MCDA) approach to planning and budgeting decisions. The MCDA framework—which is used by countries such as the Republic of Korea, South Africa, and the United Kingdom—prioritizes investment based on a diverse set of important economic, social, and environmental criteria and validates any output using a participatory approach to decision making. Such an approach to planning and investment decisions would need to be complemented by efforts to build capacity in key institutions and the effective implementation of a monitoring, reporting, and verification (MRV) system coordinated with a national greenhouse gas inventory. The Ministry of Planning and Investment (MPI), Ministry of Finance (MOF), Ministry of Natural Resources and Environment (MONRE), and other key technical ministries would need to cooperate very closely to establish an effective structure for compiling the data and analyzing and reporting developments. The government would also do well to build consensus on the definition of Vietnam's business-as-usual (BAU) scenario at the national and sectoral levels, and to develop guidelines and institutional processes for periodic update of the BAU scenario, consistent with national and international purposes.

Since much of the actual implementation of policy and regulatory measures takes place at lower levels of government, particular attention also needs to be given to strengthening local-level governance and institutions, and to provide clear incentives for LCD. This can be achieved by introducing explicit green-growth performance indicators for local governments. For instance, the promotion system for lower-level officials could be redesigned with new and specific emphasis on measuring "greenness" and quality of growth.

Note

1. The cement sector in Vietnam on average consumes 3.98 GJ/t (or around 950 Kcal/Kg of Clinker) of clinker production. That is substantially higher than the world benchmark of 650 Kcal/Kg produced. Similarly, in Vietnam, large iron and steel plants consume around 29.2 GJ/ton of crude steel, which is again far above the global best practices.

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APPENDIX A

EFFECT Model

The Energy Forecasting Framework and Emissions Consensus Tool (EFFECT) is a Microsoft *Excel*–based, inventory-style tool with some built-in optimization, used for the evaluation and comparison of various development scenarios or policy choices. It focuses on sectors that contribute to and are expected to experience a rapid growth in emissions. The model was originally developed by the World Bank with funding from the Department for International Development (DFID) for a seminal low-carbon growth study of India, and has since been used in several countries.[1]

EFFECT consists of five main modules (power generation, transport, household electricity consumption, nonresidential, and industry), and models on annual time step out to 2050. The model is controlled via the *Excel* ribbon interface and uses Visual Basic to generate the analyses, and can easily be opened and used by multiple stakeholders. EFFECT modeling focuses on specific areas where important mitigation impacts can be achieved; it is not used to model the whole economy. Normally the following two scenarios are built and compared:

1. A "reference" or a business-as-usual (BAU) scenario that portrays what is likely to happen under a normal development process in which no special emphasis is placed on the climate change impacts of that development. The BAU scenario is not a projection based on historic trends; it should take into account the policies and decisions that are likely to be taken in future years in reaction to probable changes in fossil-fuel availability and prices, technology, and consumption patterns, among other factors.
2. A "low-carbon" scenario that encompasses ways to achieve the same or better development progress than through the BAU scenario but with a lower impact on carbon dioxide (CO_2) emissions to the atmosphere.

The differences between these scenarios allow the evaluation of CO_2 mitigation opportunities, their associated cobenefits, barriers to adoption, and costs of achievement. Five broad steps toward building plausible scenarios in EFFECT are

1. Collect and process the historical data needed to define the activities (and related energy consumption and CO_2 emissions) in the base year.
2. Define the assumptions needed to evaluate how base-year levels of activity will change in the BAU scenario over the modeling time frame.
3. Build consensus on the BAU scenario; in other words, reach agreement among local stakeholders on the data and assumptions used in constructing the BAU scenario.
4. Define the change in low-carbon assumptions that are considered feasible in the local context, and can achieve the same or better development progress than in the BAU scenario with a lower level of CO_2 emissions.
5. Reach agreement among local stakeholders on the data and assumptions used in constructing the low-carbon scenario and the opportunities for mitigation that these present.

EFFECT has extensive help facilities in *Excel* and online training with over 16 hours of free, direct self-paced training courses plus multiple related studies, links, and other reference material. For more information, visit: http://esmap.org/EFFECT.

Note

1. For example, to analyze the power sector in India and Nigeria (with initial analysis in Indonesia, Malaysia, the Philippines, Thailand, and Vietnam); to analyze transport in Brazil, Georgia, India, Macedonia, Nigeria, Poland, and Vietnam (with initial work in Indonesia, Malaysia, the Philippines, and Thailand, plus nine city-level studies in Bangkok, Beijing, Chengdu, Guangzhou, Hanoi, Ho Chi Minh City, Jakarta, Manila, and Ulaanbaatar); and to analyze household electricity use in India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam.

APPENDIX B

Marginal Abatement Costs

A marginal abatement cost curve (MACC) graphically summarizes the abatement potential and cost-effectiveness of several low-carbon options. This enables policy makers to make informed decisions. It helps to prioritize the identified low-carbon intervention options and act as an input in designing policies aimed at stimulating green growth in a country. The marginal abatement costs (MACs) outlined in this report are an average of the individual MACs calculated over the 2010–30 period. The costs vary each year due to changing capital and operation and maintenance (O&M) costs. The individual MACs are defined as:

MAC (LCO) = [2010 Present Value (Low-Carbon Option Costs) – 2010 Present Value (Baseline Costs)] divided by [(Emissions Baseline) – (Emissions Low-Carbon Option)]

Where:

MAC (LCO) = the marginal abatement cost of low-carbon option
2010 Present Value (Low-Carbon Option Costs) = the 2010 cost of low-carbon option
2010 Present Value (Baseline costs) = the 2010 cost of baseline option
Emissions (Baseline) = emissions of the baseline option
Emissions (LCO) = emissions of the low-carbon option

Costs include capital expenditures (CAPEX), operating and maintenance expenditures (OMEX), and fuel expenses (FUELEX). All costs are expressed in 2010 U.S. dollars using a social discount rate of 10 percent. Emissions are expressed in metric tons of carbon dioxide (CO_2) equivalent over the modeling period (up to 2030) or over the lifetime of the low-carbon option alternative. For large physical infrastructure, such as power plants, the lifetime is clearly defined, and emissions are calculated accordingly. For more distributed energy-efficiency measures such as process improvement, the team measured the savings up to 2030 since the lifetime is not clearly defined, and savings are highly dependent on operating conditions. The MACs are expressed in U.S. dollars per ton of carbon dioxide ($/t$CO_2$) reduced by the low-carbon option.

Several low-carbon options were investigated, and the set whose MACs are shown below were selected for the following:

- *Implementation feasibility.* The abatement options have been selected based on the feasibility of their implementation in the context of Vietnam. The options have been assessed based on their required capital investment, lower or negative operational expenditure (after implementation), proven technology in other developing countries, and the capacity of the relevant industrial sectors in Vietnam to implement them.
- *"As-is" analysis of technology status.* Analysis of present industrial practices has also helped in the selection of the abatement levers. For example, the iron and steel (I&S) sector of Vietnam is presently dominated by the Small Steel Producers (SSP), using mainly electric arc furnace technology for steel production from scrap steel and iron ore. But due to limited scrap availability globally, future capacity expansions in the I&S sector are expected to come in blast furnace (BF) route. The abatement options have been selected both for existing SSPs (that is, options that can reduce the energy demand of small-scale units) and also for the upcoming steel plants coming under the BF route.

The resultant MACC is shown in figure 2.6 (in the main text), and the values are provided in table B.1. Individual MACs are listed in the main text of this report.

Table B.1 Summary of Marginal Abatement Costs in the Study

Intervention	*Mitigation potential in 2010–30* *Mt CO_2e*	*Marginal abatement cost* *\$/tCO_2e*
Transport Sector		
Inland waterways improvement	7.26	−210.11
Coastal freight improvement	0.14	−144.29
Freight modal shift to coastal	1.86	−139.63
Increased use of electric bicycles	27.13	−129.84
Freight modal shift to rail	1.95	−64.31
Technology of private vehicles	9.12	−38.29
Passenger modal shift to buses	2.78	−26.62
Fuel switching to CNG for buses	3.58	−12.65
Increased use of biofuel	3.78	21.70
Passenger modal shift to rail	0.68	432.06
Add BRT in Hanoi and HCMC	0.01	1,022.58
Household Sector		
Solar water heaters	4.84	−6.00
Refrigerators	59.23	−14.00
Air conditioners	24.90	−13.00
Residential lighting	29.30	−10.00
Fans	2.09	−12.70

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Table B.1 Summary of Marginal Abatement Costs in the Study *(continued)*

Intervention	*Mitigation potential in 2010–30* *Mt CO_2e*	*Marginal abatement cost* *$/t$CO_2e$*
Power Sector		
LNG	77.9	5.53
Supercritical coal	28.0	9.64
Nuclear	16.0	0.96
Biomass	82.7	–0.04
Hydro-CCGT	92.4	1.25
Wind-CCGT	41.3	4.90
Solar-CCGT	30.1	4.36
Iron and Steel		
Coke dry quenching	3.26	12.49
WHR-based power generation	32.93	–8.88
Heat recuperation from hot blast stoves	0.49	–0.09
Sintering plant heat recovery	3.08	–3.41
BOF gas sensible heat recovery	4.09	4.60
Natural gas injection in BF	2.89	–8.15
Pulverized coal injection (PCI) in blast furnace	2.90	–7.42
Continuous casting	16.75	6.39
Hot charging in rolling mill	2.91	3.99
Installation of the top pressure recovery turbine	3.82	–3.96
Variable speed drives in steel making	0.09	–7.81
Small Steel Producers		
Oxyfuel burners	0.62	–17.96
Eccentric bottom tapping (EBT)	0.14	4.95
Scrap preheating (FUCHS)	2.45	–28.37
Bottom stirring	0.40	–30.10
Transformer efficiency improvement	0.97	–7.33
Improved process control	3.10	–9.59
Cement		
Combustion optimization	3.37	–49.90
Waste heat recovery from cement	4.76	0.46
Dry kilns with multistage preheaters and precalcination	2.90	53.14
Vertical roller mill	2.85	11.46
Kiln shell heat loss reduction	2.17	–14.46
VFD installation	0.58	–8.17
Fertilizer		
Calcium silicate insulation of high pressure steam pipeline	0.47	–13.79
Heat recovery from medium pressure decomposer vapors in urea plant by installation of preconcentrator	0.18	–33.59
Isothermal CO conversion reactor	0.09	–18.51
High conversion rate synthesis reactor	0.00	259.80

table continues next page

Table B.1 Summary of Marginal Abatement Costs in the Study *(continued)*

	Mitigation potential in 2010–30	*Marginal abatement cost*
Intervention	*Mt CO_2e*	*\$/tCO_2e*
Steam trap management	0.01	–34.43
Energy savings by arresting steam leakages through steam traps	0.01	–33.60
Installation of variable frequency drives	0.02	–7.63
Pulp and Paper		
Heat recovery in thermo mechanical pulping	0.79	–8.10
Waste heat recovery from paper drying	1.41	–6.09
Increased use of recycled pulp	2.45	39.56
RTS pulping	0.28	33.74
Black liquor gasification	0.19	116.20
Extended nip press	0.17	47.46
Refinery		
Online cleaning of furnace	0.02	115.04
Optimization of power consumption in utility boiler drives and auxiliaries	0.04	–60.42
Steam savings by trap management	0.31	–68.79
Condensate recovery	0.03	–61.00
Flare gas recovery and utilization of recovered flare gas for process heating requirements	0.42	–52.84
Installation of low excess air burner	0.03	–54.51
Oil recovery from crude tank bottom sludge by chemical treatment	0.04	–62.77
All other industry	152	2.62

Source: In addition to industry experts, a significant amount of data came from the international sources World Bank, United Nations Development Programme, United Nations Industrial Development Organization, Denmark International Development Agency and International Finance Corporation; and local Vietnamese institutions Transport Development and Strategy Institute, Institute of Energy Vietnam, and Center for International Economic Monitoring.
Note: Due to lack of data in Vietnam, the team added an "All other" industry category. The emissions in this category are at an indicative level based on typical results achieved in other countries that have established industrial *energy-efficiency* programs. Recent studies by the American Council for an Energy Efficient Economy of extensive sets of industrial *energy-efficiency* measures document a levelized cost (LCOE) of \$30/MWhe. As the table below shows, this would imply *a* total incremental CAPEX in the range of \$37 billion with an estimated MAC in the range of \$2.62 per ton *of* CO_2e for Vietnam. BF = blast furnace; BRT = bus rapid transit; CCGT = combined-cycle gas turbine; CNG = compressed natural gas; HCMC = Ho Chi Minh City; MtCO_2e = million tons of carbon dioxide equivalent; TCO_2e = tons of carbon dioxide equivalent; VFD = variable frequency drive.

All other industry assumed MAC		*2015–2030 CAPEX BUSD*		*20 year LCOE \$/MWh*	
\$	4.00	\$	56.60	\$	55.49
\$	3.00	\$	42.45	\$	36.99
\$	2.00	\$	28.30	\$	18.50
\$	2.62	\$	37.10	\$	30.00

BUSD: Billion USD
LCOE: Levelized Cost of Electricity

Sectors such as the aviation sectors were left out because of the difficulty that the government would face in implementing the measure, while others, such as the commercial building sector, were left out because of the lack of data.
Source: World Bank estimates.

Main Assumptions

Tables B.2 through B.9 summarize the main assumptions used in each sector.

Table B.2 Iron and Steel: Abatement Options

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
Coke dry quenching	85.18	3.4	1.41 (energy generation)	Around 50% by 2030	This technology helps improve the steam recovery rate at a rate assumed to reach almost 0.5 ton of steam/ton of coke. This technology has already been widely implemented in other developing countries of Asia such as India and China; also in Japan, and Russia.
BFG, COG based power generation	20.2	0.8	Computed from calorific values of the gases	Around 50% by 2030	Power generation utilizing the coke oven and blast furnace gas has been widely implemented across the globe. In Asia, Indian and Chinese steel makers have used this technology to reduce grid dependency.
Heat recuperation from hot blast stoves	2.2	0	0.08 GJ/ton of hot metal	80% penetration rate by 2030	Implementation of this option results in improved combustion efficiency of the hot stoves. This technology has been implemented in almost all the steel factories of Japan and other developed nations.
Sinter plant heat recovery	4.7	0	0.55	80% penetration rate by 2030	Heat recovery at sinter plants help in improving the efficiency of sinter making. This technology has been widely implemented both in developed countries such as Japan and the United States as well as in developing countries such as India and China.
BOF Gas Sensible heat recovery	35.21	0	0.73	80% penetration rate by 2030	This abatement option can have a huge impact on energy savings from the BOF process and can make the BOF a net energy producer. Generally this measure can result in savings of 535 MJ/ton of steel. This technology has been implemented in particular in India and China.
Natural gas injection in BF	4.46	0	0.80	50% penetration rate by 2030	This technology option can reduce the coke requirement in the blast furnace.

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Table B.2 Iron and Steel: Abatement Options *(continued)*

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
					Availability of natural gas for the iron and steel industry would be a major deciding factor for an implementation feasibility assessment.
					Indian iron and steel companies have adopted this technology.
Pulverized coal injection (PCI) in blast furnace	11	0	0.77	40% penetration rate by 2030	In this measure pulverized coal is injected through a blast furnace as a substitute for coke, thereby reducing the coke requirement of the blast furnace.
					Availability of anthracite coal makes this option attractive in Vietnam.
					This technology has been widely implemented (India, China).
Thin slab casting (TSC) and strip casting (SC)—two main types of near net shape casting	235	0	4.89	40% penetration rate by 2030	Continuous casting dramatically improves productivity and saves energy by eliminating the need for a reheating furnace.
					All Japanese steel makers have adopted this technology option.
					Diffusion rate of CCM is very high in other developing countries such as India, China.
Hot charging in rolling mill	23.5	0	0.52	Around 80% by 2030	The energy saving potential of this option increases with the capacity of a continuous caster.
					This technology has huge potential in all developing countries due to their extensive use of electric furnaces.
					Japanese iron and steel industries can help in the implementation of this technology in Vietnam.
Installation of the top pressure recovery turbine	17.84	0.84	0.40	50% penetration rate by 2030	This technology helps reduce dependence on grid electricity.
					It has been widely implemented in India, China.

table continues next page

Table B.2 Iron and Steel: Abatement Options *(continued)*

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
Variable speed drives in steel making	0.2	0	0.01	50% penetration rate by 2030	This abatement options helps reduce the grid electricity consumption.
					It has been widely implemented across all the major steel producing countries.
					In Asia this technology has been implemented in India, China.

Source: World Bank. Ernst and Young report commissioned for this book.
Note: BF = blast furnace; BFG = blast furnace gas; BOF = basic oxygen furnace; COG = coke oven gas; GJ = gigajoule; O&M = operation and maintenance; MJ = megajoule.

Table B.3 Small Steel Sector: Abatement Options

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
Oxyfuel burners	7.5	–0.17	0.14	Around by 65% by 2030	Reduce electricity consumption by increasing heat transfer and reducing losses
					Oxyfuel burners have high implementation potential in India and China.
Eccentric bottom tapping (EBT)	5	0	0.05	Around by 50% by 2030	EBT is technologically sophisticated and requires significant investment compared to its savings potential. Therefore a lower penetration rate has been considered.
					This technology has implementation potential in China, India, and the United States.
Scrap preheating (FUCHS)	9.4	–0.8	0.43	Complete penetration by 2030	This technology is expected to be mandatory by 2030 and therefore a high penetration rate has been considered.
					This technology has huge implementation potential in all Asian countries.
Bottom stirring	0.94	0.08	0.07	Around 50% by 2030	High application potential in China, India, and the United States.
Transformer efficiency improvement	2.75	0	0.19	40% penetration rate by 2030	Helps reduce dependence on grid electricity.
					Results in reduced tap-to-tap time of the furnace and improves melting efficiency.
					Technology available in Southeast Asian countries.
Improved process control	0.95	0	0.33	Around 65% by 2030	This technology has been implemented in South America.
					Improved process control (neural networks) can help to reduce electricity consumption beyond that achieved through a classical control system.

Source: World Bank. Ernst and Young report commissioned for this book.

Table B.4 Cement Sector Marginal Abatement Costs Assumptions

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
Waste heat recovery from cement	2000 ($/kW)	80 ($/kW)	35 kWh/ton of clinker	Around 50% by 2030	Waste heat recovery from cement kilns has gained considerable prominence in countries such as India and China.
Dry Kilns with multistage preheaters and precalcination	65	0	0.2	Around 50% for new plants and around 20% for old plants	For old plants increasing the preheater stages would be a challenge due to predesigned concrete strength; therefore a low penetration rate has been considered. The majority of Indian and Chinese cement plants have already adopted this technology.
Vertical roller mill	18.89	0	20 kWh/ton	Around 50% by 2030	Vertical roller mills help reduce the power required for grinding raw material. Moreover as the feedstock holding time in the mill is short, better blending can be achieved. Indian and Chinese cement manufacturing units have already adopted this technology.
Kiln shell heat loss reduction	0.25	0	0.12	Around 65% by 2030	This can't be done for old plants that have existing insulation balanced according to the design thermal profile. System changes are hard to achieve to incorporate changes in thermal design.
VFD installation	0.2	0	0.01	Around 50% by 2030	VFD installation helps reduce dependence on grid electricity. This technology has already been implemented in major developed and developing countries.
Combustion optimization	1	0.04	2% of intensity of clinkerization	Around 50% by 2030	Energy requirement for clinkerization can be substantially reduced by changing the profile of the flame.

Source: World Bank. Ernst and Young report commissioned for this book.
Note: GJ = gigajoule; O&M = operation and maintenance; VFD = variable frequency drive.

Table B.5 Fertilizer Sector: Marginal Abatement Cost Assumptions

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
Calcium silicate insulation of high-pressure steam pipe line	0.33	0	0.78	80% penetration rate by 2030	By 2030 most fertilizer units should be using this option, as energy costs increase; hence the penetration rate has been considered relatively high.
Heat recovery from medium pressure decomposer vapors in urea plant by installation of preconcentrator	2.14	–	0.66	Around 60% by 2030.	In a urea manufacturing process, the installation of preconcentrators reduces the heat requirement that is to be provided by steam.
					It also increases the yield and therefore reduces specific steam consumption.
Isothermal carbon monoxyde conversion reactor	15.9	0.04	0.418	Around 50% by 2030	This technology has the potential to reduce process emissions.
					Some Japanese companies have already adopted this technology.
High conversion rate synthesis reactor	4.77	0.008	0.007	Around 50% by 2030	This technology has a high implementation potential in Asian countries such as India and China.
Installation of variable speed drives for cooling tower fans in fertilizer	0.20	0.00	2.77 kWh/ton	Around 80% by 2030	This technology can reduce the dependence of grid electricity.
					Most of the fertilizer units are expected to implement this technology option by 2030.
					Technology is readily available due to the presence of established players such as ABB.
					It has been widely implemented in other developing countries such as India and China
Steam trap management	0.017	0	0.0003	80% penetration rate by 2030	Steam trap management helps reduce steam leakage through programmed inspection and maintenance and use of an indication system for faulty steam traps.
					Most fertilizer industries are expected to implement this technology by 2030.
					Implemented in developing countries such as India and China

table continues next page

Table B.5 Fertilizer Sector: Marginal Abatement Cost Assumptions *(continued)*

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
Arresting steam leakages	0.07	–	0.0006 ton of gas per ton of product	80% penetration rate by 2030	By 2030 most of the fertilizer units are expected to integrate this technology. Technology is readily available in the country Implemented in developing countries such as India and China

Source: World Bank.
Note: GJ = gigajoule; kWh = kilowatt-hour.

Table B.6 Refinery Sector: Marginal Abatement Cost Assumptions

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (ton of oil/ton of product)*	*Penetration rate (%)*	*Rationale*
Online furnace cleaning	0.13	0.08	0.00003	90% penetration rate by 2030	By 2030 most refineries should be using this option, as energy costs increase; hence the penetration rate has been considered relatively high. The technology is readily available in the region.
Optimization of power consumption in utility boiler drives and auxiliaries	–	0.01	0.00018	Around 50% by 2030	Typically boiler drives are fans and feed water pumps responsible for a major portion of total power consumption. Also the consumption of electricity consumption is a function of the refinery load. Traditionally, vane-controlled fans and throttle-controlled feed water pumps are used in boilers, which result in enthalpy losses when they have to respond to changes in demand. Use of variable drives or right sizing can reduce this loss. Technology is readily available in the region due to wide-scale implementation in India and China.
Steam savings by trap management	0.0066	–	0.0004	Around 90% by 2030	Most units are expected to have this technology by 2030.

table continues next page

Table B.6 Refinery Sector: Marginal Abatement Cost Assumptions *(continued)*

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (ton of oil/ton of product)*	*Penetration rate (%)*	*Rationale*
					Technology readily available due to wide-scale implementation in India and China.
Condensate recovery	0.04	–	0.00004	Around 90% by 2030	Most units are expected to have this technology by 2030. Technology readily available due to wide-scale implementation in India and China.
Flare gas recovery and utilization for process heating requirements	0.14	0.10	0.0006	Around 90% by 2030	Most units are expected to have this technology by 2030. Technology readily available due to wide-scale implementation in India and China.
Installation of low excess air burner	0.07	0	0.000045	90% penetration rate by 2030	A low excess air burner reduces the oil consumption of a high capacity boiler, thereby optimizing its performance. Technology available due to wide-scale implementation in India and China.
Oil recovery from crude tank bottom sludge by chemical treatment	0.07	–	0.0006 ton of gas/ ton of product	90% penetration rate by 2030	Chemical treatment can recover the oil present in the sludge generated in refineries. This helps reduce the loss of oil, and the recovered oil can be used to meet process requirements. Technology available for implementation in India and China.

Source: World Bank.

Table B.7 Pulp and Paper: Marginal Abatement Cost Assumptions

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
Heat recovery in thermo mechanical pulping	21	0	7.52	Around 50% by 2030	The payback period for this technology option is, in some cases, as low as a few months. This technology has been widely implemented in countries such as Japan, India, and China. A.H. Lundberg is a major technology supplier.

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Table B.7 Pulp and Paper: Marginal Abatement Cost Assumptions *(continued)*

Abatement option	*Capital expenditure ($/ton)*	*O&M expense ($/ton)*	*Energy savings (GJ/ton)*	*Penetration rate (%)*	*Rationale*
Waste heat recovery from paper drying	18	0	5	Around 50% by 2030	This technology has seen wide implementation in China, India, and the United States. Technology is readily available in Southeast Asia.
Increased use of recycled pulp	485	0	22.4	Around 50% by 2030	Increased use of recycled pulp can significantly reduce the energy requirement for pulp production. The sludge produced by recycled pulp results in a disposal problem for industries. The United States is a major player in this technology space. A high capital expenditure requirement might be a stumbling block toward wide-scale implementation.
RTS pulping	50	0	306 kWh/ton	Around 50% by 2030	This technology option helps reduce dependence on grid electricity without sacrificing the pulp quality. The United States is a major player in this technology space.
Black liquor gasification	82	3.28	1.6	Around 65% by 2030	This technology is generally applicable for large pulp and paper manufacturing units. Significant implementation potential in developing countries. India and China–based paper mills have already adopted this. Technology know-how is readily available.
Extended Nip Press	38	2.28	1.6	Around 50% by 2030	Where total production depends on capacity of the dryer, this technology can increase plant capacity by 25%. Technology has been widely implemented in India.

Source: World Bank.

Table B.8 Residential/Household Sector: Marginal Abatement Cost Assumptions

Appliance	*Parameters*
Water heaters	The cost of electric heaters has been considered $140 The cost of solar water heaters has been considered $18 per tube
Air conditioners	As per discussion with World Bank the cost of the appliances has been considered equal in both BAU and LCD scenarios.

table continues next page

Table B.8 Residential/Household Sector: Marginal Abatement Cost Assumptions *(continued)*

Appliance	*Parameters*
	The cost figures have been estimated from manufacturer's database *Specification* / *Price ($)* WAC – 1: 396 WAC 1.5: 505 WAC 2: 564 SAC 1: 418 SAC 1.5: 561 SAC 2: 707 HAC 10: 750
Refrigerators	It has been assumed that that the price of refrigerators would remain the same both in the BAU and LCD scenarios. The electricity savings achieved due to usage of energy-efficient appliances would help in cost savings at the consumer end, making this option attractive. The cost of refrigerators has been estimated from the information provided by manufacturers.
Residential lighting	Cost of incandescent lamps: $1 Cost of CFLs: $2
Fans	The cost of fans has been estimated from a manufacturer's database.

Source: World Bank.
Note: BAU = business as usual; HAC = heating air conditioner; LCD = low-carbon development; SAC = split air conditioner; WAC = window air conditioner.

Table B.9 Power Sector: Marginal Abatement Cost Assumptions

Power generation option	*Capacity addition*	*Capital investment*	*O&M cost*	*Capacity factor*
Solar PV	1,500 MW	861 2010 $/kW	2010 $/MWh $8.04 2010 $/kW-yr $13.95	15% solar; 60% CCGT-LNG
Wind energy (on shore)	1,800 MW	1785 2010 $/kW	$38.01 2010 $/kW-yr	25% wind, 50% CCGT-LNG
Biomass-based power generation	2000 MW	1698 2010 $/kW	2010 $/MWh $9.05 2010 $/kW-yr $21.26	75%
Subcritical technology	-3,900 MW	1,432 2010 $/kW	2010 $/MWh $1.20 2010 $/kW-yr $30.40 Externality $20.00/MWh	75%; 36% efficiency
Small ROR hydro	2,800 MW	1,798 2010 $/kW	2010 $13.35/kW-yr	50% hydro; 25% CCGT LNG
Supercritical technology	–9,800 MW	1432 2010 $/kW	2010 $/MWh $1.20 2010 $/kW-yr $30.40 Externality $17.14/MWh	75%, 42% efficiency
CCGT	9700 MW	1040 2010 $/kW	2010 $/MWh $3.14 2010 $/kW-yr $$14.77 Externality $1.00/MWh	75%, 60% efficiency
Nuclear	2,000 MW	$3792 2010 $/kW	2010 $/MWh $2.30 2010 $/kW-yr $89.00	85%

Source: World Bank.
Note: CCGT = combined cycle gas turbines; kW = kilowatt; LNG = liquefied natural gas; MW = megawatt; MWh = megawatt- hour; PV = photovoltaic.

APPENDIX C

Electricity Revenue Requirements Model

To project electricity costs, we developed a revenue requirements model. The model assumes that a utility requires revenue to cover the entirety of its fuel expenditures, operation and maintenance (O&M) costs, and capital expenditure (CAPEX) financing costs (figure C.1). It then derives a per unit electricity cost by dividing the total utility revenue requirement by final electricity sales.

Fuel expenditures have two components: (i) expenditures on the primary fuels that generation plants use to produce electricity, and (ii) expenditures on imported electricity. The first is taken from the power sector modeling done to develop the business-as-usual (BAU) and low-carbon development (LCD) scenarios and, for each year, is the summation of *projected fuel price * amount of fuel required* across each fuel type. For the second component, the power sector model calculates the amount of imported electricity but not the cost. We assume that imported electricity is primarily hydro-based and that it costs about the same as the levelized cost of hydroelectricity in Vietnam.

O*perating and maintenance expenditures* have two components: (i) expenditures on generation plants, and (ii) expenditures on the transmission and distribution (T&D) system. The first is taken directly from the power sector modeling done to develop the BAU and LCD scenarios. The second is not covered in the power sector modeling, so we impute it by assuming it is equivalent to 3 percent of annual T&D financing costs.[1]

C*APEX financing costs* are slightly more complicated. We start with data on annual CAPEX. The power sector modeling provides CAPEX on new power plants and CAPEX on plant renovations, and we impute CAPEX on generation plants built in 2000–10 and CAPEX on T&D infrastructure. To impute past generation CAPEX, we used Institute of Energy Vietnam (IEVN) data on the megawatt (MW) capacity of power plants built, by type, in 2000–10 and assumed that their cost per MW was the same as the real power plant costs used

Figure C.1 Overview of the Revenue Requirements Model

Source: World Bank.

Table C.1 Breakdown of Utility Revenue Requirements under the BAU Scenario, Million $2010

	2010	*2015*	*2020*	*2025*	*2030*
CAPEX financing costs, of which	3,334	9,222	13,290	18,946	29,599
Financing generation CAPEX	2,659	7,265	9,883	13,369	18,976
Financing T&D CAPEX	675	1,957	3,408	5,577	10,623
O&M expenditures, of which	617	1,252	1,877	2,860	4,496
Generation O&M	597	1,194	1,774	2,693	4,177
T&D O&M	20	59	102	167	319
Fuel expenditures, of which	2,153	4,417	7,246	12,158	19,477
Primary fuel expenditures	1,834	4,021	6,810	11,721	19,041
Importing electricity	319	396	436	436	436
Total electricity revenue requirement	**6,104**	**14,891**	**22,413**	**33,964**	**53,572**
Electricity sales (GWh)	82,842	159,158	249,600	359,936	501,983
Per unit electricity cost ($/kWh)	**0.074**	**0.094**	**0.090**	**0.094**	**0.107**

Source: World Bank calculations.
Note: BAU = business-as-usual; CAPEX = capital expenditure; GWh = gigawatt-hour; O&M = operation and maintenance; T&D = transmission and distribution.

in the power sector modeling.[2] To impute T&D CAPEX, we assume it is equivalent to 25 percent of annual CAPEX on generation plants.[3]

CAPEX are not made all at once, however, but are instead financed through a combination of debt and equity. We assume 30 percent of CAPEX is financed with equity, and the remainder with debt. We assume the weighted average real cost of capital, across both debt and equity, is 10 percent—the assumed social discount rate in this report. We assume the 10 percent real return on equity is taxed as income at a 22 percent tax rate. We assume all loans are given for 30 years. Using these parameters, we can calculate the amount the power sector would spend each year to finance its capital expenditures.

To estimate the *electricity revenue requirement*, we calculate the utility's revenue requirement in each year by summing that year's fuel expenditures, O&M expenditures, and amount spent financing CAPEX. To derive the *per unit electricity cost*, we divide the total revenue requirement by final electricity sales. Table C.1 shows, for the BAU scenario, each component of the revenue requirement, the total revenue requirement, final electricity sales, and the per unit electricity cost. Table C.2 shows the same data for the LCD scenario.

Table C.2 Breakdown of Utility Revenue Requirement under the LCD Scenario, Million $2010

	2010	*2015*	*2020*	*2025*	*2030*
CAPEX financing costs, of which	3,334	9,222	12,899	18,120	28,198
Financing generation CAPEX	2,659	7,265	9,624	12,802	18,076
Financing T&D CAPEX	675	1,957	3,275	5,318	10,122
O&M expenditures, of which	617	1,245	1,821	2,711	4,267
Generation O&M	597	1,186	1,723	2,552	3,963
T&D O&M	20	59	98	160	304
Fuel expenditures, of which	2,153	4,258	6,951	11,557	17,684
Primary fuel expenditures	1,834	3,862	6,515	11,121	17,248
Importing electricity	319	396	436	436	436
Total electricity revenue requirement	**6,104**	**14,725**	**21,671**	**32,389**	**50,148**
Electricity sales (GWh)	82,842	157,611	241,756	335,504	447,041
Per unit electricity cost ($/kWh)	**0.074**	**0.093**	**0.090***	**0.097**	**0.112**

Source: World Bank calculations.
Note: CAPEX = capital expenditure; GWh = gigawatt-hour; LCD = low-carbon development; O&M = operation and maintenance; T&D = transmission and distribution.
* Slight decrease in revenue requirement explained by minor excess in supply capacity in earlier year.

Notes

1. Based on research on typical power sector expenditure structures conducted by a consultant for the World Bank.
2. Plants built before 2000 are not considered because they would have fairly small financing costs by 2010.
3. This is based on Vietnam's actual 2012 transmission and distribution (T&D) CAPEX and the projected generation CAPEX from the power sector modeling. Actual 2012 T&D CAPEX are taken from Vietnam Circular 17/2012/TT-BCT regulation on electricity prices.

APPENDIX D

Computable General Equilibrium Model

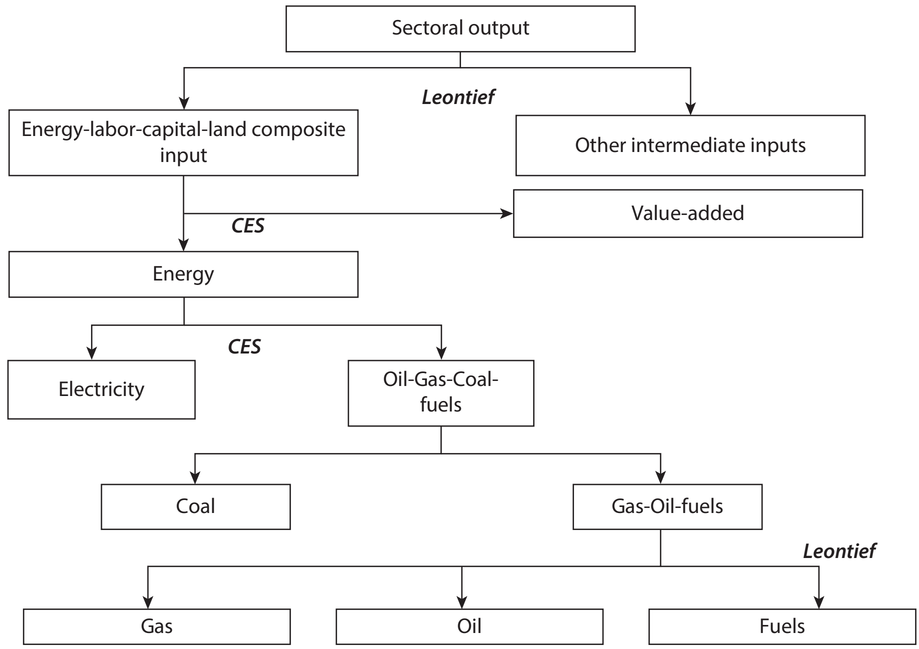
A computable general equilibrium (CGE) modeling of the low-carbon options for Vietnam was undertaken by the Central Institute for Economic Management (CIEM). The focus of the analysis was on evaluating the impacts of key low-carbon measures on important economic variables such as (i) economic growth, (ii) inflation, (iii) employment, (iv) exports, and (v) fiscal deficit.

To carry out the analysis, CIEM made extensions and modifications to a CGE model prepared by CIEM and Copenhagen University for an earlier study by (i) adding a production function to allow substitution among energy types and energy and production factors and (ii) changing the closure rules to have the model cover the 2011–40 period. Figure D.1 shows the energy substitution function in the CGE model. Figure D.2 shows the flow of production technology and commodities in the CGE model.

The model is based on a 2011 social accounting matrix (SAM) for Vietnam, which was constructed by CIEM in collaboration with the World Institute for Development Economics Research (WIDER, United Nations University). The model uses General Algebraic Modeling System (GAMS) software and is formulated as a Mixed Complementary Problem (MCP) with a system of simultaneous linear and nonlinear equations.

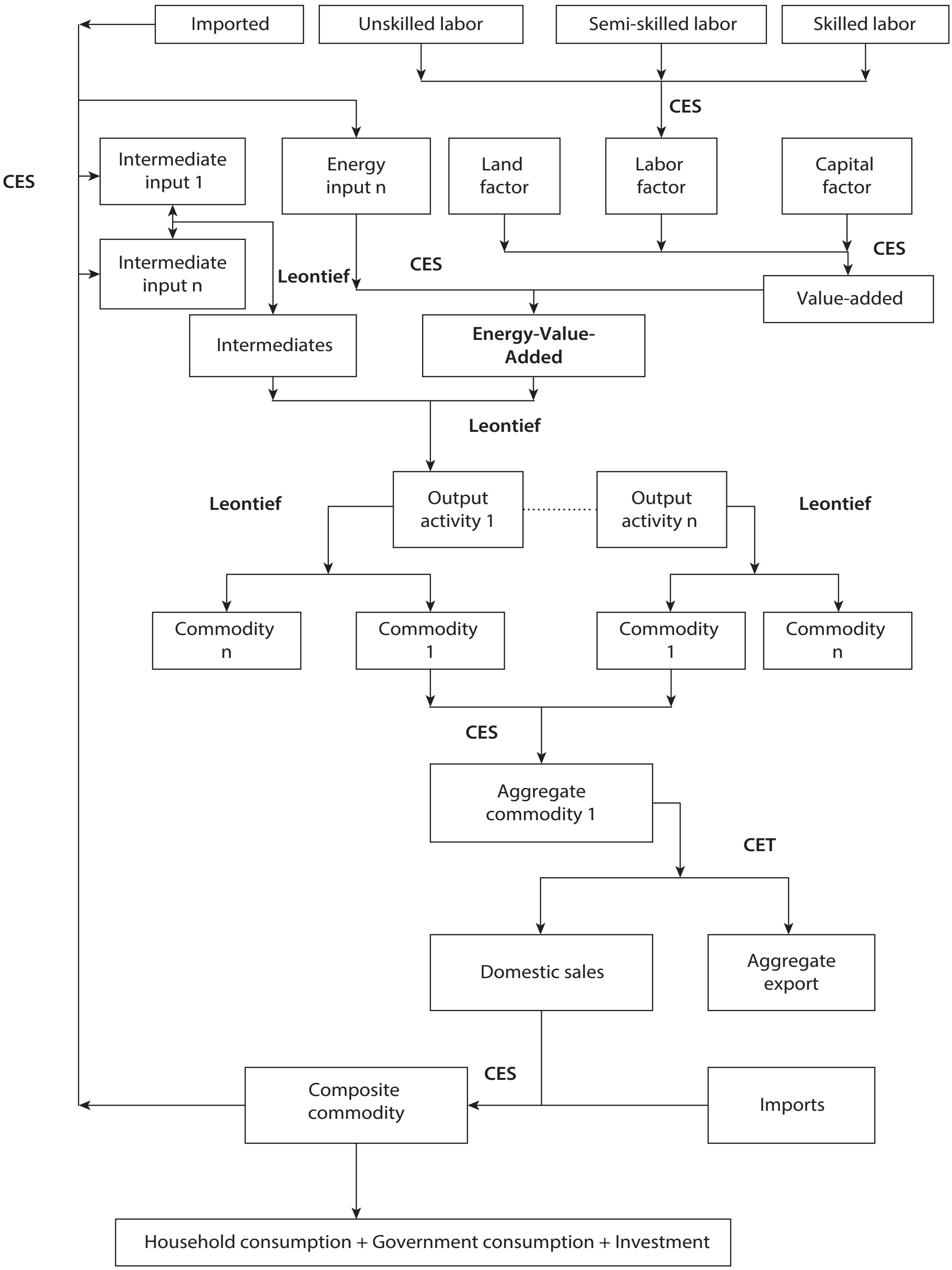
Low-carbon-option simulations are formulated based on the packages of low-carbon measures developed by the bottom-up models. The CGE model groups the low-carbon measures to, on the one hand, separate the impacts of key measures while, on the other hand, measuring the impacts of the package as a whole. In the simulation, low-carbon measures trigger multi-round impacts to the economy through several designed parameters surrounding energy efficiency, energy consumption patterns, capital costs, and investment.

Figure D.1 Energy Substitution in Production Functions



Source: CIEM.
Note: Leontief is a fixed share function; CES = constant elasticity of substitution.

Figure D.2 Production Technology and Commodity Flows in Vietnam: Low-Carbon CGE Model



Source: Adapted from Thurlow (2004).
Note: Leontief is a fixed share function; CES = constant elasticity of substitution; CET = constant elasticity of transformation; CGE = computable general equilibrium.

APPENDIX E

Key Assumptions

Annual Growth of Gross Domestic Product

This study assumes that the annual growth rate of the gross domestic product (GDP) follows the low case demand projection of the Power Development Plan VII (PDPVII). The low case demand reflects the recent slowdown of the global economy. The levels of GDP for 2010–30 are presented in figure E.1.

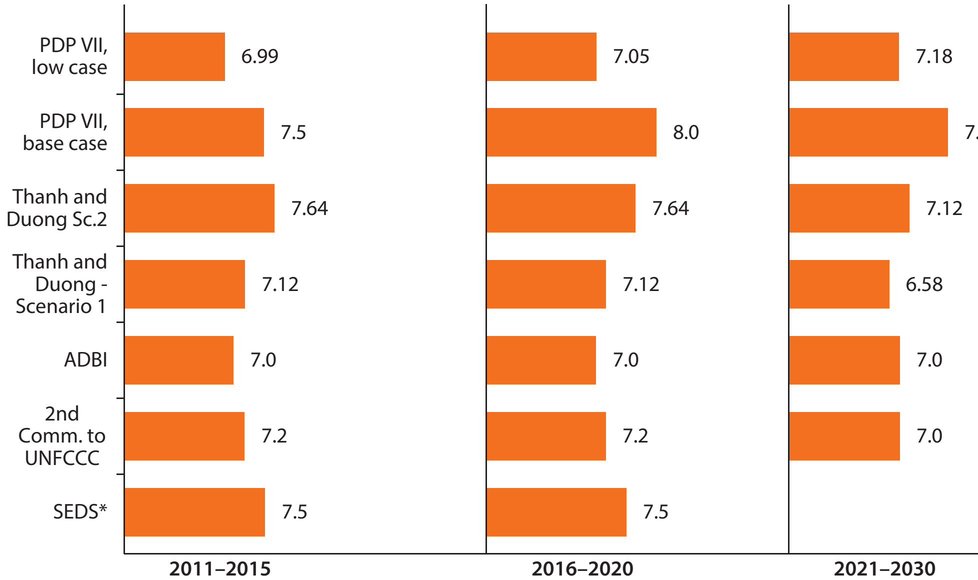
Population and Urbanization

Projections of the total population and urbanization rate are provided by Asian Development Bank (ADB). This is for the purpose of harmonizing key assumptions across complementary studies being conducted in parallel. The source of the data is Dung and Sawdon (2012), "Social and Economic Baseline Projections, Version 6," which is a background report to the ADB (2013), undertaken as part of ADB TA7779. See figure E.2.

Fuel Prices

Fuel price assumptions are common across the business-as-usual (BAU) and the low-carbon development (LCD) scenario, and are based on the projections of the Institute of Energy (IEVN). See table E.1. Fuel prices are assumed to reach full cost-recovery levels by 2015, using a two-tier fuel pricing policy with domestic fuels priced to cover production and delivery costs and imported fuels priced at projected international prices. Domestic coal prices move from subsidized prices in 2010 (approximately 70 percent of production cost) to full cost-recovery levels by 2015 and thereafter. Domestic gas prices represent long-term contract prices for specific power plants that cover all costs of production, pipeline, and delivery services.

Figure E.1 Annual Growth of GDP, % per Year, and Total GDP, 2010 VND Trillion per Year



	2010	2015	2020	2025	2030
GDP (2010 VND trillion)	1,981	2,746	3,861	5,461	7,724

Source: ADB 2013.
Note: ADBI = Asian Development Bank Institute; GDP = gross domestic product; PDPVII = Power Development Plan VII; SEDS = Socio-economic Development Strategy; UNFCCC = United Nations Framework Convention on Climate Change.

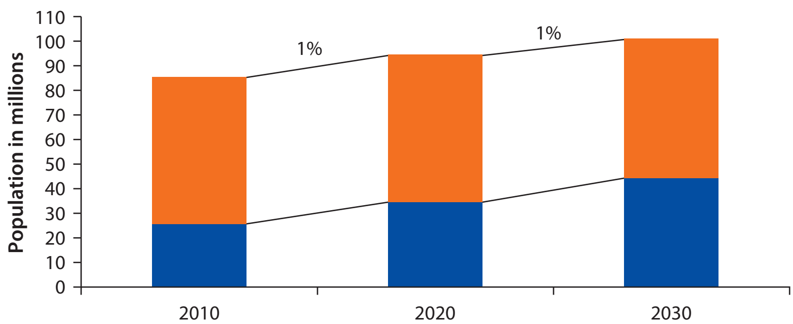
Income Elasticity of Electricity Demand

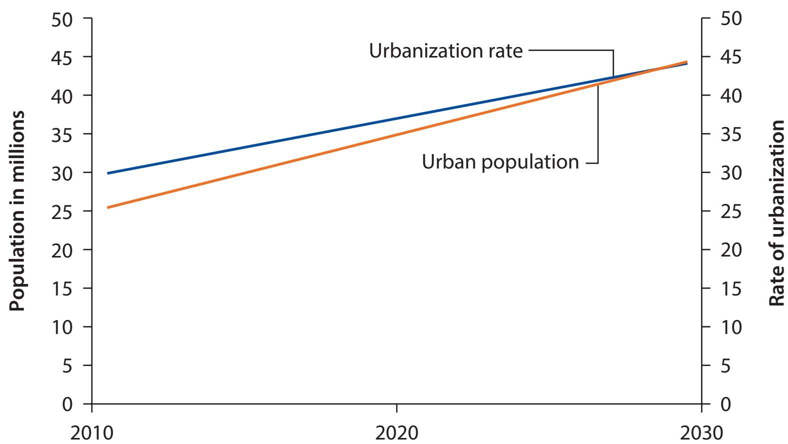
The income elasticity used in this study is shown in table E.2. It is important to note that this is not an input assumption. The elasticity is a resulting parameter based on exogenous assumptions on GDP growth and electricity demand in a National Load Dispatch Center report published by Electricity Vietnam in 2010 (and based on PDPVII low-demand forecast for 2011–30).

Number and Size of Households

The assumptions on household size and number are key drivers of the projections of the ownership of electrical appliances and private motor vehicles in this study. See figure E.3, below. The two parameters follow the projections carried out in Dung and Sawdon (2012), "Social and Economic Baseline Projections, Version 6," which is a background report to the ADB (2013), "Technical Working Paper on GHG Emissions, Scenarios, and Mitigation Potentials in the Energy and Transport Sectors of Viet Nam (draft)," undertaken as part of ADB TA7779.

Figure E.2 Total Population, Million Persons, and Urbanization Rate, Percent per Year





Source: ADB 2013.

Table E.1 Fuel Prices

Fuel type	*Unit*	*2010*	*2015*	*2020*	*2025*	*2030*
Domestic anthracite	thousand VND per ton	648	917	1,012	1,117	1,234
Imported bituminous	thousand VND per ton	1,600	1,768	1,954	2,159	2,382
Domestic natural gas	thousand VND per MMBTU	83	134	154	174	202
Imported LNG	thousand VND per MMBTU	–	–	–	296	296
Rice husk (biomass)	thousand VND per ton	372	411	455	502	554
Nuclear	thousand VND per TJ	36,192	36,192	36,966	44,102	48,704
Diesel	thousand VND per ton	14,609	16,135	17,810	19,671	21,699
Fuel oil	thousand VND per ton	11,855	13,083	14,441	15,949	17,624

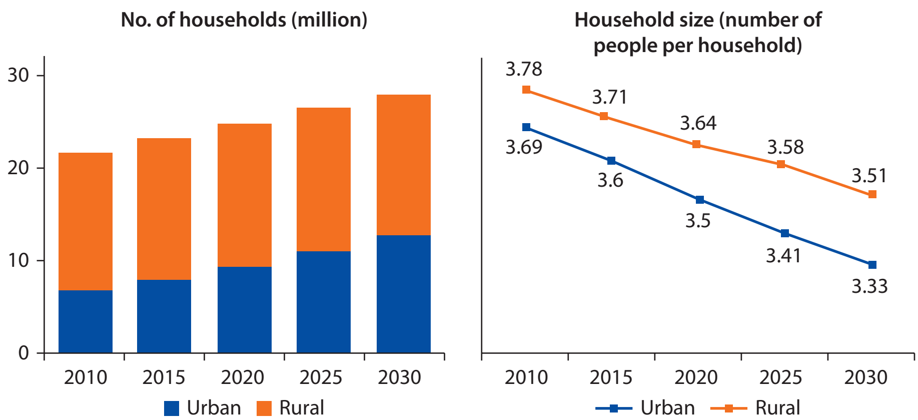
Source: World Bank.
Note: MMBTU = million British thermal units; TJ = terajoule; VND = Vietnam Dong.

Table E.2 Income Elasticity of Electricity Demand

2010	*2015*	*2020*	*2025*	*2030*
2.4	1.7	1.1	1.0	0.9

Source: World Bank estimates.

Figure E.3 Number of Households and Household Size



Source: ADB 2013.

Table E.3 Lifetime Levelized Cost of Electricity Generation

	Year of commission	
Technology option	*2020*	*2030*
Hydro - Storage	66.45	66.45
Hydro - Run of River	46.60	46.60
Hydro - Pumped Storage	40.13	43.08
Coal - Subcritical (Domestic)	54.47	60.06
Coal - Supercritical (Imported)	71.55	80.88
CCGT - Imported LNG	107.75	107.75
Nuclear	93.17	99.04
Biomass - Rice Husk	64.87	70.38
Wind Onshore	107.15	107.15
Solar PV	88.20	88.20
CCGT LNG + Hydro	79.68	79.68
CCGT LNG + Wind	113.90	113.90
CCGT LNG + Solar PV	108.28	108.28

Source: World Bank estimates.
Note: CCGT = combined cycle gas turbines; LNG = liquefied natural gas; PV = photovoltaic.

Cross-country analysis shows a wide divergence in household size for a given GDP per capita depending on the social and cultural factors. The trend in household size variation for China (with a similar social and cultural background as Vietnam) is chosen as a rough approximation for Vietnam in Dung and Sawdon (2012).

Levelized Cost of Electricity Generation

Levelized costs of electricity generation associated with different technologies are used in this study as guiding indicators for least-cost solutions and as part of the construction of the BAU and the LCD scenarios. The levelized cost estimates in this study are provided in table E.3, and are measured through the lifetime of each technology. The cost calculation in the table includes capital, operation and maintenance (O&M), and fuel costs, and does not take into account externality costs. The capital and O&M cost assumptions are based on Energy Forecasting Framework and Emissions Consensus Tool (EFFECT) base data, while fuel costs are calculated based on the fuel price scenario described above.

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Dung and Sawdon. 2012. *Social and Economic Baseline Projections Version 6.0*. Background report to ADB TA7779 (unpublished).

APPENDIX F

Data Tables

All numbers in the following tables are the authors' estimates and are the results of calculations made by the World Bank, based upon inputs and assumptions provided by the Institute of Energy of Vietnam (IEVN), the Transport and Development Strategy Institute (TDSI), the Central Institute for Economic Management (CIEM), and Ernst and Young.

Table F.1 Business-as-Usual Scenario

Electricity generation capacity by fuel type/ Technology (MW)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Hydro	7091	14452	18879	21459	22959	33%	33%	32%	26%	20%
Thermal	14426	27226	37274	58661	80491	67%	63%	64%	70%	71%
of which										
Coal subcritical	5128	16098	23648	32165	32245	24%	37%	40%	38%	28%
Coal supercritical	0	0	3150	16170	37920	0%	0%	5%	19%	33%
Gas	7798	9628	9628	9628	9628	36%	22%	16%	12%	8%
Oil	903	903	363	330	330	4%	2%	1%	0%	0%
Diesel	598	598	485	368	368	3%	1%	1%	0%	0%
Nuclear	0	0	1000	2000	8700	0%	0%	2%	2%	8%
Renewable	25	1523	1523	1523	1523	0%	4%	3%	2%	1%
of which						0%				
Wind	0	318	318	318	318	0%	1%	1%	0%	0%
Solar	0	0	0	0	0	0%	0%	0%	0%	0%
Biomass	20	237	237	237	237	0%	1%	0%	0%	0%
Others	5	968	968	968	968	0%	2%	2%	1%	1%
	21542	43201	58676	83643	113673	100%	100%	100%	100%	100%
Total										

table continues next page

Table F.1 Business-as-Usual Scenario *(continued)*

Electricity supply by fuel type/ Technology (GWh)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Hydro	24812	54806	67576	71581	73666	30%	33%	25%	19%	14%
Thermal	56662	107317	185154	293526	395259	69%	64%	70%	76%	73%
of which						0%	0%	0%	0%	0%
Coal subcritical	14541	71729	103888	125703	92080	18%	43%	39%	33%	17%
Coal supercritical	0	0	21021	107637	37920	0%	0%	8%	28%	7%
Gas	43584	35557	60018	60001	52743	53%	21%	23%	16%	10%
Oil&Diesel	1368	30	100	89	93	2%	0%	0%	0%	0%
Diesel	2	1	127	96	102	0%	0%	0%	0%	0%
Nuclear	0	0	7385	14843	64623	0%	0%	3%	4%	12%
Renewable	78	6032	6065	6094	6115	0%	4%	2%	2%	1%
of which						0%	0%	0%	0%	0%
Wind	0	680	684	687	690	0%	0%	0%	0%	0%
Solar	0	0	0	0	0	0%	0%	0%	0%	0%
Biomass	78	1625	1634	1641	1646	0%	1%	1%	0%	0%
Others	0	3727	3748	3766	3779	0%	2%	1%	1%	1%
	81552	168154	266181	386044	539664	100%	100%	100%	100%	100%

GHG emissions by fuel type/ Technology (million tCO_2)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Hydro	0	0	1179	2780	3814	0%	0%	1%	1%	1%
Thermal	32532	84091	143900	236780	318026	100%	100%	99%	99%	99%
of which						0%	0%	0%	0%	0%
Coal subcritical	14017	70441	102898	124984	92362	43%	84%	71%	52%	29%
Coal supercritical	0	0	17075	87738	204639	0%	0%	12%	37%	64%
Gas	17552	13626	23716	23890	20849	54%	16%	16%	10%	6%
Oil	960	23	75	64	68	3%	0%	0%	0%	0%
Diesel	2	0	136	104	108	0%	0%	0%	0%	0%
Nuclear	0	0	0	0	0	0%	0%	0%	0%	0%
Renewable	0	0	0	0	0	0%	0%	0%	0%	0%
of which						0%	0%	0%	0%	0%
Wind	0	0	0	0	0	0%	0%	0%	0%	0%
Solar	0	0	0	0	0	0%	0%	0%	0%	0%
Biomass	0	0	0	0	0	0%	0%	0%	0%	0%
Others	0	0	0	0	0	0%	0%	0%	0%	0%
Total	**32532**	**84091**	**145079**	**239560**	**321840**	**100%**	**100%**	**100%**	**100%**	**100%**

table continues next page

Table F.1 Business-as-Usual Scenario *(continued)*

Total freight-ton and passenger kilometers (km/yr, billions)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
On Road										
2W	168	195	228	259	281	54%	48%	43%	37%	32%
3W	0	0	0	0	0	0%	0%	0%	0%	0%
PC	6	9	17	34	62	2%	2%	3%	5%	7%
LCV	3	4	6	8	10	1%	1%	1%	1%	1%
HCV	66	110	125	162	211	21%	27%	23%	23%	24%
Total on-road	242	319	376	463	563	79%	78%	70%	67%	64%
Waterborne	**57**	**79**	**110**	**154**	**216**	19%	19%	20%	22%	24%
Rail	8	13	50	75	106	3%	3%	9%	11%	12%
Total	**308**	**410**	**536**	**691**	**886**	**100%**	**100%**	**100%**	**100%**	**100%**
Fuel consumption by type (Gg)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Petrol	3387	3110	3529	4293	5284	65%	56%	54%	52%	50%
Diesel	1792	2427	3020	3985	5221	35%	44%	46%	48%	49%
LPG	0	1	1	2	5	0%	0%	0%	0%	0%
CNG	0	3	4	17	65	0%	0%	0%	0%	1%
Total	**5179**	**5541**	**6554**	**8297**	**10575**	**100%**	**100%**	**100%**	**100%**	**100%**
GHG emissions by vehicle type (million tCO_2)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
2W	9958	8804	9336	9996	10246	61%	50%	45%	28%	22%
3W	0	0	0	0	0	0%	0%	0%	0%	0%
PC	649	1007	1929	3788	6681	4%	6%	9%	11%	14%
LCV	667	856	1166	1632	2287	4%	5%	6%	5%	5%
HCV	5010	6679	7666	9912	12918	31%	38%	37%	28%	28%
Total On-road	16284	17346	20098	25327	32132	99%	99%	97%	72%	70%
Waterborne	3634	4749	6538	9058	12557	22%	27%	31%	26%	27%
Total Rail	122	186	685	996	1422	1%	1%	3%	3%	3%
Total	**16406**	**17532**	**20783**	**35381**	**46111**	**100%**	**100%**	**100%**	**100%**	**100%**
Electricity consumption by appliance type (GWh)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Lighting	2352	4139	4817	5952	7339	8%	10%	9%	9%	8%
Entertainment	5899	5732	5322	4899	4638	20%	15%	10%	7%	5%
Kitchen Appliances	16483	20891	25953	31209	36220	56%	53%	50%	46%	40%
Heating/Cooling	4815	8764	15400	26054	42007	16%	22%	30%	38%	47%
Total	**29549**	**39527**	**51491**	**68114**	**90205**	**100%**	**100%**	**100%**	**100%**	**100%**

table continues next page

Table F.1 Business-as-Usual Scenario *(continued)*

Production by industry type (Mt)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Iron and Steel, ISP plants	1	4	8	11	14	1%	4%	5%	6%	7%
Iron and Steel, Small plants	8	8	8	8	8	6%	7%	5%	5%	4%
Aluminium						0%	0%	0%	0%	0%
Cement	56	87	112	124	138	39%	77%	74%	71%	67%
Fertilizer	6	2	2	3	3	4%	1%	1%	1%	2%
Refining	1	10	15	21	28	1%	9%	10%	12%	14%
Pulp and Paper	73	3	6	9	14	50%	3%	4%	5%	7%
Total	**144**	**114**	**151**	**176**	**205**	**100%**	**100%**	**100%**	**100%**	**100%**
Energy consumption by industry type (PJ or Mtoe)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Iron and Steel, ISP plants	25	39	60	116	148	7%	8%	9%	13%	14%
Iron and Steel, Small plants	23	36	52	60	77	7%	7%	7%	7%	7%
Aluminium	0	0	0	0	0	0%	0%	0%	0%	0%
Cement	228	291	372	413	457	67%	59%	54%	47%	42%
Fertilizer	29	47	63	78	93	8%	9%	9%	9%	9%
Refining	21	39	60	81	109	6%	8%	9%	9%	10%
Pulp and Paper	16	45	87	139	206	5%	9%	12%	16%	19%
Total	**342**	**497**	**694**	**886**	**1091**	**100%**	**100%**	**100%**	**100%**	**100%**
GHG emission by industry type (million tCO_2)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Iron and Steel, ISP plants	2412	3890	6141	11957	15496	4%	5%	5%	9%	10%
Iron and Steel, Small plants	2714	4282	6882	8225	11008	5%	5%	6%	6%	7%
Aluminium	0	0	0	0	0	0%	0%	0%	0%	0%
Cement	45599	64883	83942	91959	100817	82%	79%	75%	68%	64%
Fertilizer	1829	3032	4154	5137	6205	3%	4%	4%	4%	4%
Refining	1610	2979	4574	6165	8330	3%	4%	4%	5%	5%
Pulp and Paper	1180	3294	6685	10964	16624	2%	4%	6%	8%	10%
Total	**55344**	**82360**	**112377**	**134407**	**158481**	**100%**	**100%**	**100%**	**100%**	**100%**

Table F.2 Low-Carbon Development Scenario

Electricity generation capacity by fuel type/ Technology (MW)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Hydro	7091	14452	18879	21459	22959	33%	33%	33%	26%	21%
Thermal	14426	27226	35924	51420	65880	67%	63%	63%	63%	61%
of which										
Coal subcritical	5128	16098	23048	28565	28345	24%	37%	40%	35%	26%
Coal supercritical	0	0	2400	6990	17470	0%	0%	4%	9%	16%
Gas	7798	9628	9628	15128	19328	36%	22%	17%	19%	18%
Oil	903	903	363	368	368	4%	2%	1%	0%	0%
Diesel	598	598	485	368	368	3%	1%	1%	0%	0%
Nuclear	0	0	1000	2000	9700	0%	0%	2%	2%	9%
Renewable	25	1523	1523	6323	9623	0%	4%	3%	8%	9%
of which						0%				
Wind	0	318	318	1118	2118	0%	1%	1%	1%	2%
Solar	0	0	0	700	1500	0%	0%	0%	1%	1%
Biomass	25	237	237	1637	2237	0%	1%	0%	2%	2%
Others	0	968	968	2868	3768	0%	2%	2%	4%	3%
Total	21542	43201	57326	81202	108162	100%	100%	100%	100%	100%
Electricity supply by fuel type/ Technology (GWh)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Hydro	26052	58439	78054	89595	96380	30%	35%	30%	25%	20%
Thermal	59495	101572	165081	227026	270794	69%	61%	64%	63%	56%
of which						0%	0%	0%	0%	0%
Coal subcritical	14541	41741	86361	94991	52552	17%	25%	34%	26%	11%
Coal supercritical	0	0	16372	48360	119716	0%	0%	6%	13%	25%
Gas	43584	59825	62172	83530	98386	51%	36%	24%	23%	21%
Oil&Diesel	1370	6	176	145	140	2%	0%	0%	0%	0%
Diesel						0%	0%	0%	0%	0%
Nuclear	0	0	7957	15974	74685	0%	0%	3%	4%	16%
Renewable	78	6434	6459	26676	37824	0%	4%	3%	7%	8%
of which						0%	0%	0%	0%	0%
Wind	0	680	684	2439	4632	0%	0%	0%	1%	1%
Solar	0	0	0	920	1971	0%	0%	0%	0%	0%
Biomass	78	1625	1634	10839	14786	0%	1%	1%	3%	3%
Others	0	3727	3748	12088	16043	0%	2%	1%	3%	3%
Total	85625	166445	257551	359270	479683	100%	100%	100%	100%	100%

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Table F.2 Low-Carbon Development Scenario *(continued)*

GHG emissions by fuel type/ Technology (million tCO_2)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Hydro	0	0	0	0	0	0%	0%	0%	0%	0%
Thermal	33	64	124	166	188	100%	100%	100%	100%	100%
of which						0%	0%	0%	0%	0%
Coal subcritical	14	41	85	95	53	43%	64%	69%	57%	28%
Coal supercritical	0	0	13	39	98	0%	0%	11%	24%	52%
Gas	18	23	25	32	36	54%	36%	20%	19%	19%
Oil	1	0	0	0	0	3%	0%	0%	0%	0%
Diesel						0%	0%	0%	0%	0%
Nuclear	0	0	0	0	0	0%	0%	0%	0%	0%
Renewable	0	0	0	0	0	0%	0%	0%	0%	0%
of which						0%	0%	0%	0%	0%
Wind	0	0	0	0	0	0%	0%	0%	0%	0%
Solar	0	0	0	0	0	0%	0%	0%	0%	0%
Biomass	0	0	0	0	0	0%	0%	0%	0%	0%
Others	0	0	0	0	0	0%	0%	0%	0%	0%
Total	**33**	**64**	**124**	**166**	**188**	**100%**	**100%**	**100%**	**100%**	**100%**

Total freight-ton and passenger kilometers (km/yr, billions)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
On Road										
2W	168	196	219	246	265	54%	48%	41%	36%	30%
3W	0	0	0	0	0	0%	0%	0%	0%	0%
PC	6	9	17	34	62	2%	2%	3%	5%	7%
LCV	3	4	6	8	10	1%	1%	1%	1%	1%
HCV	66	109	132	166	206	21%	27%	25%	24%	23%
Total on-road	242	318	374	454	542	79%	78%	70%	66%	61%
Waterborne	57	79	111	156	220	19%	19%	21%	23%	25%
Rail	8	13	52	82	122	3%	3%	10%	12%	14%
Total	**308**	**410**	**537**	**692**	**884**	**100%**	**100%**	**100%**	**100%**	**100%**

Fuel consumption by type (Gg)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Petrol	3387	3000	2853	2730	2451	65%	56%	48%	41%	33%
Diesel	1792	2396	3015	3711	4706	35%	44%	51%	56%	63%
LPG	0	1	1	2	5	0%	0%	0%	0%	0%
CNG	0	7	45	148	258	0%	0%	1%	2%	3%
Total	**5179**	**5404**	**5914**	**6591**	**7420**	**100%**	**100%**	**100%**	**100%**	**100%**

table continues next page

Table F.2 Low-Carbon Development Scenario *(continued)*

GHG emissions by vehicle type (million tCO_2)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
2W	9958	8454	7172	5521	3239	61%	49%	38%	19%	9%
3W	0	0	0	0	0	0%	0%	0%	0%	0%
PC	649	1007	1901	3141	4323	4%	6%	10%	11%	12%
LCV	667	856	1165	1628	2279	4%	5%	6%	6%	7%
HCV	5010	6584	7752	9403	11905	31%	39%	41%	32%	34%
Total On-road	16284	16901	17991	19693	21746	99%	99%	96%	67%	62%
Waterborne	3634	4666	6242	8500	11659	22%	27%	33%	29%	33%
Total Rail	122	193	690	1074	1576	1%	1%	4%	4%	5%
Total	**16406**	**17095**	**18681**	**29267**	**34981**	**100%**	**100%**	**100%**	**100%**	**100%**
Electricity consumption by appliance type (GWh)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Lighting	2352	3771	3670	3460	2949	8%	10%	8%	6%	4%
Entertainment	5899	6438	5755	4888	4096	20%	16%	12%	8%	6%
Kitchen Appliances	16483	20569	24879	27267	29045	56%	52%	51%	46%	40%
Heating/Cooling	4815	8678	14557	23476	36378	16%	22%	30%	40%	50%
Total	**29549**	**39455**	**48861**	**59090**	**72468**	**100%**	**100%**	**100%**	**100%**	**100%**
Production by industry type (Mt)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Iron and Steel, ISP plants	1	4	8	11	14	1%	4%	5%	6%	7%
Iron and Steel, Small plants	8	8	8	8	8	12%	7%	5%	5%	4%
Aluminium	0	0	0	0	0	0%	0%	0%	0%	0%
Cement	56	87	112	124	137	77%	76%	74%	71%	67%
Fertilizer	1	2	2	3	3	1%	1%	1%	1%	1%
Refining	6	10	15	21	28	8%	9%	10%	12%	14%
Pulp and Paper	1	3	6	9	14	2%	3%	4%	5%	7%
Total	**73**	**114**	**151**	**176**	**205**	**100%**	**100%**	**100%**	**100%**	**100%**
Energy consumption by industry type (PJ or Mtoe)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Iron and Steel, ISP plants	25	109	191	230	227	8%	20%	25%	25%	23%
Iron and Steel, Small plants	57	55	54	52	48	18%	10%	7%	6%	5%
Aluminium	0	0	0	0	0	0%	0%	0%	0%	0%
Cement	170	263	324	338	344	54%	47%	42%	37%	34%
Fertilizer	29	47	63	77	90	9%	8%	8%	8%	9%
Refining	21	39	56	72	93	7%	7%	7%	8%	9%
Pulp and Paper	16	44	85	135	197	5%	8%	11%	15%	20%
Total	**317**	**556**	**774**	**904**	**999**	**100%**	**100%**	**100%**	**100%**	**100%**

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Table F.2 Low-Carbon Development Scenario *(continued)*

GHG emission by industry type (million tCO_2)	*2010*	*2015*	*2020*	*2025*	*2030*	*2010*	*2015*	*2020*	*2025*	*2030*
Iron and Steel, ISP plants	2210	9888	17469	21414	22726	5%	12%	17%	18%	17%
Iron and Steel, Small plants	2984	2887	2869	2805	2650	6%	4%	3%	2%	2%
Aluminium	0	0	0	0	0	0%	0%	0%	0%	0%
Cement	37591	58584	65483	70803	76009	79%	73%	65%	61%	59%
Fertilizer	1657	2725	3650	4438	5215	3%	3%	4%	4%	4%
Refining	1610	2975	4301	5503	7061	3%	4%	4%	5%	5%
Pulp and Paper	1370	3675	7062	11243	16268	3%	5%	7%	10%	13%
Total	**47422**	**80733**	**100835**	**116205**	**129930**	**100%**	**100%**	**100%**	**100%**	**100%**

Note: 2W = two wheeler; 3W = three wheeler; CNG = compressed natural gas; CO_2 = carbon dioxide; Gg = gigagram; GHG = greenhouse gas; GWh = gigawatt-hour; HCV = heavy commercial vehicle; HH = household; LCV = light commercial vehicle; LPG = liquefied petroleum gas; Mt = million tons; Mtoe = million tons of oil equivalent; MW = megawatt; PC = passenger car; PJ = petajoule; tCO_2 = tons of carbon dioxide.

APPENDIX G

Electricity Generation Capital and Fuel Expenditures by Scenario

Table G.1 Electricity Generation Capital Expenditures by Scenario

CAPEX	*BAU*	*EE$10*	*BAU-EE10*	*LCD-EE$10*	*LCD-BAU*
2015	6.5	6.5	0	0	0
2016	5.7	5.7	0	0	0
2017	0	0	0	0	0
2018	1.7	0.4	1.3	0	(1.3)
2019	5.4	4.7	0.6	0	(0.6)
2020	6.4	6.4	0	0	0
2021	7.0	5.2	1.9	0.9	(1.0)
2022	10.5	5.4	5.1	0.5	(4.6)
2023	7.2	8.1	(0.9)	0.8	1.7
2024	4.8	4.8	0	0.3	0.3
2025	5.7	5.3	0.3	1.2	0.8
2026	11.9	11.0	0.9	0.5	(0.3)
2027	12.7	11.1	1.6	0.4	(1.2)
2028	13.2	9.4	3.8	0.7	(3.1)
2029	11.5	7.7	3.8	2.9	(0.9)
2030	7.7	7.2	0.6	2.8	2.2
Total	**117.9**	**98.9**	**19.0**	**11.0**	**(8.1)**

Source: World Bank estimates.
Note: All coal and nuclear plants are included; all amounts are US$2010 billion. BAU = business as usual; CAPEX = capital expenditure; EE = energy efficiency; FUELEX = fuel expenditure; LCD = low-carbon development.

Table G.2 Electricity Generation Fuel Expenditures by Scenario

FUELEX	*BAU*	*EE$10*	*BAU-EE10*	*LCD-EE$10*	*LCD-BAU*
2015	0.6	0.6	0	0	0
2016	1.1	1.1	0	0	0
2017	1.1	1.1	0	0	0
2018	1.3	1.2	0.1	0	(0.1)
2019	2.0	1.7	0.3	0	(0.3)
2020	2.6	2.4	0.3	0	(0.3)
2021	3.5	3.0	0.5	0.2	(0.3)
2022	4.9	3.7	1.2	0.3	(0.9)
2023	5.8	4.5	1.3	0.2	(1.1)
2024	6.7	5.3	1.4	0.2	(1.2)
2025	7.9	6.3	1.6	0.1	(1.5)
2026	9.1	7.4	1.7	0.1	(1.6)
2027	10.5	8.4	2.1	0.1	(2.0)
2028	12.0	9.7	2.3	0.1	(2.2)
2029	14.5	11.4	3.1	0.1	(3.0)
2030	16.3	13.0	3.3	0.1	(3.1)
Total	**99.9**	**80.8**	**19.1**	**1.5**	**(17.6)**

Source: World Bank estimates.
Note: All coal and nuclear plants are included; $2010 billion. BAU = business as usual; CAPEX = capital expenditure; EE = energy efficiency; FUELEX = fuel expenditure; LCD = low-carbon development.

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Bringing together a large set of data and building on two years of consultations in Vietnam with Government counterparts, research organizations, state-owned enterprises, the private sector, and the country's international development partners, *Exploring a Low-Carbon Development Path for Vietnam* shows that achieving low-carbon development in Vietnam is both beneficial and feasible. To do so, this book delineates immediate and concrete policy guidance for the Government's consideration to lower the country's greenhouse gas emission trajectory.

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