Meeting the Electricity Supply/Demand Balance in Latin America & the Caribbean

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ESMAP

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ACRONYMS AND ABBREVIATIONS

$	United States Dollar
AMM	Administrador del Mercado mayorista
ARESP	Autoridad Reguladora de Servicios Públicos
ASEP	Autoridad de Servicios Públicos
BBL	Barrel
CCGT	Combined Cycle Gas Turbine
CENACE	Centro Nacional de Control de Energía
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CFE	Comisión Federal de Electricidad (México)
CNC	Centro Nacional de Control
CND	Centro Nacional de Despacho
CNDC	Comité Nacional de Despacho de Carga
CNE	Comisión Nacional de Energía
CNEE	Comisión Nacional de Energía Eléctrica
CO_2	Carbon Dioxide
COES	Comité de Operación Económica del Sistema Eléctrico
CONELEC	Consejo Nacional de Electricidad
CPE	Comisión de Políticas Energéticas
CRE	Comisión Reguladora de Energía
CREG	Comisión de Regulación de Energía y Gas
DEE	Dirección de Energía Eléctrica
DGE	Dirección general de Electricidad
DR	Dominican Republic
ENATREL	Empresa Nacional de Transmisión Eléctrica
ENEE	Empresa Nacional de Energía Eléctrica
ENS	Energy Not Served
ETCEE	Empresa de Transporte y Control de Energía Eléctrica
ETESA	Empresa de Transmisión Eléctrica
ETESAL	Empresa Transmisora de El Salvador
FO	Fuel Oil
GT	Gas Turbine
GWh	GigaWatt-hour
IAEA	International Atomic Energy Agency
ICE	Instituto Costarricense de Electricidad
ICEPAC	Illustrative Country Expansion Plans Adjusted & Constrained
IDC	Interest During Construction
INE	Instituto Nacional de Energía

IPP	Independent Power Producer
kT	kilo tons
kW	Kilowatt
kWh	kiloWatt-hour
LEAP	Long-range Energy Alternatives Planning system
LAC	Latin America and Caribbean Region
LOLP	Loss of Load Probability
MAC	Marginal Abatement Cost
MEER	Ministerio de Electricidad y Energía Renovable
MEM	Ministerio de Minas y Energía
MHE	Ministerio de Hidrocarburos y Energía
MINAET	Ministerio de Ambiente, Energía y Telecomunicaciones
MT	Million tons
MW	MegaWatt
NG	Natural Gas
O&M	Operation and Maintenance
OLADE	Organización Latinoamérica de Energía
OSINERGMIN	Organismo Supervisor de la Inversión en Energía y Minería
REDESUR	Empresas de Transmisión del Perú
SE	Superintendencia de Electricidad
SENER	Secretaría de Energía (México)
SIGET	Superintendencia General de Electricidad y Telecomunicaciones
SO_2	Sulfur Dioxide
ST	Steam Turbine
TEP	Tonne Equivalent Petrol
TDE	Transportadora de Electricidad
TRANSELEC	Compañía Nacional de Transmisión Eléctrica S.A
UPME	Unidad de Planeación Minero Energética
VMEAE	Viceministerio de Energías Alternativas y Electricidad
WASP	Wien Automatic System Planning
WDI	World Development Indicator
XM	Compañía Experto en Mercados

EXECUTIVE SUMMARY

I. Introduction

1. **The development of the power sector will be critical for the Region's economic growth over the coming decades.** In the Latin America and Caribbean (LAC) Region, economic and social development over the past forty years has been supported by a widespread program of electrification that has greatly increased the provision of electricity services to households, commerce, and industry. Over the coming decades, the supply of electric power will need to expand to meet the growing demand for electricity, but how the production and use of electricity develops will have broad ramifications for the diverse economies and societies of the Region.

2. Among the key challenges for the development of the power sector in LAC over the coming twenty years, and which have implications for near-term investments and policies, are the following:

- **Electricity for growth and access.** Between now and 2030, how much electricity will be required by individual countries and the Region to satisfy the needs of economic development and to provide access to those without electric power? How much investment – in new generating capacity, transmission, and distribution infrastructure – will be required?
- **Energy security.** Is the expansion of electricity supply likely to increase or decrease the diversity of the generation technology mix, will it make use of domestic or imported energy resources, and will the fuel sources be vulnerable to supply disruptions or large price shocks?
- **Energy efficiency.** Will the supply of electricity be provided at the least overall cost to national economies, will the power generation technologies chosen be the most efficient, and are there opportunities to avoid new power generation capacity by producing and consuming electricity more efficiently?
- **Environmental sustainability.** What will be the trend in the role of natural gas, hydro, and other clean and low-carbon electricity supplies vis-à-vis petroleum and coal, and what policies and regulatory regimes would help to promote low-carbon development in the power sector?
- **Regulatory framework.** What changes to the regulatory framework are needed to allow the power sector to meet increasing demand, address growing environmental concerns, and attract private capital to reduce the financial burden on government budgets?

3. **The objective of this study is to provide an assessment of the electric power sector in LAC to the year 2030** and in the process provide initial answers to the questions above. The study begins by examining the history of the power sector in the region, looking at the development of electricity production and the associated policies and institutions. Looking to the future, the study relies on the most recent and consistent regional data set from OLADE and uses a common modeling framework to examine possible future trends in electricity supply. To the extent possible, the modeling framework attempts to reflect the current power expansion supply

plans of the countries in the Region. Critical outputs from the modeling analysis are presented in the form of a baseline scenario to 2030 for countries and sub-regions, and include the demand for electricity, the total new supply of electric generating capacity needed, the technology and fuel mix of the generating capacity, and the CO_2 emissions of the sector. In addition, the study examines a range of options and the policies needed to meet the future electricity supply challenges in the Region. Among the options are the expansion of the use of hydropower, natural gas, and non-hydro renewable energy resources, increased regional electricity trade, and efficiency improvements on both the supply and demand sides.

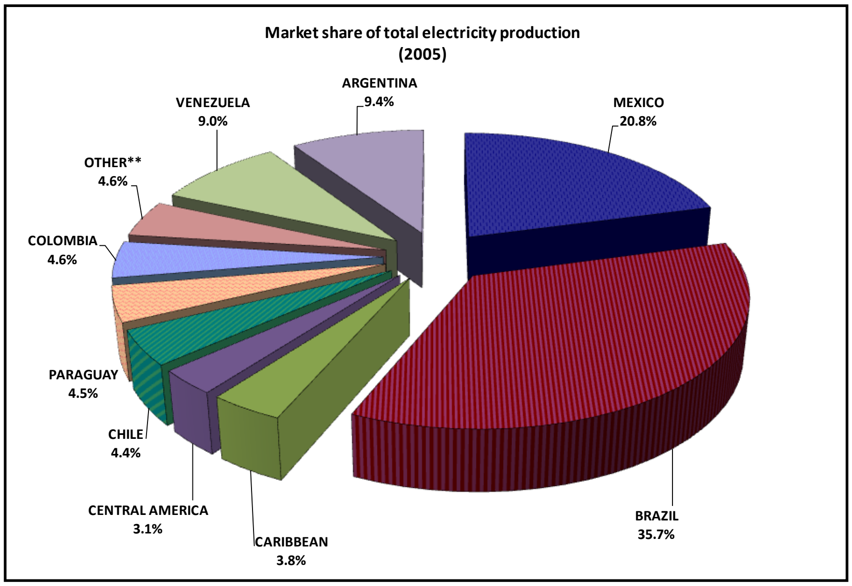
II. Historical Development of the Electric Power Sector in LAC

4. **The power sector in Latin America and the Caribbean has experienced steady growth since the 1970s.** Regional electricity production grew at an average rate of 5.9 percent per year between 1970 and 2005, compared to the worldwide average over the period of 4.3 percent.

5. **Six countries account for 84 percent of total electricity production in the LAC Region** (figure ES1). Brazil is the largest electricity producer (36 percent), followed by Mexico (21 percent), Argentina (9 percent), Venezuela (9 percent), Colombia (5 percent), and Chile (4 percent). Paraguay is a significant producer (5 percent) through its share of production from the gigantic Itaipu hydrostation, however, the majority of the electricity produced by Paraguay is sold to Brazil.

6. **There are large disparities in electricity access rates both between and within countries.** Despite the overall impression of affluence that comes from looking at average growth rates for electricity production and consumption, countries in LAC face significant supply-demand imbalances (especially during dry years), and there are large differences in connection rates and affordability. For example, there are an estimated 34 million people in the region without access to electricity (Peru: 6.5m; Brazil: 4.3m; Colombia: 3.0m; Guatemala: 2.7m).

Figure ES1



7. **Hydroelectricity has been the dominant source of electricity for the region but its share has been declining.** Historically, hydroelectricity has provided the largest share of electricity in LAC, with the largest producer, Brazil, generating around 87 percent of its electricity from hydroelectricity in 2005. For the region as a whole, hydroelectricity provided 59 percent of electricity supply (2005), the highest share from hydroelectricity of any region in the world. Nonetheless, hydropower's share has been declining over the past decade (from 66 percent in 1995), and there are indications that the downward trend will continue in the future.

8. **Natural gas usage has been growing.** A significant trend in the power sector in LAC over the past 15 years has been the growth in the use of natural gas – 10 percent of generation capacity in 1995 rising to 19 percent in 2005 (over the same period, natural gas capacity rose from 15 to 38 percent in Mexico and 19 to 33 percent in the Southern Cone). The increase in natural gas has been due to a variety of reasons, including the efficiency (and cleanliness) of natural gas for power generation, and the increased production and trade of natural gas among countries of the region (Mexico, Argentina, Brazil, Peru, Chile, Bolivia).

9. **Petroleum use has declined overall but remains significant for some countries and sub-regions.** The use of petroleum products (mainly fuel oil and diesel) for power generation has been significant for some sub-regions (75 percent in the Caribbean and 40 percent in Central America in 2005) and countries (31 percent in Mexico in 2005, down from 58 percent in 1985). For the region as a whole, however, the share of oil-fired generation accounted for only 14 percent of power generation in 2005, down from 20 percent in 1985. Dealing with the unpredictable fluctuations in the price of oil and the associated impact on balance of payments remains a central concern for those countries with a high share of oil in their electricity and overall energy supply mixes.

10. **Coal and other energy sources account for a small share of power generation in LAC.** Coal use accounted for about 6 percent of power production in 2005, up from about 4 percent in 1985. The only country in the region with significant coal development plans is Colombia, which possesses the region's largest coal reserves. All other sources of power generation (including nuclear, wind, geothermal, and biomass) accounted for less than 2 percent of overall power generation in LAC in 2005.

11. **Electricity trade in the Region has been limited but there is potential for growth with new interconnections.** Trade has significant potential for balancing electricity supply and demand between countries and sub-regions, and the potential for increased trade has been facilitated by the construction of electricity transmission infrastructure, such as within Central America (SIEPAC) and between countries (Mexico-Guatemala, Colombia-Ecuador). However, with the exception of the sale of hydroelectricity from Paraguay to Brazil and Argentina, electricity trade in the region remains limited, both in absolute magnitude and as a percentage of overall demand.

12. **From a global environmental perspective, LAC has the least carbon-intensive electricity sector of any region in the world, but carbon intensity has been rising.** The low level of greenhouse gas emissions per unit of electricity production in the Region has been due to

the high share of hydroelectricity. However, the carbon-intensity of the power sector has been rising with the increasing share of fossil fuels (including natural gas) over the past decade, and this trend is expected to continue in the future under a baseline scenario.

13. **The regulatory framework for the power sector has experienced dramatic changes in the region.** Beginning in the 1990s, new independent regulatory agencies were created, large state-owned companies were unbundled and privatized, and competitive market-oriented frameworks were implemented in a number of countries. However, the state remains an important player throughout the region in the power sector through the ownership of companies involved in generation, transmission, and distribution.

III. Baseline Electricity Supply Scenario

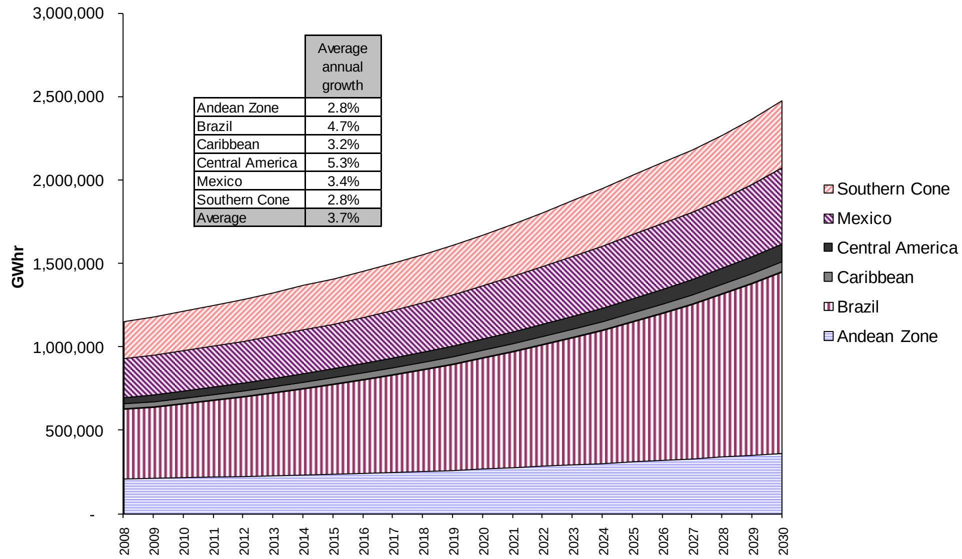
14. **Modeling of electricity supply to the year 2030 was undertaken for the LAC Region.** For the purposes of illustrating the implications of current trends in electricity development – for individual countries, sub-regions, and the Region as a whole – scenarios of electricity supply to the year 2030 were created using a simple electricity demand function and a detailed energy supply planning model.

i. **Demand Function.** The demand for electricity was estimated using GDP forecasts from the International Monetary Fund for each country up to 2014 (IMF 2009). For the period 2015 to 2030, a common set of economic assumptions – based on an average GDP growth rate of three percent per year – was used.

ii. **Supply Model.** An electricity supply scenario—intended to reflect the current power sector expansion plans in the Region— was created to illustrate electricity supply trends in the LAC Region. Using OLADE's SUPER Model and consistent country-level data, an electricity supply scenario was created which relies on the latest power sector plans of individual countries in the Region and which satisfies the demand function estimates.

iii. **ICEPAC Scenario.** Using the demand estimates and the SUPER supply model, a baseline scenario for the coming two decades was created. The "**Illustrative**" scenario is based on: (1) "**Country Expansion Plans**" to the year 2030 (where available), which are then: (2) "**Adjusted**" to account for missing data, and to extrapolate country expansion plans (most of which are available to the year 2018 or 2020), and then (3) "**Constrained**" so as not to exceed energy resource potential (such as domestic hydroelectric resources) and using a database of international technology supply costs which places a cost-minimizing constraint on the electricity supply model. From the **ICEPAC Scenario**, it is possible to observe what would happen to the scale and structure of electricity supply, the financing that would be needed for new investment, and future CO_2 emissions from the power sector.

Figure ES2. Regional Electricity Demand Scenario



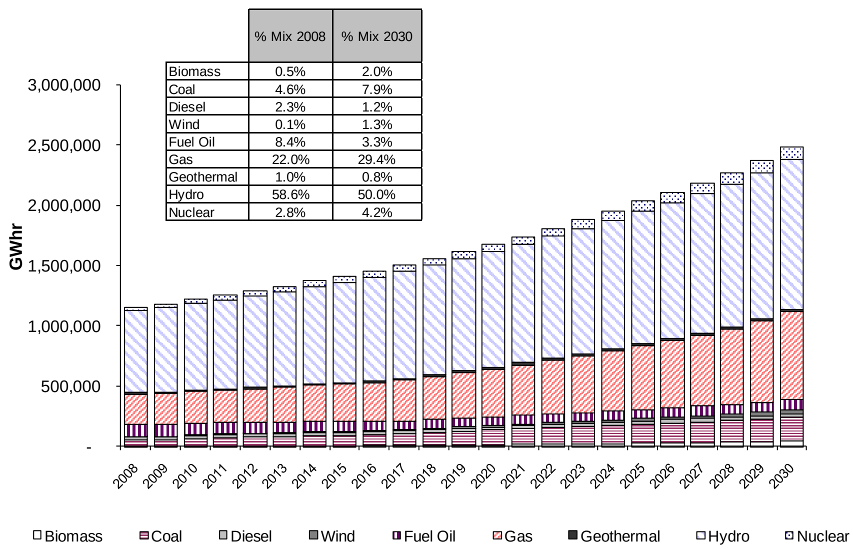
15. The key results of the electricity modeling exercise, which reflect current country expansion plans in the region, are the following:

- **By 2030, with a modest rate of economic growth, the region's demand for electricity would reach nearly 2,500 terawatt-hours (TWh), up from around 1,150 TWh in 2008** (figure ES2). Electricity demand in Brazil would more than double to around 1090 TWh. A total of 239 gigawatts (GW) of new electricity generation capacity would be needed to match demand, with Brazil adding about 97 GW, the Southern Cone 45 GW, Mexico 44 GW, the Andean Zone 30 GW, Central America 15 GW, and the Caribbean 7 GW.
  - **Hydropower and natural gas would provide the majority of additional power capacity.** Although the share of hydro will continue to decline, the combined share of hydro and natural gas will be higher. There would continue to be a decline in the use of petroleum and a slight increase in nuclear (concentrated in Argentina) and non-hydro renewables.
  - **Despite the decline in hydropower's share, many countries and sub-regions are planning to substantially increase the absolute capacity of hydropower over the coming decades,** including Brazil, the Andean Zone, the Southern Cone, and Central America. The aggregate increase in hydroelectric capacity by 2030 would be around 85 GW under the ICEPAC Scenario.
  - **In Mexico, natural gas is estimated to be the most important fuel for new power generation** (51 percent of new capacity), followed by additions of coal (23 percent), hydroelectricity (14 percent), diesel (8 percent), wind (3 percent) and nuclear (1 percent).
  - The high degree of **fuel and generation technology diversity in the Southern Cone would become even more dynamic** over the period, with the region adding sizeable generating capacity for hydro, natural gas, coal, and nuclear (in Argentina).

- ➢ **In Central America, hydroelectricity would be the largest source of new capacity (45 percent)**, while fuel oil, coal, and natural gas would together account for about 45 percent of additional capacity.
- ➢ **In the Caribbean, the generation mix would continue to be largely fossil fuel-dependent**, with gas accounting for 43 percent of the additional capacity and coal 23 percent.

- **The investment in new generation capacity under the ICEPAC Scenario is estimated to be about $430 billion between 2008 and 2030.** Investments by country and sub-region would be: Brazil $182b, the Southern Cone and Mexico $78b each, the Andean Zone $58b, Central America $25b, and the Caribbean $9b.
- **CO_2 emissions from electricity generation in LAC would more than double between 2008 and 2030** as a result of the decline in hydroelectricity and an increase in fossil fuels.

Figure ES3. LAC Electricity Generation by Technology (ICEPAC)



16. **The modeling exercise demonstrates that with modest economic growth, there will be a need for a large expansion of power generating capacity in the region, mainly fueled by hydro and natural gas.** Hydro and gas are the least-cost sources of new power capacity and will contribute to both local and global environmental sustainability. To meet the optimistic goals for hydro and natural gas – that are not explained in the modeling analysis – there is a need to reform the respective regulatory, contracting, and licensing processes in many countries of the Region. There are also a number of other options to help the Region meet its electric power needs that do not feature prominently in most national electricity expansion plans, and thus are not captured in the modeling analysis. These include an expansion of non-hydro renewables, greater regional electricity trade, and enhanced energy efficiency.

IV. Options for Meeting LAC's Growing Electricity Needs

17. Despite the numerous strengths of the modeling exercise, it does not include a number of options that are becoming increasingly attractive to power planners in Latin America. Among these options are: (a) the greater use of non-hydro renewable energy, including wind, geothermal, and biomass, which have been growing in importance globally over the past decade, (b) an increasing role of electricity trade to complement domestic generating capacity, and (c) improved efficiency in both the supply and consumption of electricity. Equally, if not more important, is the need for policies and regulatory reforms that will allow countries to meet their ambitious plans for hydropower and natural gas.

i. Renewable Energy

18. Hydroelectricity is by far the most important renewable energy source for the LAC Region, both historically and over the coming two decades as indicated in the country power expansion plans. As demonstrated in the modeling exercise, even with a dramatic expansion, the share of hydroelectricity in total electricity generation is likely to decline. If LAC is to maintain the current proportion of around 60 percent of renewable electricity in its generation mix, the use of non-hydro renewable energy would need to expand by about 150 TWh by 2030 (with non-hydro renewables going from 2 to 4 percent of total power generation), while still meeting the aggressive targets for hydropower.

19. ***Hydro.*** For the Region to maintain the current high share of hydropower, it is necessary to develop hydropower resources in those countries – Peru, Colombia, and Ecuador – that possess more than half of the hydropower potential outside of Brazil, and which today have developed only 10 percent of their hydroelectric potential. Greater integration among regional power markets could help to justify and attract financing for the development of larger hydropower projects in these countries.

20. ***Other low-carbon options.*** In addition to hydro, there are a number of other promising low-carbon options for electricity production in LAC which could allow the region to maintain its high share of renewables, even under a low hydroelectricity scenario. Under such a scenario, about 480 TWh of new output from non-hydro sources would be required, which could potentially be supplied through a combination of electricity production from wind (220-340 TWh), biomass (55-150 TWh), and geothermal (25-125 TWh). Other renewable power generation technologies were not evaluated in this brief review.[1]

[1] Solar PV can play an important role in providing least-cost electricity access in isolated areas, but the total potential (in TWh) of both off-grid and on-grid PV is not expected to be large by 2030. This excludes the possibility that some countries may choose to support grid-connected or "roof-top" solar PV programs as is popular in several OECD countries (Japan, Germany, U.S.). Solar collectors for the production of hot water could provide a large amount of energy to the region, by substituting residential and commercial hot water that is currently produced from electricity and natural gas. In Mexico, it is estimated that a large-scale program could displace as much as 23 TWh per year (Johnson and others 2010).

ii. Electricity Trade

21. Regional electricity trade could help meet Latin America's electricity needs by making better use of regional energy resources (such as hydropower that typically has scale economies), and by linking a larger set of generators and consumers in a single market. The potential for trade is being facilitated by new interconnections, including between: (i) Mexico and Central America, (ii) Central America (through the SIEPAC system), and (iii) countries of South America.[2] The history of energy trade in the Region provides valuable lessons, both on the benefits as well as the constraints, to greater regional integration of electricity markets.

22. **Electricity trade has a number of potential benefits compared to relying exclusively on domestic generation.** Trade can: (i) enhance the reliability of the local network by linking together a larger number of generation sources and thus increasing the diversity and competitiveness of generation, (ii) have a positive impact on reducing capital investment and generation costs (both operational and capital expenses) due to the economies of scale associated with power generation from large facilities and the reduction in the need for reserve capacity, (iii) lead to an important reduction of recurrent expenses as countries do not need to import costly fuels, (iv) free up capital from domestic electricity capacity expansion programs, and (v) permit the linking of areas with different hydrology or wind regimes, thus increasing the supply of "firm" energy from variable or intermittent energy sources such as hydropower and wind.

23. Based on a quantitative exercise undertaken for Central America, increased trade could increase the share of hydroelectricity from 46 to 54 percent, simply by relying on hydroelectricity plants that could be built in Central America. Tapping increased hydroelectricity from North or South American markets would likely raise the share of hydropower in the sub-region. From the increase in hydroelectricity (from Central America only) and the consequent reduction in thermal power that would be needed, CO_2 emissions were found to fall by 14 percent. There would also be significant savings from trade in domestic investment in the power sector by lowering the need for reserve capacity.

24. **New institutions and regulations are needed to facilitate electricity trade.** Despite the potential benefits of trade, experience shows that countries in LAC have not taken advantage of electricity trade due to a number of reasons, including perceived energy security and national sovereignty issues. Interconnection, such as the SIEPAC system in Central America, is an essential step in the process, but what is also needed is a regulatory framework to facilitate trade between different countries with different regulatory policies and power sector institutions.

[2] (i) Brazil, Paraguay, Argentina, and Uruguay; (ii) Mexico and Central America; and (iii) Colombia, Ecuador, and Venezuela.

iii. Energy Efficiency

25. While there have been no comprehensive studies of energy efficiency potential in LAC – and this study does not attempt to fill that void – there is sufficient evidence to show that there is significant untapped energy efficiency potential in the Region. In addition, based on the energy efficiency and conservation programs that have been implemented in the region, efficiency is one of the least-cost ways of satisfying growing energy demand.

26. **Energy efficiency gains can be achieved on the supply-side by improving the production of electricity and by reducing transmission and distribution losses.** Electricity distribution losses alone in the region in 2005 were equal to the entire electricity consumption of Argentina, Chile, and Colombia combined. Distribution losses vary significantly in the Region, ranging from a low of 6 percent in Chile to a high of above 40 percent in the Dominican Republic, with a LAC average of around 16 percent. If distribution losses could be reduced to the levels of the best performers in the Region over the coming twenty years, annual electricity savings from distribution improvements alone could reduce demand by about 78 TWh (6 percent of the incremental demand of 1,325 TWh) by 2030.

27. **On the demand-side, efficiency can be improved by adopting policies and programs that encourage the efficient consumption of electricity by end-users.** Among the energy efficiency measures that can be expanded in the region are standards for widely-used industrial and residential equipment, building codes, consumer education, and energy management programs within industry, the buildings sector, and public utilities. Electric motors, pumps, fans, and compressors, which are estimated to account for as much as two-thirds of industrial electricity consumption worldwide, can reduce their electricity consumption by around 40 percent through the use of variable-speed drives. The Inter-American Development Bank has estimated that electricity consumption in LAC could be reduced by about 10 percent (143 TWh) over the coming decade through the investment in widely available energy efficiency equipment and technologies, and that these savings could be achieved at about one-third the cost of installing new generation capacity.[3] Other estimates of the potential for demand-side efficiency improvements, based on energy efficiency programs implemented in LAC, range from 18-30 percent of estimated additional electricity demand in the Region by 2030.[4]

28. **Additional incentives – such as electricity tariff and subsidy reform – could improve the efficiency of electricity use.** While industry often has a sufficient direct financial incentive to improve its electricity efficiency – depending in part on the level and structure of electricity tariffs – the market alone often provides inadequate incentives to promote energy efficiency in the residential, buildings, and public sectors. Overcoming information, principal-agent, budgeting and finance, and regulatory constraints through dedicated public energy efficiency programs can help improve efficiency in these sectors.

[3] For reference: $16b for 143 TWh (IDB 2009) = $112m/TWh for energy efficiency; compared to an investment cost of $430b for 1,325 TWh from the supply model in this study, which equals $315m/TWh.

[4] Reference: 18 percent is the estimate for regional potential based on an extrapolation of Argentina's estimates of EE potential in the industrial, residential, and commercial sectors in 2008.

V. Summary and Conclusions

29. **Under modest GDP growth assumptions, the demand for electricity in LAC would more than double by 2030.** Under current expansion plans, the Region would need to add more than 239 GW of new power generating capacity to meet demand. A higher rate of economic growth, and/or a higher demand for electricity, would require even more new capacity. Under any economic scenario, it will be challenging for the Region to meet future electricity demand by relying on current power sector expansion plans.

30. **Under the baseline scenario, the vast majority of the increase in generating capacity between now and 2030 would be met by hydropower (36 percent) and natural gas (35 percent).** The baseline scenario represents a "best-case" scenario, since many of the country expansion plans for hydro and natural gas are already quite optimistic. Under the baseline, an estimated 85 GW of new hydro capacity would be required, compared to only 76 GW that were built in the Region over the past 20 years. In addition, in some countries many of the best sites in terms of construction costs and low environmental and social impacts have already been developed. The relatively long payback periods, high capital costs, and environmental and social risks have reduced private sector involvement in hydroelectric plants, and thus reduced the scale and pace of hydro development.

31. **Natural gas is one of the Region's best alternatives (both economically and environmentally) for new power generating capacity, and under the baseline, gas-fired capacity would grow from 60 GW to more than 144 GW in 2030.** Many countries in the Region have been expanding the use of natural gas for power generation using efficient combined-cycle technology. However, in some countries of the Region low "preferential" prices for natural gas and low electricity tariffs has resulted in the inefficient use of gas, including the use of "open-cycle" gas plants, as well as reduced incentives for producing and distributing gas for power generation.

32. **Alternatives for meeting future electricity needs.** The analysis suggests that meeting the demand for electricity in LAC can be achieved by not only building new generating capacity, but by relying on an increased supply of non-hydro renewables, expanding electricity trade, and making use of supply and demand-side energy efficiency to lower the overall demand for electricity.

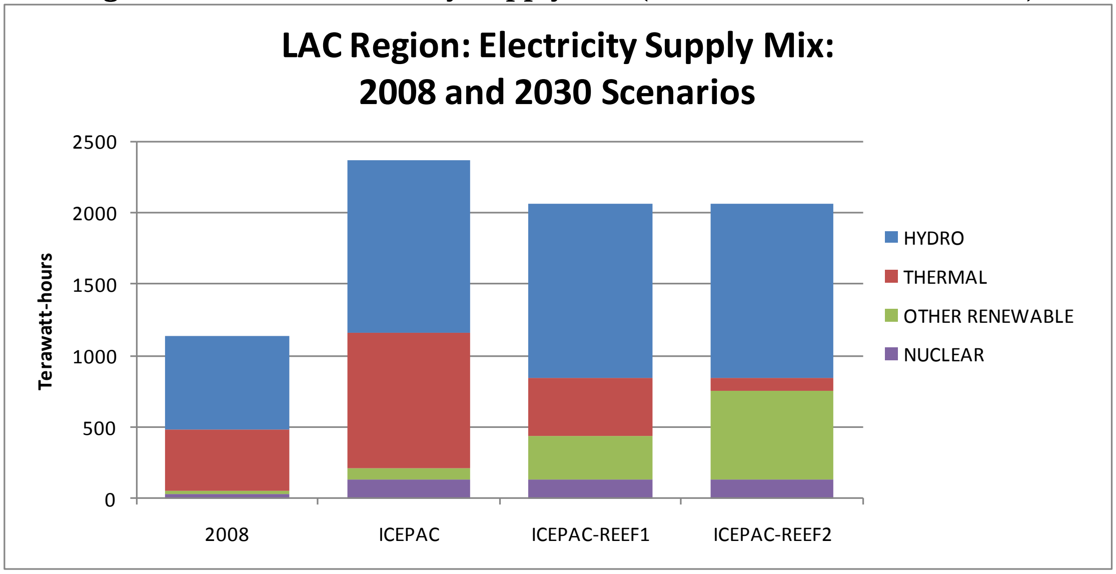
- **Non-hydro renewables.** There is significant potential for expanding the use of non-hydro renewable in the LAC region, ranging from extensive wind resources from Mexico to Argentina, to geothermal resources along the tectonically active Pacific rim and the in the Caribbean, to biomass resources (such as sugarcane bagasse) throughout the Region. These energy resources can help diversify the overall electricity supply mix in LAC, and in many instances non-hydro renewable technologies are becoming cost-competitive with conventional power technologies.

- **Increased electricity trade.** Trade could provide significant new capacity by enlarging the LAC electricity market and lower overall supply costs in the process. Increased trade could also help the Region make use of its hydroelectric and other energy resources by linking energy supplies to a larger market, thus justifying some larger-scale projects and attracting Regional investment.

- **Improved energy efficiency.** Energy efficiency is the most cost-effective way of meeting future energy demand, with significant potential on both the supply and demand sides. Many investments pay for themselves quickly, such as reducing transmission and distribution losses, and tapping the huge amount of cogeneration potential in industry. The potential for improving the efficiency of energy use on the consumption side is even greater, ranging from residential and commercial lighting, broadly used electrical appliances such as refrigerators and air conditioners, to industrial motors and pumps. Recent studies in Mexico and Brazil confirm the extent of the energy efficiency potential that could be tapped at low cost.

33. **The aggregate affect of these alternatives, in terms of lowering the requirements for new generation capacity, much of it thermal, could be large.** The analysis suggests that: (1) an aggressive program to expand non-hydro renewables could provide between 15 and 30 percent of the total electricity supply by 2030, (2) increased trade could lower electricity costs by allowing the development of larger-scale and in some case regional projects, including more renewables, and also reduce investments in reserve capacity, and (3) overall electricity demand in the Region could be lowered by at least 10-15 percent through limited supply-side and demand-side energy efficiency measures at a fraction of the costs of constructing new power generating capacity (Figure ES4).

Figure ES4. LAC Electricity Supply Mix (Various ICEPAC Scenarios)



VI. Recommendations

34. There are a number of recommendations that flow from the conclusions of this report, and which have been identified in other recent energy sector analyses by the World Bank.[5]

35. **Strengthening regulations and market design of hydropower and gas power generation projects.** Hydro and natural gas are indigenous and proven energy resources that can help the Region achieve a supply/demand balance for electricity over the next two decades. To meet the proposed increases in hydroelectric capacity will require significant changes in the way power plants have been financed – requiring a greater role for the public sector in regulating and guaranteeing hydroelectricity construction and a greater role for the private sector in taking on long-term construction and/or operation contracts. There is also a need to improve the management of social and environmental issues, and the licensing and commissioning process will need to be strengthened and stream-lined. To reach the hydroelectric goals for the Region will require reforms in the way that hydroelectric plants are designed, prepared, and financed. Among the most important issues for natural gas development is gas pricing. While low prices of domestic natural gas for power generation have been meant to stimulate gas development, they have resulted in the inefficient use of gas and a lack of incentives for new gas development. To ensure that regional natural gas resources are not wasted, a combination of pricing reforms and technology standards are required.

36. **Supportive policies for renewable energy and energy efficiency.** Effective regulations and institutions are needed to provide incentives to both the public and private sectors to invest in and develop renewable energy technologies and promote energy efficiency measures. A number of countries in LAC have put in place new renewable energy laws and regulations, including tax credits, long-term purchasing contracts, and dispatch priorities for renewable. What are also needed are payments that reflect marginal costs for the system, plus capacity payments, and payments to reflect the environmental benefits (both local and global) that renewable energy sources typically bring. Supportive policies for energy efficiency include standards for efficient plants and energy-consuming equipment, the establishment of utility and other programs for promoting and disseminating energy efficient measures, and electricity tariffs that provide incentives for end-users to acquire and use energy-efficient equipment and processes.

37. **Domestic energy planning.** There is a need to expand and strengthen power sector planning in the Region. While most countries carry out power sector planning, several have not yet developed electricity-specific demand and supply growth scenarios. In several country cases, the time horizon for planning is too short (12 years or less), or the plans are not updated frequently. Given the long-term nature of power sector investments, governments should engage in longer-horizon planning. Consultation with constituencies about medium- to long-term power sector development should be undertaken, be realistic, and include a diverse range of supply and demand-management options.

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[5] Among the recent reports by the Bank that address key policy and institutional issues of the power sector in Latin America are: Low-Carbon Development for Mexico, 2010; Brazil Low-Carbon Study; Peru Gas Study, Peru Hydro Study, Central America Power Sector Series, Electricity Auctions (forthcoming).

38. **Regional power sector tools.** In undertaking this study, it became clear that there is a lack of tools for regional power sector analysis. There is thus a need for robust and user-friendly regional power planning tools that can be used and discussed by individual countries, regional and international organizations, and the private sector. In addition to optimizing electricity generation decisions for specific countries, a key aspect of a regional planning tool would also be the ability to optimize across larger geographic regions. Furthermore, additional research is required to include demand price sensitivity, as well as testing the robustness of supply models with additional scenarios that do not limit the range of generation technologies or other measures (such as trade and efficiency) for meeting energy demand.

39. **Reliable inventory information.** One of the requirements for electricity development, especially for renewable energy resources, is improved information on the size, quality, and location of energy resources. Publically-supported inventories of wind and geothermal resources, for example, can help to reduce production risks and accelerate development of wind and geothermal resources.

CHAPTER I. INTRODUCTION

40. In the Latin America and Caribbean (LAC) Region, economic and social development over the past forty years has been supported by a widespread and largely successful program of electrification. That effort has greatly increased the provision of electricity services to households, commerce, and industry and led to electricity access rates[6] that are among the highest in the developing world. Over the coming decades, the supply of electric power will need to expand to meet the growing demand for electricity, but how the production and use of electricity develops – in terms of the amount of new capacity, the technology mix, the source and type of fuel, the structure of demand, and the efficiency of consumption – will have broad economic, social, and environmental implications for LAC and the world.

41. There are a number of critical issues that will affect the expansion of the power sector in LAC, and that in turn will have implications for that expansion. Among these are the rate of economic growth, the energy resources available in the region or through trade, the types of power technologies that are adopted, and the cost of power sector investments and the sources of financing. Government policies will also affect power sector expansion, including distributional policies related to electricity access, energy pricing and other policies affecting both demand and supply decisions, and environmental policies at both the national and international levels that will affect the technology and fuel mix of new generating capacity and affect the consumption decisions of households, government, and industry.

42. The objective of this study is to provide an assessment of some of the key electricity challenges that the LAC Region will face in the coming decades to meet its development, security, efficiency, and environmental goals. The two focal areas of the study are: (1) evaluating the trends in the power supply mix and the implications of the generation mix on investments and environmental outcomes, and (2) exploring the options that the Region has for making greater use of renewable and low-carbon energy resources, tapping the potential benefits of increased electricity trade, and mitigating the need for new capacity additions through energy efficiency improvements.

I. Electricity and Development

43. A sufficient supply of affordable and reliable electricity is a core precondition for the Region's economic growth as well as for an improved quality of life of its poorest inhabitants. Industrial and commercial activity and the development of modern cities require electricity to power a broad range of end-uses such as pumps and motors, HVAC (heating, ventilation, and air conditioning), municipal lighting, elevators, metro systems, and traffic signals. As a macroeconomic variable, electricity consumption is universally highly correlated with national income. While the causality works in both directions – that is, electricity determines GDP and

[6] The electricity access rate refers to the percentage of the population, sometimes measured as the percentage of households, that have "access" to electricity, either through a centralized electricity grid or through stand-alone household or community systems.

GDP determines electricity consumption – there is little doubt that electricity is a critical enabling factor for economic development.

44. Electricity and other modern forms of energy are also critical elements for improving the welfare of low-income groups, and for allowing rural areas to develop economically in the broader sense, including providing opportunities for financial livelihoods, improving human health, and raising education levels. In addition to clean water, the provision of electricity is perhaps the most important way to reduce rural poverty and why rural electrification programs are often high on a country's national rural development agenda.

45. The social and economic benefits of providing electricity to households have been studied for more than three decades. One of first and universal uses of electricity by households is for lighting, which allows activities (such as reading, studying, or household chores) to continue into the evening (Barnes and others 2003). Other household uses of electricity include for consumption purposes (radio, television, cell phone charging) and productive uses (sewing machines, small appliances, shop lighting), which can have important economic, social, and cultural benefits (World Bank 2004b). Women and children are usually the prime beneficiaries of electrification. A study in India found that women from homes with electricity were better able to manage paid work, household chores, and leisure time than women from homes without electricity (World Bank 2004a). Over the long term, there is evidence of a positive relationship between electricity consumption and household income. Providing electricity to households can thus be seen as an overall positive investment for the economy.

II. LAC's Electricity Challenge

46. Despite the pressing need for reliable and affordable electricity, the power sector is characterized by a long-term planning and investment horizon, which is complicated by a number of risks and uncertainties. Among these are fluctuations in long-term demand, the multiple sources of fuel and technologies for power generation, high and volatile prices of fossil fuels, the political risks of relying on bi-lateral trade in fuels or electricity, and environmental and social impacts associated with the production, transmission, and distribution of electricity. One certainty is that as countries in the region become more prosperous, the demand for electricity will increase and the challenges faced by the region's economies to meet their energy requirements will intensify.

47. Among the electricity challenges that LAC (and other regions of the world) confront are:

- ***Economic Growth and Access***: the need to provide for a multiple of current electricity supply over the coming 20 years to support increases in income and to provide electricity access to un-electrified households and communities;
- ***Energy Security***: the increasing risk of electricity supply disruptions and price shocks as a result of the growing dependence on imported fossil fuels, and the constraints faced in tapping national and regional renewable (like hydroelectricity and wind) and low-carbon (like natural gas) energy resources;
- ***Economic Efficiency***: the need to limit the cost of providing new electricity by promoting competitive contracts and financing by the private sector, improve the

efficiency of supply, and avoid new construction when and where demand-side efficiency is least-cost; and

- ***Environmental Sustainability***: the desire to incorporate environmental goals, both local and global, into power sector planning, policymaking, and investment.
- ***Conducive Regulatory Framework:*** the need to put in place policies and regulations to allow the power sector to meet increasing demand, address growing environmental concerns, and attract private capital to reduce the financial burden on government budgets.

48. Countries seek practical and feasible strategies to meet the increasing demands for power. Currently, a number of countries in the Region are experiencing inadequate supply which has been one of the factors behind recent unplanned power outages. Demand has been increasing over the past decade at a rate of 5 percent per year on average, and while the recent financial turmoil is anticipated to result in lower levels of growth in the near term (and demand projections are being adjusted downwards), over the medium to longer term, demand is anticipated to rebound, which will require additional investment. Regardless of the ultimate growth in electricity demand, putting in place rational short- and medium-term pricing structures and demand-side efficiency measures can help improve the ability to supply electricity.

49. In meeting future electricity demand, policymakers need to consider how, when, and through what means they plan to scale up capital investment in the electricity sector. As mentioned above, the electricity supply and demand balance is tenuous in some countries of the Region, both in the short and the longer term. In today's environment of lower reserve margins, an underestimation of electricity demand or under-investment in power supply can lead to brownouts or blackouts. Short-term imbalances can result from unanticipated demand (like a hot summer or cold winter) or supply disruptions (like drought), and are exacerbated by low reserve margins. Long-term investment decisions affect not only reserve margins, but also the security of supply, depending for example, on the type and price volatility of the fuel.

50. It is important to identify trends in the Region's electricity markets. An analysis of electricity demand and supply is an important input for decision-making, allowing policymakers to explore the impact of different assumptions on future investments, such as the rate of growth of the economy, generation fuel prices, and environmental constraints. Electricity sector planning and policy-making in LAC will thus require an analysis of: (i) the future supply of power generation, including an identification of sector investment needs; (ii) the mix of technologies from the perspective of cost, environmental impact, and diversification among other factors; and (iii) the opportunities for efficiency gains, notably in generation, distribution, and consumption. Such an analysis also allows policymakers to consider the effect of different policies on electricity demand and supply, such as tariffs and energy pricing, trade policies, efficiency norms and standards, and environmental regulations.

51. Like other large-scale infrastructure investments, power sector planning requires a long-term perspective. Even if future electricity demand could be well-anticipated, it takes many years to plan and build new power generating capacity, transmission lines, and distribution networks. As such, a modeling framework of at least 20 years is needed to see the impacts of changes in the

supply mix and to allow policymakers and power sector planners time to adjust their long-term expansion plans.

52. While already relatively "clean" in terms of its electricity generation mix, countries in the LAC Region need to examine the effect of their long-term power expansion plans on CO_2 emissions. Even if it is assumed that the majority of countries in the Region will not have binding CO_2 emission reduction targets anytime in the near future, the carbon intensity of the power sector is important for a number of reasons. Knowing the trends in carbon-intensity and the options for reducing them will be important for setting a country's "baseline emissions" trajectory, which will inevitably be "negotiated" with bilateral countries (such as Europe, Japan, or other countries with climate change mitigation legislation) in order to sell carbon offsets or with the international community (such as under the Kyoto Protocol's Clean Development Mechanism or a subsequent system) for emission reduction credits. Understanding the trend in the power sector is also important for those countries (such as Mexico) that have made voluntary commitments to reduce their emissions. There are likely to be other incentive programs (such as the GEF, the Clean Investment Funds, and new mechanisms under the UNFCCC) for countries that promote low-carbon development of their power sectors.

III. Scope of the Study and Methodology

53. In light of the electricity challenges outlined above, this study focuses on two main issues that have major implications for planning and investment in the electric power sector: (1) the future supply and demand for electricity in LAC, and (2) "new" options for meeting future electricity demand in light of international technology, market, and regulatory trends.

54. The first focal area of the study is an analysis of future electricity demand and supply. Making use of the most complete regional data compiled by the regional electricity organization, OLADE,[7] and constructing a modeling framework, the study evaluates potential future trends in electricity supply and demand in LAC through the year 2030. Signifying that the estimates are not "forecasts" or "predictions," the study uses the term "scenario" to reflect what would happen if certain policies and trends are pursued. In the case of electricity demand, a conservative estimate of economic growth has been used. In the case of electricity supply, the scenario developed is meant to reflect what would happen if countries continue along the path of their current long-run power expansion plans.

55. While many countries in the Region have done detailed analyses of their own electricity demand and supply situations, they are less familiar with what other countries are doing and even less aware of how individual country contribute to Regional demand and supply. One of the contributions of this study is thus the aggregation of individual country plans to the Regional and Sub-Regional level using a consistent set of data and a common methodology.

[7] OLADE is the regional organization for Latin America and the Caribbean by which its Member States undertake common efforts to achieve integration and development of the energy market. As part of its coordinating and planning activities OLADE developed a statistical data base in the energy sector which includes information from Member Countries on electricity and other energy sector historical series since 1970.

56. Through the demand and supply scenario exercise, it is possible to view the implications for the role of different generation technologies and fuels in the electricity supply mix, estimate the level of investment that would be required, and view the changing "carbon intensity" of the power sector in the Region. Sensitivity analysis on the effect of a carbon tax ($20 and $50/ton of CO_2) on fossil fuel generating capacity is also undertaken.

57. The supply analysis makes use of the individual country expansion plans for the short- and medium-term that are available from national energy planning agencies. Country estimates are aggregated and presented in terms of six sub-regions: Mexico; Central America; the Caribbean; Andean Countries (Bolivia, Colombia, Ecuador, Peru, and Venezuela); the Southern Cone (Argentina, Chile, Paraguay, and Uruguay); and Brazil.

58. The scenario analysis in Chapter III applies an approach developed in partnership with OLADE. The study team estimated electricity demand using a simple regression model, with electricity demand becoming an input to OLADE's SUPER model (*Sistema Unificado de Planificación Energética Regional*). The SUPER model allows an evaluation of a diverse array of alternatives for expanding electricity generation in Latin America (details of the model are provided in Chapter III and in annexes).

59. A second focal area of the study is on the range of "new" or additional options for meeting electricity demand that are not explicitly or consistently considered within the national power sector plans of individual countries. The options discussed were selected based on international trends in power sector technology and market development, and on environmental policies and regulations, most importantly, those related to climate change. The options evaluated include the potential for expanding non-hydro renewable sources of electricity generation, increased regional trade in electricity, and greater energy efficiency in both the supply and demand of electricity.

60. The information on renewable energy, trade, and energy efficiency was provided through specific assessments commissioned for the study, drawing on expert opinion and analysis and making use of the World Bank's work in these topics, both regionally and globally. Like the modeling exercise, the options analysis presented in Chapter IV uses a timeframe of 2030 in order to allow a comparison with the potential contributions from non-hydro renewable energy, regional electricity trade, and energy efficiency.

IV. Structure and Content of the Report

61. The report is organized as follows. Chapter II provides the historical context of the electric power sector in LAC by presenting past trends in the electricity sector, and also providing global comparisons. The chapter examines historical trends in the production of electricity, by country and sub-regions, as well as the changes in the generation mix. The chapter also looks briefly at the trends in regional trade in electricity as well as the organization and regulation of the power sector in LAC. Given the recent international financial crisis, the chapter briefly discusses how this has affected the power sector in the short term and the implications for the future.

62. Chapter III presents the results of the electricity modeling exercise that was conducted to the year 2030. The methodology, major assumptions, and strengths and weaknesses of the demand function and supply model are discussed, with further details about the models included in annexes. The chapter highlights the focus of the modeling analysis on the supply-side, and describes how the methodology reflects the current country expansion plans of the individual countries in the Region. The chapter then presents the results of the electricity scenario analysis, identifying regional and sub-regional patterns and discussing some of the key challenges posed by the results. The analysis identifies the amount of new power production capacity that would be needed under the baseline scenario, how the expansion would affect the generation mix, and concludes with the implications for the carbon-intensity of the power sector in the Region.

63. In light of the challenges posed by the modeling results from Chapter III, Chapter IV discusses other options for meeting LAC's growing electricity needs that were not well addressed in modeling exercise. Chapter IV attempts to compensate for some of the inherent deficiencies of current planning in the Region by explicitly examining a number of important options for meeting future electricity demand. Part one presents an analysis of the region's renewable energy potential, both hydro and non-hydro alternatives, and discusses how that potential compares to the planned investments included in individual country expansion plans. Part two examines the benefits and implications of regional electricity trade, efforts to promote cross-border integration, and discusses the range of obstacles to greater cross-border initiatives in the Region. Part three examines the role of supply-side and demand-side energy efficiency options, including estimates of the magnitude of potential efficiency gains.

64. Chapter V briefly discusses the overall conclusions of the study, including a comparative summary of the scenario assessment presented in Chapter III and the options analysis presented in Chapter IV. The chapter concludes with a set of recommendations related to energy policies, power sector regulations and institutions, and the benefits and requirements of doing better long-term power sector planning.

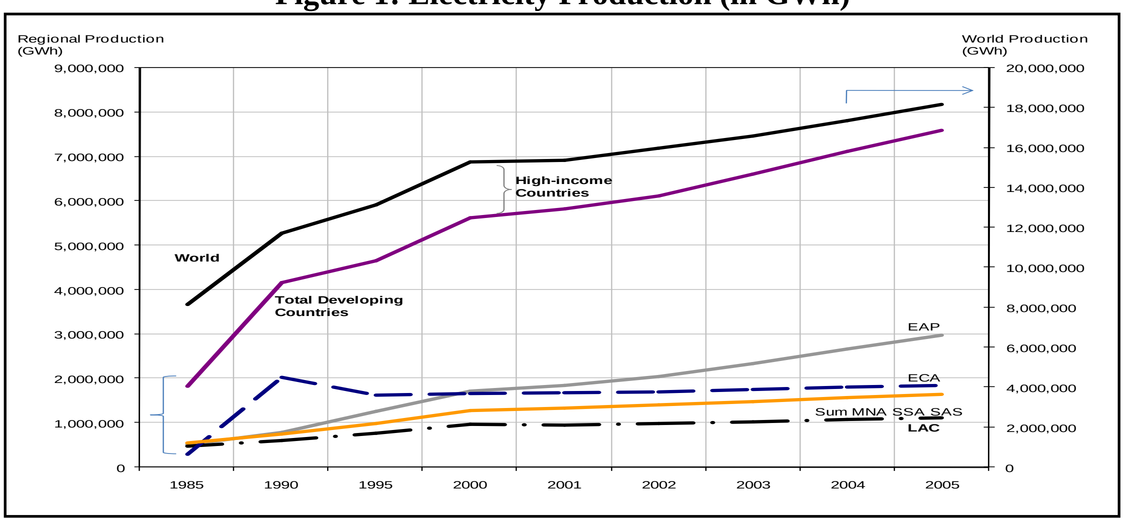
CHAPTER II. HISTORICAL TRENDS IN THE ELECTRICITY SECTOR

65. Before considering where the Region's electricity sector is going, it is important to know where it has been. This chapter examines the development of the electric power sector in Latin America and the Caribbean since the 1970s, looking at the growth in production by countries and sub-regions, the changing mix of generation technologies, and the role that electricity trade has played in meeting electricity needs. The chapter also looks at the governance and regulatory structure for the power sector in different countries, which has implications for sector development, both past and future. Lastly, the chapter discusses the impact that the global financial crisis, beginning in 2007-2008, has had on both power demand and supply. Prior to examining the history of the power sector in LAC, it is useful to place the Region in an international context.

I. LAC in a Global Context

66. Worldwide electricity production increased fourfold from 1970 to 2005, implying an average annual growth rate of 4.3 percent. In LAC, electricity production increased at a faster rate, growing by 5.9 percent over the same time period. The growth rate over the period was not even, however. During the 1970s, electricity production grew at an average rate of 8.7 percent per year. The growth in electricity production peaked in 1978-1979, and in the following two decades (1980s and 1990s) electricity production grew by 5.4 percent and 4.3 percent, respectively. In 2001, there was an absolute decline in electricity production, the only year over the past forty in which production in the Region was negative.

Figure 1: Electricity Production (in GWh)



Source: Own elaboration based on the World Development Indicators, 2009.

67. Figure 1 shows the global development of electricity production over the past 20 years. North America (NA) has been the largest electricity producer since the mid-1980s. While Europe and Central Asia (ECA) followed directly behind NA until the late 1990s, East Asia and the Pacific (EAP), led by China, became the second largest producer in 2000. EAP has historically had higher annual growth rates than other regions, driving the overall growth in the developing world's electricity production as shown in Figure 1. However, LAC too, has remained an important producer, ahead of South Asia (SA), the Middle East and North Africa (MENA), and Sub-Saharan Africa (SSA).

68. The differences in regional electricity production trends are largely explained by differences in GDP growth rates. As seen in Table 1, the region with the fastest economic growth between 1971 and 2004 was East Asia and the Pacific, where GDP grew by an average of 6 percent per year. The second fastest growth in GDP was experienced by South Asia, where the average annual economic growth rate was 4.7 percent. The difference between GDP growth rates between LAC and EAP was not large in the 1970s, however, the debt crisis in LAC during the 1980s led to what is now known as the "lost decade"— growth in EAP has continued at a high and sustained rate.

Table 1. Electricity Production and GDP (Average Annual Growth Rates)

Electricity Production	1971-1980	1981-1990	1991-2000	2001-2004
World	4.8%	5.6%	2.5%	4.2%
Latin America and Caribbean	8.7%	5.4%	4.3%	4.0%
East Asia & Pacific	8.3%	8.2%	8.0%	12.7%
Middle East and North Africa	12.2%	8.1%	6.5%	7.1%
South Asia	7.2%	9.3%	6.3%	5.0%
Sub-Saharan Africa	7.8%	4.0%	2.5%	4.4%
Norrth America	4.0%	2.9%	1.7%	2.6%
GDP	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2004**
World	3.8%	3.1%	2.8%	3.1%
Latin America and Caribbean	5.7%	1.2%	3.3%	3.4%
East Asia & Pacific	6.6%	7.6%	8.4%	8.9%
Middle East and North Africa	5.1%	2.8%	3.9%	4.5%
South Asia	3.0%	5.4%	5.2%	7.2%
Sub-Saharan Africa	3.7%	1.9%	2.3%	4.9%
Norrth America	3.7%	3.1%	3.1%	2.5%

Source: Own elaboration based on the World Development Indicators, 2009

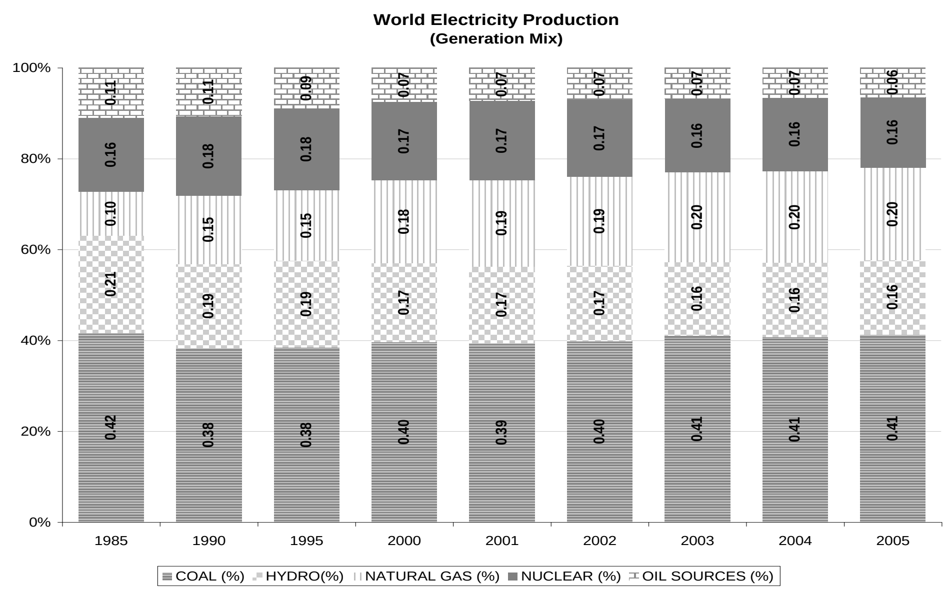
69. The electricity generation mix across the world's regions has varied over time. The different electricity production fuel sources considered for this analysis, based on the World Development Indicators (WDI) database, are: (i) coal; (ii) hydro; (iii) natural gas; (iv) nuclear; and (v) oil.

70. Natural gas has become increasingly important for electricity production globally (and in LAC) over the last 20 years, gaining ground at the expense of oil and hydroelectric sources. As can be seen from Figure 2, the share of electricity produced from oil in the world's generation

mix declined from 11 percent in 1985 to only 6 percent in 2005. Hydroelectricity experienced a similar decline worldwide, falling from 21 percent to 16 percent. By comparison, the share of electricity from hydroelectricity in LAC remains above 58 percent.

71. Coal has remained the world's primary fuel for electricity generation and its share has not changed significantly since 1985. A similar trend can be observed in the case of electricity production from nuclear sources: its share ranged between 16 and 18 percent of total electricity production between 1985 and 2005. Coal plays a dominant role in the generation matrices of a number of regions (EAP, SA, SSA, and NA), where electricity production from coal has represented more than 50 percent of total production. Considering that a number of industrialized countries from EAP and ECA are excluded from the data, coal is also an important source of electricity generation in other countries and regions. For example, in Australia and Japan – which represented 73 percent of electricity production from high-income countries in EAP in 2005 – coal accounted for 80 and 23 percent of power generation,[8] respectively. Compared to the global average (41 percent in 2005), the share of electricity production from coal is quite small in LAC and has never exceeded 5.6 percent.

Figure 2. World Generation Mix



Source: Own elaboration based on the World Development Indicators, 2009.

II. Energy Access in LAC

72. The LAC Region has relatively high electricity access rates compared to other parts of the world. In comparison with Africa's average electricity access rate of 40 percent and the world average of 78 percent, LAC's electricity access rate reached nearly of 93 percent in 2008 (Table 2).

[8] Furthermore, Germany and the United Kingdom use 50 and 35 percent, respectively, of coal in their generation mixes. Similarly, half of the United States electricity production is coal-based.

73. Although electricity access rates for the region as a whole are high, there are large inequalities both within and between countries. For instance, while nearly 98 percent of Brazil's population has access to electricity; the access rate in Haiti is only 38 percent.[9] Within countries with high overall access rates, the disparity between the urban and rural access rates is startling in some cases. For example, in Peru, which has an overall national electrification rate of 77 percent, the figure for urban areas is 96 percent while the electricity access rates in rural areas is only 28 percent. Large disparities can also be seen in the rural and urban electrification rates in Bolivia, Nicaragua, Haiti, Honduras, and Argentina.

Table 2. Latin America Electricity Access Rates (2008)[10]

Country	Total (%)	Urban (%)	Rural (%)	Without Electricity (Mill)
Argentina	97	100	70	1.1
Bolivia	78	98	38	2.2
Brazil	98	100	88	4.3
Chile	99	99	95	0.3
Colombia	94	100	76	3.0
Costa Rica	99	100	98	0.0
Dominican Republic	96	98	90	0.4
Ecuador	92	100	78	1.1
El Salvador	86	97	70	0.9
Guatemala	81	94	68	2.7
Haiti	39	69	12	6.0
Honduras	70	98	45	2.1
Jamaica	92	100	83	0.2
Nicaragua	72	95	42	1.6
Panama	88	94	72	0.4
Paraguay	95	99	88	0.3
Peru	77	96	28	6.5
Trinidad and Tobago	99	100	99	0.0
Uruguay	99	100	86	0.0
Venezuela	99	100	85	0.3
Latin America	**93**	**99**	**70**	**34.1**
Africa	**40**	**67**	**23**	**589.0**
World	**78**	**93**	**63**	**1456.0**

[9] Brazil has expanded access to electricity in rural areas through a program known as Luz Para Todos. Begun in 2003, the program is a partnership between the federal government, state agencies, and distribution companies.

[10] There are differences in estimates of electricity access rates among different database sources. We used the World Energy Outlook Database to ensure consistency in the methodology in order to compare countries in the LAC region with the rest of the world.

III. Electricity Capacity and Production Trends in LAC

74. The installed electricity generation capacity in the region has increased from 93 GW in 1980 to approximately 295 GW in 2008. According to OLADE (2009), 53 percent of total electricity generation capacity was hydroelectric, while 44 percent was thermal (coal, natural gas, and petroleum). Nuclear and other types of generating plants accounted only for about 3 percent. By country, the largest producers of electricity in the Region were Brazil and Mexico, accounting for almost 56 percent of the total amount of electricity generated in 2008.[11]

75. The analysis of electricity production trends within LAC distinguishes between the following sub-regions: (i) Brazil; (ii) Mexico; (iii) Central America: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama; (iv) the Caribbean: Barbados, Grenada, Guyana, Haiti, Jamaica, the Dominican Republic, and Trinidad and Tobago; (v) Southern Cone: Argentina, Chile, Paraguay, and Uruguay; and vi) the Andean Zone: Bolivia, Colombia, Ecuador, Peru, and Venezuela. Within these sub-regions, there are seven countries, namely Brazil, Mexico, Argentina, Venezuela, Colombia, Paraguay, and Chile, that together accounted for about 89 percent of the region's overall electricity production (Figure 3).

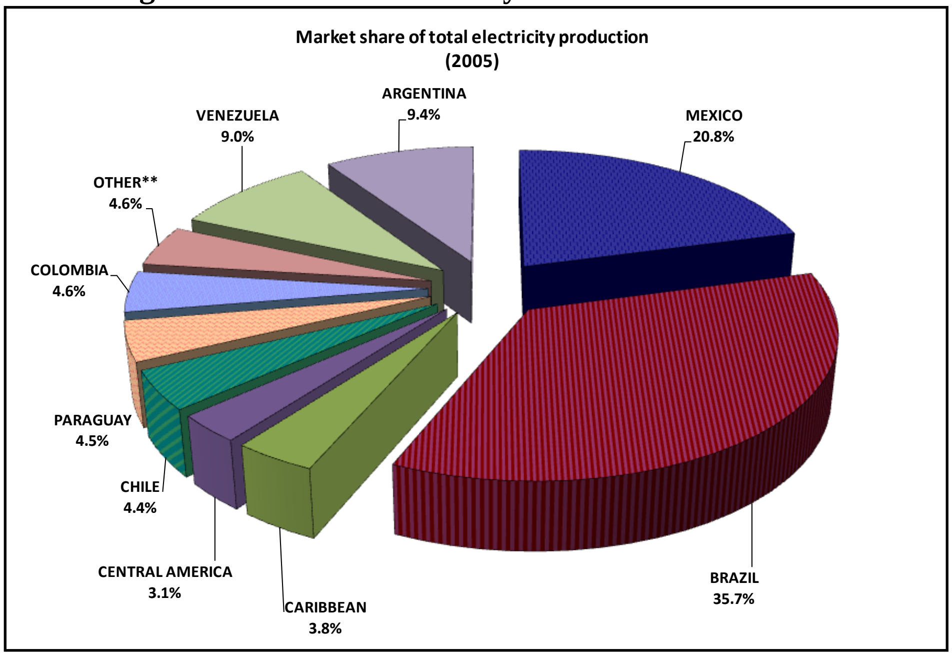
Table 3. LAC's Electricity Production (by source)

Year	1985	1990	1995	2000	2001	2002	2003
Total	**470,745**	**592,069**	**749,144**	**946,245**	**934,984**	**961,399**	**1,001,067**
Coal	14,628	22,968	31,947	45,405	46,263	48,473	56,340
Hydro	311,146	386,434	491,278	584,508	544,483	566,472	585,252
Nat Gas	41,590	55,663	77,277	127,866	146,356	163,800	185,747
Nuclear	9,147	12,455	18,028	20,444	30,064	29,404	31,426
Oil	94,234	114,549	130,614	168,022	167,818	153,250	142,302

Source: Own elaboration based on the World Development Indicators, 2009.

[11] Electricity generation capacity refers to the total installed capacity capable of generating electricity. It differs from electricity generation which refers to the actual electricity production in a given period of time. There is often a significant difference between a country's installed capacity and power generation from a specific source, depending on resource availability (such as water flow), maintenance, and other variables affecting the "plant factor."

Figure 3. Shares of Electricity Production in LAC

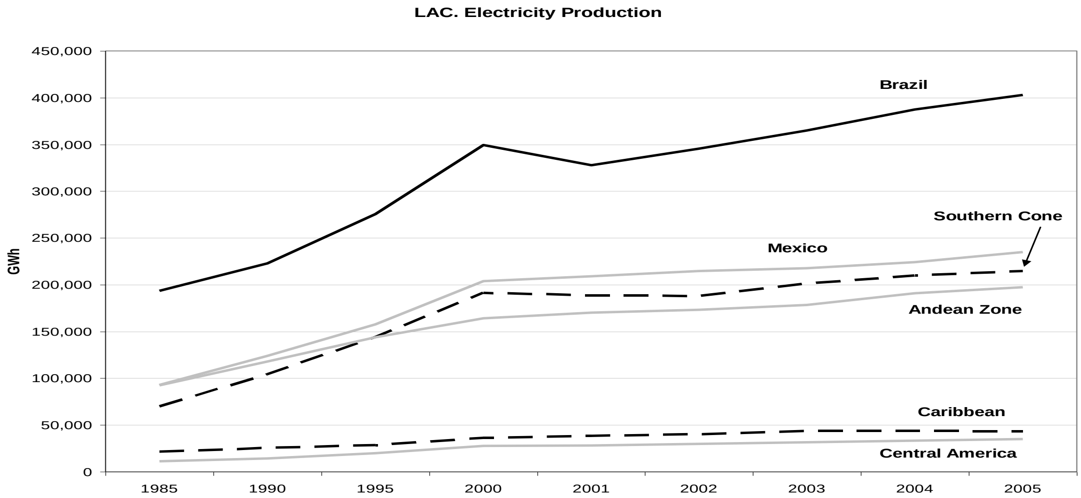


Source: Own elaboration based on the World Development Indicators, 2009.

76. With over one-third of the share of total production, Brazil can greatly affect regional generation mix statistics. Specifically, Brazil's reliance on hydroelectricity directly contributes to the high proportion of hydroelectricity in the Region, which in turn has made LAC the region with the highest share of renewable energy in the world (Figure 4). Conversely, as the share of electricity contributed by hydroelectricity has fallen in Brazil, this has raised the carbon-intensity of LAC's electricity production. Following Brazil, Mexico is the second largest electricity producer in the region, with almost 21 percent of total production in 2005. If Bolivia, Colombia, Ecuador, Peru, and Venezuela are treated as a regional cluster –the Andean Zone - their combined electricity production closely follows the pattern displayed by Mexico and the Southern Cone.[12] The visible change in slope that occurs after 2000 is due to the change in the time scale used in the chart.[13] There was a slight decline in the region's electricity production between 2000 and 2001, primarily due to a drought and other supply problems in Brazil, where hydroelectric production decreased from 349 to 328 TWh.[14]

[12] Countries grouped as Southern Cone in this analysis are: Argentina, Chile, Paraguay, and Uruguay.
[13] From 1985 until 2000, the scale in the chart is for 5 year periods, after 2000 the scale is annual.
[14] Between June 2001 and February 2002, Brazil was forced to ration electricity, but there were no forced outages. The rationing program was quite successful in reducing demand, achieving nearly a 20 percent reduction in consumption in a very short time period. The experience demonstrates that consumers can react to price and other signals. Over the longer term, permanent improvements in efficiency were only about one-quarter of the temporary reduction in consumption that was achieved.

Figure 4. Electricity Production over Time by Sub-Region



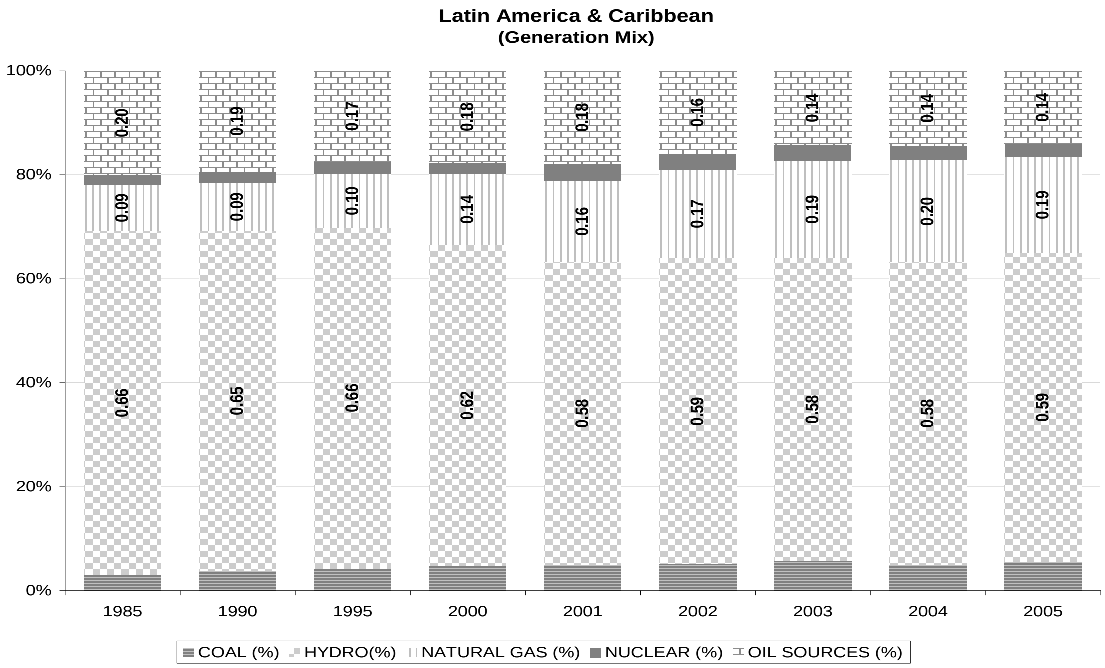
Source: Own elaboration based on World Development Indicators, 2009.

IV. The Regional Generation Mix

77. The generation mix – that is, the share of electricity production from different power technologies and fuels – has evolved in LAC over the past twenty-five years (Figure 5). The major changes in the overall generation mix have been a decline in the contribution of oil (fuel oil and diesel), a decline in the share of hydroelectricity (but with hydroelectricity remaining the most important source of electricity), and an increase in the share of natural gas. The share of electricity production from nuclear and coal has historically been very low in LAC and has remained relatively steady since 1985.

78. The increasing relevance of natural gas as a source for LAC's electricity production occurred simultaneously with an overall shift away from hydroelectric and oil sources (diesel and fuel oil), which decreased their shares of electricity production from 66 to 59 percent and 20 to 14 percent, respectively. As shown in Figure 5, the share of natural gas increased from 9 percent in 1985 to 14 percent in 2000, reaching 19 percent in 2005.

Figure 5. Generation Mix: Latin America and Caribbean

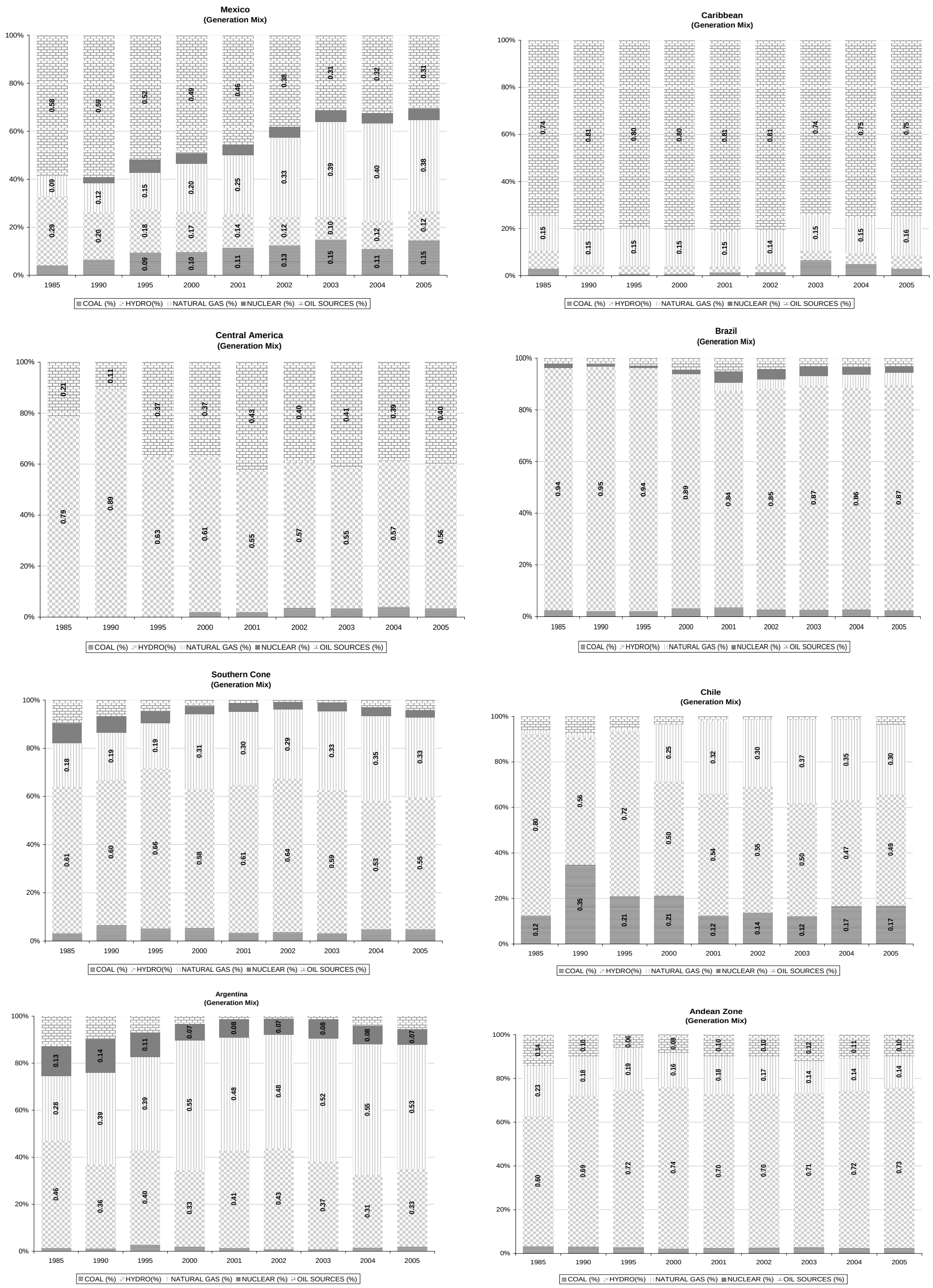


Source: Own elaboration based on the World Development Indicators, 2009.

79. The decline in the role of oil for power generation in LAC is reflected quite strikingly in the case of Mexico. As shown in Figure 6, in 1985 electricity production from oil sources accounted for 58 percent of Mexico's total production. By 2000, with the rapid increase in new combined-cycle natural gas plants and the concerted effort by the national utility CFE to close fuel-oil based generating plants, the share of oil had declined to 47 percent, and by 2005, oil accounted for only 31 percent of electricity production in Mexico.

80. Mexico's relative share of coal-based generation has been comparatively more volatile in the last few years. Total electricity production between 2002 and 2005 increased steadily, reflecting infrastructure investments made towards the end of the six-year federal political cycle. Of the total production, the share of coal-fired electricity experienced major shifts during these four years. Similarly, the trend in the share of natural gas-based production was uneven, first increasing abruptly (by 14 TWh) from 2002 to 2003, then slowing to a lower pace (5 TWh) from 2003 to 2004, and, finally, decreasing by 2.3 TWh in 2005.

Figure 6. Generation Mix in 2009 by Sub-Region (Based on World Bank WDIs)



81. In the Caribbean region, where oil sources play a key role in the overall generation mix,[15] there has been relative stability in the use of oil vis-à-vis other fuels for power generation. As shown in Figure 6, the share of oil sources in the electricity production fuel mix has ranged

[15] While power generation in Caribbean countries is dominated by oil, countries in the sub-region that have the highest percentage contribution from hydroelectric sources are the Dominican Republic and Haiti.

between 74 and 81 percent since 1985. In Central America, electricity has historically been produced mainly from oil and hydroelectric sources (Figure 6). However, since 2000, when coal was introduced in the sub-region's generation mix, production from oil and hydroelectric sources has experienced a slight decline in relative terms.

82. From 1985 to 1990 the share of hydropower generation in Central America increased from 79 to 89 percent. Between 1990 and 1995, hydro's share dropped from 89 percent to 63 percent, with a corresponding increase in power generated from oil products, and the introduction of a small amount of coal-fired capacity. The drastic changes observed in Central America's energy matrix from 1985 to 1990 and from 1990 to 1995 were mainly driven by changes in Guatemala. Production from hydroelectric sources in Guatemala increased more than three times between 1985 and 1990, but had dropped by 5 percent by 1995.

83. The increasing influence of natural gas as a source of electricity production in LAC is largely the result of the evolution of the generation mix in the Southern Cone, Brazil and Mexico. The Southern Cone has followed a similar general pattern to that of Mexico. Although starting with a higher share of natural gas in its generation mix relative to Mexico (18 percent compared to Mexico's 9 percent in 1985), by 2005 the Southern Cone had converged with Mexico in terms of the relative importance of natural gas-based generation - 33 percent (Figure 6). The increase in the overall use of natural gas in the Southern Cone can be explained by developments in two countries, namely Argentina and Chile, with the former showing an annual increase of 1.14 percent during 2000-2005 and the latter a 1.48 percent annual increase. While natural gas has become an increasingly important source of electricity generation in both countries, the role of hydro- and coal-based production has declined.

84. Chile's generation mix, in particular, has changed considerably since 1999. There has been a rapid expansion of natural gas relative to other sources and a steep decline in the share of coal-based production, particularly from 2000 to 2001, when it dropped by nearly 10 percent. Unlike in Brazil, the declining role of hydroelectric production in Chile was not caused by climatic conditions. Instead, it can be attributed to the considerable increase in investment in natural gas-based generation facilities, compounded by the lack of investment in hydropower.

85. In the case of Brazil, while the generation mix has remained comparatively homogeneous with the bulk of the country's electricity generated at hydroelectric plants, natural gas has become more significant since 2000 (see Figure 6). In particular, the most notable transition in terms of Brazil's generation mix occurred from 2000 to 2001, when production from hydroelectric sources dropped by 12 percent in absolute terms due to a severe drought, while production from natural gas (and nuclear) more than doubled.

86. The absolute levels of production from coal sources during these years remained almost unchanged. The production of electricity from nuclear has been comparatively insignificant in the region's generation mix through the years, not accounting for more than 3.2 percent since 1985. The only countries with nuclear plants have been Mexico, Brazil and Argentina. In Argentina, nuclear energy, while far behind hydroelectric energy and natural gas in its relative importance, has nevertheless been an important generation source, representing 7 to 8 percent of the total generation mix since 2000.

V. Regional Electricity Trade

87. Cross-border electricity trade and integration is a cross-cutting issue and has been particularly important for some countries and sub-regions. A total of about 56 TWh was traded (i.e., the aggregate of power exchanges between countries) by the region in 2006, of which 41.5 TWh were accounted for by Brazil. Of the region's total electricity exports of around 54 TWh in 2006, Paraguay was the single largest trading country, accounting for 46 TWh (primarily exports from the large Itaipu and Yacyreta hydro power plants). Electricity trade occurs primarily in three separate zones: (i) Brazil, Paraguay, Argentina, and Uruguay; (ii) Mexico and Central America; and (iii) Colombia, Ecuador, Venezuela, and Panama.

88. Table 4 presents historical data on electricity exports and imports in LAC. Aggregating the figures for all the countries in the region, the resulting trade balance[16] does not equal zero, which is explained by Mexico's electricity trade "outside" the region with the United States. The data shows a slowdown in trade after 2000, reflecting a growing trend of countries to supply domestic needs first.[17] Paraguay plays the most important role in the region's electricity trade, being the largest net exporter. With an average of 45 TWh exported annually since 2000, Paraguay is a major electricity supplier to Brazil and Argentina. Brazil's demand for electricity from international trade can be inferred from Table 4, which shows the difference between the countries' own production and domestic consumption. In 2007, this difference was around 39 TWh, a figure equivalent to its trade balance (exports minus imports) for that year. Brazil has structured its electricity supply system taking into account imports from Paraguay.

Table 4. Electricity Imports and Exports (GWh)

		1985	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007
Argentina	Exports	-	32	220	6,023	5,662	2,856	2,543	4,144	4,140	6,193	2,628
	Imports	2,674	2,682	2,343	7,250	7,417	8,776	7,579	7,613	8,018	7,418	10,275
Brazil	Exports	5	7	-	7	6	7	6	7	160	283	2,034
	Imports	1,918	26,538	35,343	44,333	37,844	36,570	37,141	37,392	39,202	41,447	40,866
Chile	Exports	-	-	-	-	-	-	-	-	-	-	-
	Imports	-	-	-	1,190	1,386	1,813	1,667	1,744	2,152	2,285	1,628
Colombia	Exports	-	-	-	37	210	618	1,182	1,682	1,758	1,813	877
	Imports	-	200	370	77	40	8	69	48	16	21	39
Ecuador	Exports	-	-	-	-	-	-	67	35	16	1	39
	Imports	-	-	-	-	22	56	1,120	1,642	1,723	1,570	861
Mexico	Exports	237	1,946	1,944	195	271	344	954	1,006	1,291	1,299	1,451
	Imports	140	575	1,164	1,069	327	531	71	47	87	523	277
Paraguay	Exports	2,860	24,797	35,369	47,331	39,109	41,770	45,173	45,003	43,784	45,706	45,133
	Imports	40	48	-	-	-	-	-	-	2	1	-
Peru	Exports	-	-	-	-	-	-	-	-	8	-	-
	Imports	-	-	-	-	-	-	-	-	-	-	-
Venezuela	Exports	2,678	2,589	233	942	1,377	2,287	1,138	1,138	841	16	995
	Imports	-	51	188	1,328	123	559	434	2,348	1,585	2,835	788
Central America	Exports	212	512	354	1,493	877	965	851	1,257	560	261	305
	Imports	229	497	372	1,484	944	969	845	1,207	565	275	307

Source: OLADE, SIEE (Demand & Supply module)

[16] According to OLADE's figures, domestic supply equals the country's total production, minus exports, plus imports.
[17] Trade reemerged in 2004.

89. Trade between Mexico and the countries in Central America is expected to grow with the completion of the SIEPAC[18] network. To date, Mexico has been exporting an average of about 1 TWh annually over the last twenty years; at the same time, its imports relative to domestic production have remained insignificant.

90. In Central America, there are currently power interconnections between each of the countries, in both directions. In terms of capacity, the largest interconnection is from Panama to Costa Rica (110 MW), while the smallest interconnection is from Costa Rica to Nicaragua (60 MW). Table 5 presents the complete list of interconnections within Central America.

Table 5. Central America Electricity Interconnections

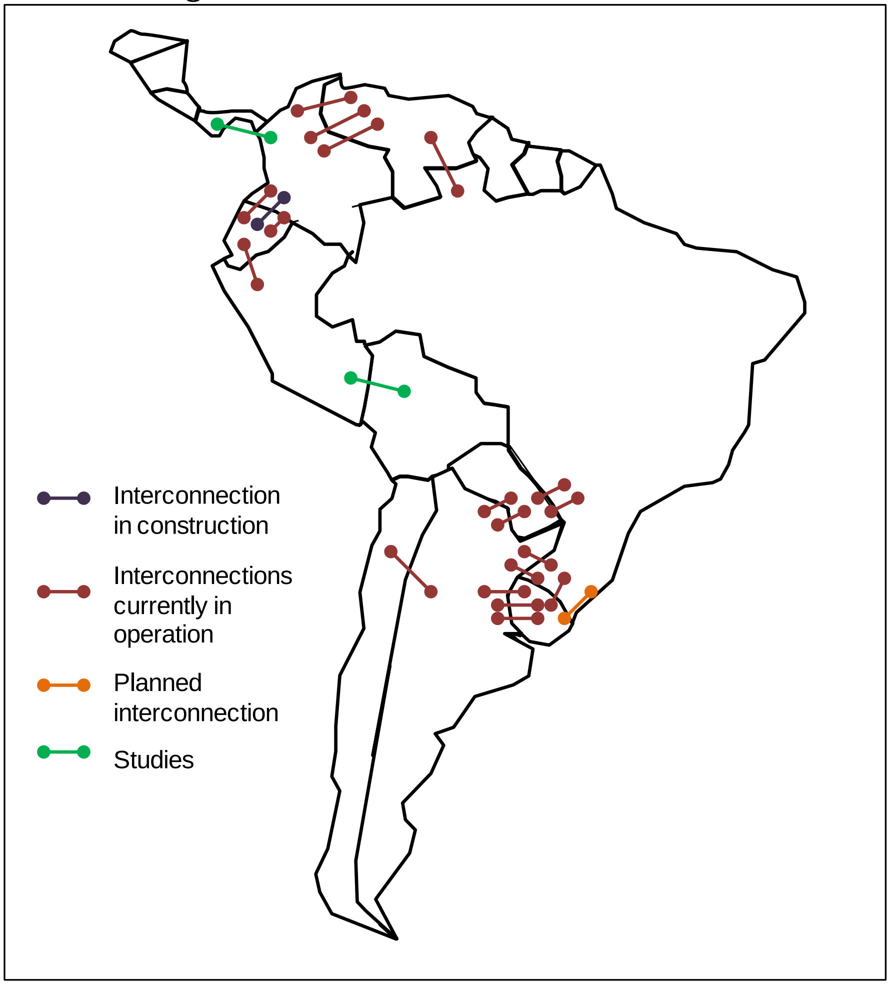
To/From	Capacity (MW)
Guatemala → El Salvador	100 MW
El Salvador → Guatemala	95 MW
El Salvador → Honduras	100 MW
Honduras → El Salvador	100 MW
Honduras → Nicaragua	80 MW
Nicaragua → Honduras	80 MW
Nicaragua → Costa Rica	60 MW
Costa Rica → Nicaragua	60 MW
Costa Rica → Panama	70 MW
Panama → Costa Rica	110 MW

Source: CRIE

91. Figure 7 illustrates the interconnections currently in operation, ones under construction, planned, or studied. Brazil, Paraguay, Uruguay, and Argentina have the most interconnections currently in operation. The figure also indicates the planned interconnection lines between Bolivia, Peru, and Chile. A new interconnection is also underway between Colombia and Panama.

[18] *Sistema de Interconexión Eléctrica para América Central* (Central American Electrical Interconnection System)

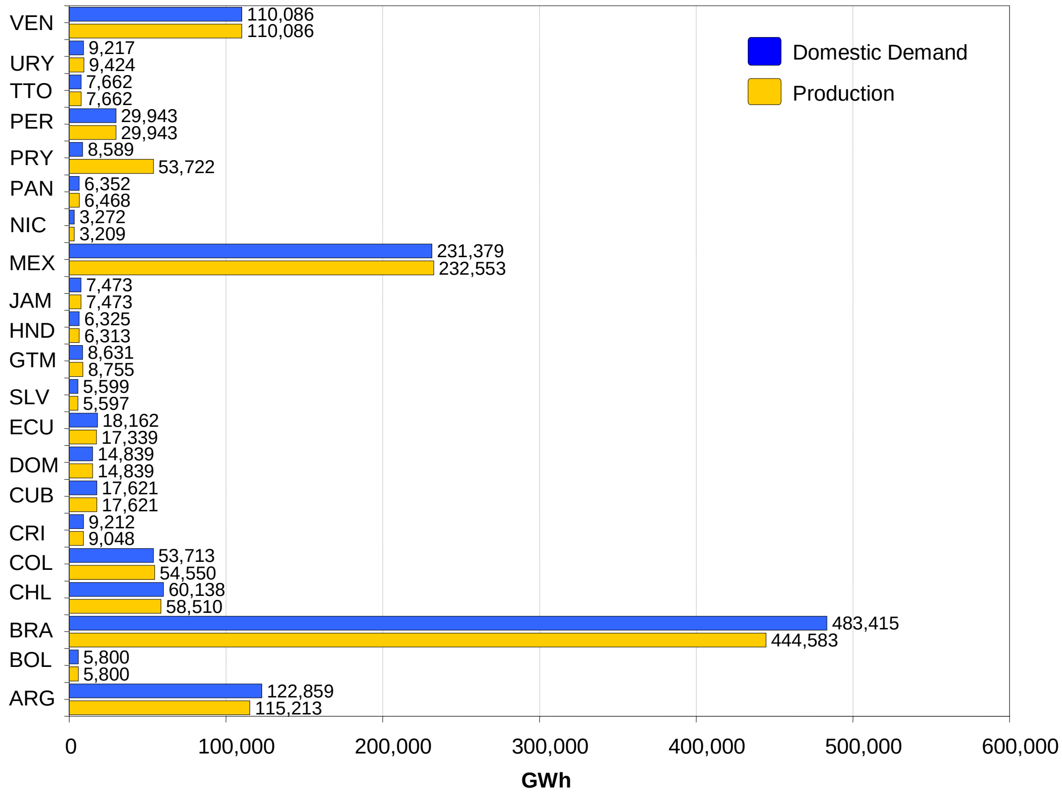
Figure 7. South America Interconnections



Source: By Authors using CIER (2008) & potential interconnections included by Manuel Brugman

92. Colombia stands out as an important net exporter, with export volumes becoming increasingly significant since 2000. Ecuador has been the main recipient of Colombian electricity exports. In addition to Ecuador, Colombia has also been engaged in electricity trade with Venezuela, which, at the same time, has also provided electricity to Brazil's north.

Figure 8. (2007) Electricity Production and Domestic Demand in LAC



Source: OLADE, SIEE (Demand & Supply module)

VI. Power Sector Structure in LAC

93. The electricity sectors in different Latin American countries have distinct regulatory and market structures. Some countries have a completely vertically-integrated and state-owned structure, such as Costa Rica, Paraguay, and Ecuador. At the opposite end of the spectrum, the power sectors in Chile and Panama have fully market-oriented structures with private sector participation in all segments of the market. Other countries currently fall somewhere in between, although the structure of the power sector in many countries has been in a constant state of flux over the past 30 years. During the economic crisis of the 1980s, private sector investment retreated from the power sector in many LAC countries. In order to guarantee the provision of service, many governments nationalized the power sector, giving state-owned utilities vast control over electricity markets. During the 1980s and 1990s, the growing electricity capacity requirements and the lack of private sector investment led to a strain on public utilities. This in turn led some governments to provide incentives and a competitive investment climate for private sector companies in certain segments of the market, including generation in some countries and distribution in others.

94. Economic liberalization of the power sector in Latin America began in Chile in 1982 with the privatization of its utility companies, the creation of a spot market, and the opening of the

sector to new investors. Following the Chilean experience, many Latin American countries introduced a range of similar policies to restructure their electric power sectors. New independent regulatory agencies were created, large state-owned companies were unbundled and privatized, and competitive market-oriented frameworks were implemented throughout the 1990s in a range of countries; the process continues today.

95. In Mexico, liberalization in the 1990s opened the generation segment of the market to large independent power producers, mainly building and operating combined-cycle natural gas plants. In Central America, reforms were implemented in Guatemala, El Salvador, Nicaragua and Panama, which liberalized their entire electricity markets. In Costa Rica and Honduras, the reforms were limited to the opening of the generation segment. In South America, the most extensive reforms were introduced in Colombia, Peru, Bolivia, Argentina and Brazil, which introduced new liberalized markets with significant private participation. Ecuador introduced a competitive wholesale electricity market, although it has not been opened to significant private participation. Paraguay and Venezuela's electricity markets have remained largely unchanged with a dominant public sector presence. Chile kept in place its already privatized market.

96. New regulatory frameworks have redefined the conditions for electricity service in most Latin American countries, frequently providing for a structure under which the role of the state is limited to only the formulation of policies, the exercise of regulatory functions for their respective power sectors, and the administration of concessions. However, in most countries the state remains an important player in the sector through its ownership of companies involved in generation, transmission and generation (including, to varying degrees, in countries such as Mexico, Brazil, Colombia, Guatemala, the Dominican Republic, and Uruguay).

VII. Impact of the Financial Crisis

97. Since the last quarter of 2008, forecasts for the majority of macroeconomic variables have changed as a result of the international financial crisis. Changes in economic growth forecasts have major implications for the growth in electricity demand, and the forecasts of GDP have been frequently modified over the course of preparing this study.

98. In August 2008, the GDP forecasts for most countries of the region were positive and followed the trend of stable economic growth that has characterized LAC over the previous five years. The 2009 GDP growth forecast was 3.7 percent, according to the Latin American consensus.[19] Changes to the previous survey (June 2008) have been done, but these were not substantial except for Costa Rica. The June 2008 average GDP growth forecast for the LAC region was 3.9 percent, indicating that no major changes were foreseen in the summer before the start of the financial crisis. However, a striking difference can be observed between the August 2008 forecast and the one done in February 2009. Growth expectations were revised downward and the probable scenario of positive growth rates for the region was replaced by a *zero-growth* scenario. Furthermore, LAC's economic outlook had worsened by March 2009. The zero-growth

[19] The survey date was June 16th 2008, with the disclaimer made by the Latin American consensus that its estimates are based on surveys of 120 prominent LAC economic and financial forecasters.

scenario turned into a negative one, and the only countries which were forecast to have significantly positive GDP growth rates were Peru and Bolivia.

99. Given the long-term outlook of this study, past experience shows that with a time horizon of greater than 20 years, any slowdown in demand and supply of electricity in the short-term is likely to be made up over time. The IMF GDP growth assumptions used in this study are from the April 2009 World Economic Outlook (WEO) IMF publication. According to its projections, global GDP was forecast to decrease by 1.3 percent in 2009, but then recover with an overall increase of 1.9 percent in 2010. Emerging and developing economies as a whole are forecast to grow at 4.0 percent in 2010, but among LAC countries, the projected GDP growth in 2010 is only 1.6 percent. The two largest countries in the region, Mexico and Brazil, are forecast to have 1.0 percent and 2.2 percent GDP growth in 2010 respectively, with the longer term projections (through 2014) looking more optimistic with 4.9 percent and 4.5 percent respectively. It should be noted that there was a mid-year update of key WEO projections released by the IMF in July 2009, which included modest adjustments to the GDP growth forecasts. This study relies on the IMF's April 2009 GDP growth projections, since the July 2009 update does not provide country-by-country projections, and because over the longer term (through 2030), the short-term bumps in the next two years will not have a major impact.

CHAPTER III: BASELINE ELECTRICITY SUPPLY SCENARIO TO 2030

100. As seen in the previous chapter, the LAC Region has been quite successful in expanding the supply of electricity and in achieving relatively high electricity access rates. Due to the predominance of hydroelectricity, the Region as a whole has the lowest carbon-intensity of any region in the world, while the countries with large amounts of hydroelectricity have benefitted from relatively low and stable electricity prices compared to those relying on fossil fuels. Going forward, the Region will need to respond to the electricity challenges laid out in Chapter I, specifically: (1) meeting future demand growth, (2) maintaining the security of energy supply, (3) minimizing cost and maximizing efficiency, (4) limiting environmental impacts, and (5) putting in place the necessary policy and regulatory regime to achieve (1) through (4).

101. The main purpose of this chapter is to present electricity demand and supply scenarios for the LAC Region to the year 2030. The scenarios reflect the currently available country power expansion plans, and can therefore be viewed as the "baseline" for the Region going forward. The supply side scenarios illustrate the collective future of the generation mix for the Region. The first part of the chapter describes the specific assumptions and tools used in the construction of the supply scenarios. The second part presents the results of the scenario analysis for individual countries and sub-regions. The analysis identifies cost-minimizing investment and production strategies to meet the projected demand as well as the amount of investment required to implement such a strategy. The third part presents estimates of CO_2 emissions followed by a brief sensitivity analysis that examines the effect of carbon taxes on the generation mix.

I. The Modeling Framework

102. For the purposes of illustrating the implications of current trends in electricity development – for individual countries, sub-regions, and the Region as a whole – scenarios of electricity demand and supply to the year 2030 were created using a simple electricity demand function and a detailed energy supply planning model. The scenario that results, referred to as the ICEPAC Scenario, reflects the current expansion plans of individual countries in the Region, to the extent that information was available.

i. Demand Function

103. To estimate electricity demand, a log-linear model was developed using GDP and electricity prices as explanatory variables. The demand model makes use of energy statistics from OLADE's database, which is the largest and most complete set of energy data for the region. Working with OLADE, an electricity demand scenario for the region was created to the year 2030. The supply scenario was then developed that would meet the estimated demand.

104. The estimation of electricity demand uses the most simplified specification for electricity demand considering GDP and electricity prices.[20] The demand scenario for each country was generated using the GDP demand elasticity and a forecast for GDP up to 2030. In order to simplify the demand scenario, a constant GDP growth rate of 3 percent between 2015 and 2030 was assumed. An additional simplifying assumption was that real electricity prices are constant over the period.[21] Given the long-term nature of the exercise, the preference for the exercise was to follow the historical trends in the demand for electricity, rather than forecast the expected changes in one or more explanatory variables. Historical data from 1978-2007[22] were used to approximate a linear logarithmic regression (shown below), where α, β and γ are the parameters to be estimated. Beta represents the long-term GDP-electricity demand elasticity and gamma represents the long-term electricity price elasticity of demand.[23]

$$\text{Ln (Total electricity demand)} = \alpha + \beta \text{ Ln (Gross Domestic Product)} + \gamma \text{ Ln (Electricity Price)}$$

105. **GDP Growth Rate and Electricity Price Assumptions:** The GDP data that was used was taken from the IMF's World Economic Outlook report (April 2009).[24] The document contains the forecast for each country's expected GDP growth rate up to the year 2014. Table 7 contains the annual percent GDP growth assumptions by country that were used in the model. For GDP forecasts from 2014 to the year 2030, a constant annual GDP growth rate of 3 percent was assumed for all countries. As noted, a constant real electricity price was assumed for all of the countries of the region.[25]

[20] The "Electricity Price" variable refers to each country's weighted average electricity tariff according to OLADE's database.

[21] Electricity demand models are typically estimated using economic growth and electricity prices.

[22] Using IMF's information on GDP and OLADE electricity prices for countries across the region.

[23] We initially used an econometric specification where electricity demand is jointly driven by "GDP", "population", and electricity price. However, high multicollinearity between GDP and population growth produced artificially inflated standard errors and R^2. While it is known that multicollinearity does not violate any of the standard model's assumptions, the nature of this exercise requires the highest possible precision on the coefficient estimates, particularly the GDP elasticity. As such, the preferred model only includes GDP and electricity prices as explanatory variables.

[24] http://www.imf.org/external/pubs/ft/weo/2009/01/weodata/index.aspx

[25] Based on both practical and theoretical considerations the team considered it was reasonable to hold electricity prices constant throughout the projection period. All else equal, the GDP elasticity estimate characterizes the partial effect of economic growth on electricity demand, independent of changes in prices for fuels used in electricity generation or capital costs. Furthermore, because electricity prices are endogenous, a full supply-demand system of equations would need to be estimated; which is beyond the purpose of this exercise. Moreover, such specification would require precise assumptions (and forecasts) on the fuels and technologies used in generation.

Table 6. GDP and Price Coefficients[26]

	Coeff GDP	Coeff Price
Argentina	1.02	-0.78
Bolivia	2.06	-0.62
Brazil	1.55	-0.91
Chile	1.14	0.03
Colombia	1.17	-0.36
Costa Rica	1.26	-0.84
Ecuador	1.60	-1.06
El Salvador	1.52	-0.55
Guatemala	1.45	-0.70
Honduras	1.66	-1.67
Mexico	1.28	-0.76
Nicaragua	2.24	-0.36
Panama	1.29	-0.36
Paraguay	0.95	-1.38
Peru	1.13	-0.72
Uruguay	1.64	-1.83
Venezuela	0.48	-0.05

106. The results derived for the GDP and Price coefficients (Table 6) are fully consistent with economic theory: the demand for electricity is positively correlated with income and negatively correlated with price. The higher the income of a country the more power it consumes. As countries develop, the share of the industrial and service sectors (which consume relatively large amounts of power) in the economy rise, while the share of agriculture (which uses relatively little electricity) tends to fall. Also, higher household income levels are associated with higher electricity consumption, reflecting the increase in the use of durable goods.

107. The GDP-electricity demand elasticity is always greater than unity, except for Paraguay and Venezuela. While faster GDP growth may be associated with higher electricity demand, the GDP-electricity elasticities are a measure of energy intensity, as they represent the percentage increase in electricity demand for every percentage increase in GDP. The lower the elasticity, the less power is required per percentage point of GDP growth. However, while intensity can be attributed to the efficient use of electricity, it also depends on the structural composition of the

[26] GDP coefficients were statistically significant for all countries. Price coefficients were not statistically significant for Chile, Colombia, Nicaragua and Venezuela. The results derived for the GDP and Price coefficients are fully consistent with economic theory: GDP growth is positively correlated with electricity demand and electricity prices are negatively related.

economy. For the Region as a whole, a one percentage point increase in GDP on average results in a 1.37 percent increase in electricity consumption.

108. Despite the limited analysis of the effect of electricity prices, the estimates confirm that the higher the price, the lower the demand for electricity. The estimates of the price elasticity show that the demand for electricity is inelastic in most countries with most elasticity estimates being less than one. Except for Ecuador, Honduras, Paraguay and Uruguay, the demand for electricity falls by less than one percent for every percentage increase in price.

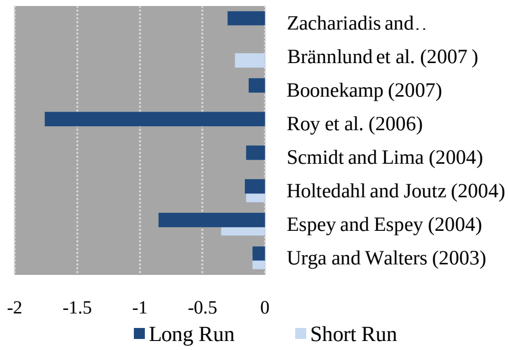
Table 7. IMF World Economic Outlook GDP Forecasts, Constant Prices (Annual % Change)

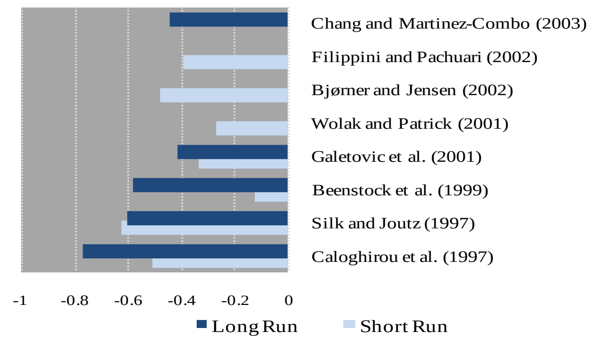
Country	2008	2009	2010	2011	2012	2013	2014
Argentina	7%	-2%	1%	3%	3%	3%	3%
Barbados	1%	-4%	1%	3%	3%	3%	3%
Bolivia	6%	2%	3%	3%	3%	3%	4%
Brazil	5%	-1%	2%	3%	3%	4%	4%
Chile	3%	0%	3%	4%	5%	5%	5%
Colombia	3%	0%	1%	4%	5%	5%	5%
Costa Rica	3%	1%	2%	4%	5%	5%	5%
Dominican Republic	5%	1%	2%	5%	7%	7%	7%
Ecuador	5%	-2%	1%	2%	2%	3%	3%
El Salvador	3%	0%	1%	2%	4%	4%	5%
Guatemala	4%	1%	2%	4%	4%	4%	4%
Haiti	1%	1%	2%	3%	3%	3%	4%
Honduras	4%	2%	2%	2%	3%	3%	3%
Mexico	1%	-4%	1%	5%	5%	5%	5%
Nicaragua	3%	1%	1%	2%	3%	4%	4%
Panama	9%	3%	4%	7%	7%	7%	7%
Paraguay	6%	0%	2%	3%	4%	5%	5%
Peru	10%	3%	4%	7%	6%	6%	6%
Suriname	7%	3%	3%	4%	5%	5%	5%
Trinidad and Tobago	3%	1%	2%	3%	3%	3%	3%
Uruguay	9%	1%	2%	4%	4%	4%	4%
Venezuela	5%	-2%	-1%	1%	1%	1%	1%

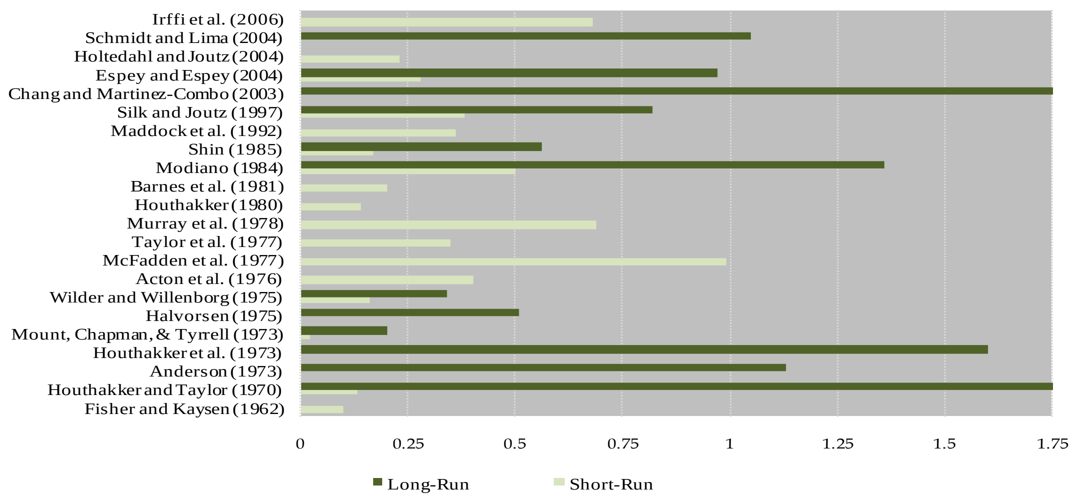
109. For reference, Box 1 provides an overview of the various ways in which other models have attempted to incorporate the income and price elasticity of demand into electricity demand forecasts. Annex 2 also provides additional detail on the academic literature surrounding income and price elasticity of electricity demand.

Box 1: Price and Income Elasticity of Electricity Demand

As summarized in the figures below, academic research to date shows substantial variation in the estimates of the price and income elasticity of electricity demand, with the short-run and the long-run values:







However, in analyzing the variations in price and income elasticity, it is important to identify the country, time period, sector(s) in which the study was conducted in order to ensure a fair comparison. The table below provides additional details on the LAC-specific studies:

Author/Year	Country	Time Period	Sector(s)	Elasticity Type	Short Run/ Long Run	Findings
Irffi et al. (2006)	Brazil	1970-2003	Residential	Income	Short Run	0.84
Schmidt & Lima (2004)	Brazil	1980-2000	Residential & Industrial	Income	Short Run	1.1
			Industrial	Price	Long Run	-0.13
			Residential			-0.15
Chang & Martinez-Combo (2003)	Mexico	1985-2000	Residential	Income	Long Run	1.95
				Price		-0.44
			Industrial	Income		1.29
				Price		-0.25
Maddock et al (1992)	Colombia	1986	Residential	Income	Short Run	0.33
				Price		-0.32
Galetovic et al (2001)	Chile	2001	Residential	Price	Short Run	-0.33
					Long Run	-0.41
			Commercial		Short Run	-0.19
					Long Run	-0.21

ii. Supply Model

110. To illustrate electricity supply, the SUPER (Sistema Unificado de Planificacion Electrica Regional) model was used to calculate the electricity generation mix and the investment requirements that would meet the demand scenario. The SUPER Model was developed by OLADE and is aimed at the prioritization, scaling, and selection of electricity projects to meet the growth in electricity demand. In each phase, the model determines generation targets for each of the system's power plants, minimizes the expected value of the operating and capital costs throughout the period, and estimates selected environmental impacts, such as CO_2 emissions, associated with the future development of the electric power sector.

111. The supply model was used to calculate the electricity generation mix and the investment requirements that would optimally meet the demand scenario for each country. After the total annual demand is calculated, the supply model is used to determine the optimal, cost-minimizing generation mix to meet the demand.

112. In addition to the demand scenario as an input to the model, various data are also inputted into the SUPER model, including hydrology, reference prices for fuels, existing power plants with their operational features, projects under construction or bidding, which are fixed, and their entry dates, as well as eligible projects with their earlier entry dates and operational features, investment costs and operational variables, among other inputs.

113. **Advantages and Constraints of the Supply Model.** The SUPER Model has several advantages for simulating electricity supply systems. It allows the minimum cost generation alternatives that meet the demand requirements in an electricity system to be found. In addition, the SUPER model allows an evaluation of the generation expansion considering both renewable and thermal technologies. For the modeling done for this study, the SUPER model was used to calculate the electricity generation mix considering the minimum cost of the electricity depending on the capital and variable costs of the electricity generation technologies available in the country. The capital and variable costs of technologies used to calculate the supply-side optimal technology mix were fixed across the region. For example, the variable and fixed costs to generate a unit of electricity (GWh) with a combined cycle technology were the same for all the countries in the region. The generation technologies used in the model considered country available capacity in 2007 and the information available from the country's electricity expansion plan. One of the limitations of this approach is that it does not reflect potential large scale changes in the base-case country expansion plans (i.e. such as potential shifts towards a larger proportion of cleaner technologies as a result of concessional climate funds or carbon taxes).

114. Although the SUPER model allows for an integral evaluation of the electricity generation in a country, the information available limits the scope of the analysis. In order to more precisely estimate the electricity generation mix in the coming years, the model is based on information from the electricity expansion plans of the countries in the region. The more information available on the technologies and the fuel sources available in a specific country, the more accurate the forecast of future generation composition.

iii. ICEPAC Scenario

115. Based on the outputs from the demand and supply models, this study presents the ICEPAC Scenario (Illustrative Country Expansion Plan, Adjusted & Constrained). The scenario was created using the results of the demand model, which is then used as an input to OLADE's SUPER model, which is used to calculate the optimal, least-cost generation mix that would satisfy the demand. The ICEPAC scenario is thus "**Illustrative"** of the current power planning within the Region because it is based on: (1) "**Country Expansion Plans**" to the year 2030 (where available), which are then: (2) "**Adjusted**" to account for the lack of data, and to extrapolate country expansion plans (most of which are available to the year 2018 or 2020), and then (3) "**Constrained**" so as not to exceed energy resource potential (such as domestic hydroelectric resources) and using a database of international technology supply costs which places a cost-minimizing constraint on the electricity supply model. From the ICEPAC scenario, it is possible to compare electricity supply to demand, estimate the financial needs for meeting new supply, and provide a baseline with which to compare alternative means for meeting supply and regulating demand.

116. The ICEPAC model for the expected generation mix takes into account a variety of factors:

- **Fuel prices.** Fuel prices are one of the main factors affecting the composition of the generation mix. Fuel-based technologies have high variable costs and low capital costs compared to renewable technologies; thus, in the long term, a comparison of the fuel costs of different technologies is crucial to estimating the supply mix.
- **Resource availability.** Resource availability also affects the technology composition, as it may impose a constraint on the feasibility of each country's best economic alternative.
- **National expansion plans.** Country-level generation plans, too, are an important factor to be taken into account when forecasting the future generation mix.

117. **However, an important limitation of the ICEPAC is that it is based on current Country Expansion Plans, namely those in existence prior to 2009. While th**ese plans provide a uniform basis for projecting expansion into the future, one of the limitations of this approach is that many country expansion plans do not reflect the contribution of non-hydro renewables, electricity trade, and energy efficiency.[27] These shortcomings of the modeling analysis are addressed in Chapter IV.

II. Modeling Results

118. This section presents the results of the demand modeling and the resulting ICEPAC scenario. The first part presents the electricity demand scenario by sub-region. The second part presents the ICEPAC supply scenarios, both region-wide and by sub-region, and the

[27] For the years in which no expansion plan data was available, the ICEPAC scenario uses thermal generation as the expansion alternative. The decision was made to rely upon this assumption because thermal technologies are considered tradable goods in the market, while renewable generation sources, while not fixed, are more determined by available resource potential. This assumption is a significant constraint to the ICEPAC scenario, and the results should be considered with this in mind.

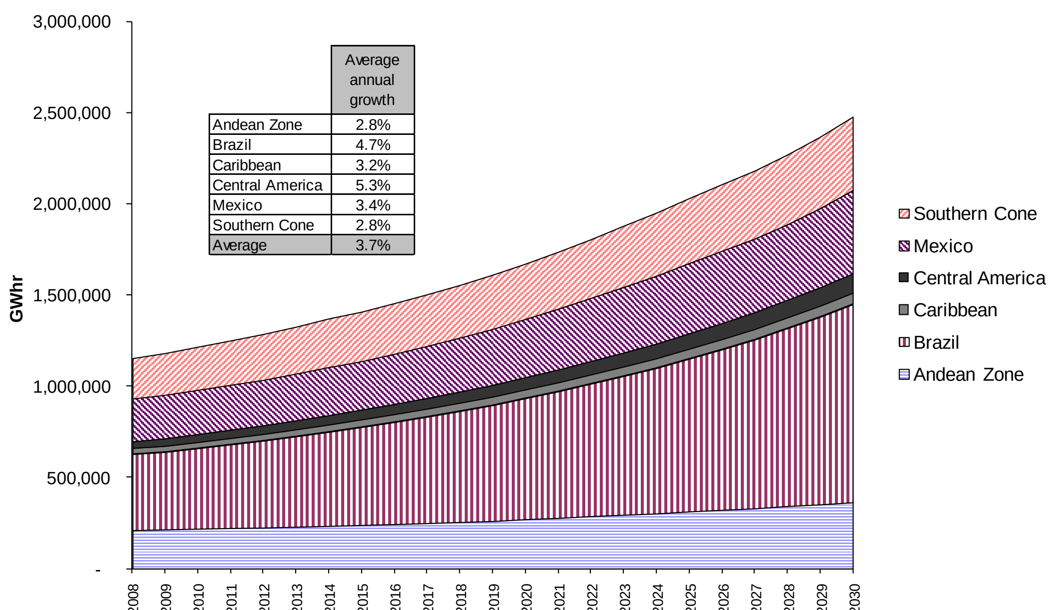
corresponding generation mix of technologies through 2030. Considering that the time horizon of the Study is quite long, the interpretations of the results are focused more on the general forecasted trends and patterns in supply, demand, and generation mix, rather than on individual numbers. The remaining sections of this chapter explore how much additional investment will be needed on a regional and sub-regional level in order to meet the ICEPAC scenario generation volume and specific technological mix, and the estimated CO_2 emissions per sub-region and region-wide through 2030 considering the fuel mix forecasted in the generation matrix.

i. Electricity Demand

119. The electricity sector in Latin America and the Caribbean will experience substantial growth over the next 20 years. According to the electricity demand modeling exercise conducted, the area's total demand for electricity will reach nearly 2,500 TWh in 2030, approximately twice the 2008 level. From 2008 to 2014, the average annual growth is estimated to be approximately 3.7 percent, with total demand increasing nearly 22 percent by 2015. A subsequent 78 percent increase in demand will occur from 2015 to 2030. The share of each sub-region's electricity production is estimated to remain roughly the same throughout the 2008-2030 timeframe. This is to be expected, given the average annual GDP growth assumptions used in the calculations.

120. Although no one particular sub-region distinctly dominates the cumulative increase in electricity demand, electricity demand in Central America increases at a slightly faster pace than in other sub-regions, with an average annual growth in demand of 5.3 percent. Brazil and Mexico, with their respective electricity demand growing at 4.7 and 3.4 percent annually, together represent nearly 62 percent of the region's total demand in 2030, while the Andean Zone and the Southern Cone countries comprise another 31 percent.

Figure 9. Electricity Demand by Sub-Region

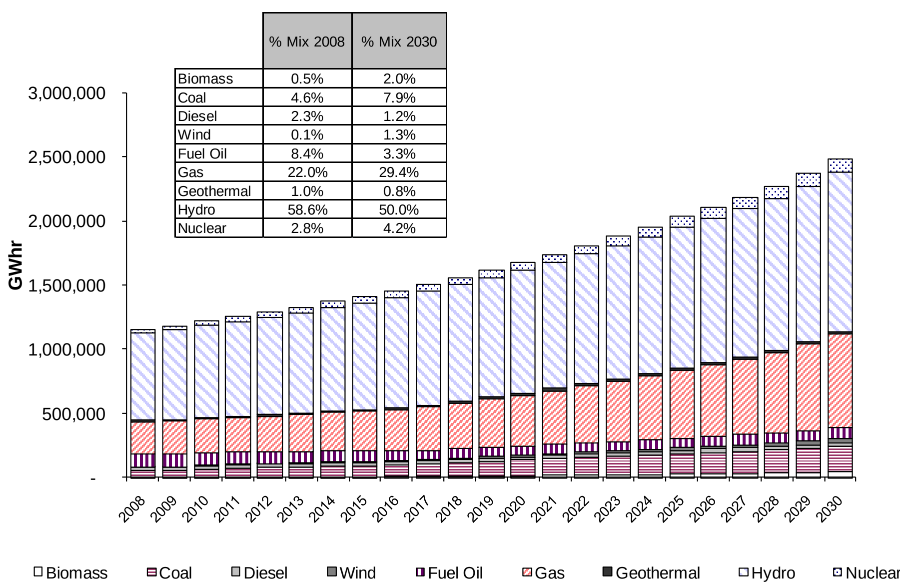


ii. The Supply Side: The ICEPAC Scenario

121. **Level and Generation Mix for the LAC Region**: In the Latin America and the Caribbean region as a whole, under the ICEPAC modeling exercise it is estimated that an additional 239 GW of installed capacity will be required to satisfy the estimated demand. To meet this demand, the total electricity generation mix in LAC by the year 2030 under baseline economic conditions is expected to be dominated by hydroelectricity and natural gas, with shares of 50 and 30 percent, respectively. The future technology mix is not expected to change significantly from 2008 onwards. The main change estimated by the model is a slight decrease (of about 9 percent) in the share of hydroelectric generation, which will occur as a result of expansion in gas and coal, whose respective shares in the total generation mix will increase by 7 and 3.0 percent (Figure 10).

122. Figure 10 shows the region-wide ICEPAC scenario generation mix from 2008 to 2030. The modeling exercise indicates that the Latin America and the Caribbean region will experience a modest decline in the share of hydropower (from 59 to 50 percent) and a steep decline in the share of fuel oil (from 8 to 3 percent), compensated by an increase in the share of coal by approximately 3 percent (from 5 to 8 percent), an increase in the share of natural gas by 7 percent (from 22 to 29 percent), and a moderate increase of nuclear energy (from 3 to 4 percent).

Figure 10. Region-Wide Electricity Generation Mix (2008-2030)



	% Mix 2008	% Mix 2030
Biomass	0.5%	2.0%
Coal	4.6%	7.9%
Diesel	2.3%	1.2%
Wind	0.1%	1.3%
Fuel Oil	8.4%	3.3%
Gas	22.0%	29.4%
Geothermal	1.0%	0.8%
Hydro	58.6%	50.0%
Nuclear	2.8%	4.2%

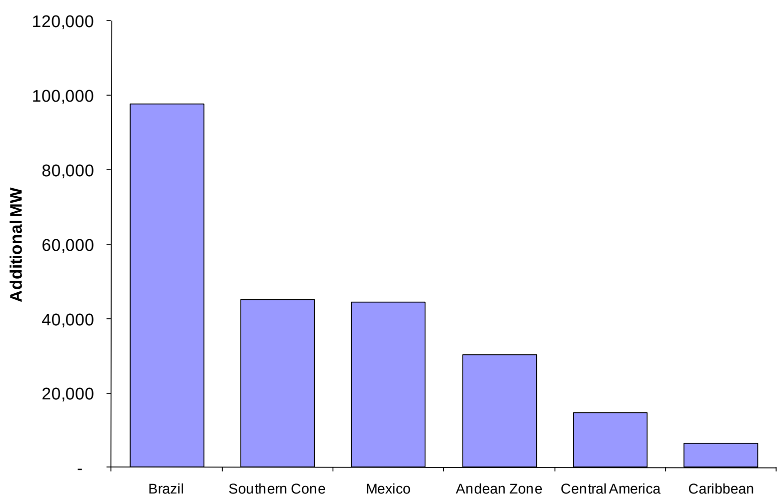
123. The changes in the relative shares of each generation source are a result of a relatively small compounded annual growth in hydroelectric generation (of only 2.8 percent) against the 5.1 and 6.1 percent annual growth rates projected for gas and coal technologies. Hydroelectric energy will thus continue to be the most important source of generation in the region, with Brazil, Paraguay, and Colombia as the largest producers of hydro-based electricity. However,

thermal generation will also continue to represent an important share, mainly due to the preference for natural gas-based technologies, Mexico being the strongest example of that tendency. Among renewable sources other than hydro, wind is estimated to grow at the fastest pace (16.2 percent annually). Still, it is not expected that wind-based generation will exceed more than 1 percent of the region's total generation by the end of the estimation period.

124. The region-wide implication of these shifts is that LAC will become slightly more carbon-intensive over the forecast period, driven mainly by the decline in the share of hydropower. However, it is difficult to make definitive conclusions about the future technological advances and market development of technologies in long-term estimation scenarios. For example, while windpower is only expected to increase its share in LAC's electricity generation mix by a modest degree (from 0.1 to 1.3 percent of the total), many argue that, following the trajectory of development of windpower in other regions, the share of this generation source in LAC's electricity mix could grow to a much higher level than currently estimated.

125. In the Latin America and the Caribbean region as a whole, under the ICEPAC modeling exercise it is estimated that an additional 239 GW of installed capacity will be required to satisfy the estimated demand. As shown in Figure 11, it is estimated that Brazil will add approximately 41 percent of this additional capacity. The Southern Cone is expected to be the second largest contributor, with about 45 GW, followed closely by Mexico and the Andean Zone, with about 44 and 30 GW each.

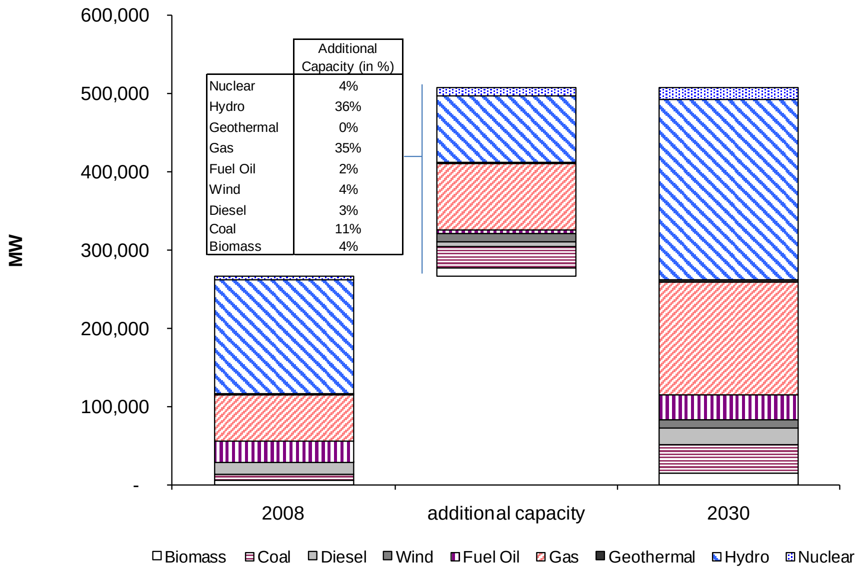
Figure 11. Additional Capacity (MW) for the Region and by Sub-Regions



126. Figure 12 provides a breakdown of the additional and total region-wide capacity by technology under the ICEPAC Scenario. The middle column presents the incremental change (the delta) and the table depicts the percentage breakdown of capacity by technology to be added between now and 2030, showing that the new generation will come mainly from hydropower and natural gas (36 and 35 percent each). Under the ICEPAC Scenario, the additions of hydropower capacity would bring its share in the 2030 region-wide total generation mix to nearly 50 percent.

Coal would represent 11 percent of the added capacity. Lastly, nuclear energy region-wide would comprise 4 percent of the added capacity, most of which would be contributed by Argentina.

Figure 12. Additional Capacity from 2008 to 2030 by Technology: LAC



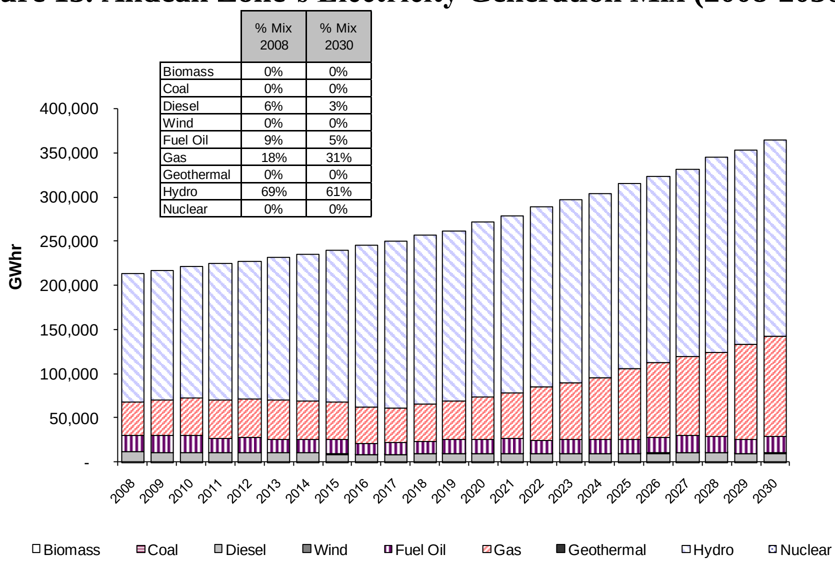
127. One of the questions that arises from the results of the ICEPAC Scenario is whether there are alternatives to LAC's current plans for meeting its electricity needs are feasible, environmentally sustainable, and efficient. Chapter IV addresses some alternatives to achieving region-wide electricity security, including through more focused attention on renewable energy sources, increased regional integration and electricity trade, and through improved supply and demand-side energy efficiency. A second question is whether some of the plans for hydroelectric (and to some extent for natural gas) are realistic given the current policy environment in some countries. To achieve the projected steep increase in hydropower between 2007 and 2030, the countries in the Region will likely need to devote large up-front investments to hydropower, more effectively attract private investment, and ambitiously pursue the development of untapped hydropower potential, while addressing the potentially negative environmental and social impacts of hydropower development.

128. **Results for the Sub-Regions.** The results of the ICEPAC Scenario for the generation mix by sub-region vary and are revealing in their similarities and differences. They also provide further insight into the implications and drivers of the energy mix over time.

129. **<u>The Andean Zone:</u>** Under the ICEPAC scenario, the Andean Zone's generation demand is expected to grow 75 percent during the period of analysis. The generation mix is expected to be composed mainly of hydropower. Figure 13 illustrates how, in the short run, the mix holds constant, reflecting the fact that the current infrastructure is not being utilized to its maximum capacity. However, beginning in 2016, the share of fossil fuel-based generation is expected to increase, reaching 40 percent by 2030. The sub-region is not expected to diversify its generation mix by expanding into nuclear, geothermal, or wind technologies. The implications for the

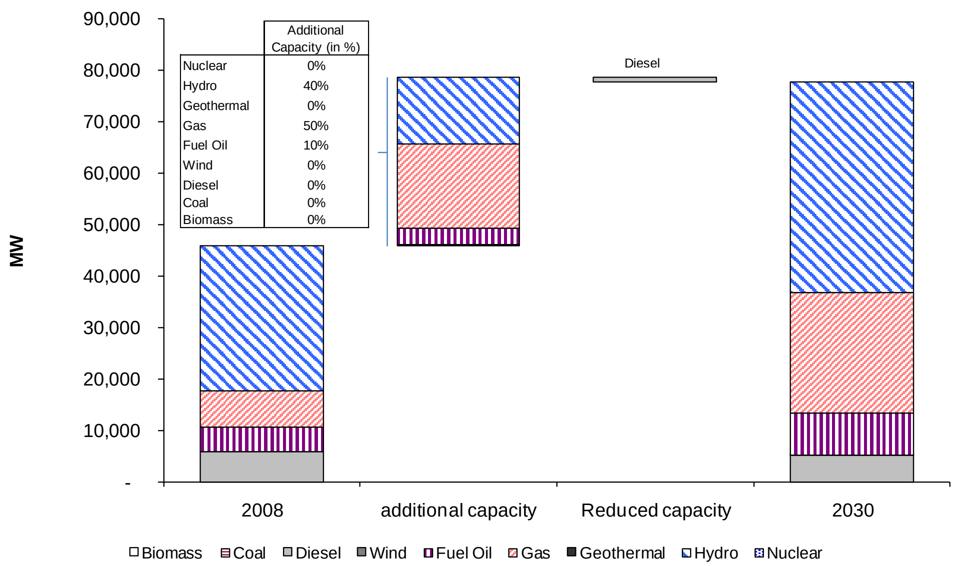
Andean Zone are that the sub-region will become increasingly dependent on fossil fuels (mainly natural gas) after 2016, and, as a result, more affected by volatile fossil fuel prices. However as noted in Annex 1, the projected trends vary within the sub-region, with an expected increase in the share of hydropower in Ecuador.

Figure 13. Andean Zone's Electricity Generation Mix (2008-2030)



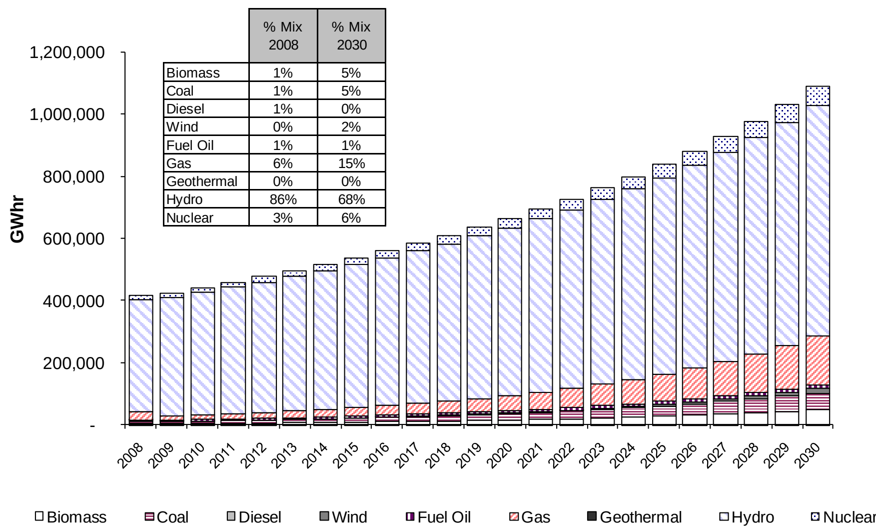
130. Similar to the region-wide estimations, the additional capacity requirements from 2008 to 2030 in the Andean Zone under the ICEPAC scenario will be met largely by natural gas (50 percent of the additional generating capacity) and hydropower (40 percent) as illustrated in Figure 14 below.

Figure 14. Additional Capacity (2008 to 2030) by Technology: Andean Zone



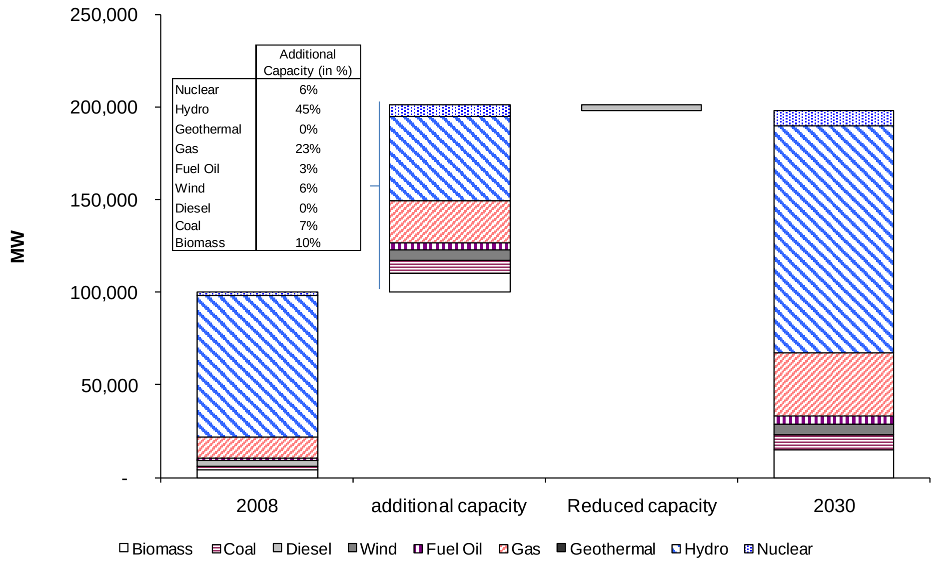
131. **Brazil**: Under the ICEPAC scenario, demand in Brazil increases by more than 160 percent. Figure 15 presents Brazil's generation mix under the ICEPAC scenario. Hydropower-based generation has prevailed historically in Brazil, and this trend is expected to hold under the ICEPAC scenario through 2030. In the latter part of the estimation period, however, the country is expected to experience a decline in available hydropower sources – a factor that will be compounded by a significant increase in overall electricity demand. Despite a continued increase in production from hydro in absolute terms, the aforementioned factors would necessitate an increased reliance on natural gas as well as on coal. Additionally, the country's future plans include the addition of the "Angra 3" nuclear power plant.

Figure 15. Brazil's Electricity Generation Mix (2008-2030)



132. For Brazil, the ICEPAC scenario indicates that hydropower will remain the dominant source in the electricity generation mix and, as indicated in Figure 16, will represent the largest share of the additional capacity - 45 percent. However, although the overall increase in hydropower capacity will be substantial in absolute terms, the share of hydropower in the electricity matrix will actually decline, from 86 percent in 2008 to 68 percent in 2030. Brazil's additional hydropower capacity is still expected to be the dominant contributor to the region-wide increase in the share of hydropower, while the Southern Cone and the Andean Zone are forecasted to follow with 12 GW and 13 GW each. It is also important to mention that the projected increase in biomass-based generation, largely from sugarcane bagasse, will be from around 1 percent to 5 percent between 2008 and 2030.

Figure 16. Additional Capacity by Technology: Brazil



133. **Southern Cone:** Under the ICEPAC Scenario, demand in the Southern Cone will grow nearly 80 percent. Figure 17 shows the Southern Cone's generation mix. The existing high degree of diversification in the region in terms of generation technologies and fuels will become even more dynamic over the period from 2008 to 2030 under the ICEPAC Scenario. The fuel source that increases the most in the ICEPAC Scenario is coal, which rises from 7 percent to 12 percent. Nuclear power accounts for 6 percent of additional capacity as a result of new capacity planned in Argentina. Renewable sources, including wind and geothermal power, are expected to increase modestly, with their share rising from close to zero to 3 percent. This increase is partially driven by an anticipated increase in the Argentinean wind market. The share of coal is expected to nearly double from 7 to 12 percent, largely as a result of the cost minimization assumptions in the model (which do not include global environmental costs). It is important to note that the increases in nuclear, coal, and non-hydro renewables will take place at the expense of hydropower and natural gas, whose shares are estimated to decline. Nonetheless, as illustrated in Figure 18, the Southern Cone's additional capacity is projected to be dominated by natural gas (33 percent) and hydropower (28 percent).

Figure 17. The Southern Cone's Electricity Generation Mix (2008-2030)

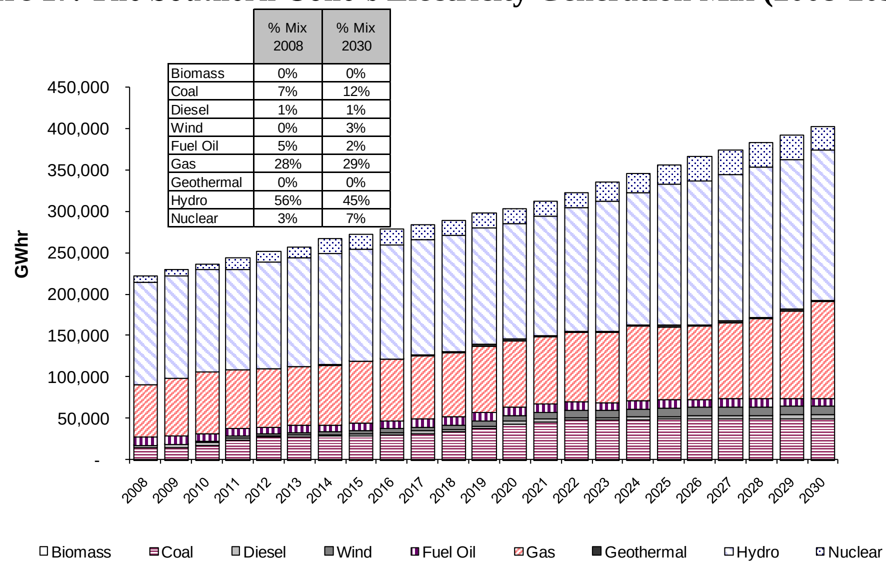
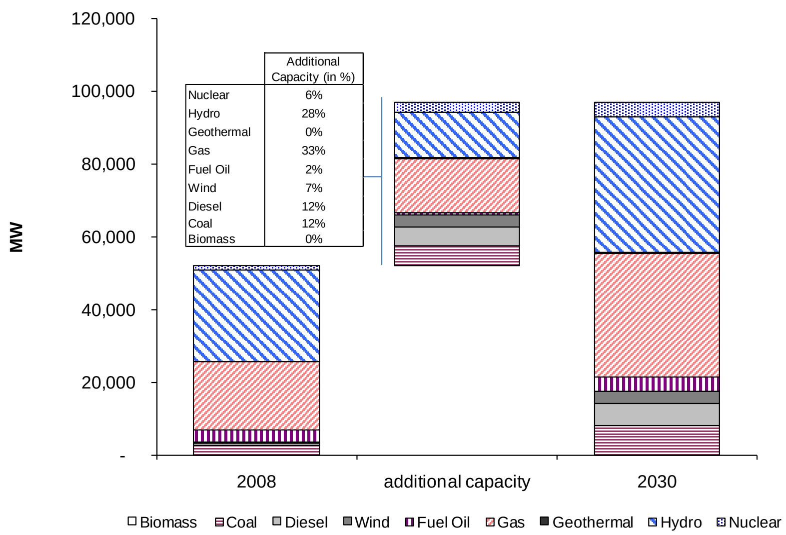


Figure 18. Additional Capacity by Technology: Southern Cone



134. **Mexico.** According to Mexico's official development plan, the bulk of the additional generation capacity will be based on integrated gasification combined cycle (IGCC) technologies (Figure 19). Given the country's natural resource base, natural gas technologies will remain the dominant source of electricity in both the short and the long term. Under Mexico's baseline plan, the share of natural gas remains relatively constant through 2014, and then increases rapidly. The share of natural gas in the electricity generation mix rises by 15 percent (from 50 to 65 percent), with a parallel decline in the share of fuel oil. The share of coal increases marginally, from 12 to 15 percent. The shares of other technologies remain largely proportionate to their 2008 levels (Figure 20).

Figure 19. Mexico's Electricity Generation Mix (2008-2030)

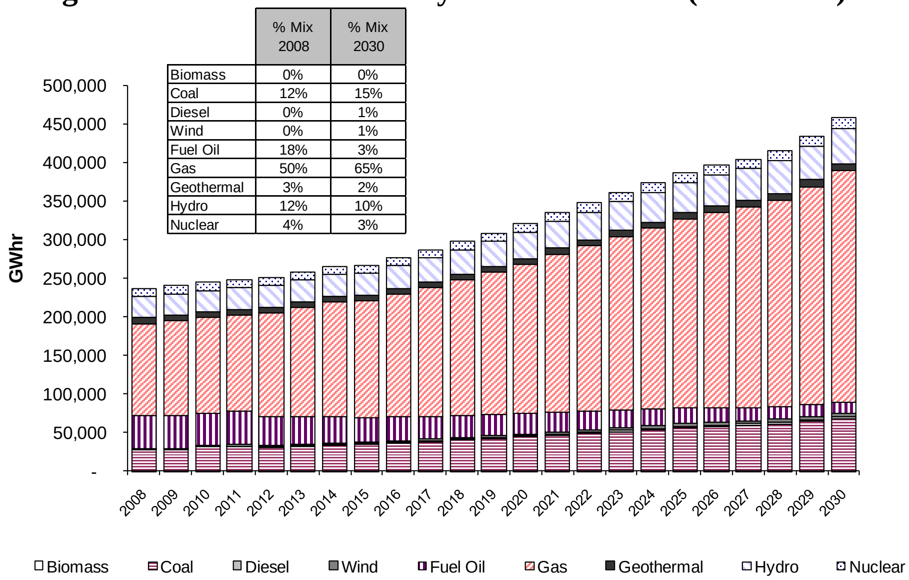
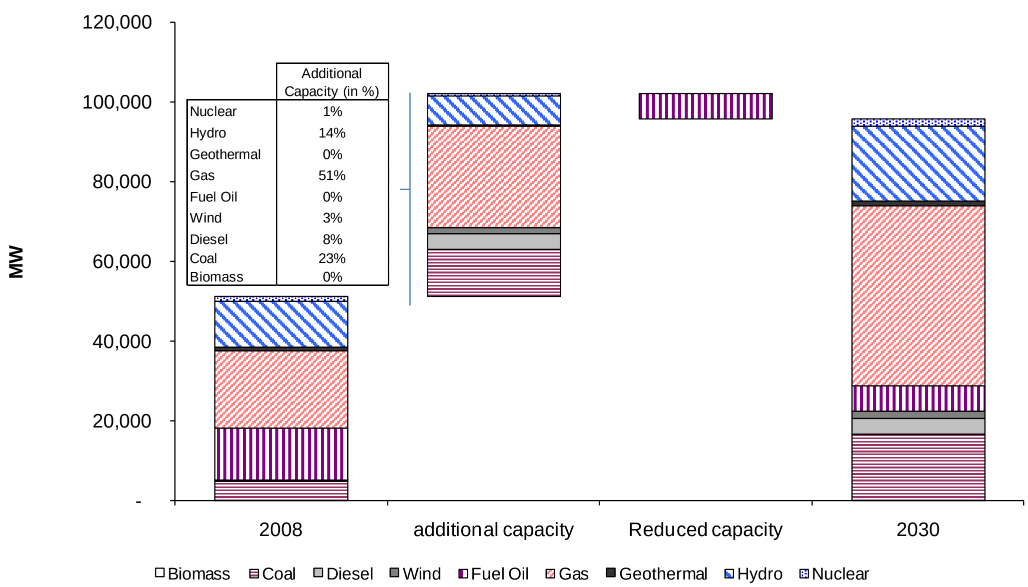
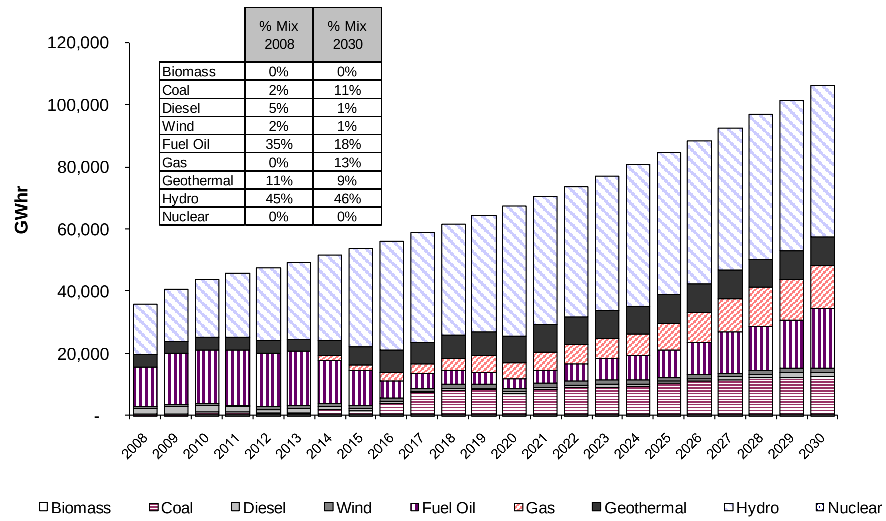


Figure 20. Additional Capacity by Technology: Mexico



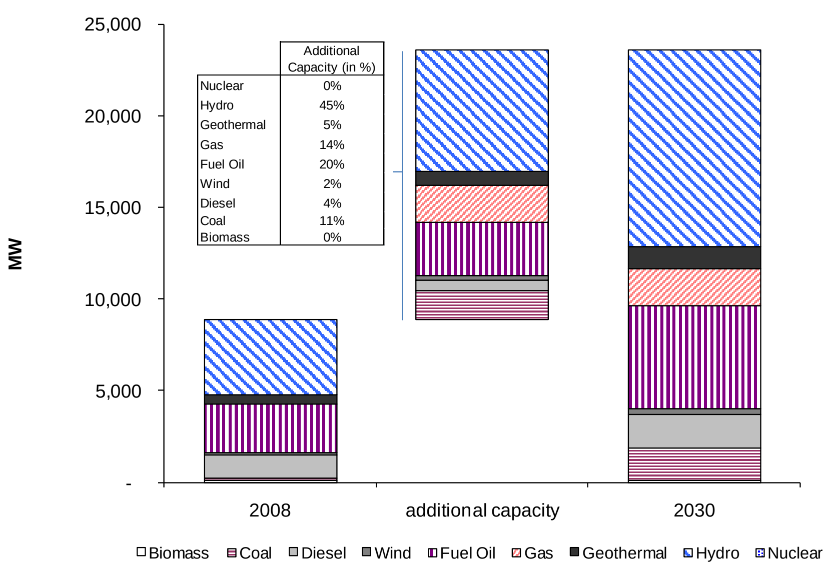
135. **<u>Central America</u>**: For Central America, under the ICEPAC Scenario the share of natural gas increases dramatically between 2008 and 2030 from zero to 13 percent. Central America is also the only sub-region where the share of hydropower marginally increases between 2008 and 2030 (from 45 to 46 percent of total generation). Similarly, the sub-region is expected to increase its reliance on coal, from around 2 percent in 2008 to over 11 percent by 2030. By contrast, the share of fuel oil and diesel is expected to decline significantly, due largely to the preference to diversify away from fossil fuels and due to expected changes in relative generation costs.

Figure 21. Central America's Electricity Generation Mix (2008-2030)



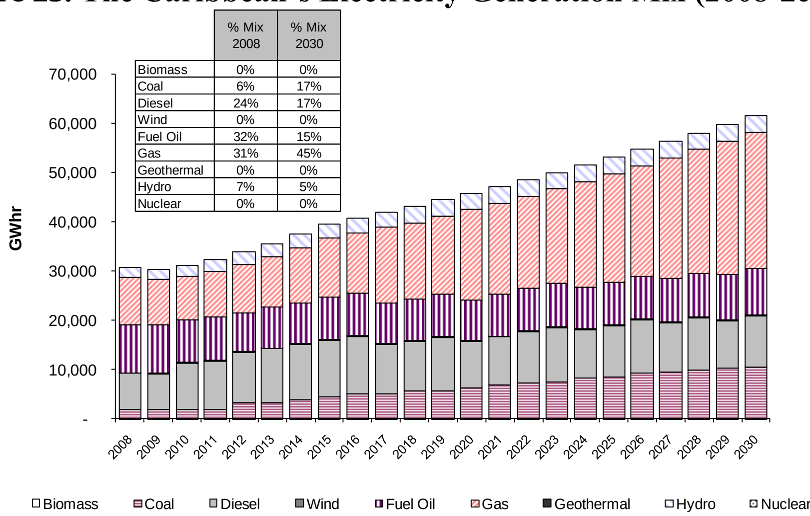
136. As shown in Figure 22, the bulk of generating capacity to be added in Central America between 2008 and 2030 is projected to be largely represented by hydropower (45 percent), with coal, fuel oil and natural gas also playing important roles (11, 20 and 14 percent of additional capacity, respectively). Renewable energy sources, such as wind and geothermal energy, begin to play an increasingly important role in Central America under the ICEPAC scenario, and together represent about 7 percent of the new generating capacity installed by 2030. The potential and prospects for windpower in the sub-region are analyzed in more detail in Chapter IV.

Figure 22. Additional Capacity by Technology: Central America



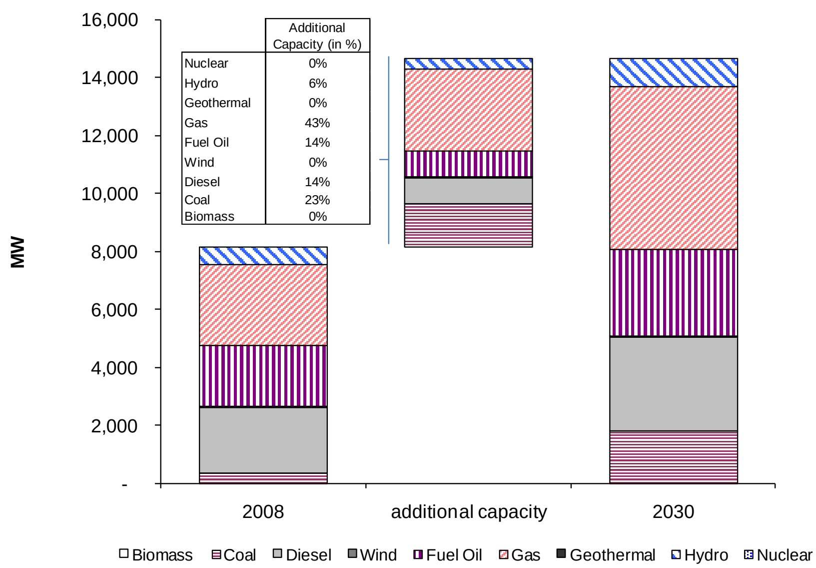
137. **<u>The Caribbean:</u>** In the Caribbean, the generation matrix is expected to remain largely fossil fuel-dependent. Over the entire period, the share of fossil fuel based technologies increases slightly from 93 to 95 percent. One important development under the ICEPAC scenario is an increase in natural-gas based generation in the Dominican Republic. By contrast, the proportion of hydropower in the sub-region is expected to decrease: no additional hydropower (or other renewable) capacity is included in the expansion plans used for this analysis.

Figure 23. The Caribbean's Electricity Generation Mix (2008-2030)



138. Under the ICEPAC Scenario, the Caribbean sub-region continues to rely largely on conventional electricity generation sources with fuel oil and diesel contributing 32 percent of the added capacity between 2008 and 2030 and coal contributing 17 percent. The bulk of future capacity (45 percent) in this scenario is based on gas technologies, driven mainly by the Dominican Republic.

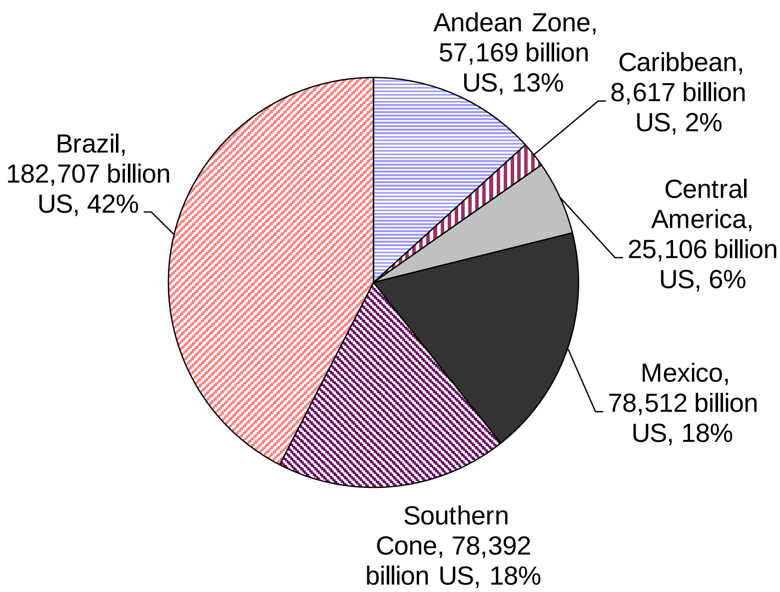
Figure 24. Additional Capacity by Technology: Caribbean



III. Implications for Investment Needs

139. Under the ICEPAC Scenario, the total investment for additional electricity generation infrastructure in LAC reaches US$430 billion over the period 2008-2030. This total is estimated using the additional capacity requirements for each sub-region, and the assumed fixed costs per installed MW for each technology (see Chapter I, Part II for cost assumptions). This amount does not include variable and fuel costs, and would be higher when considering the necessary investments for additional transmission and distribution infrastructure. The distribution of investment requirements by sub-region is as follows: Brazil – 42 percent, Southern Cone – 18 percent, Mexico – 18 percent, the Andean Zone – 13 percent, , Central America – 6 percent, and the Caribbean – 2 percent (Figure 25).

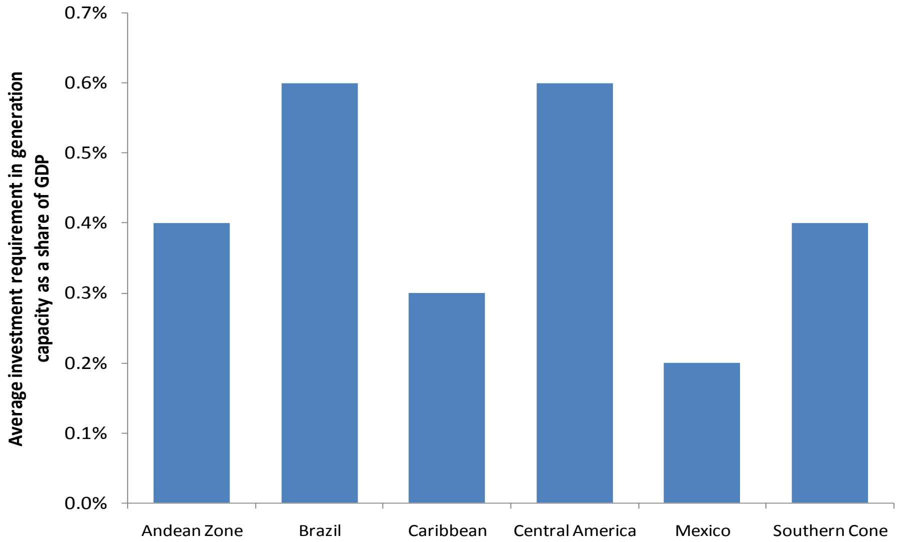
Figure 25. Share of Investment Requirements by Sub-Region



140. In terms of the required investment as a share of GDP (Figure 26), the ICEPAC exercise indicates that Central America and Brazil will have the highest spending requirements, with each requiring an average of 0.6 percent of their GDP per year. This cost estimation does not include fuel costs.[28] The Southern Cone and the Andean Zone would need additional investment amounting to 0.4 percent of GDP per year on average. The Caribbean is projected to require additional investments equivalent to 0.28 percent of GDP. Mexico has the lowest additional investment requirements as a share of GDP (0.20 percent), mainly as a consequence of its current excess capacity.

[28] In the last decade, the cost of oil imports as a share of GDP has shown a slow but steady rise for LCR as well as for the Central American and Caribbean sub-regions. The cost of oil imports in LCR increased from 1 percent of GDP in 1998 to 4 percent in 2008. However, for Central America and the Caribean the cost of oil imports in 2008 was 6 percent and 8 percent respectively. Furthermore, there are specific countries within Central America and the Caribbean where the oil share of GDP was 10 percent or higher in 2008; Guyana at 20 percent, Jamaica at 16 percent and Nicaragua at 10 percent.

Figure 26. Investment as a Share of GDP



IV. Implications for CO_2 Emissions

141. With the ICEPAC Scenario's generation mix by technology, CO_2 emissions from the power sector in LAC would more than double by 2030. In 2008, 244 million metric tons of CO_2 (million $MtCO_2$) were emitted into the atmosphere; by 2030 emissions would reach nearly 569 million Mt.[29]

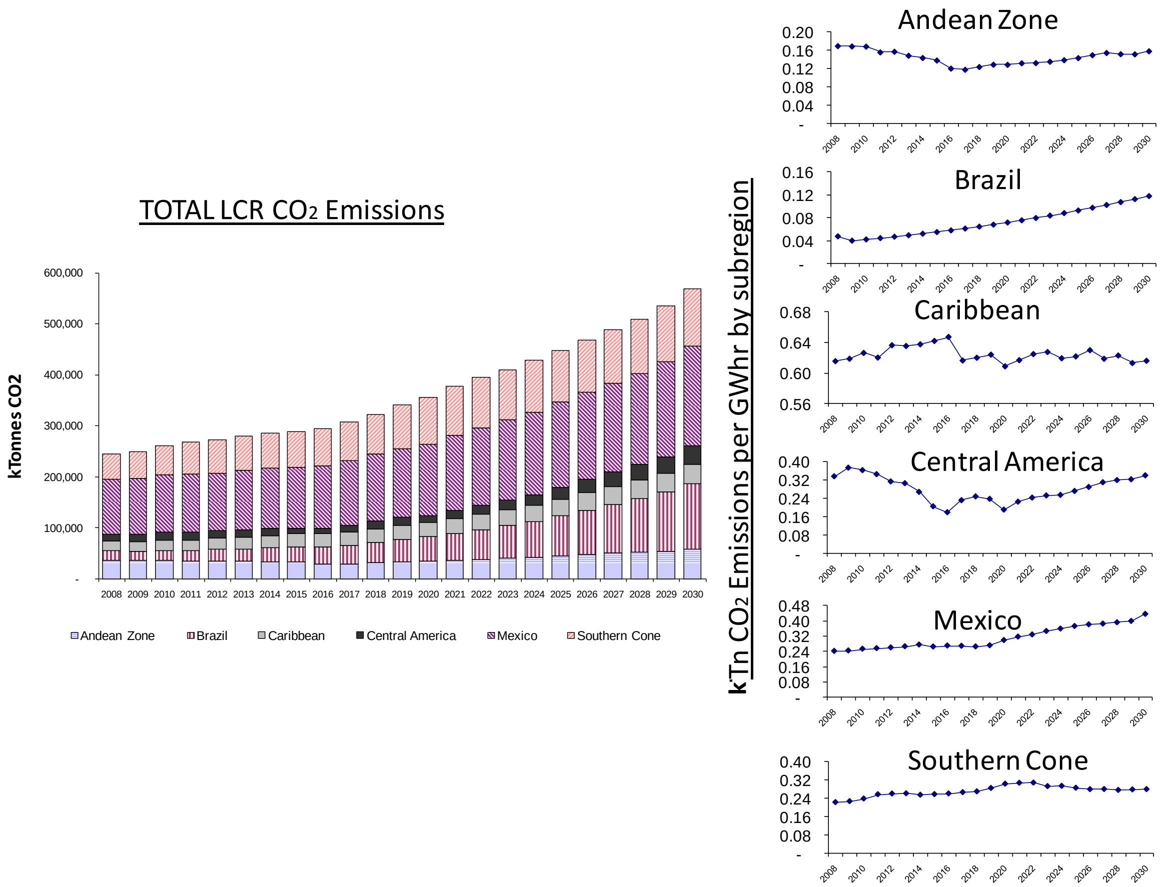
142. The ICEPAC Scenario shows that Brazil and Mexico would emit more CO_2 per generated unit of electricity (GWh) in 2030 than in 2008. Brazil's gradual increase in emissions per GWh during the latter part of the 2008-2030 time period is driven by the diversification of its energy matrix away from hydropower.

143. Coal consumption is projected to increase in Central America under the ICEPAC Scenario, however, there would be a decrease in its reliance on fuel oil for power generation. Combined, the two trends produce a relatively constant amount of CO_2 emissions per GWh. Similarly in the Andean Zone and the Southern Cone emissions levels would vary slightly in the medium term; however, over the entire forecast period, the levels are expected to remain relatively constant.

144. Despite Mexico's strong efforts to diversify its generation mix by adding more renewable energy to the grid, the hydrocarbon sector (mainly gas) would remain the dominant fuel for power generation under the ICEPAC Scenario and the country's overall emissions intensity would increase slightly.

[29] Authors estimation considering the power generated by technology in 2008

Figure 27. ICEPAC Scenario Emissions by Sub-Region



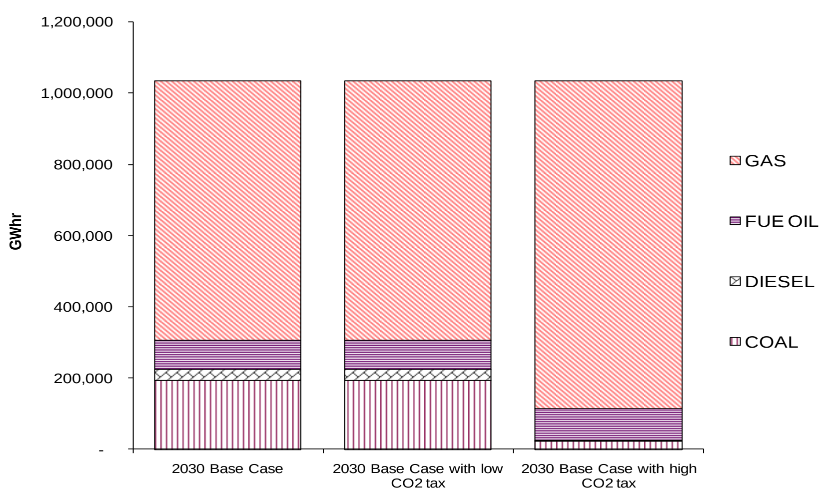
145. It is worth repeating that the purpose of the long-run ICEPAC exercise is to provide a view of the overall regional and sub-regional trends in supply and demand, rather than provide specific numbers for individual countries and individual technologies. The results are based on the assumptions, limitations, and constraints of the modeling exercise. A comparison of the ICEPAC assumptions and those of the latest country expansion plans are provided in Annex 4.

V. Carbon Taxes: Illustrative Impact on Choice among Fossil Fuels

146. Limited sensitivity analysis was undertaken with the model to show the impact of a carbon tax. The sensitivity analysis was limited in the sense that effectively only electricity generation using fossil fuels was allowed to vary with the imposition of carbon taxes. In the model, the projected share of renewables in the generation mix is based on the maximum levels projected in the countries' own expansion plans, and thus is treated as a fixed input into the model. As a result, the sensitivity analysis is a fossil fuel-based generation sensitivity analysis only, rather than a sensitivity analysis inclusive of all technologies.[30] Because the model assumes that the amount of gas, coal, fuel oil, and diesel is unconstrained, the carbon tax does have an impact on how much electricity from these sources is demanded.

147. With these important caveats in mind, the effect of the introduction of carbon taxes on the choice of fossil fuels was considered. As noted in the assumptions about price, the baseline oil price used in the modeling exercise was a real price of US$100 between 2008 and 2030. For the sensitivity analysis two carbon tax scenarios were evaluated: US$20/ton of CO_2 and US$50/ton of CO_2. The conclusion from the analysis (Figure 28) is that a CO_2 tax of US$20/ton does not have any effect in the selection of fossil fuel-based generation technologies. However, with a higher CO_2 tax of US$50/ton, there is sufficient motivation to cause a change in technology selection. Natural gas, the lowest-carbon fossil fuel, increases its share of the generation mix. Coal based technologies almost disappear in the generation mix under the higher CO_2 tax.

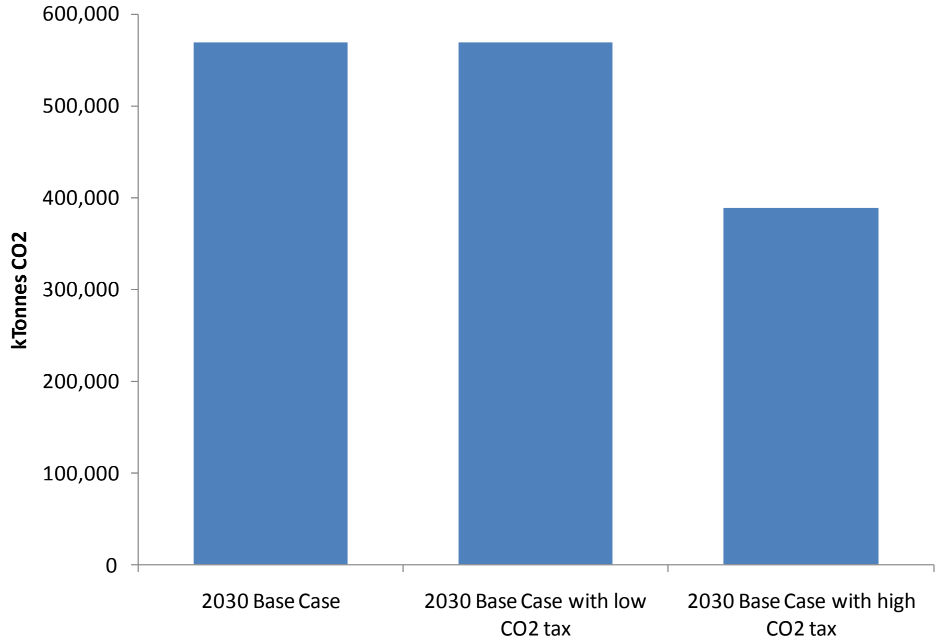
Figure 28. Sensitivity Analysis: CO_2 Tax. Composition Generation Mix (only fossil fuels)



[30] This distinction under the model is most evident when viewing the share of hydropower; namely, the hydropower share in each country's generation mix, similarly to those of nuclear, wind, geothermal, and biomass energy, remains constant irrespective of the oil price and carbon tax, as the baseline scenario already uses the maximum hydropower potential. As carbon taxes are imposed, hydropower becomes relatively cheaper, but the share under the model does not increase because the resource is limited.

148. The amount of CO_2 emitted under each of the carbon tax scenarios was also estimated in the sensitivity analysis (Figure 29). As expected, a carbon tax does in fact reduce the projected carbon emissions. In the scenario with a high carbon tax (US$50/ton), emissions are as much as 30 percent lower than with no carbon tax. The impact of the carbon tax would be expected to be considerably larger if the model allowed for the substitution of renewables for fossil fuels, as opposed to simply switching between fossil fuels of differing carbon intensity.

Figure 29. Sensitivity Analysis: LAC Greenhouse Gas Emissions



CHAPTER IV: ALTERNATIVES FOR MEETING FUTURE ELECTRICITY NEEDS

149. Given the electricity demand and supply picture presented in the Chapter III, it is clear that it will be challenging for the Region to meet its future electricity needs. As noted previously, however, the electricity expansion plans for most countries in the Region (and thus the basis of the modeling exercise in Chapter III) fail to fully account for a number of important options that could increase supply and lower demand. The purpose of this chapter is to briefly outline several of these alternatives. The first section examines the potential for renewable energy sources, including not only an assessment of hydropower resources, which are already a large and important component of current expansion plans, but also potential contributions from non-hydro renewables for power generation including biomass, geothermal, and wind. The second section looks at the potential and benefits of greater cross-border trade within LAC, an option that could also help to catalyze a greater share of the Region's renewable energy potential. The third section discusses the potential for supply-side and demand-side energy efficiency measures.

I. Renewable Energy Potential

150. In 2007, the share of renewable energy in LAC was about 59 percent of the total power generation, the highest percentage of any region in the world. Of this, 57 percent was from hydropower and only 3 percent was from other renewable energy sources. As seen in the previous chapter, the existing national expansion plans are quite aggressive with respect to large hydroelectric projects, but are very modest regarding small hydro and non-hydro renewables. Nonetheless, there are reasons to believe that small hydro and non-hydro renewables could be expanded much more than is envisioned under current country power expansion plans. The Region has large renewable energy resources, ranging from wind in Argentina, to hydroelectricity and biomass in Brazil,[31] to geothermal in Central America, and solar is

[31] In addition to hydroelectricity, Brazil uses a lot of sugarcane bagasse for heat and electricity generation, much of it used by the sugar industry itself. During the 20 year period between 1975 and 2005, the contribution of sugarcane bagasse to Brazil's final energy consumption increased from 4 percent to 11 percent. Bagasse's 11 percent share of total energy production in 2005 compares to the 4 percent of energy provided by ethanol, but is not nearly as widely publicized.

Brazil's Final Energy Consumption
(Million TEP - Tonne Equivalent Petrol - and %)

	1975	2005	% in 1975	% in 2005
Natural Gas	0.364	13.41	0%	7%
Firewood	25.839	16.119	31%	8%
Sugar Cane Bagasse	3.72	21.147	4%	11%
Other renewable sources	0.269	4.249	0%	2%
Electricity	6.005	32.267	7%	16%
Ethyl Alcohol	0.276	7.321	0%	4%
Petroleum sources	42.107	83.683	50%	43%
Other (Charcoal, Steam Coal, Gas Coke, Coal Coke)	5.424	17.515	6%	9%

Source: http://www.mme.gov.br

ubiquitous.[32] Climate change concerns are spurring renewable energy development in many parts of the world, including Latin America, and countries are finding that there are other important benefits of renewable energy, including making use of local resources, energy diversification, and cleaner energy production.

151. The high proportion of renewable energy in LAC, mainly hydropower, has been gradually falling over the past two decades and is projected to decline even more rapidly through 2030. It is illustrative to consider what changes in the future power generation mix would be needed to halt this decline and to maintain the current share of renewable energy through 2030. Two conclusions seem clear: (1) the region must also work hard to achieve the aggressive plans for new hydropower plants, and (2) the use of renewable resources other than hydropower must expand significantly more than is currently projected in country expansion plans.

i. The Role for Hydropower

152. It is estimated that somewhere between 800 and 1,360 TWh of economically viable hydropower potential remains to be developed in the LAC Region. The wide range of values reflects the incomplete information available about inventories of hydroelectricity potential as well as inherent uncertainties in development, which is discussed in the next section. Under the most optimistic estimates, there is enough hydroelectricity to supply the entire Region's projected power expansion needs to 2030. Under the lower hydroelectricity scenario, there would still be enough to supply about two-thirds of the expansion.

153. However, it is highly unlikely that all of the remaining hydropower potential in Latin America would be developed within the next 20-25 years. Hydropower resources are unevenly distributed – many in remote areas – and typically do not match the distribution of demand centers. In addition, hydropower takes time to develop. It is not unusual for a hydropower plant to take ten years from planning to production. Brazil, which has about 40 percent of the region's hydropower resources and currently produces more than half the Region's total, plans to develop almost all of its exploitable potential by 2030. Outside Brazil, however, the situation is quite different. For example, three countries – Colombia, Peru and Ecuador – possess more than half of the total remaining potential but have developed less than 10 percent. Unless the hydropower potential of these countries can be integrated into the Regional Grid, it is unlikely that significant portions of their hydro potential can be developed before 2030 given insufficient domestic demand.

154. In the supply scenarios presented in Chapter III, the share of hydroelectricity in the Region falls substantially, as shown in Table 8. While there is some increase in the share of "other renewables," this does not come close to compensating for the projected fall in hydro. To maintain the 2008 share of renewables in 2030 would require an increase in other renewable electricity of about 150 TWh (or about 6 percent of total generation in 2030).

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[32] At least for the time being, solar's importance for electric power generation in LAC lies in the use of solar photovoltaic panels, primarily for off-grid and rural applications. While PV systems serve a vital social and development purpose, their total contribution to power generation will be limited. As such, solar is not addressed extensively in this report. Nonetheless, solar hot water systems and passive solar designs, while not directly contributing to electricity generation, are universally large in the Region and could offset large amounts of electricity.

Table 8. Baseline Supply Scenario –
LCR's Required Expansion to Maintain the 2008 Share of Renewables

	Generation (TWh)			Share of Generation		
	2008	2030	Δ 2008-30	2008	2030	Δ 2008-30
Hydro	675	1,239	564	58.58%	49.98%	42.50%
Other Renewable	18	102	49	1.59%	4.13%	3.69%
Total Renewable	***694***	***1,342***	***608***	***60.17%***	***54.11%***	***45.80%***
Total Generation	**1,153**	**2,480**	**1,326**	-	-	-
Increase to maintain 2008 share of renewable			150.3			

155. The potential for expanded use of renewable electricity other than hydro has not been extensively studied at a regional level. It is clear that the physical potential of non-hydro renewable resources is far greater than that needed to maintain the overall share of renewables at today's levels until 2030. Seriously considering a substantial increase in the share of renewables by 2030 is also very relevant in light of the commitments that some countries have made to reduce their GHG emissions. The need to expand electricity supply will not stop in 2030. Therefore, for strategic planning, which includes mitigating climate change, it is also important to identify the renewable energy resources that have the greatest potential to compensate for the inevitable decline in the Region's hydropower share of new generation after 2030.

ii. Wind

156. Short of a revolution in solar photovoltaic technology, wind would appear to be the renewable energy resource (aside from hydro) with the largest potential over the coming two decades. Development of this technology could fundamentally change the perception of the role that renewable energy could play in many countries' power expansion plans. A key question has been the extent to which a power system can absorb the inherent variability of the wind resource without excessive costs for back-up. The cost per MWh of the diverse "ancillary services" for the grid to provide back up to wind capacity will vary from one system to another and will tend to increase as the share of wind power in a given system increases. Based on diverse studies published to date (e.g. EERE/USDOE, 2008 and NAS/NAE/2009) a cost of US$5 seems to be a conservatively (high) value to cover all the increased costs of providing backup for wind power when it has reached a 20 percent share of capacity in thermally dominated power systems. Taking 20 percent of system generating capacity as an upper bound with currently deployed grid technology would be equivalent to 9-14 percent of generation output, depending on the capacity factor. Assuming this capacity ceiling and a regional output in 2030 of 2,500 TWh of generation, wind could supply up to 220-340 TWh.

157. Reaching the higher value of wind production by 2030 would be challenging, and would probably require a substantially greater level of electricity trade between countries in the region. Facilitating trade in wind would be an additional reason for the more extensive interconnections already recommended for the optimized development of hydropower in the region. Stronger intra-regional interconnections are desirable to provide complementarity between different wind resources and with hydrologic resources. Greater interconnections would also help address the problem of intermittency. While the output of individual wind turbines will vary considerably

over the short-term, the aggregation of a network of wind turbines over a larger area substantially reduces this variation, as has been shown in several European countries with large wind systems.

158. Based on current estimates of wind resources in the Region, which have not been extensively surveyed, the wind resource base in some countries may be too small to reach 20 percent of capacity. In other countries, such as Mexico and Argentina, there are abundant high quality wind resources. The overall regional potential from high quality resources is probably substantially larger than the 220-340 TWh "ceiling" set from the perspective of system integration. "High quality" means at least "Class 4" (7.0 m/s or more) or even "Class 5" (7.5 m/s) [33] - because higher capacity factors can be obtained, which substantially reduces the cost gap with conventional fossil fuel generation technologies.

The perception that wind energy is costly has reduced the interest in this technology by many regional power sector planners until recently. In the Brazilian energy auction in December 2009, in which 1,806 MW of wind were contracted, the costs for wind power were significantly less than expected. Indeed the average cost of about US$83 per MWh[34] was slightly lower than the average price in some recent auctions in Brazil for fossil-fueled capacity.

159. Estimated at around US$60 per MWh in 2008 (World Bank 2010), Mexico has some of the lowest costs of wind power generation in the world due to its high-quality wind resources. Unlike Brazil, where wind must compete with relatively low-cost hydro, in Mexico wind is quite attractive relative to the costs of electricity produced from natural gas, fuel oil, LNG, and coal.

160. The variations in wind and hydroelectric output are largely independent of each other, which, along with the storage capabilities of hydropower dams, make wind and hydropower resources good complements. This makes it easier to incorporate wind energy in a power system with large amounts of hydropower, as demonstrated by the Nordic power exchange, Nordpool, and may increase the share of generation from wind that can be accommodated by the system.[35] This is why it is important to evaluate hydro and wind resources together – something which is not typically done. In the context of Latin America, where there is already a large share of hydropower and an even larger potential, wind power may be a logical choice for policymakers due to its complementarities with hydropower.

iii. Biomass

161. Biomass, particularly residues from the sugar industry, currently provide a significant amount of electricity in Brazil, and could make a further contribution in Brazil and elsewhere in the future. For countries using biomass from sugar, the potential depends on the amount of sugarcane harvested, the technology which sugarcane mills adopt, and the extent to which "field

[33] Reference is made here to the Battelle Wind Power Classification which is widely used in windpower mapping. The average wind speed cited is measured at a height of 50 meters.

[34] Brazilian R$148.33 per MWh at R$1.80 per US$.

[35] In Denmark, maximum wind generation can provide more than 100 percent of the country's power generation, demonstrating that previous assumptions that the amount of wind in the system would need to be limited are proving not to be true. Spain, has also installed a large percentage of wind capacity, and has not experienced difficulties due to "intermittency." The fact that European countries are interconnected, and that there is a significant capacity of hydropower, has contributed to the absorption of wind and other renewables.

trash" can be used. The current tendency in the sugar industry is to install power generating equipment operating at 67 atmospheres (bar) pressure steam. More aggressive policies, that are becoming standard in Brazil and India, may raise the standard to above 80 atmospheres. At the same time, mechanized harvesting and prohibitions on burning field trash (the tops and other sugarcane biomass that is left in the field after harvest) are opening the possibility of increasing the biomass fuel available for power generation. Table 9 provides an example of how much electricity might be available to the grid in Brazil, depending on the technology, and the degree of use of field trash.

Table 9. Illustrative Matrix of Generation Options from Sugarcane Residues
(Increase in TWh/year sold to the grid from 2006 to 2030) [a]

	67 bar	82 bar	BIGTCC [b]
Assumes use of 1/4 of field trash	54.9	139.4	208.3
Assumes use of 1/2 of field trash	64.9	161.9	251.8
Assumes use of 3/4 of field trash	74.9	184.3	295.2

[a] Values refer to the electricity which could be sold (or "exported") to the grid and refer to the possible increase between 2006 and 2030. Sugarcane output is assumed to increase from 660 million tons to 1.2 billion tons. Each value assumes that all the sugarcane output in 2030 goes to that option.
[b] The technology option "Biomass gasifier with combined cycle gas turbines" is not yet technically proven.

162. If 67 bar technology were used and one fourth of plants used field trash for fuel, an increase of 55 TWh would be possible, compared to about 9 TWh sold to the grid in 2007. This is not far from the trend that is already underway in Brazil. If there were a jump to 82 bar steam technology, and one half of all plants used field trash for fuel, around 160 TWh of power might be available. If there were a technology breakthrough in gasification/combined cycle plants (BIGTCC), sales of electricity to the grid by sugarcane mills could increase more.[36]

163. The values assume a sugarcane industry growing at 2.5 percent/year – roughly the historic rate of the previous decade – and reaching an output of about 1.2 billion tons of cane in 2030. This implies that there is no large-scale expansion of sugarcane for ethanol or to satisfy global sugar demand (which would make more biomass available), and that the biomass residues are not diverted for the production of liquid biofuels from cellulose (making less biomass available for electricity production). Other sources of biomass (residues of the pulp and paper industry, rice, urban solid wastes), which have not been considered here, could also add to the expansion of electricity generation from biomass, though historically they have been relatively small. The important point is that if policies were put in place to promote biomass electricity, such as the ones that have been put in place in recent years in Brazil for sugarcane bagasse, there would likely be increasing supplies of biomass residues available that could be used for electricity generation.

iv. Geothermal

164. Geothermal is a proven technology and is currently commercially exploited in several countries in Latin America, both for direct heat and for power generation. However, the potential

[36] However, this latter breakthrough would seem unlikely to occur in time to substantially affect the output of biomass electricity before 2025.

is very uncertain, especially for the region as a whole. Exploratory drilling has been limited and the range of estimates is quite broad. For example, a review of geothermal in Central America cites a range between 2 and 16 GW, with the most probable values being between 2.8 and 4.4 GW. Extrapolating from the experience in the United States, where there has been a large amount of exploratory drilling, the potential of "conventional" geothermal resources in Latin America might be as much as 300 TWh per year. Of this, perhaps 125 TWh could be developed by 2030, compared with the 11 TWh currently generated.[37] The most important geothermal potential is concentrated along the tectonically active Pacific Rim from Mexico to Chile and in some Caribbean islands. Although capital intensive, geothermal energy has high capacity factors and can be quite competitive. It could be an important component of the power expansion in some of these countries if the commercial environment for developing projects can be improved.[38]

v. Solar

165. Solar electricity generation – mainly concentrated solar thermal – will require breakthroughs to reduce costs if it is to contribute significantly in the next twenty years to grid-supplied electricity. While small-scale photovoltaic (both off-grid applications and for grid-connected building applications, including residential) will undoubtedly grow, it is not clear to what extent this will significantly add to the "other renewables" category of power generation in the Region. Given the high cost of solar thermal, and the uncertainties with respect to large-scale (and grid-connected) solar PV development, no estimates of solar potential for power generation have been made in this report. In the near term, solar hot water applications could contribute significantly in a number of countries, as evaluated in both Mexico and Brazil, and thus replace large amounts of electricity and natural gas currently used for water heating.[39]

166. Considering the potential of the non-hydro renewable resources discussed above, it should be possible to maintain the current regional share of renewables (~60 percent) even if it is not possible to increase the rate of expansion of hydroelectricity as indicated in Chapter III. Against a shortfall of about 150 TWh, the potential of new non-hydro output might be in the following ranges:

***Wind*:**	220-340 TWh
***Sugarcane*:**	55-150 TWh[40]
***Geothermal*:**	25-125 TWh
***Solar*:** probably small for electricity generation (but potentially significant in hot water apps)	

[37] This value is equivalent to what might be developed in the USA by 2015, adjusted to account for land area and a heat flux which is 25 percent higher on average than in the US/Canada, as discussed in Section 4.

[38] If there is a breakthrough in the use of nonconventional geothermal resources, especially from deep hot dry rocks (HDR), the potential output could be substantially increased.

[39] Both the Mexico and Brazil low-carbon studies have estimated very large potential for residential and commercial solar hot water applications, which in Mexico have costs that are competitive with electric and LPG hot water systems. In the Mexico analysis, a large-scale solar water heating program was estimated to be able to reduce CO_2 emissions by around 18.9 million tons per year, which is equivalent to the reduction of about 23 TWh of electricity.

[40] This range assumes sugarcane production of about 1.2 billion tons in 2030 in Latin America as a whole. If there were a large expansion of ethanol production sugarcane production would be substantially higher and hence the associated range of electricity generated. For example, the Brazil Low Carbon Study (World Bank, 2010), discussed in the following section, presents a scenario of 1.73 billion tons of sugarcane in Brazil alone (a gen of 200 TWh).

167. These estimates, especially the high ones, assume concerted policies to promote the development of renewable resources. Nonetheless, the increase in the cost of generation relative to the projected costs outlined in Chapter III, could be quite small. Significantly increasing the regional share of renewables over the next two decades seems to be an economically feasible goal if governments are willing to put in place new policies that promote renewable energy resources, including the possibilities for greater interconnection and trade of electricity.

vi. A Closer Look at Hydropower

168. With roughly 58 percent of the 60 percent of renewable energy coming from hydropower in LAC, the undeveloped hydropower potential in LAC warrants a closer look. Table 10 provides estimates of the hydro potential in the countries of the region and compares it with the hydro capacity existing in 2007. The source of the information is OLADE, with adjustments made in the cases of Brazil and Argentina, where additional information is available.

Table 10. Hydroelectricity Potential Compared with Hydroelectricity Generation in 2007

Country	**Existing Hydro**		**Total Potential**		**Existing/Potential**	
	Capacity GW	Output TWh	Capacity GW	Output TWh	Capacity %	Output %
Argentina [a]	9.94	31.06	40.40	130.00	25%	24%
Bolivia	0.49	2.32	1.38	4.81	35%	48%
Brazil [b]	76.94	374.38	251.49	1.213.00	31%	31%
Chile	5.37	22.80	25.16	26.56	21%	86%
Colombia	8.53	43.02	96.00	420.48	9%	10%
Costa Rica	1.41	6.77	6.41	28.08	22%	24%
El Salvador	0.47	1.74	2.17	9.48	22%	18%
Guatemala	0.78	3.01	4.10	15.21	19%	20%
Haiti	0.06	0.48	0.17	0.50	36%	97%
Honduras	0.50	2.30	5.00	21.90	10%	11%
Jamaica	0.02	0.17	0.02	0.11	90%	162%
Mexico	11.34	27.04	53.00	232.14	21%	12%
Nicaragua	0.10	0.31	1.77	7.74	6%	4%
Panama	0.85	3.87	3.28	14.38	26%	27%
Paraguay	8.13	53.71	12.52	54.82	65%	98%
Peru	3.23	20.03	58.94	385.12	5%	5%
Rep Dominicana	0.47	1.68	2.01	8.80	23%	19%
Surinam	0.19	1.36	2.42	10.60	8%	13%
Trinidad & Tobago	0	0	0	0	0	0
Uruguay	1.54	8.07	1.82	7.95	85%	102%
Venezuela	14.60	80.81	46.00	201.48	32%	40%
Total	**147**	**694**	**646**	**2.911**	**23%**	**24%**
Subregions						
Central America	*4.1*	*18.0*	*22.7*	*96.8*	*18%*	*19%*
Caribbean[41]	*0.6*	*2.4*	*2.2*	*9.4*	*25%*	*26%*

Source: OLADE, 2008 (except Argentina and Brazil)

[41] Excluding Cuba

169. The numbers presented in Table 10 represent an overall optimistic view of hydropower potential. In addition, the way hydropower potential is defined does not take into account the technical and economic feasibility of exploiting that potential. In some countries the OLADE estimates may present more realistic or restrictive estimates of hydropower potential than others. Thus, there is great uncertainty about the potential size of the ultimate hydropower resource.

170. Nonetheless, it is clear that the remaining exploitable hydropower potential in the region will be significantly less than the value shown in Table 9. Within the timeframe of 20-25 years, the feasible limit is even lower, although the major part of the remaining potential could be developed within this period. For illustrative purposes, this report assumes a minimum of 50 percent development of the potential in Table 9 and a maximum of 70 percent for Latin America as a whole. Appropriate ranges for individual countries will be different and are not discussed here. Within this range, the quantity of remaining hydropower potential would be:

- *50 percent development -* ***802 TWh***
- *60 percent development -* ***1084 TWh***
- *70 percent development -* ***1366 TWh***

171. These values can be compared with hydroelectricity production in the Region in 2007, which was 649 TWh. The potential does not cover the category of small hydro for most countries. While the definition of "small hydro" differs, and the inventories of potential are less complete than for larger plants, the inclusion of small hydro is unlikely to increase the overall hydropower potential by much more than about 5 percent.42 Table 11 presents a different version of hydropower potential that conservatively assumes that only 50 percent of the remaining untapped potential in each country is viable.

172. It is important to distinguish between ultimate development and that which would be feasible in the next 20-25 years. Even the lowest scenario (50 percent of potential) would represent more than a doubling of the current capacity, which was built over a period of more than 50 years. A factor to consider is that more than half of the potential outside of Brazil is in countries which today use 10 percent or less of their resource (Colombia, Ecuador, Peru, and the Guyanas). Relying on the internal markets of these countries alone would be insufficient to absorb roughly half of their hydroelectricity potential over the next 20-25 years.

[42] For example, in Brazil, small hydro (> 30 MW) technical potential was estimated to be about 17.5 GW (EPE, 2007), compared with 252 GW of larger hydro**.** Brazil's definition of "small hydro" is larger than in most countries. Note also that small hydro plants tend to have a lower capacity factor than larger plants (i.e., fewer kWh of output per kw of capacity.

Table 11. Hydroelectricity Potential Compared with Hydroelectricity Generation in 2007, Assuming 50 Percent of OLADE's Potential

Country	Existing Hydro		Total Potential		Existing/Potential	
	Capacity GW	Output TWh	Capacity GW	Output TWh	Capacity %	Output %
Argentina [a]	9.94	31.06	20.2	65	49%	48%
Bolivia	0.49	2.32	0.69	2.405	71%	96%
Brazil [b]	76.94	374.38	125.745	606.5	61%	62%
Chile	5.37	22.8	12.58	13.28	21%	86%
Colombia	8.53	43.02	48	210.24	18%	20%
Costa Rica	1.41	6.77	3.205	14.04	44%	48%
Cuba	0.04	0.12	0.325	0.65	12%	18%
Ecuador	2.06	9.04	11.875	48.385	17%	19%
El Salvador	0.47	1.74	1.085	4.74	43%	37%
Guatemala	0.78	3.01	2.05	7.605	38%	40%
Guyana	0	0	3.8	9.82	0%	0%
Haiti	0.06	0.48	0.085	0.25	36%	97%
Honduras	0.5	2.3	2.5	10.95	20%	21%
Jamaica	0.02	0.17	0.01	0.055	90%	162%
Mexico	11.34	27.04	26.5	116.07	43%	23%
Nicaragua	0.1	0.31	0.885	3.87	11%	8%
Panama	0.85	3.87	1.64	7.19	52%	54%
Paraguay	8.13	53.71	6.26	27.41	65%	98%
Peru	3.23	20.03	29.47	192.56	11%	10%
Rep Dominicana	0.47	1.68	1.005	4.4	47%	38%
Surinam	0.19	1.36	1.21	5.3	16%	26%
Trinidad & Tobago	0	0	0	0	0%	0%
Uruguay	1.54	8.07	0.91	3.975	85%	102%
Venezuela	14.6	80.81	23	100.74	63%	80%
Total	**147**	**694**	**323**	**1455.5**	**46%**	**48%**
Central America	*4.1*	*18*	11.35	48.4	36%	37%
Caribbean[43]	*0.6*	*2.4*	1.1	4.7	55%	51%

Source: Authors with data from OLADE, 2008 (except Argentina and Brazil)

[43] Excluding Cuba

vii. Case Studies of Renewable Energy Potential

173. Detailed "low-carbon" development studies for two of the major countries in the LAC Region have recently been completed by the World Bank. The renewable energy results of studies for Brazil and Mexico are presented below to provide an indication of the potential size of the untapped renewable energy resources. Based on these and other detailed country studies, it is possible to infer that the renewable energy potential in other countries of the Region is likely to be significant, and that the current planning estimates understate the potential.

a. Brazil

174. For the Brazil low-carbon study (World Bank 2010), the renewable energy-based mitigation options that were analyzed include wind, sugarcane bagasse, and solar energy for water-heating systems. For wind generation, the national energy plan (PNE 2030) foresees a ten-fold increase in capacity—reaching 4.7 GW—and supplying about 1.5 percent of Brazil's electricity in 2030. This estimate assumes that a number of barriers can be overcome, including high upfront investment costs and the short-term difficulty of procuring equipment. Both of these problems relate in part to the current structure of public auctions for renewable energy in Brazil which includes a 70 percent domestic content rule (under the PROINFA program), which has delayed the scheduling of wind power projects and raised costs given the small number of local manufacturers of turbines and components. Assuming these barriers can be overcome, and based on projections made by the Brazilian Wind Energy Association, the low-carbon study estimates that the expansion of installed wind capacity could be as high as 15 GW by 2030. With regard to sugarcane bagasse cogeneration, the study suggests that around 40 GW of installed capacity would be available by 2030 that could provide electricity to the grid—compared to 6.8 GW in the reference scenario—corresponding to about 100 TWh of electricity being generated in 2030.

175. The PNE 2030 already assumes that hydropower will represent close to 70 percent of power generation in 2030, implying an unprecedented increase in the production of hydropower, and virtually the full exploitation of Brazil's hydroelectricity potential. The low-carbon study explores the option of increasing hydropower production even further. By interconnecting the electricity systems of Brazil and Venezuela, whereby the existing and the planned hydropower plants located in hydrologically-complementary regions in the Amazon Basin would be linked, there could be an exchange of 21.7 TWh of power between the two countries and the displacement of thermal plants that are currently used for providing power during the low periods in both countries (so-called "valley filling").

176. In terms of the financing needs for implementing a low-carbon strategy in the electricity sub-sector, investment requirements for 2010-2030 amount to US$66 billion: US$52.3 billion of investment would be required for sugarcane bagasse cogeneration, US$12.9 billion for wind-based generation, and about US$0.45 billion for the transmission line connecting Brazil and Venezuela.

177. The study outlines several policy and regulatory measures that would help increase the participation of renewable energy sources in Brazil's electricity mix. For hydropower, the simplification of the environmental licensing process is considered critical. For bagasse and

wind-based generation, an important barrier is the cost of interconnection with the sometimes distant or capacity-constrained sub-transmission grid, with a key question being the responsibility for financing the grid connection. The study recommends the ambitious development of a smart-grid program as a way of optimizing the contribution of distributed wind- and bagasse-based electricity generation potential. For expanding the use of solar energy, it is recommended that there be a substantial reduction in the industrialized products tax on solar energy products, such as for solar thermal hot-water collectors and solar photovoltaic panels.

b. Mexico

178. The Mexico low-carbon study (Johnson and others 2010) evaluates 40 low-cost interventions across key emissions sectors in Mexico, developing a low-carbon scenario through 2030 and assuming no major improvements in technology or reductions in technology costs. Among the renewable energy technologies that were evaluated for Mexico were technologies offering baseload (geothermal) as well as intermittent (wind), and peak generation (biomass, most small hydro, and cogeneration).

179. According to the baseline scenario, even at a net cost of CO_2 of as little as US$10/ton, additional low-carbon energy technologies, such as small hydro, wind, biomass, geothermal, and cogeneration, could replace much of Mexico’s fossil fuel generation. Under a low-carbon scenario, the contribution of renewable energy increases substantially, from 1.4 to 6 percent for wind—primarily by developing wind farms in Oaxaca, with additional wind capacity by 2030 of 10.8 GW; from 2 to 11 percent for geothermal power (7.5 GW); and from 14 to 16 percent for hydropower (2.7 GW). Other renewable and non-conventional energy sources in the low-carbon scenario for Mexico include cogeneration from PEMEX facilities (3.7 GW), industry (6.8 GW), sugar mills (2 GW), and other biomass (5 GW) would provide 13 percent of new power capacity, and through fuelwood co-firing in existing plants (2.1 GW). The projections were based on calculations that compare the net costs of each renewable energy technology with the costs of the displaced fossil fuel capacity (mainly natural gas and coal).

180. Relative to the baseline, an estimated US$10 billion of net investment would be required to implement the low-carbon scenario in the power sector. The corresponding required new investment in wind-based generation over the 2010-2030 timeframe would amount to US$5.5 billion, while US$1.1 billion would be required for biogas electricity, US$2.63 for small hydropower, US$11.8 for geothermal power, US$3 billion for cogeneration in Pemex, and US$3.7 billion for cogeneration in industry.

181. The Mexico low-carbon analysis assumes that the majority of investment (under IPPs) in the power sector would be undertaken by the private sector, with the public sector (through the state monopoly CFE and regulatory agencies) continuing to play a major role. To reach the increased contribution of renewable energy in Mexico’s electricity mix, the low-carbon analysis identifies a number of policy changes that would need to be implemented, including removing the regulatory restrictions that currently exist for small-scale and renewable energy technologies. Other key obstacles to renewable energy development in Mexico include the absence of externalities for new fossil fuel-based power generation and the lack of capacity payments for intermittent energy sources such as wind.

II. Regional Trade and Cross-Border Integration

182. Regional electricity trade could play an important role in allowing LAC to meet its growing electricity needs in a cost-effective way, and could also help to foster the expanded use of Regional energy resources. By linking countries and regions, interconnections allow the optimization of electricity supplies, which can improve efficiency and may reduce the need for domestic investment in high-cost generation capacity and back-up. As discussed in the previous section, the development of large-scale hydroelectric, wind, and other energy resources could benefit through increased trade by expanding the market into which the projects would sell. This section discusses the benefits of trade as well as the barriers that inhibit greater regional market integration. The section also summarizes the basic characteristics of the regional electricity market operating in Latin American countries today and the new and planned interconnections that could allow greater electricity trade. The section also presents the results of an electricity trade simulation exercise for Central America that provides preliminary estimates of the benefits of regional trade.

183. As shown in Chapter II, there are already a number of electricity interconnections in LAC and new ones are being developed. Nonetheless, it has also been seen that electricity trade plays a very small role in meeting supply needs in the region. In order for trade to increase, it is important to overcome countries' fears that supply contracts will be broken and energy supplies interrupted. While there are examples in the Region – both for electricity and natural gas – where trade has been interrupted, such cases are the exception rather than the rule, and it is important to move forward with clear principles and rules so as to reduce the risks associated with regional trade.[44]

i. Benefits of Cross-Border Integration

184. In principle, regional interconnection and electricity trade between countries is an attractive approach for expanding the supply of electricity.

- Trade can enhance the reliability and security of the local network by linking it with a larger grid and a greater number of generation sources, thus increasing the diversity of the generation system.
- Trade may reduce generation costs due to economies of scale associated with power generation from larger facilities. Optimizing capital requirements for the electricity sector can free up capital resources for other investments and improve the domestic fiscal situation.
- Interconnection (and the ability to acquire power through trade) allows individual countries to have lower "reserve" requirements, which reduces the need (and cost) of investing in reserve power capacity.

[44] As a part of the Initiative for the Integration of South American Infrastructure, or IIRSA there is an important hydro electrical project under construction. The Madeira River project is an initiative to integrate Brazil, Bolivia and Peru. The project consists of two hydroelectric dams: Santo Antonio (installed generating capacity 3,150 MW) and Jirau (installed capacity 3,300 MW).

- Trade may allow more competition in open markets as it increases the availability of electricity from different sources at varying costs. In addition, interconnections between markets may allow for some convergence of electricity prices, since the connected areas can function as a single market. Interconnection may lead to an important reduction in variable costs as countries do not need to import expensive fuels.
- In the case of seasonal renewable resources such as hydropower, interconnection allows the linking of basins with different hydrology. This increases the firm energy that can be supplied by the same set of dams. This balancing of variable renewable resources also applies to wind and even biomass energy.

185. Despite the potential benefits of interconnections, electricity trade, and cross-border electricity projects (defined as those that rely on multi-country markets), there have been significant political and regulatory barriers in LAC that have hindered trade. When planning and beginning a project across borders, there are likely to be different technology standards, regulatory regimes, pricing policies, environmental concerns, and legal frameworks. More significantly, there can be different views about investment costs and how they are shared. Nevertheless, such issues can be resolved if there is a clear economic and commercial motivation behind the project that benefits all countries. Other issues that can affect project development are market changes, the emergence of new sources of fuel or electricity, and demand shocks, such as a financial crisis, that may dramatically alter the conditions for trade. Ultimately, the greatest uncertainties tend to be connected with political decision-making, and these may be particularly difficult to predict or address.

186. In the context of climate change, regional interconnection could expand the share of renewable energy in the electricity supply mix, and this benefit of regional trade deserves more attention than it has traditionally received. Brazil's experience in expanding its hydropower resources is instructive. Brazil, which has 40 percent of the estimated hydro resources in the region, is responsible for 54 percent of the region's hydropower generation. While about 84 percent of Brazil's electricity comes from hydro,[45] that share is only 27 percent in the rest of the region. And under the ICEPAC scenario, this differential would be maintained. The large disparity in the development of hydropower does not appear to be due to Brazil's superior hydro resources (indeed the remaining resources outside Brazil are probably substantially larger). A more likely hypothesis is that by integrating at a continental scale (almost unique in the world), Brazil has been in a better position to exploit hydropower resources than the relatively small and fragmented markets in the rest of Latin America.

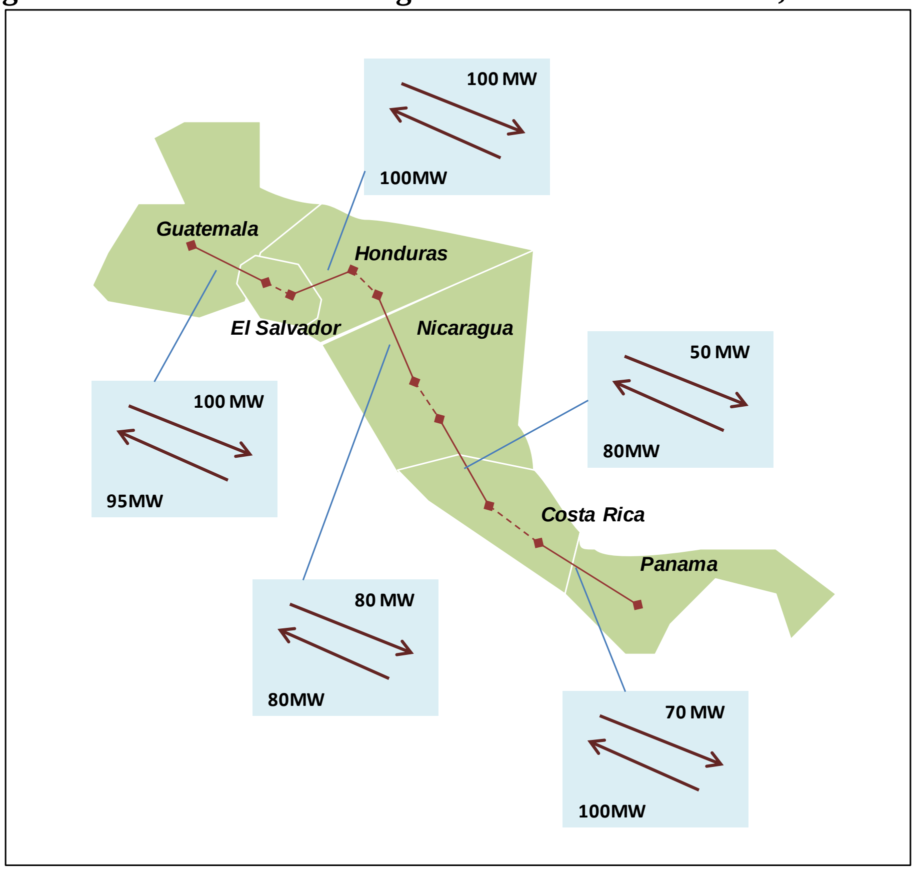
187. In Latin America there are three primary clusters in which electricity trade currently occurs: (i) Mexico and Central America; (ii) Colombia, Ecuador, Venezuela, and (iii) Brazil, Paraguay, Argentina, and Uruguay.

[45] The differences are even more dramatic if Brazil's imports of Paraguay's share of Itaipú are taken into account.

ii. Mexico and Central America Interconnection

188. In 1996, the Central American countries agreed to the creation of the Regional Electricity Market ("Mercado Eléctrico Regional, MER") through the Framework Treaty for the Central American Electricity Market. To support the MER, the Treaty also created a regional regulatory commission (Comision Regional de Interconexión Electrica, CRIE), a regional system operator (Ente Operador Regional) and a company owning the grid (Empresa Propietaria de la Red, EPR). Figure 30 illustrates the existing Central America regional transmission grid (Red de Transmisión Regional, RTR), as it was defined during the transition period up to the commissioning of SIEPAC (Sistema de Interconexión Eléctrica Paises de America Central). The system consists of individual 220 kV interconnection links connecting the power systems of neighboring countries and is used to provide short-term international power exchanges.

Figure 30. Central America Regional Interconnection Grid, 2006



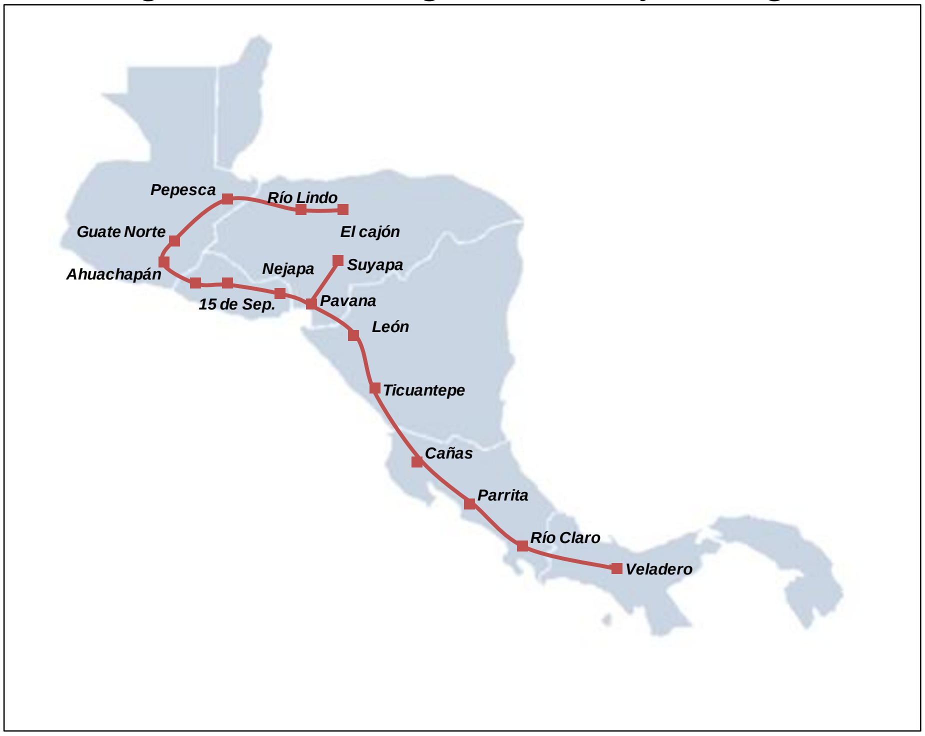
Source: Authors based on CRIE

189. To reinforce the regional interconnection, the main transmission companies of Central America (and ENDESA - Spain, ISA – Colombia and CFE - Mexico) are participating in the regional transmission company, EPR, through the SIEPAC project which is in charge of the reinforcement of the RTR. The system consists of a 230 kV interconnection system with 300 MW of transmission capacity between the countries. The project interconnects the six countries

in Central America into a single system. The countries of the region agreed to strengthen the interconnectivity of the region and create a standard regulatory framework for the power sector. Figure 31 illustrates the SIEPAC project.

190. In 2007 the interregional trade through SIEPAC represented less than 2 percent of the total supply to the market. Even though the system has not had a significant impact on intraregional trade, the project itself is a significant achievement for the region from a political, regulatory and technical point of view.

Figure 31. SIEPAC Regional Electricity Exchange



Source: Authors with information from SIEPAC

191. The connection with Mexico provides a link to Mexico (and the rest of North America) that can help buffer the variability of electricity production in individual SIEPAC countries.[46] The Mexican Secretariat of Energy (SENER) and the Ministry of Mines and Energy of Guatemala (MME), entered into an agreement in 2003 to develop the interconnection project, which was opened in October 2009. The initial connection consists of a 400 kV transmission line, 103 km in length with associated substation expansions. INDE has already contracted with CFE the purchase of 120 MW, and it is expected that the remaining capacity of the line would be traded in the Guatemalan Opportunity Market. By connecting to Mexico, SIEPAC establishes a link northwards to a major electricity producer.

[46] Mexico has a connection with Belize for a number of years, providing small (from Mexico's perspective) but important (from Belize's perspective) amounts of power. The fact that Belize already benefits from the interconnection with Mexico is one of the main reasons why Belize is the only country is Central America that is not part of the SIEPAC system.

iii. Colombia - Panama Interconnection

192. The Colombia-Panama interconnection connects Central America with its southern neighbors, with the potential to tap low-cost hydroelectricity and other energy resources in the future. The Colombian and Panamanian authorities agreed to construct a 614 kilometer power transmission line at 250 - 400 kV (HVDC) and with capacity of 300 MW and possible expansion to 600 MW. Investment costs are estimated at US$210 million, including the required expansion of the substations. The project is under construction and commissioning is expected to take place in 2013. The execution of this project opens the possibility for the physical connection of the electricity markets between the Andean Countries and Central America and Mexico.

iv. South America Integration Potential

193. The electrical interconnections in South America are concentrated in two clusters. The northern cluster includes Colombia, Ecuador and Venezuela, while the southern cluster includes Brazil, Paraguay, Argentina, and Uruguay. Currently, a capacity of more than 20 GW is available for regional trade in the southern cluster. More than half of that capacity is attributable to Itaipú (12.6 GW). Itaipú, Rincon-Garabí and Yacyretá interconnections concentrate more than 80 percent of the total capacity available for interregional trade in the southern cluster. The three facilities link Brazil, Argentina, and Paraguay.

194. Table 11 summarizes the basic characteristics of the bi-national power plants in South America and Table 12 shows the international power exchanges among interconnected countries in 2007. International power interchanges reached 52 TWh in 2007, of which 45 TWh (around 90 percent) were associated with Argentina and Brazil's power purchases from the Yacyretá and Itaipú bi-national power plants.

Table 12. Bi-National Power Plants in South America

Countries	Name	River	Installed Capacity	Status
Br-Py	Itaipu	Parana	12.600 MW	Operating
			1.400 MW	(additional capacity)
Ar-Uy	Salto Grande	Uruguay	1.890 MW	Operating
Ar-Py	Yacyreta	Parana	2.100 MW	Operating
			3.100 MW	(additional capacity)
Ar-Br	Garabi	Uruguay	1.500 MW	Evaluation
Ar-Py	Corpus	Parana	3.400 MW	Evaluation

Source: CIER, 2008[47]

[47] The 1400 additional MW of Itaipu has been operating. On the additional 3100 MW of Yacireta, 2000 MW is unused existing capacity and 1100 is additional capacity under construction.

Table 13. International Power Interchanges in South America (2007, GWh)

		EXPORTER							Total
		Argentina	Brasil	Colombia	Ecuador	Paraguay	Uruguay	Venezuela	Imp.
IMPORTER	Argentina		1.999	-	-	7.479	971	-	10.449
	Brasil	5		-	-	37.936	34	537	38.512
	chile	1.628	-	-	-	-	-	-	1.628
	Colombia	-	-		38	-	-	6	44
	Ecuador	-	-	877		-	-	-	877
	Uruguay	574	215	-	-	-		-	789
	Total Exp.	2.207	20214	877	38	45.415	1.005	543	52.299

Source: CIER

195. Latin America has a diversity of interconnections for the regional trade of electricity as shown in Table 12. Electricity trade requires not only physical investments in transmission systems but regulatory processes governed by regional, as opposed to national, rules. The experience of success and failure with the interconnection agreements is quite rich and diverse, and is useful for planning and promoting future projects in the region. Even though the possibilities for new interconnections are ample and have the potential to boost interregional trade, there are obstacles to execution. Most countries in the region have been reluctant to give up national regulatory processes for the pursuit of potential regional gains. The possibility for successfully expanding trade and collaboration among countries depends critically on the real and perceived economic and political costs and benefits.

v. Risks and Potential Barriers to Cross-Border Integration

196. Economic feasibility is a necessary condition for implementation of cross-border electricity trade projects but it is not sufficient. A recent study (Soreide, Benitez and Haladner 2009) shows that the economic rationale for a proposed interregional electricity supply project is a critical condition for success. In addition, there are other conditions that need to be met to overcome non-market obstacles. Factors that may help with the implementation of interconnection projects are an appropriate regulatory framework and ultimately, political will.

197. Cross-border long-term investment involve for a high degree of uncertainty to both governments and investors. In the case of Latin America, cross-border electricity supply agreements have always been subject to changes in incentives and conditions for trade, such as shifts in political regimes, in political priorities, and in the economics of the projects themselves. Such changes apply to both supply and demand in long-term interregional trade agreements.

198. On the diplomatic front, frictions between countries often impact trade agreements including cross-border electricity contracts. This was the case with natural gas contracts in South America, where diplomatic disagreements made some countries more vulnerable. Furthermore, because of such risk and the associated implications on energy security, countries opt for developing further domestic energy supplies, which are not necessarily the most efficient option (even accounting for geopolitical risk). To ease such risks, deeper and broader diplomatic relations would be required, though some of the risk might persist. Table 14, presents a summary of the potential obstacles surrounding cross-border electricity supply projects.

Table 14. Potential Obstacles to Cross-Border Electricity Exchanges

- **Changing motivations:** strategic factors influence choice of buyer or seller
- **Cost-recovery**: the debt burden from the project becomes politically difficult
- **Financial crisis:** critical changes in the macro-economic environment
- **Free-rider problems:** one part involved avoids its share of investment costs
- **Inappropriate regulatory framework:** weak regional or bilateral context for collaboration
- **Incomplete contracts:** different views on contingencies not covered by a contract
- **Incentive problems**: those responsible for risk are not the same as those who bear the burden
- **Institutional framework:** red tape cause obstacles to monitoring efforts, maintenance and trade
- **Market changes:** alternative sources of energy available or higher demand in exporting country
- **Political instability:** a shift in political regime leads to changes in the commitment to the deal
- **Private agendas in politics**: private agendas influence the design and function of the project
- **Sunk cost**: terms of the deal are altered after investments have been made
- **Vested interests:** those who benefit from status quo oppose cross-border collaboration
- **Weak property rights and contract enforcement:** deals are not upheld as intended and contracts not enforced

Source: Soreide, Benitez and Haladner (2009).

199. Interregional trade would allow countries to diversify their sources of power generation in addition to the gains from trade associated to the specialization from the most efficient producers. Moreover, a regional approach could reduce the emission of GHGs as the share of renewables and low-GHGs would increase through greater integration. Current interconnections and those being actively studied (as shown in Figure 31) would only tap a fraction of the complementarity of hydro resources inherent in the fact that South America straddles the Equator. An example of an "inter-hemispheric" connection was evaluated in the Brazil Low-Carbon Study. In the case study example, the Simon Bolivar hydro plant (formerly Guri) on the Caroni River would be linked to the proposed Belo Monte plant on the Xingu River, both with a capacity over 10 GW. The two rivers' seasonal hydrology are almost a mirror image of each other and the interconnection would effectively link the two national grids. A preliminary estimate is that almost 22 TWh could be exchanged with gains for both sides, including substantial financial benefits and reductions in GHG emissions.

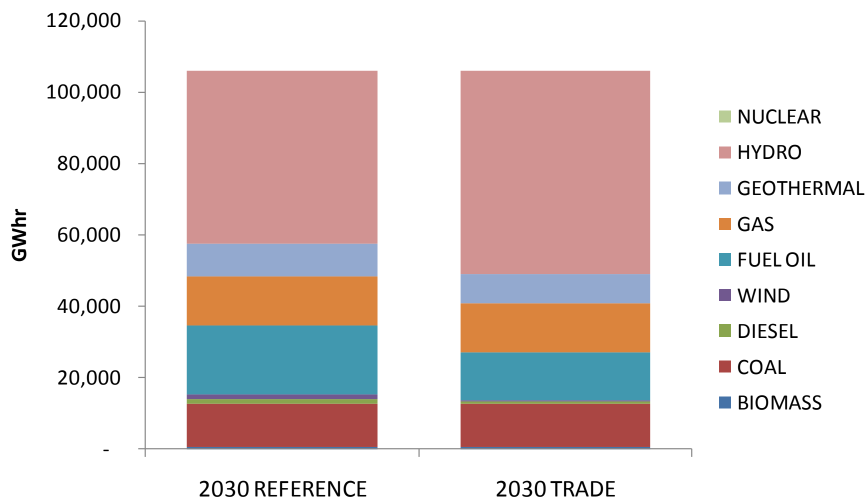
200. A key determinant of the success of an inter-regional approach to the cross-border supply of energy is the regulatory framework; which among other things involves technical factors (such as types of voltage, frequency in place), price structures, market operations, and openness to private sector investment, contract enforcement, and monitoring and environmental aspects. In fact investors look for compatible regulatory frameworks in the pursuit regional projects. Differences in prices and variations in the rules across countries make the harmonization of interconnection protocols in the power sector difficult.

vi. Evaluating the Impact of Interconnections: An Example from Central America

201. What are the likely consequences of increased electricity trade? This section presents an estimate of the impact of interconnecting the electricity grids of Central America based on the results of the modeling exercise carried out in Chapter III. This exercise evaluates the supply and demand investment requirements of the unified sub-region of Guatemala, Honduras, Nicaragua, El Salvador, Costa Rica and Panama. In the scenario with no trade, each country minimizes the costs of meeting its electricity requirements by itself. In the trade scenario, a cost minimization exercise is conducted for the Central America region as a whole, essentially assuming that the sub-region behaves as one market. One of the key assumptions of the trade scenario is that the SIEPAC interconnection transmission system is complete. Other assumptions within the model, including fuel prices, electricity demand, technology costs, and resource availability, are the same for both scenarios.

202. Figure 32 shows the results of the trade scenario for Central America. A principle factor that changes the results for the trade scenario is the economies of scale of integrating the sub-region. This leads to a mix of technologies that is different from the generation mix without trade, and which leads to lower average generation costs as a result of trade. The modeling exercise indicates that Central America would have a higher percentage of hydropower under a trade scenario, and a lower percentage of fuel oil plants. The increased hydropower comes mainly from the hydropower resources available in El Salvador, Nicaragua and Costa Rica. If Central America were integrated with both its southern and northern neighbors (something not carried out in the exercise), there would be even more room for trade and presumably lower costs of supply. The sub-regional market scenario would also allow for a decrease in the redundant, recurrent expenses that countries face by maintaining higher reserve capacity, and would also lower fuel imports (and the variability that has accompanied fossil-fuel prices).

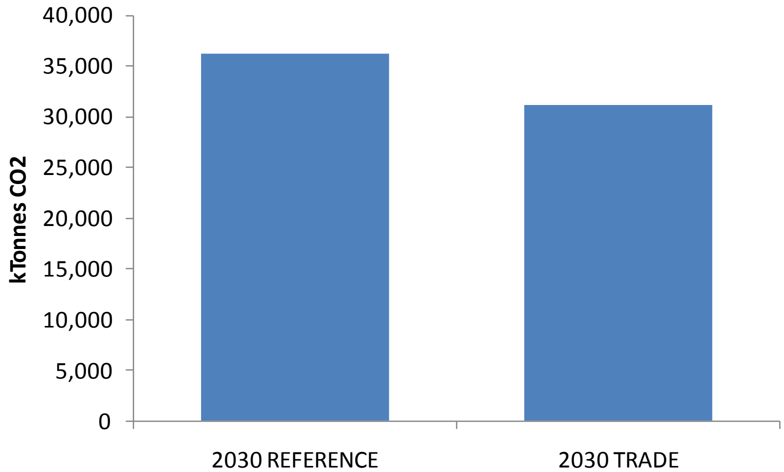
Figure 32. Central America: The Impact of Trade



203. Another implication of the results is that the sub-region would become less carbon intensive over the forecast period. Figure 33 illustrates the levels of CO_2 emissions for both the

base case and the trade case. Emissions from the trade scenario are lower largely due to a higher share of hydropower in the trade scenario's generation mix.

Figure 33. CO2 Emissions in the Baseline vs. Trade Case



III. Energy Efficiency

204. Of all the options for meeting future electricity supply, energy efficiency measures are almost always the cheapest (from a financial and economic perspective). And despite the growing awareness of, and focus on, energy efficiency benefits, there remains a gap between energy efficiency potential and implementation. This section presents a brief review of some of the supply-side and demand-side energy efficiency options available in LAC, including estimates of how much energy efficiency might contribute to the future electricity supply needs of the region.

i. Supply-Side Efficiency: Options and Potential

205. Supply-side energy efficiency in the electricity market essentially encompasses all the measures that can help conserve or save energy in the production, transport, and delivery of electricity.[48] Over the past few decades, countries in the Region have had diverse experiences implementing reforms and programs aimed at improving supply-side energy efficiency in the electricity sector. For instance, during the 1990s Argentina was able to achieve efficiency improvements in the production, transmission, and distribution of electricity as a result of the electricity reform process, which contributed to the country's power and gas sector being among the most competitive in the region. A range of supply-side efficiency measures are given in Figure 34.

206. Investments in power transmission, including with private sector participation in construction and maintenance of lines, offer a large potential for energy savings. For example, power transmission improvements through the development of superconducting power transmission cables are estimated to help achieve energy savings of up to 40 percent for high

[48] For comparison, load management only changes the time when the energy is consumed (Lovins 2005).

load connections, while the most important losses in such cable systems occur due to thermal insulation and cooling machine inefficiencies. Especially in countries where the location of power generation is far from the demand centers, even a small percentage reduction in power transmission losses over thousands of kilometers can save considerable amounts of energy, and provide a more cost-effective alternative than investments in additional generation.

Figure 34. Measures for Increasing Supply-Side Energy Efficiency

Power generation	Plant rehabilitation/refurbishment; Improved operation and maintenance practices and better resource utilization (higher plant load factors and availability) in existing generation facilities; New thermal power plants (combined cycle, supercritical boilers, IGCC); Fuel switching; Co-generation, or combined heating, cooling, and power (CHP);[49]
Power Transmission & Distribution	Efficient and low-loss transformers; High-voltage (HV) lines; Improved insulation of conductors; Use of capacitors; Improved metering systems and instrumentation; Sub-station rehabilitation; Smart Grids, system optimization.

207. In geographically large countries, improving the efficiency of transformers and reducing the instances of overloading has proved important for enhancing the quality of power supply, as has the use of Ultra High Voltage (UHV), due to its suitability for delivering large quantities of power with very little loss. Transmission systems intended for long distances – in countries such as Brazil – generally need to incorporate both advanced hardware and software technologies to improve power transfer and increase the utilization of the facilities already in place, thus avoiding additional transmission capacity investments and environmental impacts.

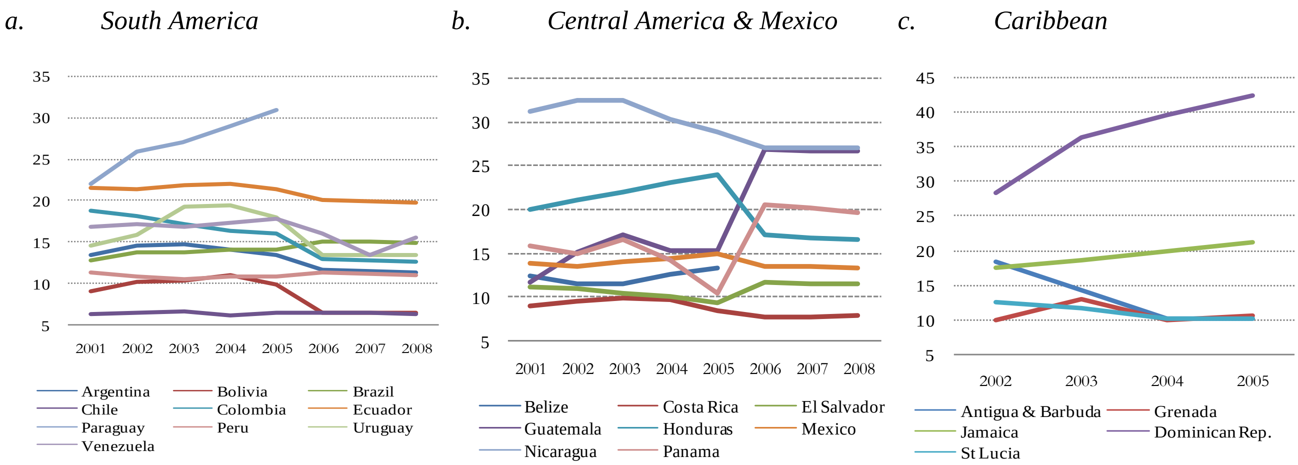
208. The LAC Region's countries differ markedly in terms of both the absolute levels and the trends in supply-side energy efficiency and, particularly, in the electricity losses and associated costs due to the inefficiencies in power transmission and distribution. As shown in Figure 35, electricity distribution losses in Latin America range from as low as 6-7 percent in Chile to about 15-20 percent in most other countries of the sub-region. Also for the region's biggest electricity consumer, Brazil, distributional losses in the past seven-eight years have fluctuated between 15 and 20 percent. Paraguay has been an outlier among the countries of the region in terms of the absolute level of distribution losses, where the figures have shown a steep increase over the past several years, going from about 22 percent in 2001 to above 30 percent in 2005.

209. The average energy efficiency of electricity distribution in most of Central America and Mexico has been in a range similar to the rest of the Region. Electricity losses have been relatively stable over the past five years, ranging from about 10 percent in Costa Rica to about 17

[49] CHP uses upward of 80 percent of the useful energy in fuel, compared to 35-50 percent of the useful energy in the case of power generation alone (Expert Group on Energy Efficiency 2007).

percent in Guatemala and Panama. Exceptions from this general trend are Nicaragua, which has had high though somewhat declining levels of distribution losses, and Honduras, which has experienced a continuous increase. The electricity sector in Mexico has been characterized by overall distribution losses that compare to most other countries in the region. At the same time, however, its level of technical losses– at about 10 percent—is relatively high, compared not only to countries of similar average per capita incomes, such as Brazil and Chile, but also to Paraguay and El Salvador. Before being taken over by CFE, the electricity utility Luz y Fuerza del Centro (LFC), serving the greater Mexico City area, had distribution losses several times higher than the national average and among the worst in the world (Komives and others 2009). The company was liquidated in the fall of 2009 in large part due to the high losses and large subsidies that were required from the federal government to keep LFC afloat.

Figure 35. Total Distributional Electricity Losses in the LAC, %

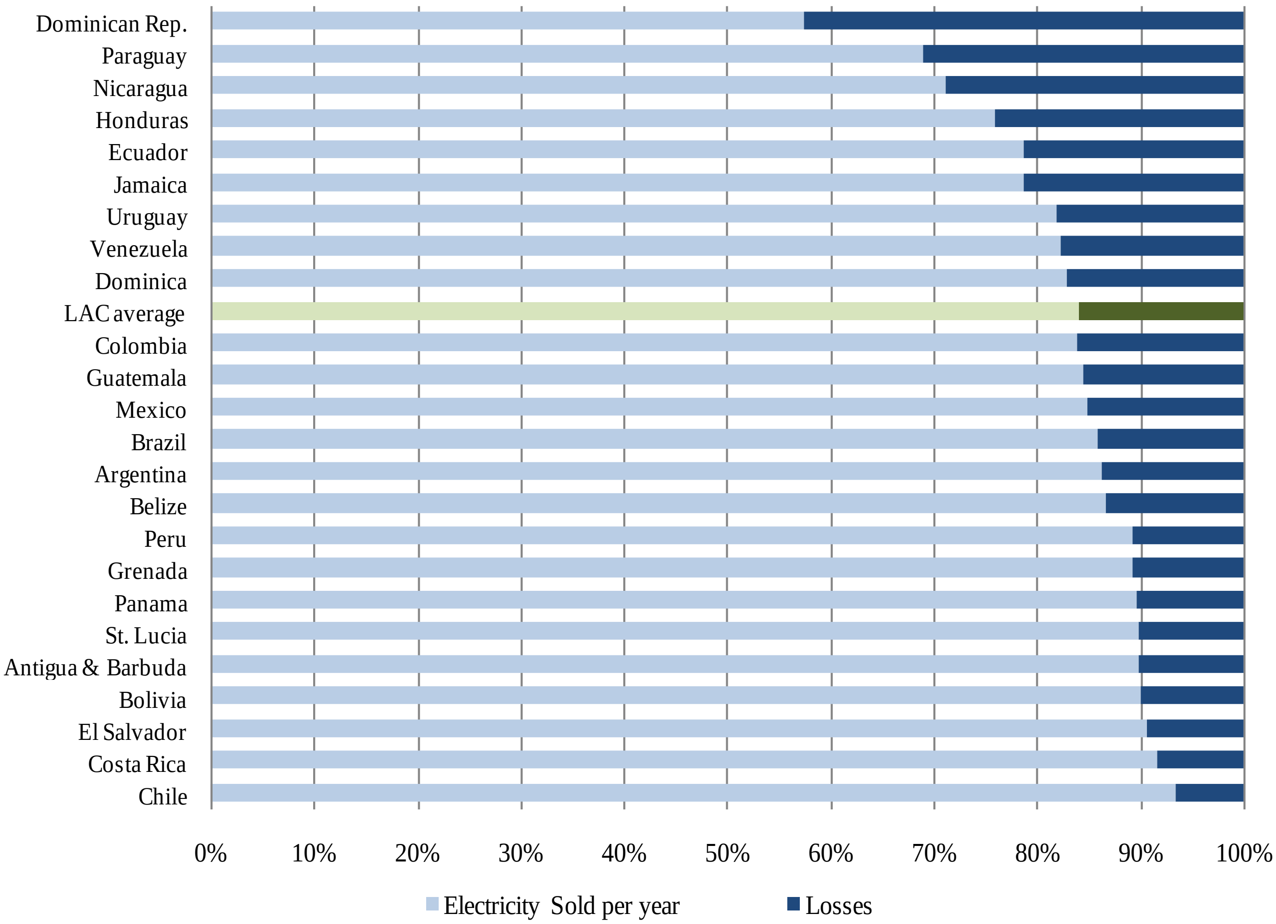


Sources: Own calculations based on OLADE 2009 (for years 2006-2008); World Bank, *Benchmarking Data of the Electricity Distribution Sector in the Latin America and Caribbean Region 1995 – 2005*(for years 2001-2005)

210. In the Caribbean sub-region, the level of absolute distribution losses are comparable to the Southern Cone and Central America, with the exception of the Dominican Republic, where losses are about 10 percent higher than in the rest of the region, and have been increasing in recent years for which data is available. Similarly, in Jamaica, where the electricity sector represents about 23 percent of overall energy consumption, losses have been on the rise, although there are indications that they may be on the decline.[50]

[50] The country's Ministry of Energy projects a reversal in the trend by 2010 and a reduction in total losses to about 18 percent by 2020, compared to 24 percent in 2008. (Watson 2009).

Figure 36. Annual Electricity Sales and Distributional Electricity Losses, 2005



Source: Own calculations based on World Bank, *Benchmarking Data of the Electricity Dist Sec in the LAC 95-05*

211. In addition to transmission and distribution improvements, there can also be large energy efficiency savings by improving the technology and operations and maintenance of generation facilities. Due to the higher average efficiency of natural gas plants (at 40 percent, on average) compared to coal- and oil-based plants (34 percent and 37 percent, respectively), the average efficiency of electricity generation in the LAC Region—with natural gas as the dominant fuel for thermal plants in most countries —is already higher than in regions relying on coal and oil (IEA 2008a). Nonetheless, there is typically large potential for improving the efficiency, as well as increasing the effective capacity, of both thermal and hydro plants by retrofitting key power production or auxiliary equipment. Large "repowering" investment opportunities have been identified in major countries in the region, including Brazil and Mexico, with costs that are often a fraction of those of new power capacity.

212. Cogeneration – using the waste heat from electricity or heat-only applications to generate electricity – has great potential in many countries. In Mexico, an estimated 80 percent of the cogeneration in industry (oil refining, petrochemicals, food processing, pulp and paper, sugar, textile and glass industries) has not been developed. Cogeneration in Pemex's facilities alone is estimated to be more than 3,600 MW, or more than 6 percent of Mexico's total installed electricity capacity (Johnson and others 2010).

ii. Demand-Side Efficiency: Options and Potential

213. In addition to being the least-cost way of meeting future electricity needs, increasing the efficiency of energy end-use has been identified as the single most effective means of contributing to the goals of energy supply security, improved affordability of energy services, and environmental sustainability (IEA 2008). In countries with effective and conducive regulatory systems, energy efficiency programs (such as through bulk procurement of efficient lighting and appliances) have proven effective in significantly reducing the cost of demand-side energy efficiency measures. Efficiency programs run by electric power utilities have been introduced in a number of countries and in many cases have resulted in significant reductions in electricity bills and for deferring investments in new generation capacity for power utilities. There are a range of ways to promote demand-side energy efficiency. One of the key principles that works in favor of demand-side EE is that the cost of conserved energy is lower than the cost of new power generating capacity.

214. As summarized in Figure 38, numerous instruments are available for improving demand-side energy efficiency. These include national energy efficiency resource standards (utility energy saving targets), energy codes for new buildings, appliance standards, national and state-level energy efficiency tax incentives, programs to promote comprehensive energy retrofits to existing buildings, energy efficiency labeling and disclosure programs, and support for the dissemination of solar water heating and efficient appliances. As outlined above, these measures generally fall into two categories: (i) those that are aimed at changing the load pattern and encouraging less demand at peak times and peak rates, and (ii) those implemented to reduce demand through more efficient processes, buildings, or equipment.

Figure 37. Demand-side energy efficiency instruments (World Bank 2009b; UNIDO)

Load management	Demand charges; direct load control; demand response programs; tariff incentives and penalties (e.g. power factor penalties, time-of-use rates, real-time pricing);	
End-use energy efficiency	*Industrial*	Energy audits/performance measurements; energy efficiency financing, services provided by ESCOs; combined heat and power (co-generation); fuel switching; waste heat recovery; efficiency improvements of industrial motors/drive systems; equipment regulations/standards; monitoring and verification of system-wide energy flows;
	Buildings	Integrated building design; building codes; building retrofits; envelop measures (insulation, windows); efficiency standards for lighting; use of passive lighting; efficient pumping and space/water heating/cooling; application of solar water heaters and passive space heating; timers and temperature controls on electric hot water cylinders; reduced standby losses in appliances and equipment; energy management systems;
	Residential	Building codes; appliance standards; labeling; consumer education; improved cooking stoves; improved district heating (e.g. through boiler rehabilitation, pre-insulated piping, compensators, pumps, heat exchangers)
	Public	Efficient street lighting; efficient water pumping and sewage removal systems; combined heat and power; "watergy" (i.e. energy and water efficiency in water supply and wastewater treatment); internal information campaigns to promote energy efficiency and best practices in the operations of public agencies;[51]
	Agriculture	Efficient irrigation pumping/drip irrigation; efficient agricultural equipment.

[51] For example, campaigns to promote energy savings are a requirement for public entities in Peru (Aita 2008).

215. Load management is used by utilities to relieve constraints on distribution and transmission networks and, in the long term, can defer the need for new power capacity. By redistributing the load, such as by moving consumers from peak to off-peak hours, utilities can lower the costs of producing electricity by deferring the use of high-cost peak-load. Since peak-load plants in some countries rely on diesel or fuel oil, load management can also lower the carbon intensity of generation. However, unlike energy efficiency, load management does not directly result in less electricity being generated. Load management programs, although generally easier to implement than other DSM strategies that are not under the direct management of utility companies, are largely short-term responses that have direct financial benefits to the utilities. But load management is a small part of the total demand-side potential, and a combination of load management programs with end-use energy efficiency programs can raise the effectiveness of both approaches and lead to greater demand reductions.

216. Increasingly used as part of a comprehensive utility management strategy, DSM has generally been feasible whenever its implementation cost has been lower than the cost of new power supply. However, because improving energy efficiency, and thus reducing the amount of electricity sold, is usually contradictory to the business interests of electricity supply utilities,[52] DSM programs have generally been successful only where the utilities are relatively responsive to public sector mandates, and when energy efficiency efforts are promoted in combination with such measures as power factor correction and load-management efforts that are clearly in the utilities' financial interests (Taylor and others 2008).

217. ***Standards and Labeling.*** In developing and transition economies, programs to enhance energy efficiency across all sectors have primarily focused on the establishment of energy performance labels for motors and other mass-produced equipment, certification of energy managers and auditors, energy audits of government buildings, and assistance to industry in energy use benchmarking. For setting appliance labels and standards, the strategies typically consist of minimum consumption standards for specific equipment; prohibition of manufacture, sale, and import of equipment not conforming to standards; and mandatory labeling to enable consumers to make informed choices.

218. Appliance labeling is a common instrument for mainstreaming energy efficiency in the household sector in OECD and many middle-income countries, as it allows buyers to take into account not only the initial cost of the appliance, but also the otherwise invisible factor of appliance energy consumption. The range of appliances labeled across countries varies—typically including refrigerators, freezers, and air conditioners—as do the types of labels used. The endorsement label, also used in Brazil and currently under consideration in Uruguay, typically defined as voluntary, is used to indicate products that belong to the most energy-efficient class or meet predetermined standard or eligibility criteria. Comparative labels, by contrast, are primarily mandatory, and allow customers to judge the energy efficiency and relative ranking of all products that carry the label. In the LAC Region, this type of label is common in Colombia, Costa Rica, and Mexico (Harrington and Damnics 2004).

[52] Among the exceptions are where DSM programs help reduce peak load requirements, where DSM reduces consumption among non-paying customers, or where there is a shortage of new power capacity and the DSM program can free up power and allow the connection of new customers.

219. ***Industrial Sector End-Use Efficiency.*** Energy use in the industrial sector accounts for about 40 percent of the world's electricity consumption. Industrial energy efficiency thus offers an important opportunity for developing countries with expanding industrial infrastructure to increase their competitiveness by adopting best energy efficiency practices from the outset in new industrial facilities. Since about 65 percent of electricity in the industrial sector is being consumed by electric motor systems, energy efficiency improvements in this area have large potential for energy savings. For example, the use of variable speed drives, efficient pumps, motors, compressors and fans presents an energy savings potential of about 40 percent. In the aluminum industry, which involves the energy-intensive production of aluminum from bauxite, large energy savings—as much as 90 percent—can be obtained by making aluminum from recycled products.[53]

220. Industrial facilities (much like the buildings sector) have rarely achieved energy efficiency through the competitive pressures of the marketplace alone. Moreover, unlike in the case of commercial and residential buildings, the presence of individual energy-efficient components, such as pumps, boilers, compressors, does not ensure that entire industrial systems will be energy-efficient, with major losses occurring due to equipment misapplications and the energy conversion process.

221. An alternative solution is a policy of voluntary commitments for energy efficiency improvement by industry, where the government and industry agree to negotiated targets for up to ten years, allowing for planning and implementation of strategic energy efficiency investments. Other alternatives include industrial energy management standards and requirements for companies to set energy efficiency goals and to adopt appropriate practices. Such mandatory standards for energy management are currently in place in countries such as Denmark, Sweden, and Ireland. In the future, the dissemination of energy-efficient industrial technologies to other countries can be expected to accelerate through international standardization of testing procedures and norms pursued by the International Organization for Standardization (ISO).

222. ***Residential Sector End-Use Efficiency.*** The various energy and electricity end-uses in the residential (and buildings) sector can be ranked according to their importance in terms of their share in total energy use as well as according to their potential for energy efficiency improvements. According to estimates for OECD economies (IEA 2008), space heating is by far the most important energy user in the residential sector accounting for 53 percent of household energy end-use in 2005, followed by appliances (21 percent), water heating (16 percent), and lighting and cooking (5 percent each).

223. Global experience shows that very little of the efficiency potential in the residential sector has so far been captured, and that it is unlikely to be tapped based on market-based incentives alone. Some of the reasons why households do not undertake "profitable" energy efficiency measures include: (i) a lack of information on the benefits of energy-saving lights and appliances, (ii) principal-agent problems, where the beneficiaries (residents) of energy efficiency improvements are different from those who make the investments (landlords); (iii) the higher up-

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[53] Greenpeace International & the European Renewable Energy Council. 2007. *Energy [Re]volution: A sustainable world energy outlook*. January.

front cost of more energy-efficient equipment and the lack of financing of such equipment; (iv) the fact that building designers and developers under-invest in energy-efficient designs and systems to lower "first cost," but which raises life-cycle costs to occupants; and (v) electricity subsidies to residential customers, hindering investments in efficient building retrofits and end-use technologies.

224. Additional barriers to demand-side energy efficiency, applicable not only to the residential sector but across all consumer groups and common in the LAC Region, include: limited technical and risk management skills in the energy efficiency field; limited incentives for power distribution companies to promote decreased electricity consumption; inadequate or absent policy/regulatory incentives for energy efficiency, including rigid procurement policies and regulatory frameworks that fail to allow utilities to finance investments in energy efficiency by allowing customers to repay through their electricity bills.

225. Efficiency improvements are also typically inhibited by a lack of access to commercial financing for energy efficiency projects. While the ESCO[54] industry has developed in many industrialized countries for the purpose of financing energy efficiency investments, there is a general absence or underdevelopment of ESCOs in developing and middle-income countries. Part of the reason why ESCOs have not arisen to the same extent in developing countries is due to the legal and contract-intensive nature of the ESCO business. Where ESCOs do exist, they often have limited access to capital and operate as fee-for-service energy efficiency consultants rather than financing the investments themselves.

226. ***End-Use Efficiency Potential.*** A number of industries in LAC have significant potential for further efficiency improvements. For instance, in Brazil's chemical and petrochemical industry, the International Energy Agency estimates a potential energy efficiency improvement of 21 percent (IEA 2008a). In Mexico, significant energy savings in the industrial sector could be achieved through cogeneration, with an estimated 85 percent of the potential not yet utilized. Cogeneration could provide as much as 12.5 percent of new electricity capacity in Mexico, at costs that are significantly lower than the country's current marginal costs of power generation (Johnson and others 2010).

227. According to the same study, measures to improve the efficiency of industrial motors alone could result in electricity savings of about 114 TWh by 2030, approximately equivalent to the amount of electricity consumed by Mexico's industrial sector in one year. Extrapolating the assumptions about the available savings from improvements in industrial motors to other countries in the LAC Region, more than 500 TWh of electricity could be saved by 2030, or about 22 TWh per year.

228. In Mexico's residential sector, several large-scale energy efficiency projects have been implemented as part of a program under the state utility CFE, managed by the Trust Fund for

[54] The so-called "energy service company," or ESCO, represents a range of company types that invest in energy efficiency, often providing the upfront financing and entering into "guaranteed savings" contracts with industrial or commercial customers. Such contracts provide the consumer with a guarantee that their energy bills will be lower by an agreed-to amount after the investment. The ESCO uses the energy savings to recoup the investment. See Taylor and others 2009.

Electricity Savings (*Fideicomiso para el Ahorro de Energia Electrica* or FIDE). As a result of the program's first phase alone (from 2002 to 2006), about 25,000 homes were insulated and 623,000 refrigerators and 130,000 air-conditioning units replaced, with associated electricity savings of 2.1 TWh. In its second phase, planned for 2009-2012, the program is expected to generate electricity savings of as much as 13.5 TWh (The World Bank 2009a), equivalent to the annual combined consumption of Uruguay and the Dominican Republic.

229. Mexico's new Special Program for Climate Change (Programa Especial de Cambio Climático, or PECC, 2009-2012) identifies several high-impact energy efficiency measures that could, in the near future, be cost-effectively implemented in the residential, commercial and industrial sectors. Measures specific to the residential sector include the replacement of refrigerators and air conditioning equipment as well as thermal insulation of buildings, estimated to result in electricity savings of 7.4 TWh over the period 2009-2012. The application of similar energy efficiency tools in selected commercial and municipal buildings are expected to save 2.1 TWh over the same period.

230. Over the longer term, as much as 200 TWh could be saved by 2030 through investments in residential air conditioning, lighting and refrigeration. This is more than four times Mexico's current annual residential sector electricity consumption. If the same efficiency potential is assumed for other countries in the LAC Region, the electricity savings by 2030 in the residential sector alone could amount to as much as 1,000 TWh, comparable to the combined annual electricity demand for Mexico and Brazil.

231. In Argentina, studies indicate that there is significant untapped potential for energy savings across the economy, particularly in the industrial sector. Assuming reasonable rates of market penetration of energy efficiency technologies and practices, electricity savings of about 20 percent could be achieved, while 30 percent of electricity could be saved in the commercial sector through improved efficiency in lighting and air conditioning (World Bank 2008).[55] In the country's residential sector, replacement of inefficient lamps and appliances could help reduce residential electricity consumption by up to 30 percent, and similar electricity savings, in percentage terms, are feasible through upgrades in public lighting.

iii. Supportive Energy Efficiency Policies

232. The experiences of the LAC Region show that positive changes in energy efficiency have generally been driven by a combination of factors, including higher energy prices, better design/organizational measures and technical improvements, new technologies, energy conservation programs, and competition. Demand-side efficiency programs have in general been more successful when: (i) electricity tariffs reflect market values (opportunity costs and the long-run marginal cost of supply); (ii) legislation and regulatory policies promote energy efficiency, such as the enforcement of sound environmental, building and appliance standards; and (iii) fiscal policies penalize the production and import of energy-inefficient technologies and reward energy efficiency.

[55] Based on the electricity consumption figures for 2008, these combined potential electricity savings in Argentina's industrial and commercial sectors are roughly equivalent to the entire amount of electricity consumed in 2008 in Bolivia, Costa Rica and Guatemala combined (OLADE, 2009).

233. Dedicated energy efficiency and energy conservation policies have yielded sizeable results and, from the viewpoint of costs, can be seen as an alternative source of energy for the future as the region faces the need to respond to growing electricity demand. In the future, further energy efficiency gains could be achieved through improvements in the manufacturing of products, as well as through social education and information campaigns promoting corporate social responsibility and addressing the importance of energy saving that are already playing an important role in the EU and other industrial countries.

234. The key remaining barriers to the market penetration of energy-efficient technologies include the absence of financial intermediation by lending institutions to develop energy efficiency lending, weak incentives for building efficient new buildings due to the principal-agent problem, and a relative paucity of ESCOs and other private sector energy efficiency service delivery mechanisms. As in other regions, in LAC there is a need to more consistently pursue efficiency investments by electricity and gas distributors, with each rewarded for saving either form of energy.

235. Further improvements in power sector efficiency are also dependent on such factors as the definition of comprehensive national strategies for the overall energy sector; policy and financial support for the modernization of electricity grids and transmission and distribution infrastructure, as well as a realignment of utility regulations and rate structures to provide utilities with incentives for efficiency rather than increased generation. Other factors which can promote energy efficiency include:

a) Establishment of national energy efficiency labeling requirements, like those already in place in Argentina, Brazil, Cuba, Chile, Colombia, Costa Rica, Jamaica, Mexico, and Peru, and further efforts towards creating a *harmonized system* of standards and labeling programs, such as those currently pursued by the MERCOSUR Standards Organization (AMN) and the Pan-American Standards Commission (COPANT);
b) Introduction of national certification schemes for electric and electronic equipment in countries where they are absent (e.g., Dominican Republic);
c) Design of well-targeted promotion programs (including mass procurement to lower costs and subsidy schemes for low-income consumers) for compact fluorescent lamps (CFLs) and other energy-efficient equipment;
d) Establishment of an appropriate policy and financing framework (e.g., through the establishment of loan guarantee facilities by local commercial banks and the introduction of a utility *public wire charge* as in Brazil) to ensure the economic sustainability of the desired market transformations;
e) Introduction of customized financial products by commercial banks to match the characteristics of energy efficiency projects;
f) Mainstreaming of energy efficiency in government procurement strategies, as is already being done in Mexico and Peru, to ensure that only high-efficiency equipment is being purchased;[56]
g) Introduction of tax incentives to accelerate demand for efficient technologies and services;

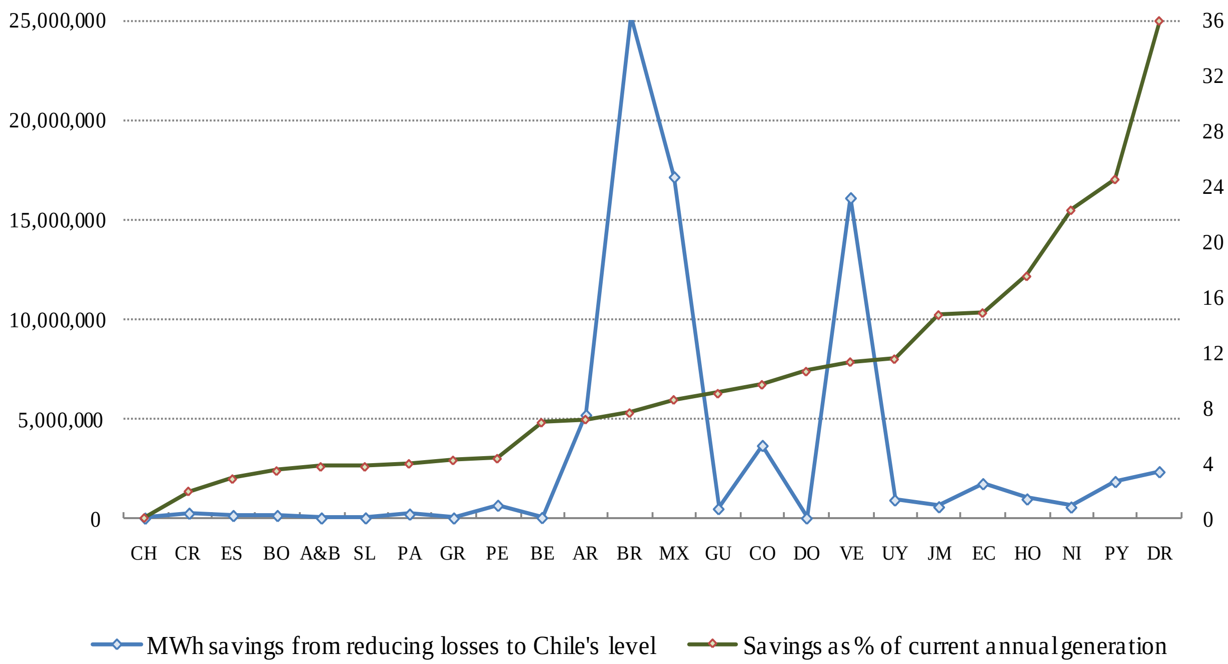
[56] Aita 2008; Expert Group on Energy Efficiency 2007

h) Development of appropriate legal norms and sanctions to prevent illegal manufacturing and distribution of inefficient or uncertified appliances.

iv. Aggregate Energy Efficiency Potential

If each country in LAC could reduce its distributional electricity losses to the region-best of about 6 percent – the level of Chile— the Dominican Republic, Paraguay, and Nicaragua could obtain electricity savings of above 20 percent of the current total annual generation (Figure 38). The combined annual savings for the region from reaching Chile's benchmark would amount to about 78 TWh (78,000 GWh) – comparable to the combined annual amount of electricity sold in all of Central America, Chile, and Peru, or equivalent to about one-fourth of the annual electricity sales in Brazil. While this may be an extemely optimistic scenario for distribution loss reduction, it is conservative since no savings are assumed for improved supply efficiency.

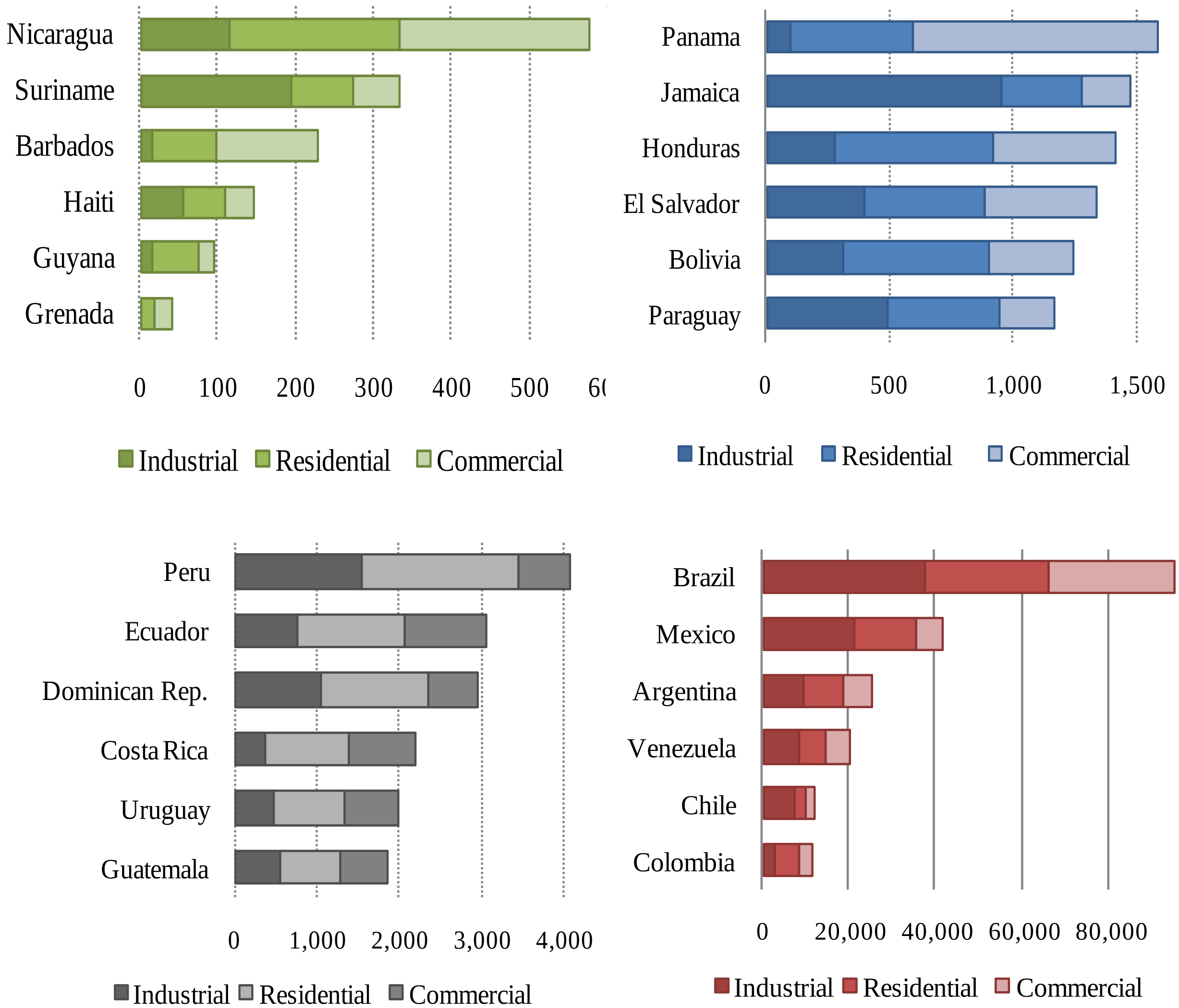
Figure 38. Annual Electricity Savings from Reducing Distributional Losses to Chile's Level



Source: Own calculations based on World Bank, *Benchmarking Data of the Elec. Dist. Sector LAC Region 95 –05*

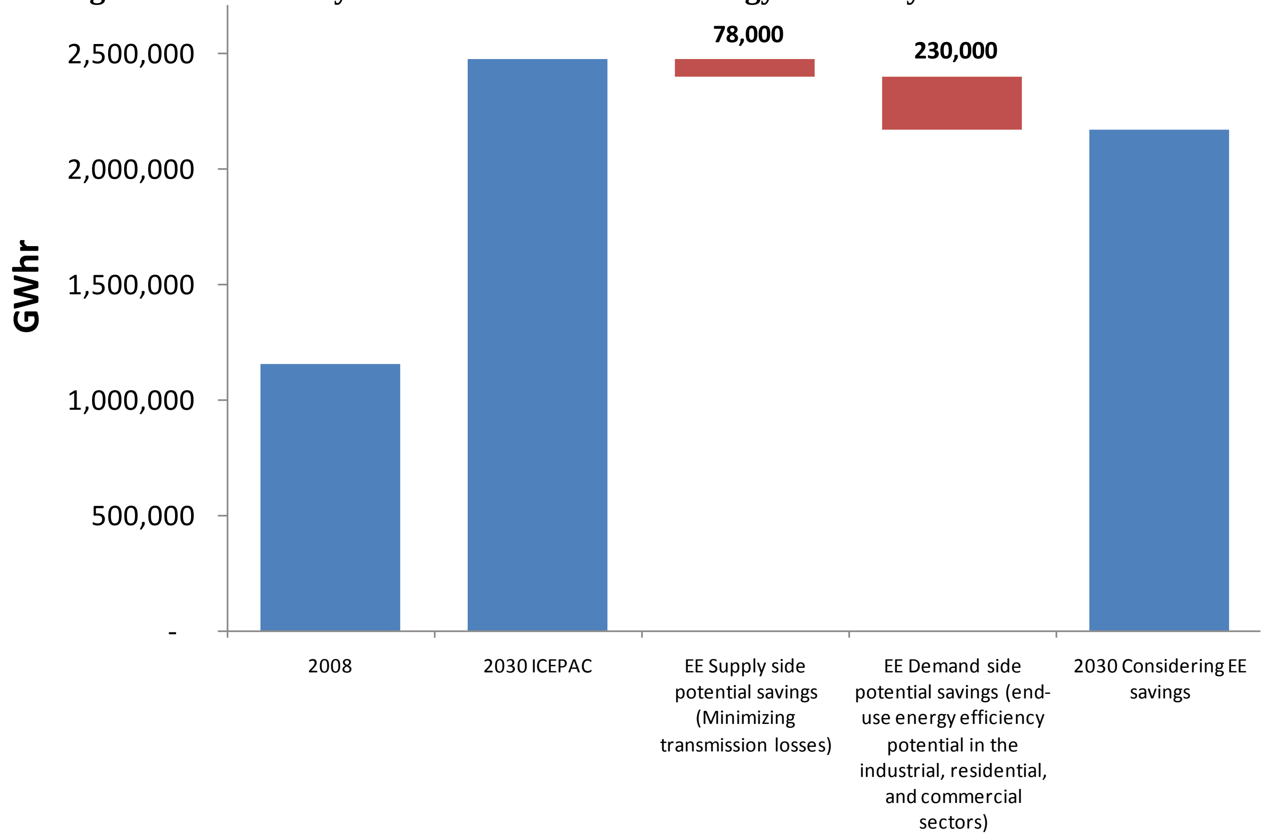
236. Using Argentina's estimates of end-use energy efficiency potential in the industrial, residential, and commercial sectors and extrapolating them across the LAC region results in annual electricity savings of 230 TWh (using 2008 electricity consumption figures), ranging from 42 GWh in Grenada to 95 TWh in Brazil (Figure 39).

Figure 39. Extrapolating Argentina's Efficiency Level: Annual Savings (GWh)



237. Taking the estimates of the supply- and demand-side energy efficiency potential outlined above, it is possible to compare this with the results of the modeling exercise presented in Chapter III. The supply-side measures could reduce energy demand by 78 TWh, while the demand-side measures were estimated to be 230 TWh. Together, these rather simple estimates show that overall demand could be reduced in the range of 12 percent.

Figure 40. Electricity Demand Scenario with Energy Efficiency Potential Realized



CHAPTER V. CONCLUSIONS

238. This report contributes to the discussion of future power supply in Latin America and the Caribbean by: (1) supporting the integration of a large database on electricity production and consumption for the majority of countries in the region and developing a methodology for assessing future electricity supply using a consistent framework across countries (Chapter 3); and (2) examining a range of promising alternatives for meeting future electricity demand requirements (Chapter 4).

Baseline Electricity Supply Scenario

239. Under quite modest GDP growth assumptions – essentially 3 percent per annum from 2014-2030 – the demand for electricity would more than double from 1,150 TWh to around 2,500 TWh. Under a baseline scenario, the LAC Region would need to add more than 239 GW of new power generating capacity over the coming twenty years, much of it from thermal generating capacity. Under a higher income growth scenario, generating capacity would need to grow even more. Regardless of the exact rate of growth of GDP and the ultimate demand for electricity, it is clear that the countries of the region must plan for a significant expansion of electricity generating capacity.

240. Under a baseline scenario for the Region for 2030 – aggregating and extrapolating current country power expansion plans – the majority of new generating capacity would be met by hydropower (36 percent) and natural gas (35 percent). In many ways, this is a "best-case" scenario, as the current expansion plans for hydropower and natural gas-based generation are quite optimistic. The amount of new hydro that would be required under the baseline scenario is more than 85 GW. This compares to 76 GW of hydropower capacity that was commissioned in the LAC Region over the past 20 years, and many of the best sites in terms of power capacity, financial returns, and environmental and social risks have already been exploited. In order to tap the Region's extensive hydro resources, there will need to be changes in regulatory policies in most all countries.

241. A large increase in the use of natural gas power generation is also envisioned under the baseline, growing from the current capacity of 60 GW to more than 144 GW in 2030. Compared to petroleum and coal, the growth of natural gas for power generation would have positive efficiency benefits through the use of combined-cycle technology, and positive environmental benefits by the reduction in local pollutants and lower carbon emissions. Realizing the expansion of natural gas-fired generating capacity will require more regional cooperation in building pipelines and negotiating bilateral gas contracts, since gas resources are not evenly distributed throughout the region. Some countries – such as Mexico – will need to expand domestic gas production and rely on increased trade to meet the aggressive expansion plans for gas-fired power generation. In some countries, low prices for domestically-produced natural gas have led to the inefficient use of natural gas which could be overcome by a combination of pricing reforms and technology standards. For example, by converting "open-cycle" natural gas plants to more efficient combined-cycle technology, Peru could add 800-900 MW of power capacity, equivalent to about two years of new capacity additions at current rates of growth.

Alternatives for Meeting LAC's Power Demand

242. In addition to hydropower and natural gas, there are a number of other options for meeting the electricity demand needs of the Region. Data limitations and the fact that most of the alternatives explored do not feature prominently in current country power expansion plans were the reasons why they were not addressed in the modeling exercise in Chapter III. Among the findings and preliminary conclusions of "alternatives" analysis from Chapter IV are:

- **Non-hydro renewables** – especially wind – could provide an important new source of electricity in most countries of the region, which would help to diversify the overall electricity supply mix. Wind and other renewables have been aided considerably over the past five years by significant reductions in technology supply costs and the prospects of a growing carbon market. As noted above, hydropower is by far the most important renewable energy option for the region, but the supply of hydro (and natural gas) can be complemented by significant contributions of non-hydro renewable to meet growing demand.

- **Increased electricity trade** could provide significant new capacity by enlarging the LAC electricity market and lower overall supply costs in the process. While the Region is poised to make greater use of trade for supplying electricity demand, there remain obstacles, both regulatory and political, that have inhibited trade in the past that can be overcome through more concerted regional actions.

- **Greater energy efficiency** can help reduce electricity demand and increase the effective electricity supply in a cost-effective manner. There is major potential for improving the efficiency of electricity supply, including reducing transmission and distribution losses, and tapping the large amount of cogeneration potential in industry. There is probably even greater potential to reduce energy demand by improving end-use efficiency, with significant potential in all major sectors. As elsewhere, the lack of a supportive regulatory and policy framework makes investments in energy efficiency less attractive than building new power capacity, but the costs to society of not taking advantage of efficiency potential are large.

243. While difficult to quantify, it is clear that these "alternatives" could significantly reduce the amount of new thermal generating capacity that would be needed in LAC over the coming 20 years. Perhaps more importantly, these alternatives can help to produce a more diversified and stable power sector and many options have lower costs than traditional power generation solutions. Initial and partial estimates of the contribution of "alternatives" suggests that: (1) actively promoting a program of non-hydro renewable, including wind, biomass, and geothermal, could provide between 15 and 30 percent of the total electricity supply by 2030, (2) expanded electricity trade is likely to lower costs by allowing the development of larger-scale projects, and also reduce the need for reserve capacity,[57] and (3) Regional electricity demand

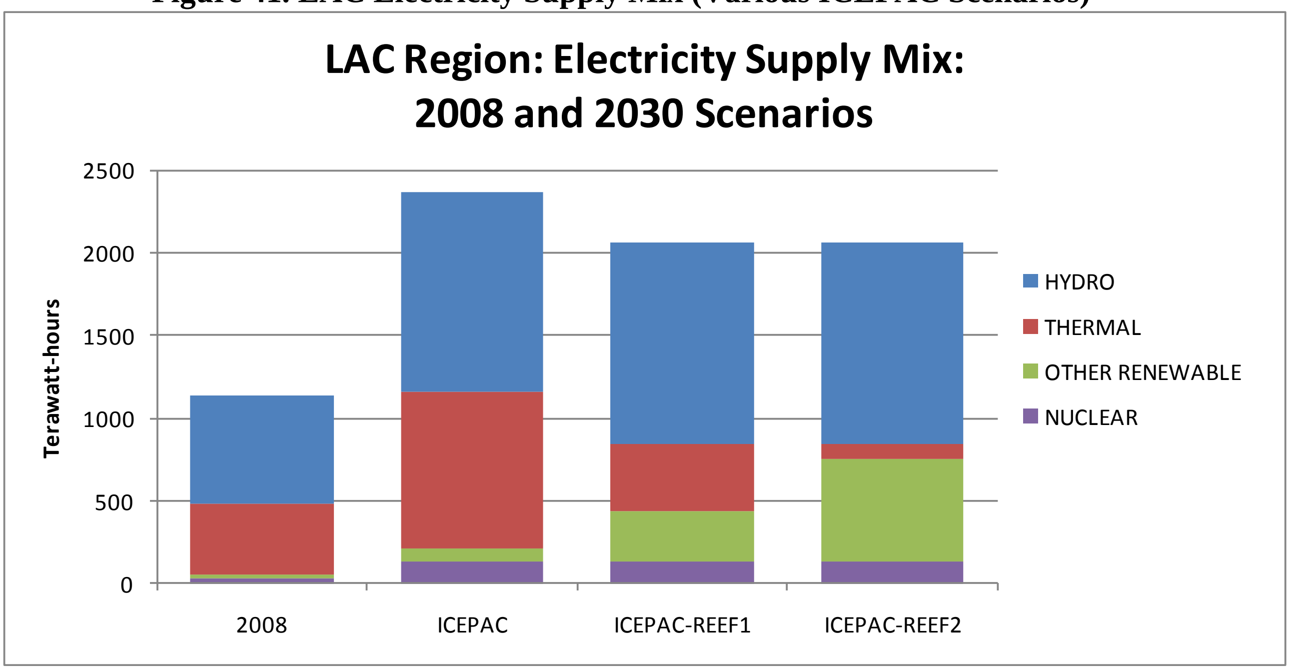
[57] The impact of increased trade is complicated to quantify. From the exercise undertaken for Central America, increased trade resulted in share of hydro rising from 46 to 54 percent, simply by increasing the scale of hydro plants that could be built in Central America. If trade was expanded beyond Central America, to either Mexico or South

could be reduced by 10-15 percent through limited supply-side and demand-side energy efficiency measures at costs that are less than those of building new power generation capacity. The overall results are shown in Table 15 and Figure 41.

Table 15. Summary Electricity Demand and Supply (Terawatt-hours, TWh)

	2008	ICEPAC	ICEPAC-REEF1	ICEPAC-REEF2
DEMAND	**1,153**	**2,479**	**2,171**	**2,171**
EFFICIENCY	0	0	308	308
Supply-side			78	78
Demand-side			230	230
SUPPLY	**1,153**	**2,479**	**2,171**	**2,171**
	2008	**ICEPAC**	**ICEPAC-REEF1**	**ICEPAC-REEF2**
HYDRO	675	1,239	1,239	1,239
THERMAL	431	1,036	530	215
OTHER RENEWABLE:	18	102	300	615
Wind			220	340
Biomass			55	150
Geothermal			25	125
NUCLEAR	32	102	102	102

Figure 41. LAC Electricity Supply Mix (Various ICEPAC Scenarios)



America, the gains to trade in terms of lower costs of electricity for Central America could be even larger. From the rising share of hydroelectricity and the consequent reduction in thermal power, CO_2 emissions in Central America were found to fall by 14 percent.

Recommendations[58]

244. The focus of this report is on long-term electric power needs and supply options for Latin America and the Caribbean. While an extensive analysis of the policy and institutional issues confronting electric power development in LAC is beyond the scope of this report, there are a number of policies that are needed to allow the Region meet its growing electricity needs in an efficient, diversified, and environmentally sustainable manner. Developing institutional capabilities and tools for analyzing electricity supply needs for individual countries and the Region would also help improve the development of the power sector.

245. ***Policies and regulations for hydropower.*** The proposed increases in hydroelectric capacity in many countries will require changes in the way power plants have been financed – requiring a greater role for the public sector in regulating and guaranteeing hydroelectricity construction and greater role for the private sector in taking on long-term construction and/or operation contracts. Hydropower development has also been hindered by the real and perceived social and environmental risks of developing large-scale plants. As such, there is a need to improve the process for identifying and managing social and environmental issues associated with hydropower plants, and to improve the environmental consultation, licensing, and commissioning process. The development of hydropower has also suffered from preferential prices for domestic natural gas in several gas-producing countries.

246. ***Price and institutional reform for natural gas.*** Numerous countries in the Region have used low preferential pricing for domestic natural gas resources as a way to stimulate gas-fired power generation. While such policies have been partially responsible for the expansion of natural gas-fired power generation in several countries, low prices have also resulted in the inefficient use of natural gas for power generation ("open-cycle" plants), and inadequate incentives for new gas development. Countries that continue to subsidize natural gas for power generation should begin to phase out such subsidies, while at the same time strengthening the development of natural gas through planning and resource inventory assessment, support for pipeline and infrastructure construction, and by adopting transparent and consistent bidding processes for natural gas power capacity.

247. ***Support for renewable energy and energy efficiency.*** The technical aspects of identifying renewable energy potential and energy efficiency opportunities must be coupled with appropriate regulatory and institutional frameworks. In the case of promoting renewable energy technologies, promotion policies and mechanisms are needed, such as tax credits, long-term purchasing contracts, and dispatch priorities. Another important aspect for both renewable energy and energy efficiency is the definition of appropriate tariffs that allow producers or consumers to recover the cost of their investments. Several LAC countries have already approved and implemented new laws and regulations that promote energy efficiency and renewable energy use.

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[58] The policy recommendations presented in this study build upon the lessons learned and issues discussed in several other recent studies by the World Bank on the energy sector, including: *Low-Carbon Development for Mexico (2010), Low-Carbon Development for Brazil (2010), Overcoming The Barriers to Hydropower in Peru (2010), Low Carbon Development: Latin American Responses to Climate Change (2009), An Overview on Efficient Practices in Electricity Auctions (Forthcoming),* and *Peru: Downstream Natural Gas Study (Forthcoming)*.

248. ***Strengthen power sector planning.*** Countries in the Region should improve their power sector planning. While the majority of LAC countries already have power expansion plans, several countries have not yet developed electricity-specific demand and supply growth scenarios. Governments should undertake longer-horizon planning to match power sector investments which are similarly long-term in nature. Among the countries that do have power expansion plans, in several cases the time horizon is limited to 12 years or less, while for others the plans are not updated frequently.[59] There is also a need for countries to be able to develop and discuss with their constituencies realistic power expansion plans that include a wide range of supply options and information on evolving power technologies and international market developments.

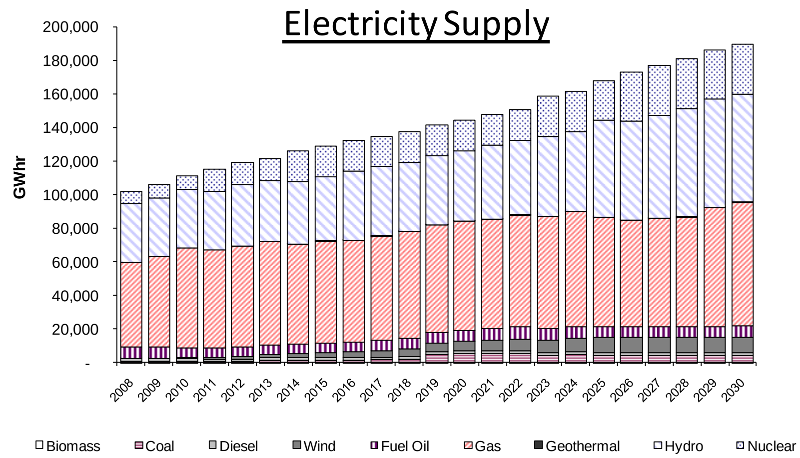
249. ***Improving regional power planning tools***. There is a need to develop robust and user-friendly regional power planning tools for individual countries and regional organizations. Such tools would greatly enhance the ability and usefulness of conducting regional power planning exercises. For the current study, the World Bank relied on externally-developed power planning models and software that required substantial amounts of data and technical information. Other power planning tools that are typically used by the World Bank and other institutions include MARKAL and WASP, which are also difficult to use and adjust. The development of more robust power planning tools would improve the ability of organizations to engage with countries in the Region on power planning exercises.

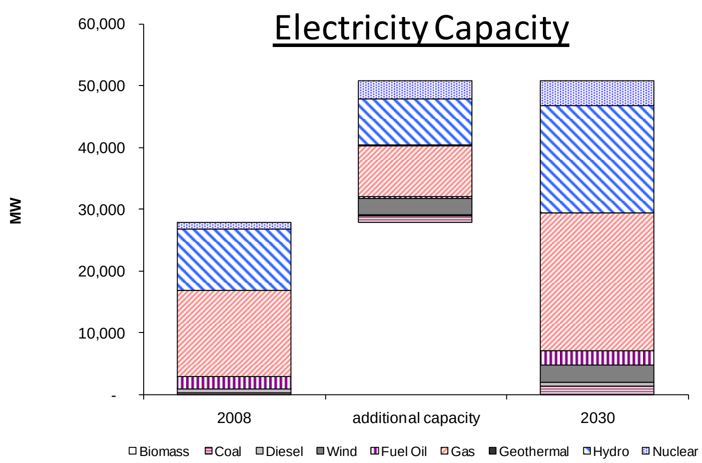
250. ***More reliable inventory information.*** As the demand for new electricity investments increases and regulations and policies are developed for both new and conventional electricity sources, it is critical to improve information on the magnitude, location, and quality of energy resources. There is an especially urgent need to improve information on renewable energy resources, which have been less studied than conventional energy resources. Information is important not only for individual countries to identify their energy resource potential, but also for the identification of bi-national or regional energy potential.

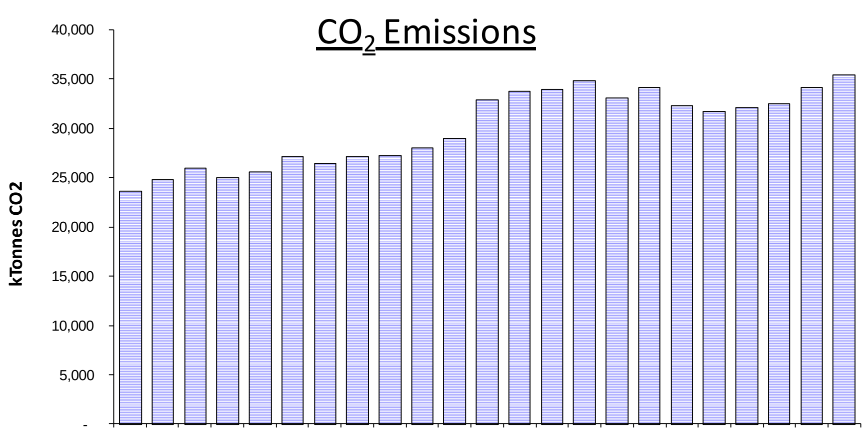
[59] For example, Peru's expansion plan provides projections through 2015, and Panama's through 2014. Although El Salvador's expansion plan provides projections through 2020, it has not been updated since 2003.

ANNEX 1: COUNTRY-LEVEL ESTIMATIONS

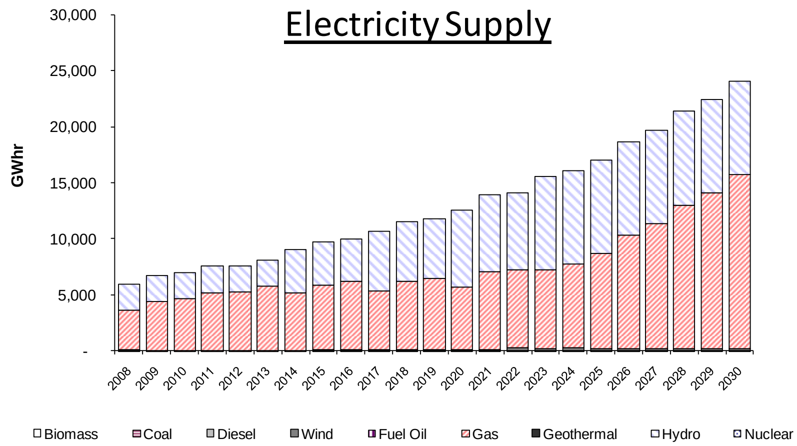
ARGENTINA

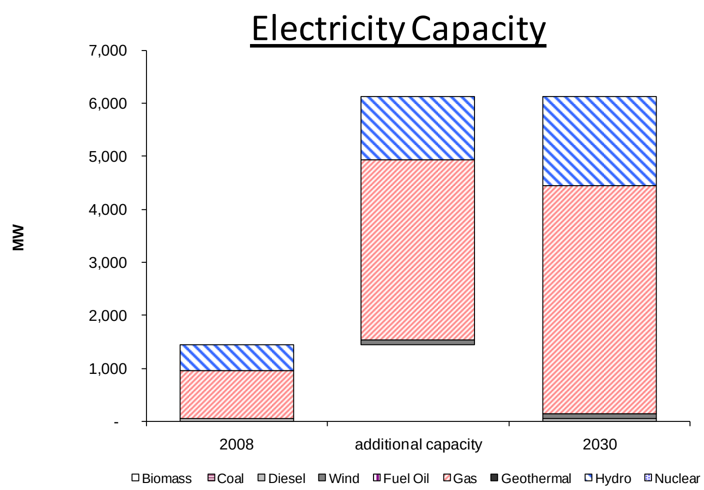


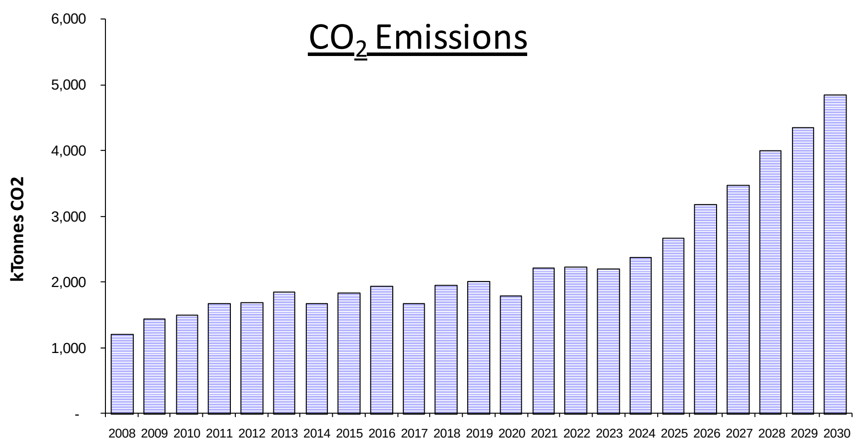




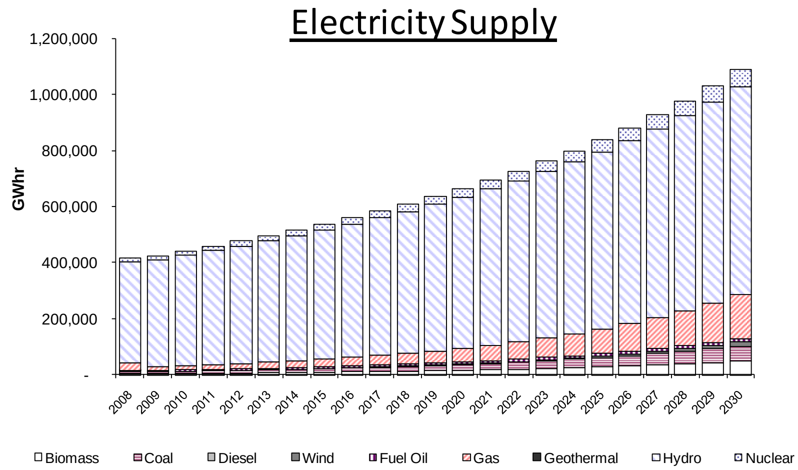
BOLIVIA

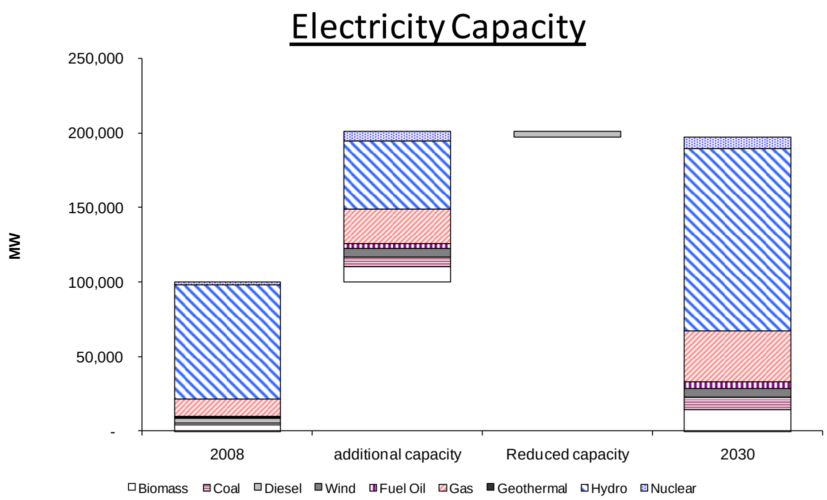

Electricity Supply
30,000
25,000
20,000
15,000
10,000
5,000
-
GWhr
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

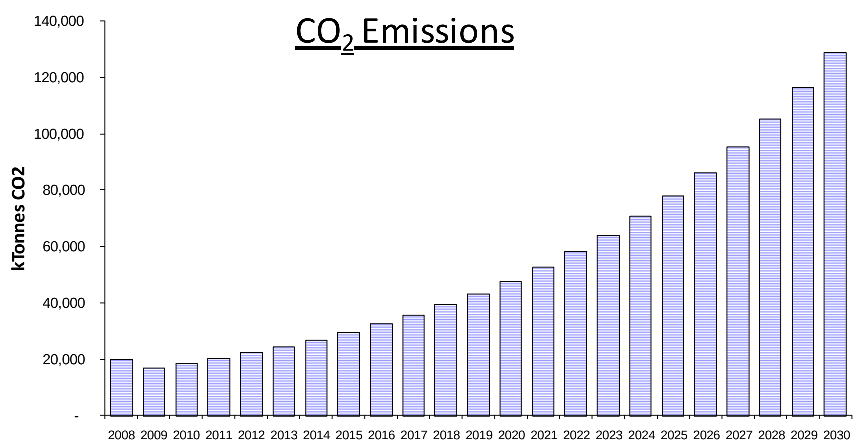

Electricity Capacity
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
MW
2008
additional capacity
2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear


CO2 Emissions
6,000
5,000
4,000
3,000
2,000
1,000
-
kTonnes CO2
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

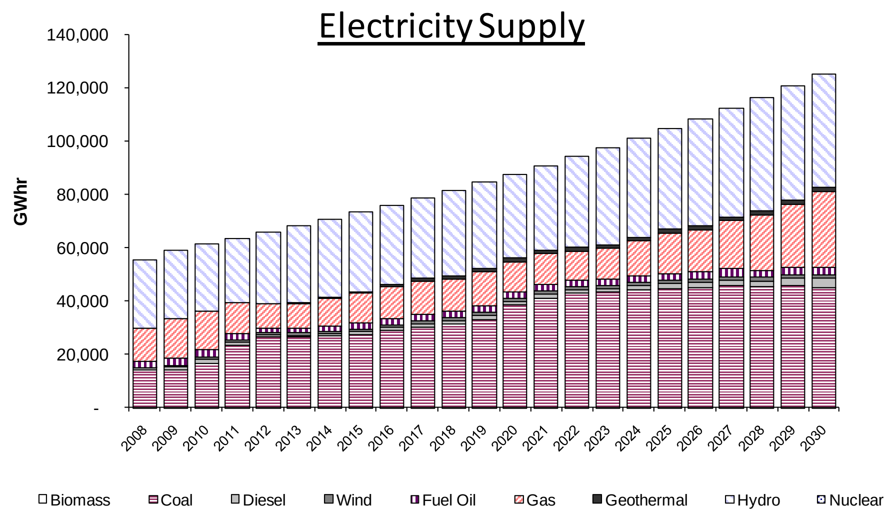
BRAZIL


Electricity Supply
GWhr
1,200,000
1,000,000
800,000
600,000
400,000
200,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

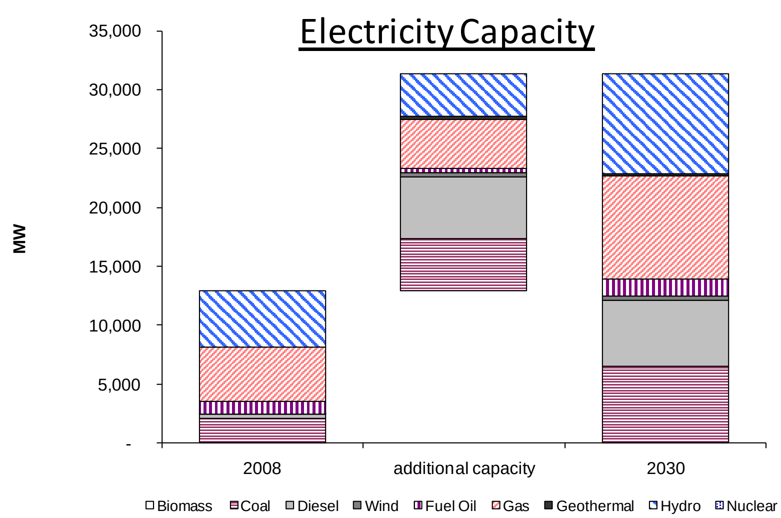

Electricity Capacity
MW
250,000
200,000
150,000
100,000
50,000
-
2008
additional capacity
Reduced capacity
2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear


CO2 Emissions
kTonnes CO2
140,000
120,000
100,000
80,000
60,000
40,000
20,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

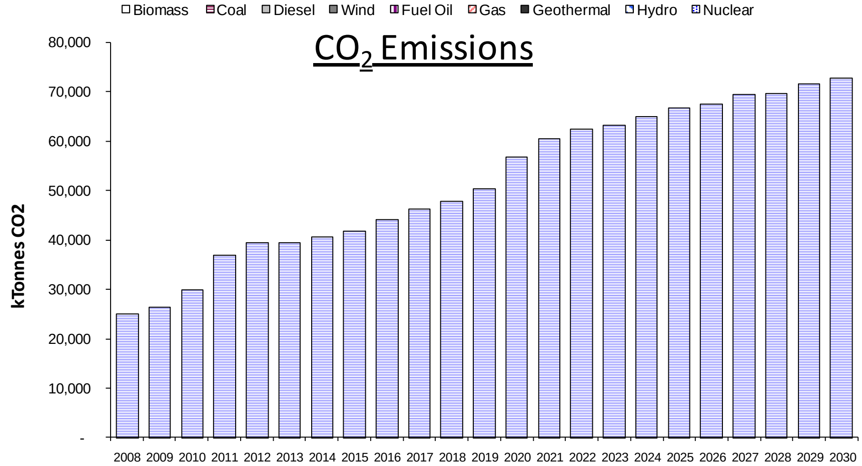
CHILE



Electricity Supply
GWhr
140,000
120,000
100,000
80,000
60,000
40,000
20,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

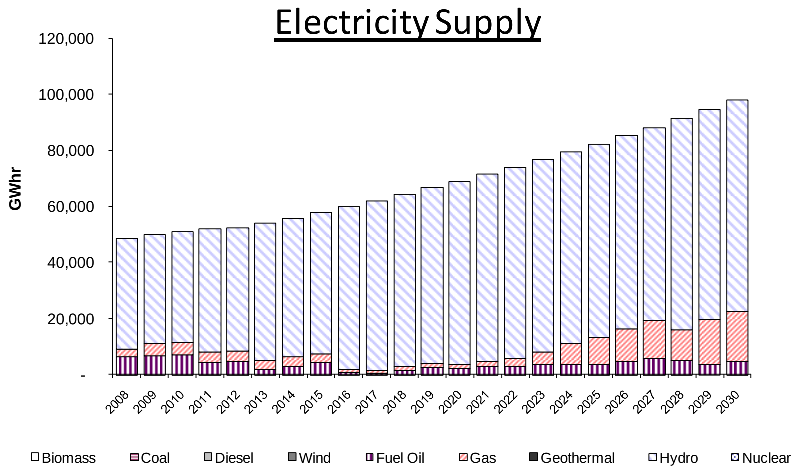


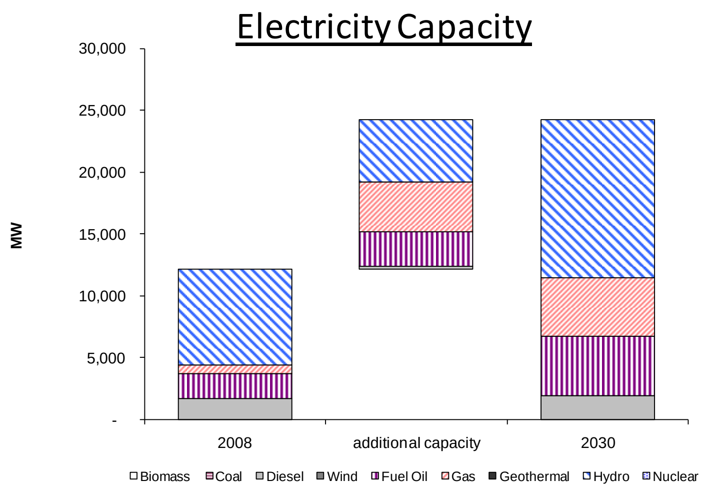
Electricity Capacity
MW
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

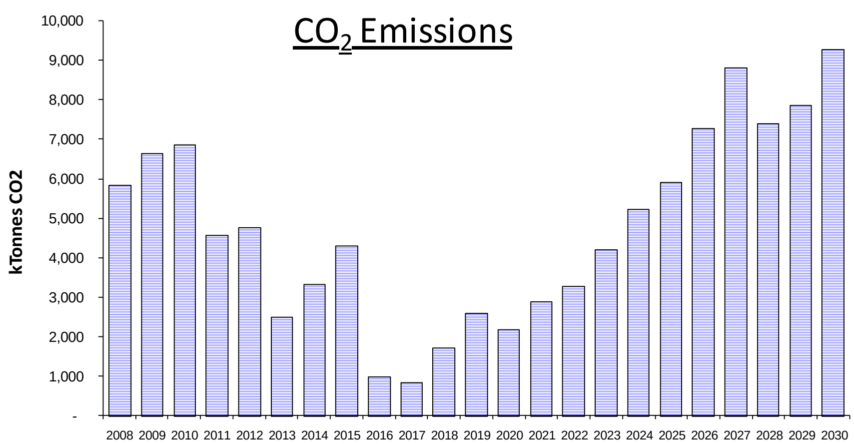


CO2 Emissions
kTonnes CO2
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

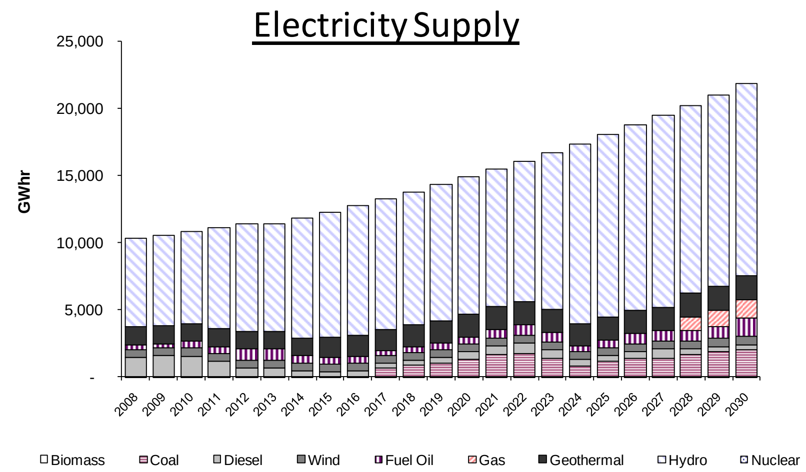
COLOMBIA


Electricity Supply
GWhr
120,000
100,000
80,000
60,000
40,000
20,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

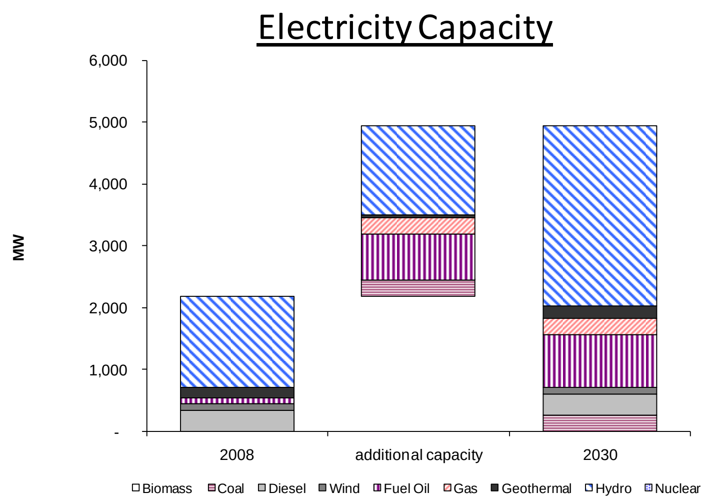

Electricity Capacity
MW
30,000
25,000
20,000
15,000
10,000
5,000
-
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear


CO2 Emissions
kTonnes CO2
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

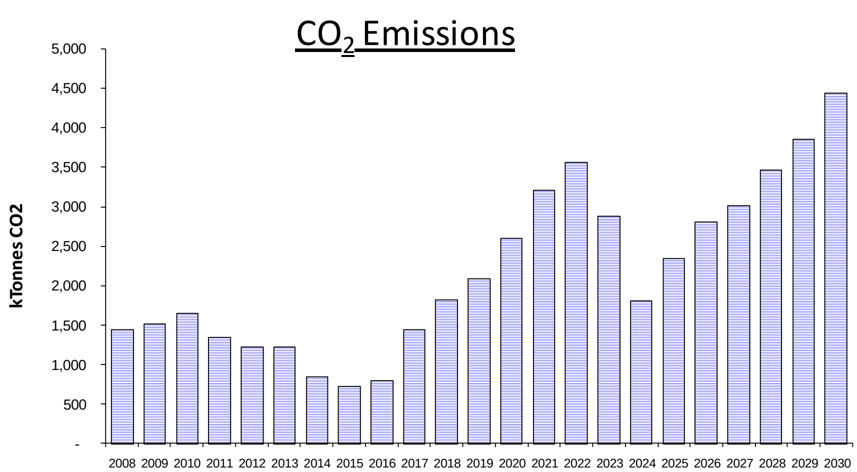
COSTA RICA



Electricity Supply
GWhr
25,000
20,000
15,000
10,000
5,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

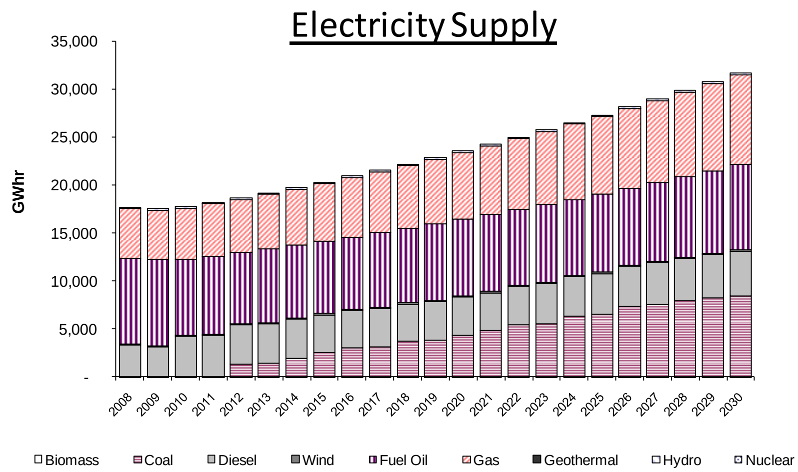


Electricity Capacity
MW
6,000
5,000
4,000
3,000
2,000
1,000
-
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

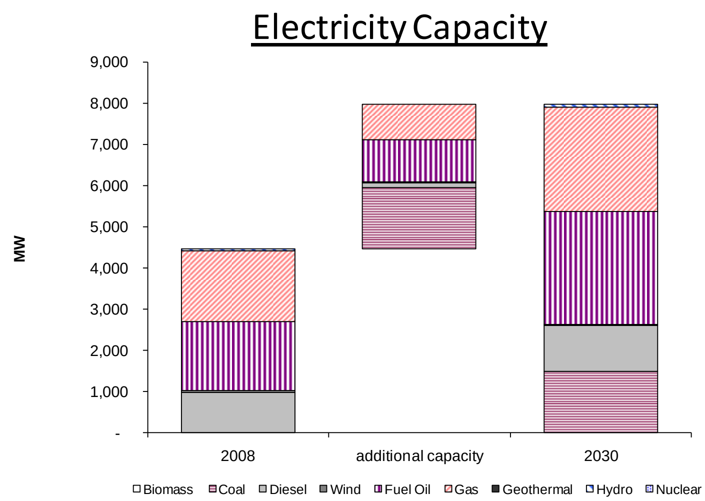


CO_2 Emissions
kTonnes CO2
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

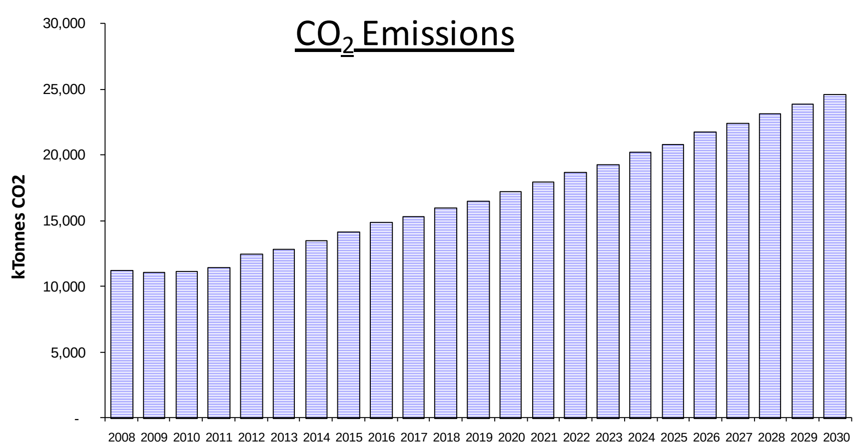
CARIBBEAN



Electricity Supply
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
GWhr
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

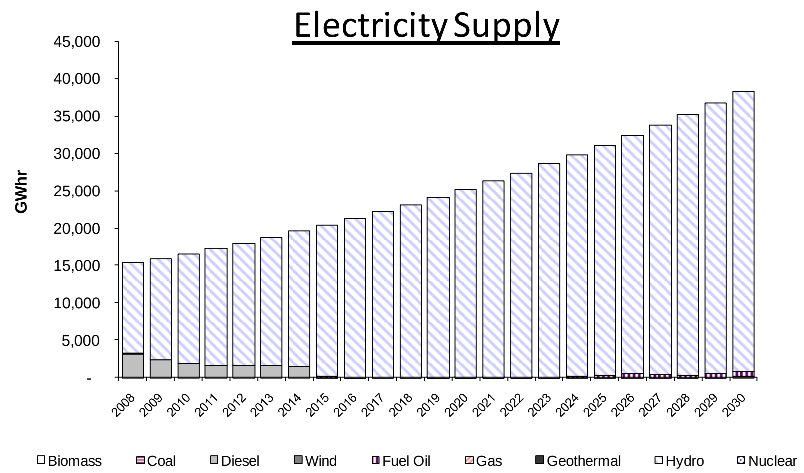


Electricity Capacity
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
MW
2008
additional capacity
2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

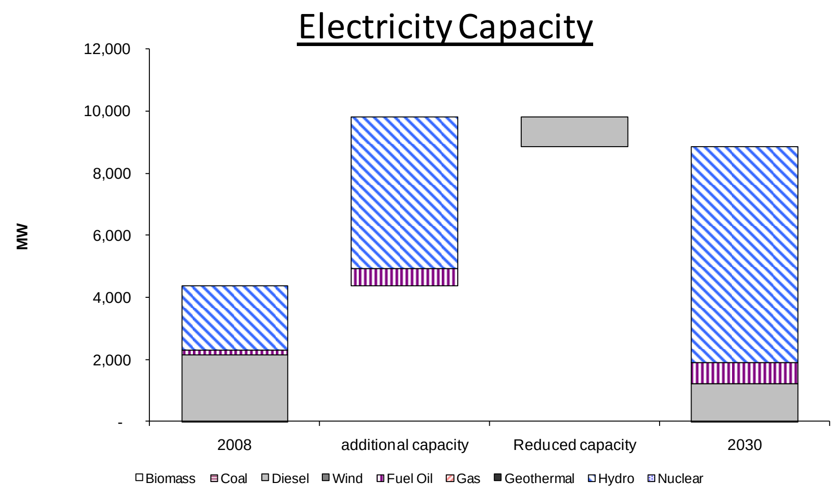


CO2 Emissions
30,000
25,000
20,000
15,000
10,000
5,000
-
kTonnes CO2
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

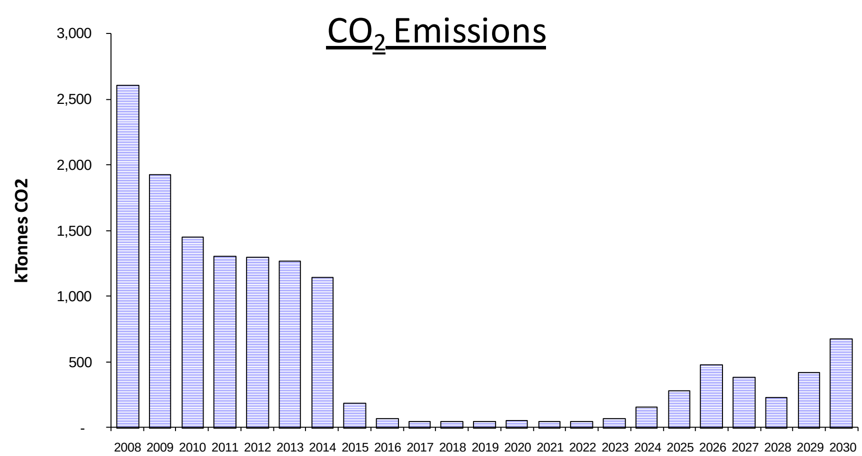
ECUADOR



Electricity Supply
GWhr
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

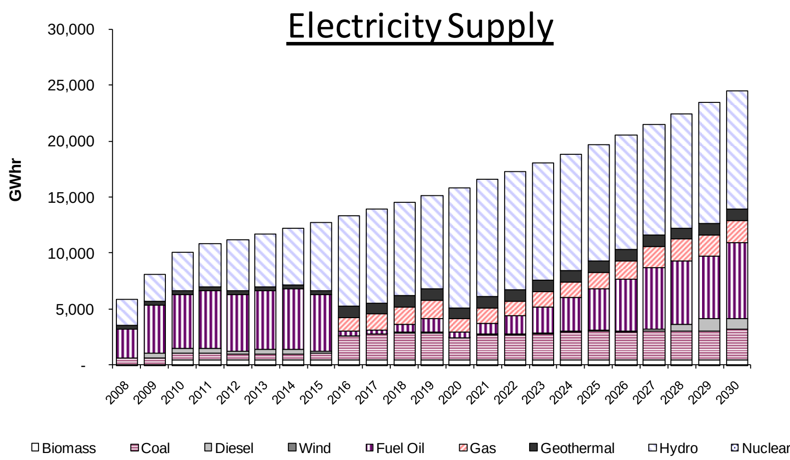


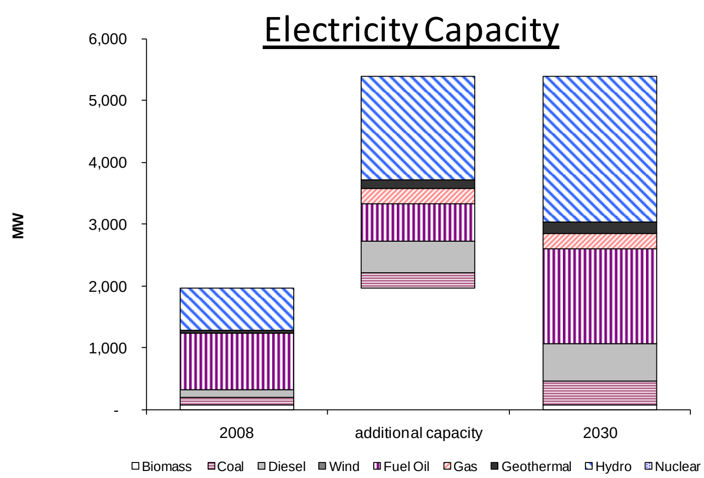
Electricity Capacity
MW
12,000
10,000
8,000
6,000
4,000
2,000
-
2008
additional capacity
Reduced capacity
2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

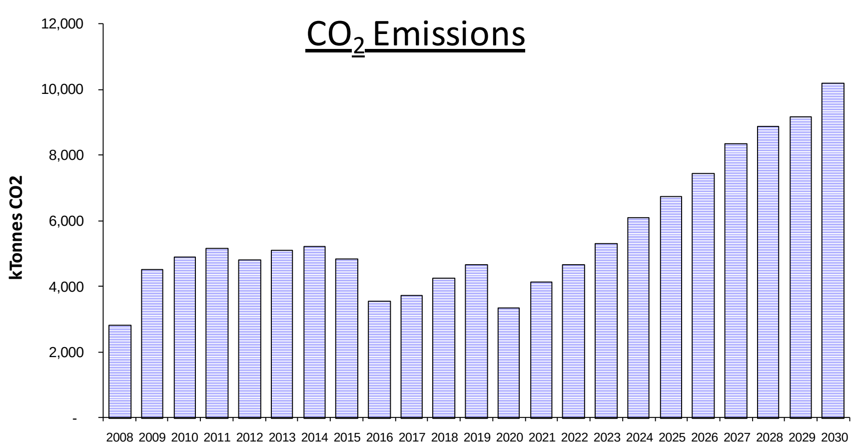


CO_2 Emissions
kTonnes CO2
3,000
2,500
2,000
1,500
1,000
500
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

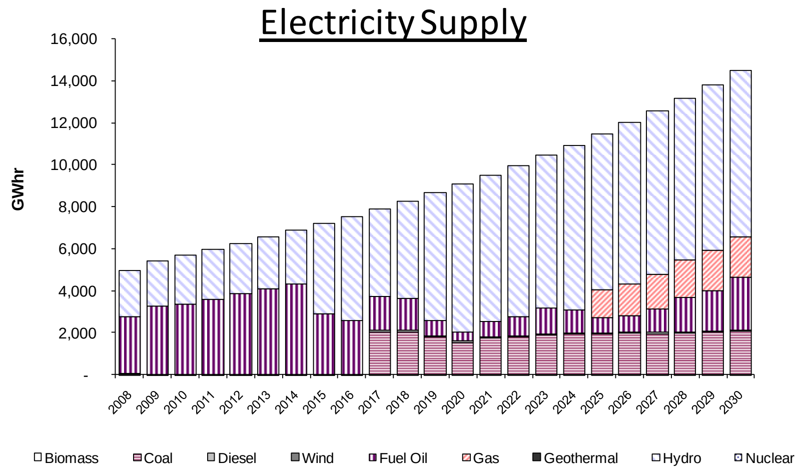
GUATEMALA


Electricity Supply
GWhr
30,000
25,000
20,000
15,000
10,000
5,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

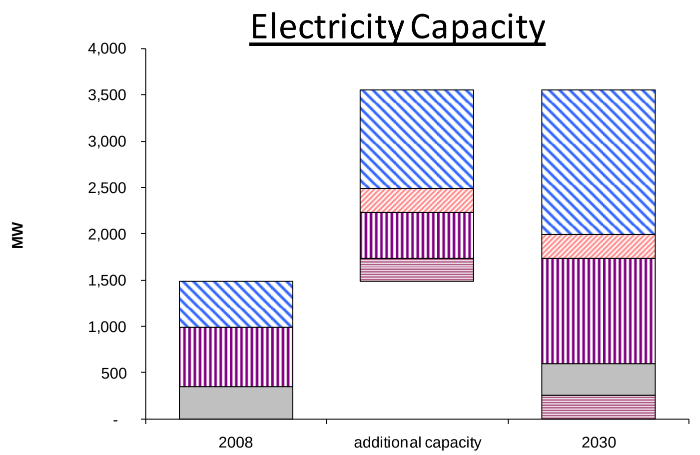

Electricity Capacity
MW
6,000
5,000
4,000
3,000
2,000
1,000
-
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear


CO2 Emissions
kTonnes CO2
12,000
10,000
8,000
6,000
4,000
2,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

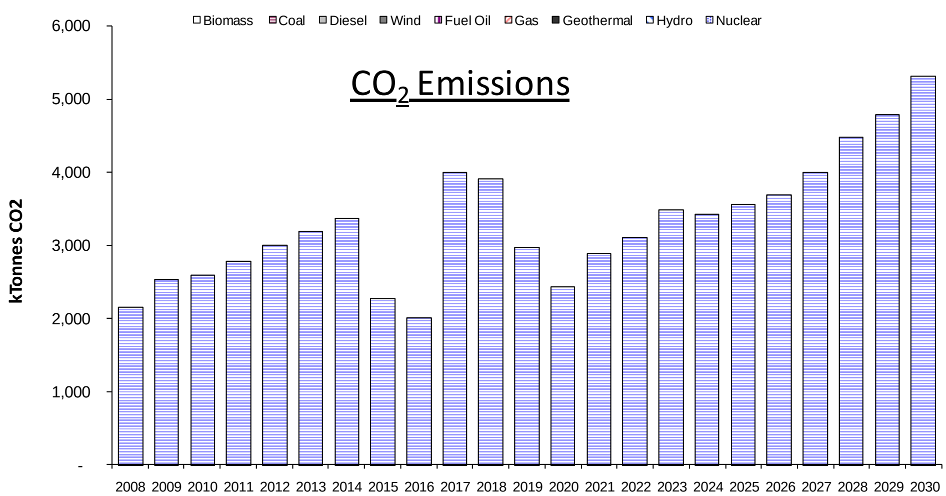
HONDURAS



Electricity Supply
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
GWhr
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

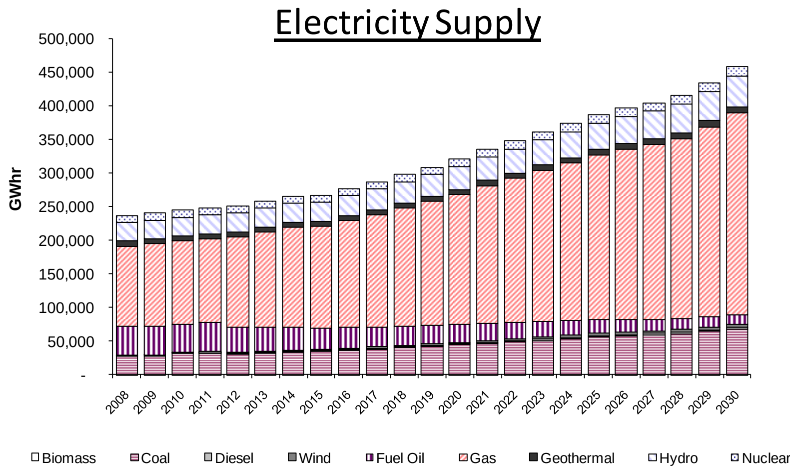


Electricity Capacity
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
MW
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

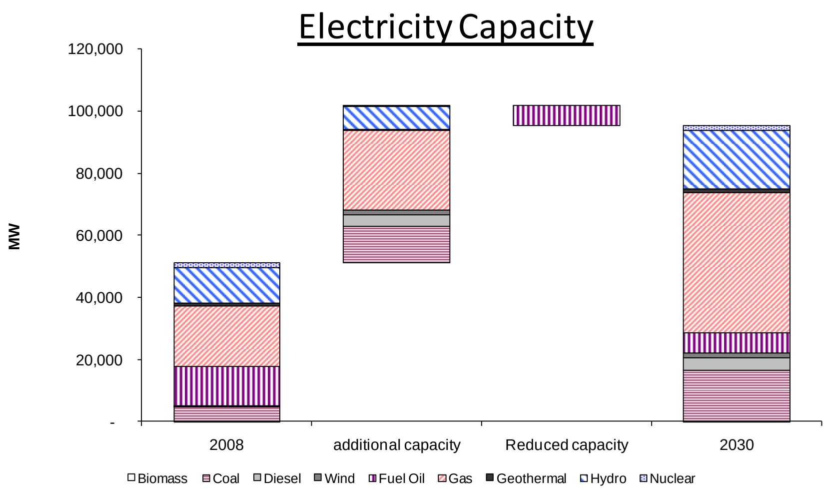


CO2 Emissions
6,000
5,000
4,000
3,000
2,000
1,000
-
kTonnes CO2
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030

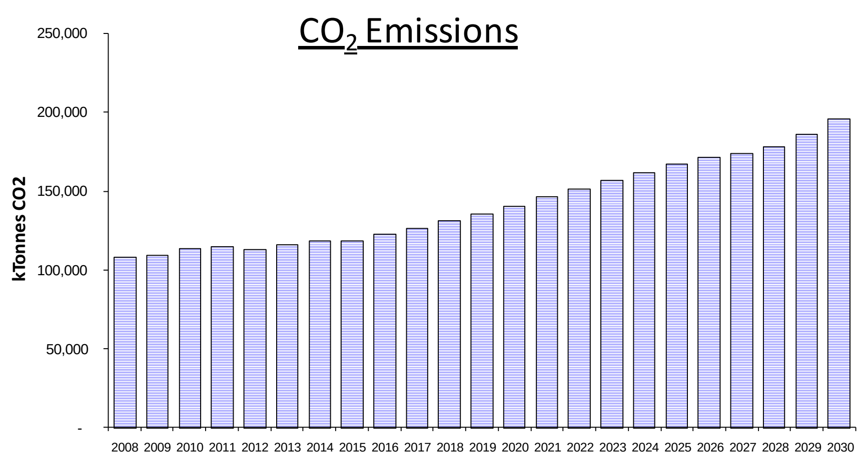
MEXICO



Electricity Supply
GWhr
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

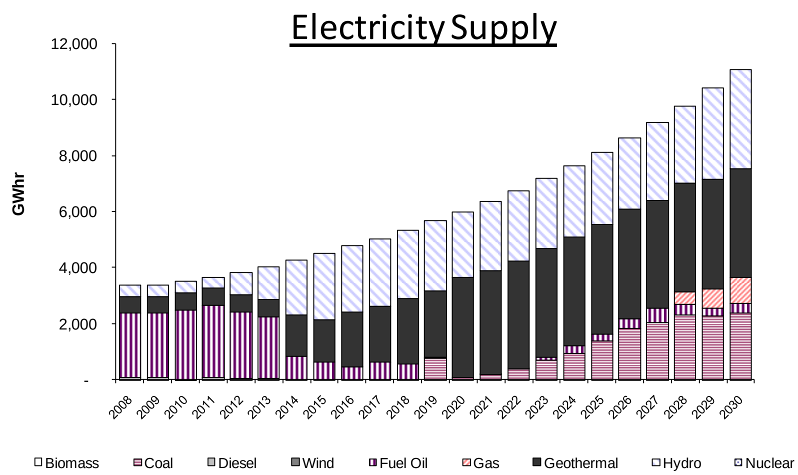


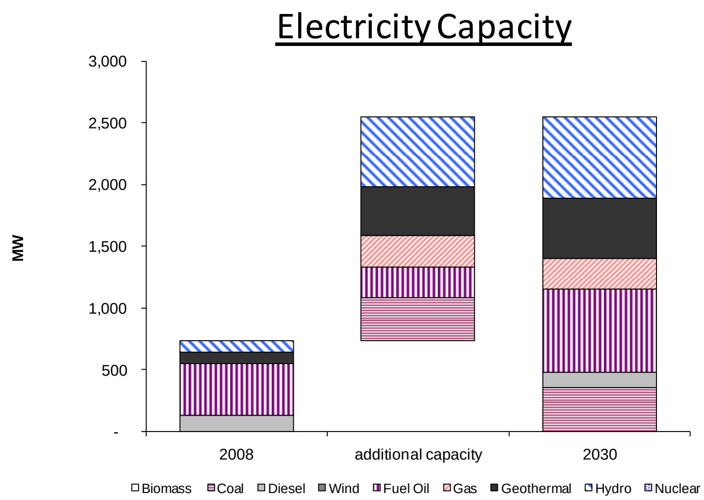
Electricity Capacity
MW
120,000
100,000
80,000
60,000
40,000
20,000
-
2008
additional capacity
Reduced capacity
2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

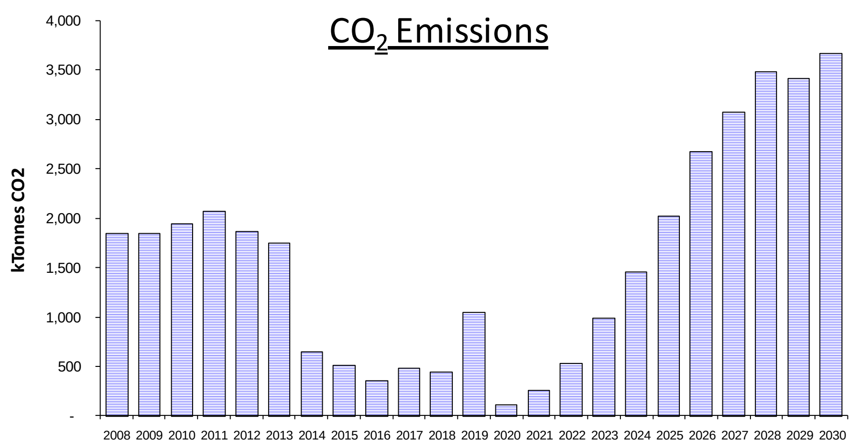


CO_2 Emissions
kTonnes CO2
250,000
200,000
150,000
100,000
50,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

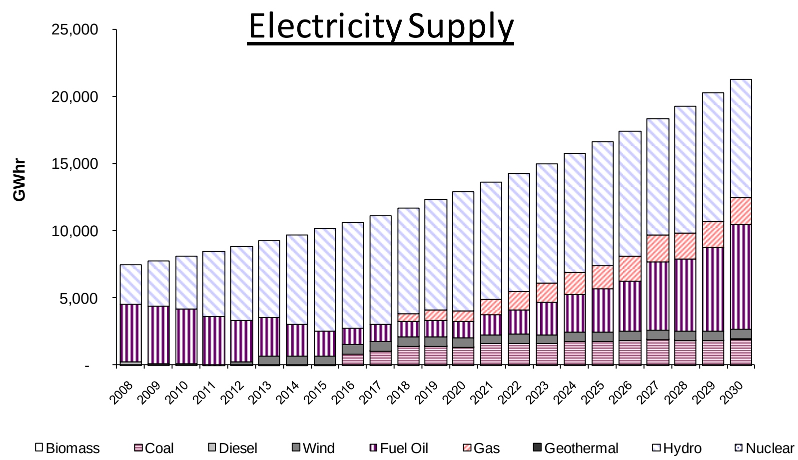
NICARAGUA


Electricity Supply
GWhr
12,000
10,000
8,000
6,000
4,000
2,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear

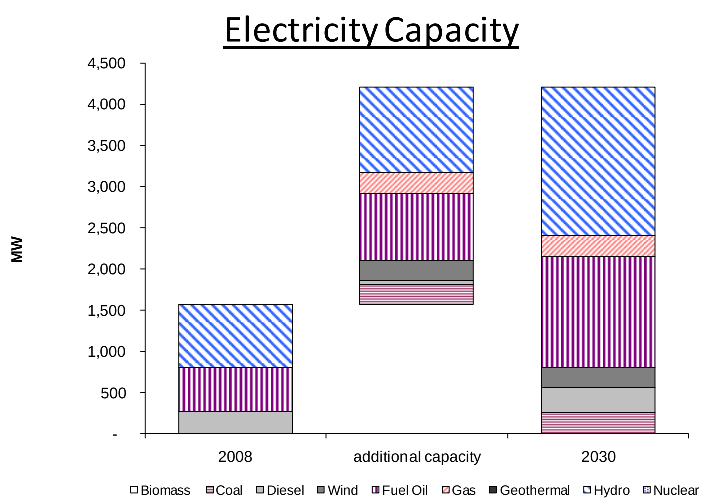

Electricity Capacity
MW
3,000
2,500
2,000
1,500
1,000
500
-
2008
additional capacity
2030
Biomass Coal Diesel Wind Fuel Oil Gas Geothermal Hydro Nuclear


CO_2 Emissions
kTonnes CO2
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

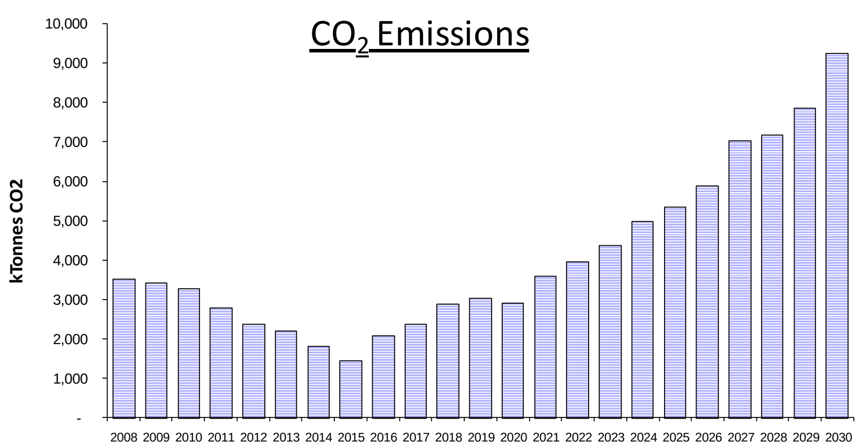
PANAMA



Electricity Supply
GWhr
25,000
20,000
15,000
10,000
5,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

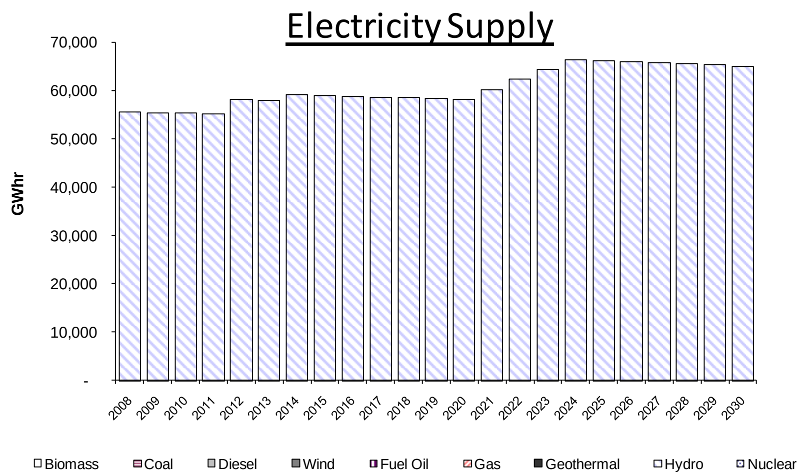


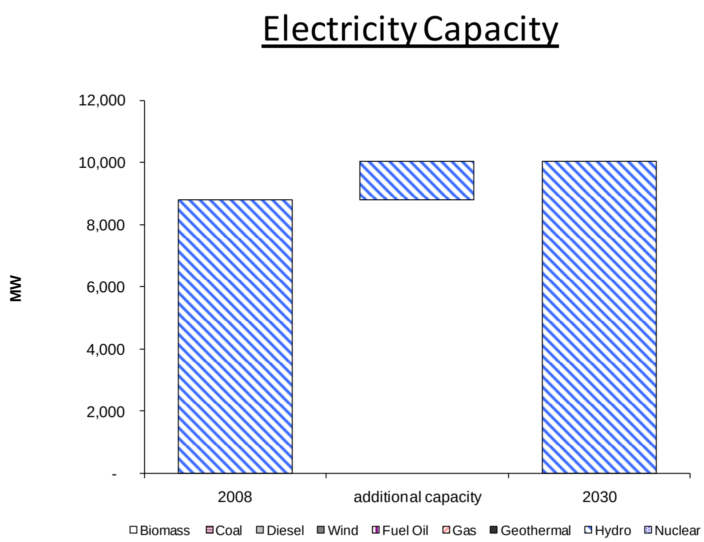
Electricity Capacity
MW
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear



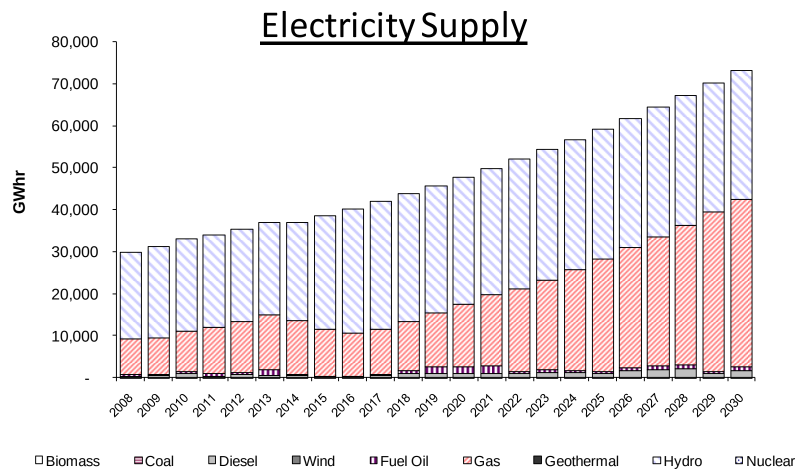
CO2 Emissions
kTonnes CO2
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

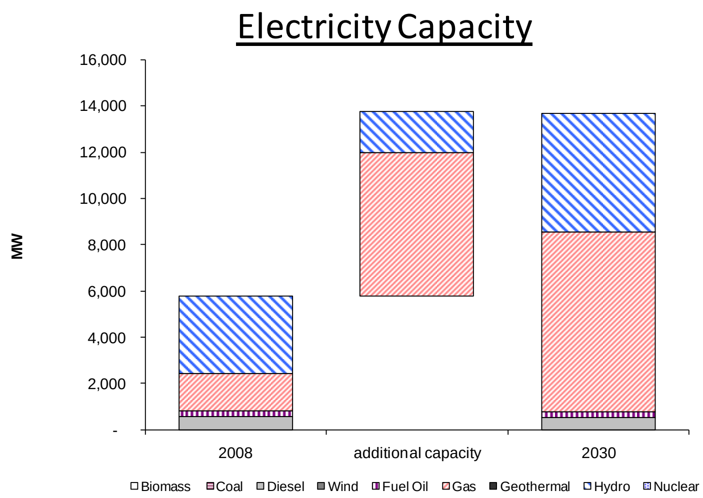
PARAGUAY

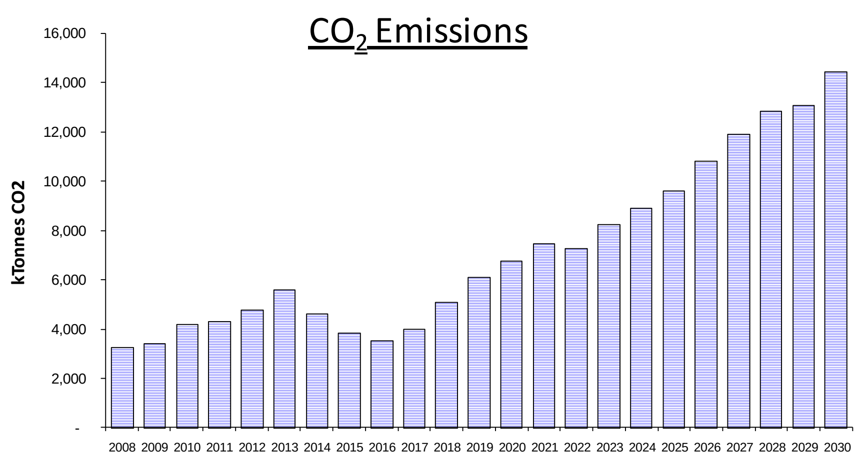

Electricity Supply
GWhr
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear


Electricity Capacity
MW
12,000
10,000
8,000
6,000
4,000
2,000
-
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

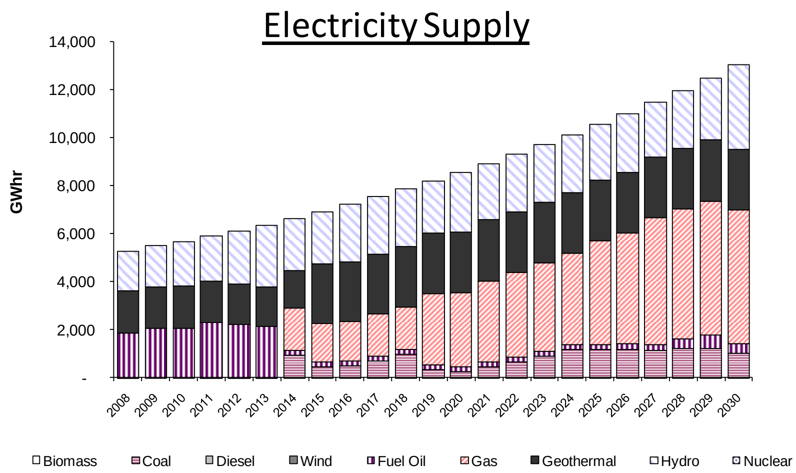
PERU

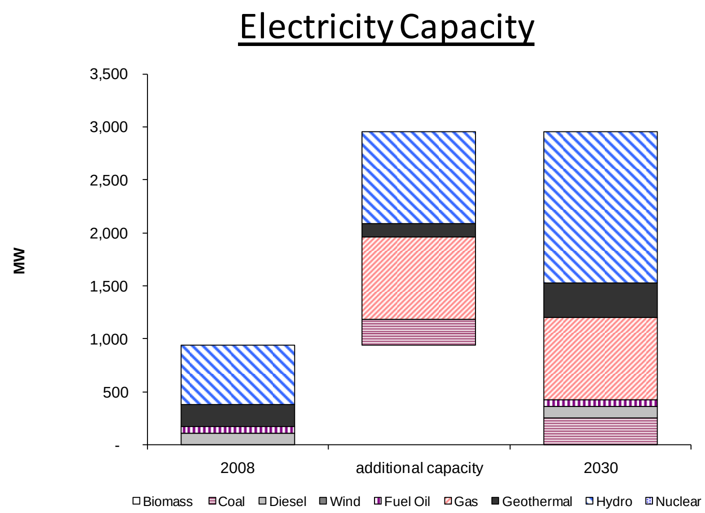

Electricity Supply
GWhr
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

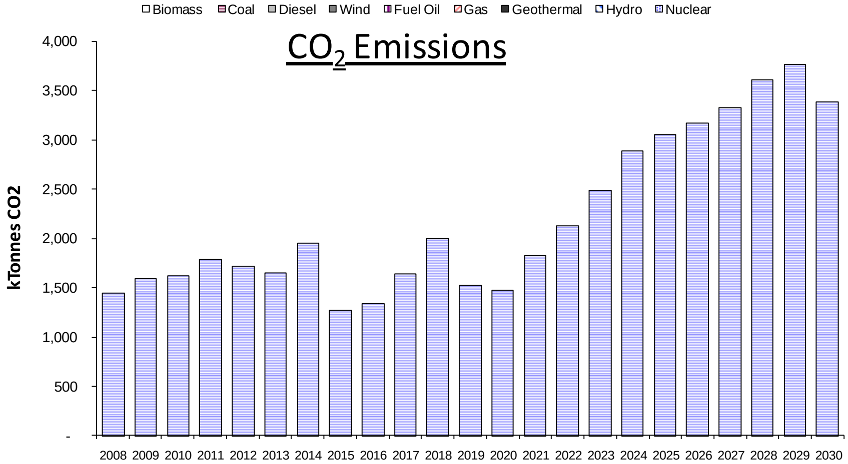

Electricity Capacity
MW
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear


CO2 Emissions
kTonnes CO2
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

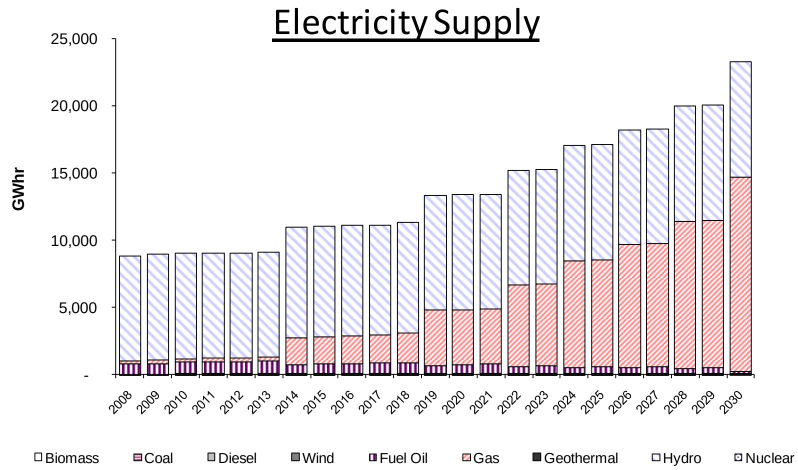
EL SALVADOR

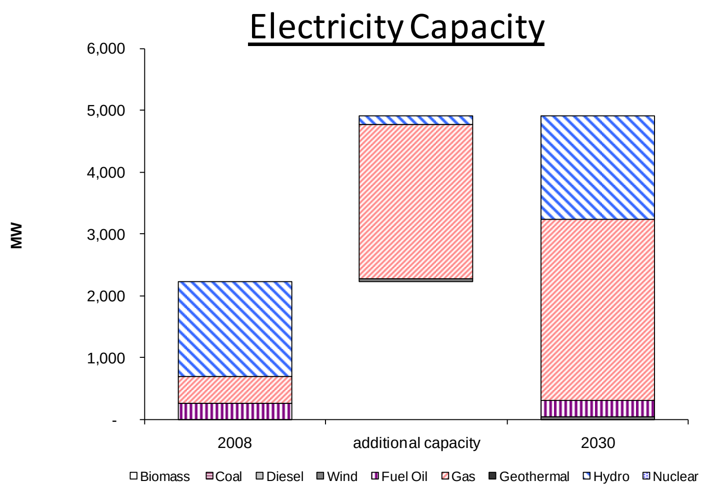

Electricity Supply
GWhr
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear

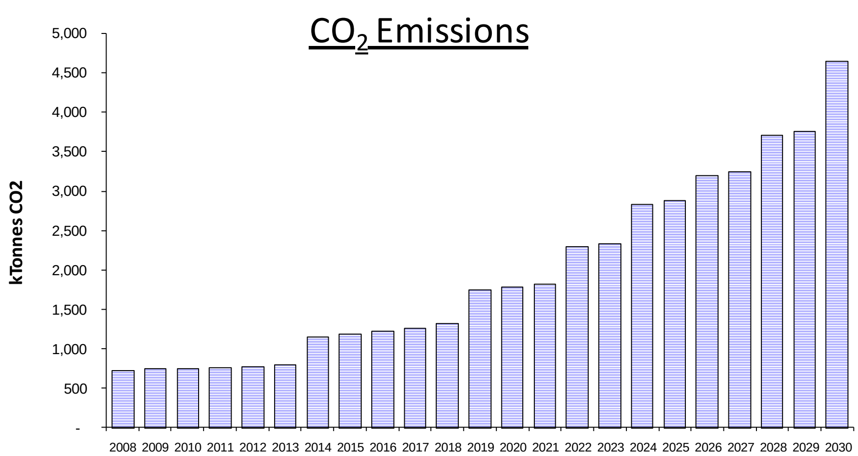

Electricity Capacity
MW
3,500
3,000
2,500
2,000
1,500
1,000
500
-
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear


CO2 Emissions
kTonnes CO2
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

URUGUAY


Electricity Supply
25,000
20,000
15,000
10,000
5,000
-
GWhr
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear


Electricity Capacity
6,000
5,000
4,000
3,000
2,000
1,000
-
MW
2008
additional capacity
2030
Biomass
Coal
Diesel
Wind
Fuel Oil
Gas
Geothermal
Hydro
Nuclear


CO_2 Emissions
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
kTonnes CO2
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030

ANNEX 2: PRICE AND INCOME ELASTICITY OF DEMAND

1. Similarly to other *normal* goods, the consumption of electricity is expected to increase with a rise in disposable income and the resulting increase in economic activity and purchases of electricity-using appliances, while a rise in electricity prices, *ceteris paribus*, should lead to a fall in the quantity demanded. Empirical studies focusing on estimating the price and income elasticity of electricity demand generally distinguish between ***long-term*** elasticities, ***short term*** elasticities (1 year or less), and time-of-use or ***real-time*** elasticities. Particularly in academic research, such as that surveyed by Halvorsen (1974), Taylor (1975), and others, there has been explicit analysis of the distinction between long- and short-run effects of price and income. In non-academic research, such as the models of the California Energy Commission (1991) and the US Energy Information Administration (1990), on the other hand, the analysis is specific to particular electricity end-uses, and the difference between the long- and the short-run effects is thus generally attributed to the rate of market penetration of various types of housing and appliances. The basic premise of both academic and applied research in specifying the time dimension is that time affects the dependence of capital stock on economic factors, whereby, over the long run, the demand for new housing and intensity of energy use can affect the size of the stock and efficiency of appliances. In the short run, on the other hand, the demand for electricity is limited to changes in the utilization rates given the fixed stock of electricity using appliances.

2. Caves, Eakin, and Faraqui (2000), Boisvert, Cappers, and Neenan (2002), and Kirschen (2003) have argued that increasing the ***short-run*** price elasticity of the demand for electrical energy would improve the operation of the market – i.e. that significant benefits would accrue if the demand of even a relatively small number of consumers became at least moderately price responsive. The main benefit of this increased overall demand elasticity is an immediate reduction in the magnitude of price spikes, which, in turn, leads to lower average spot price of electrical energy and, ultimately, affects the price of long-term contracts. Thus, promoting demand responsiveness to price fluctuations can be an efficient instrument for increasing energy supply security, as opposed to simply retaining large amounts of spare generating capacity. Similarly, the specific assumptions about the elasticity of demand for electricity are important in the context of the market power of an electricity provider – namely, the more price-elastic the demand, the less market power can be exercised.

3. In particular, the ***real-time*** price elasticity of electricity contains important information on the demand response of consumers to the volatility of peak prices. Yet, while excess demand may, in theory, be effectively counteracted by increasing the price responsiveness of demand, in reality, most end-users do not observe real-time prices and hence cannot react to them. Only a few authors, such as Wolak and Patrick (2001), have explicitly addressed the real-time elasticities, finding fairly low price elasticities—from virtually zero to −0.27[60]—for the five industrial sectors analyzed, although with somewhat higher values at peak demand hours. More recently, Lijsen (2007) analyzes the hour-to-hour price elasticity of electricity demand in the Netherlands, similarly, finding a low value for the real-time price elasticity, which the author

[60] The highest responsiveness (as low as -0.27) to changes in the price of electricity was found in the water supply industry, while the steel tube industry was found to be the least price-elastic (-0.007).

attributes to the fact that not all users observe the spot market price, as many small consumers are supplied by retailers, often on bilateral contracts with a fixed per unit price.

4. Also according to a number of authors, such as Yusta and Dominguez (2002), and Faraqui and George (2002), and Kirschen (2003), who have focused on the short-run as opposed to the real-time elasticity, while demand does decrease in response to a short-term price increase, that this effect is relatively small. Presumably, this weak elasticity can be explained by the fact that, while the cost of electrical energy represents only a small portion of the total cost of producing most industrial goods or of the cost of living for most households, it is nevertheless indispensable in manufacturing and is regarded as essential to the quality of life by most individuals in industrialized societies. As also argued in Heffner and Goldman (2001) and Roos and Lane (1998), even if one was to assume that all consumers are buying electrical energy on the spot market and that they are instantaneously informed of its price, the importance of electricity in daily life represents another barrier to enhancing the elasticity of demand in the immediate term. In the ***long run***, this elasticity is typically higher, as consumers have considerably more options, such as switching to gas for heating, purchase of more efficient appliances or relocation of industrial facilities to a region with lower average electricity prices. However, as stated by Holtedahl and Joutz (2004), when applied in a developing country context, both short- and long-term energy demand models may require an altogether different framework and interpretation, since economic growth and structural change associated with rapid development suggest that income and price elasticities will not be stable.

5. Most importantly, however, as summarized in the figure at the end of this Annex, academic research to date shows substantial variation in the estimates of both the price and the income elasticity of electricity demand. For instance, while Elkhafif (1992), Jones (1995), Beenstock *et al*. (1999), Filippini and Pachuari (2002), Urga and Walters (2003), and Holtedahl and Joutz (2004), find short-term price elasticities in the range from −0.04 to −0.18, the estimates found by several other studies, such as Silk and Joutz (1997) and Bjørner and Jensen (2002), are somewhat higher – at about -0.5 or -0.6. As shown by the comprehensive review of econometric studies on the topic by Taylor (1975), the estimates of short-run price elasticity of residential electricity demand typically vary from -0.90 to -0.13, with the long-run price elasticity estimates ranging from -2.00 to zero. For commercial electricity demand, the respective values were at -0.17 and -1.36. Subsequently, a similar review done by Bohi and Zimmerman (1984) reveals comparable average estimates of short- and long-run price elasticity of residential electricity demand—at about -0.2 and -0.7, respectively—with the results focusing on commercial electricity demand too diverse to arrive at conclusive consensus values. Most recently, Espey and Espey (2004), in their review of 36 studies focusing on residential electricity demand, show the range of short- and the long-run price elasticity estimates as between -2.01 and zero and between -2.25 and -0.04, respectively. The range of income elasticity estimates, on the other hand, is between 0.04 to 3.48 for the short-run and between 0.02 and 5.74 for the long-run models.

6. Moreover, as shown by studies such as Kamerschen and Porter (2004), there is a difference in magnitude between the residential and the industrial price and income elasticities of electricity demand. Estimates show that residential customers are more price-sensitive than industrial customers, and industrial variable price elasticities fluctuate less than the residential

estimates, which is consistent with the view that households spend a larger share of their budget on electricity. Likewise, a number of other studies, such as Barnes, Gillengham and Hageman (1981), who relate the households' level of electricity consumption to their stock of electrical appliances, find substantial variation in the residential electricity demand short-run price and income elasticities across *end-use categories*. Namely, while relatively higher price elasticity is common to the heating and air conditioning categories, water heating and lighting, on the other hand, are generally price inelastic and less susceptible to marginal use changes despite their high average and potential usage level.

7. Finally, marked differences in opinion among academic researchers exist also with regard to the very approach to measuring price and income elasticity of demand – specifically, whether the price and income elasticities should best be estimated at the ***marginal*** or the ***average*** price of electricity. For instance, Wilder and Willenborg (1975) defend the use of average price on the grounds that the consumer responds to his total monthly bill and rarely knows what his marginal rate is; several other researchers, such as Houthakker (1962), Houthakker *et al*. (1973), Taylor (1975), Taylor *et al*. (1977) and Berndt (1984), on the other hand, have argued that marginal price is the relevant price variable. Part of the reason for this debate is the fact that electricity has typically been sold according to a "multi-step block pricing" schedule, under which marginal price is a step function, usually declining, of quantity purchased. Studies by Hausman, Kinnucan and McFadden (1979), Barnes, Gillingham, and Hageman (1981) and Dubin (1982) have found the estimate of the marginal price elasticity of demand to be significantly biased away from 0 in the presence of declining-block rate schedules, and, as stated by Henson (1984), the bias in elasticity estimates of the marginal price tends to be larger the greater the number of blocks in the rate schedule and the more steeply the rate schedule declines or increases.

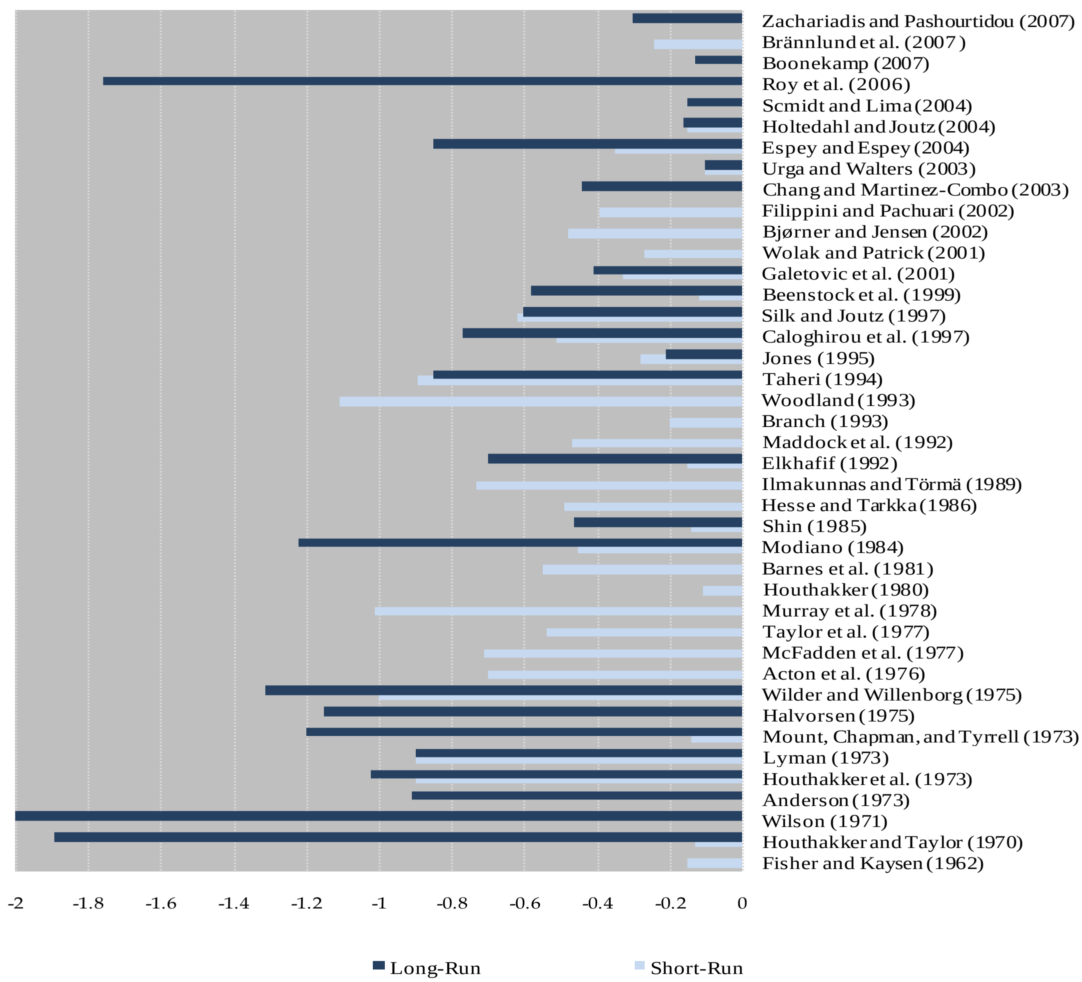
I. LAC-specific elasticity studies

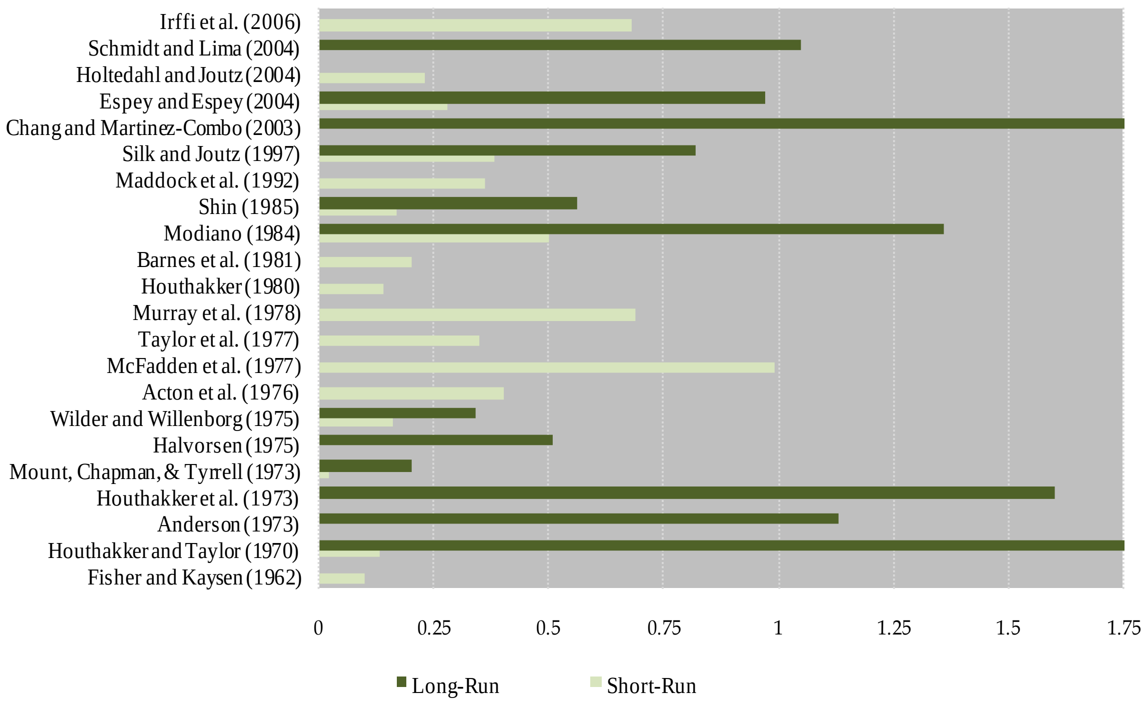
8. In the LAC Region, studies on the price and income elasticity of electricity demand are still relatively scarce and, similarly to the research focusing on other parts of the world, display some variation in the specific estimated coefficients. However, most of the LAC-specific elasticity estimates tend to fall in the lower range of the overall spectrum. Estimates for Brazil carried out by Eletrobrás and researchers such as Schmidt and Lima (2004), for instance, show an income elasticity of demand at above unity for both the residential and the industrial sector, illustrated, between 1980 and 2000, by the high average annual increase in electricity demand compared to the average annual growth in GDP – at 5.4 and 2.4 percent, respectively. On the other hand, the long-term price elasticity is estimated at a very low level: -0.15 for the residential and -0.13 for the industrial sector. Irffi *et al*. (2006), focusing on the country's Northeast and covering the period 1970-2003, specifically focus on the short-run income elasticity for residential demand, estimating it at about 0.84. Yet other researchers, such as Andrade and Lobão (1997), analyzing data for the period from 1963 to 1995, have found the short-run price and income elasticities to exceed the long-run ones. Finally, the models developed by Carlos et al. (2009) highlight the comparatively higher sensitivity of residential consumers relative to industrial ones to variations in the price of electricity, as well as find that the exact elasticity coefficients need not be constant over time.

9. Studies on Mexico, such as Chang and Martinez-Combo (2003), covering the 1985-2000 timeframe, similarly, find the long-run price elasticity of residential electricity demand to be fairly low – at about -0.44, - with the industrial sector demand being even less elastic – at -0.25. With regard to demand responsiveness to changes in income, the Study estimates the residential and the industrial sector long-term elasticities at 1.95 and 1.29, respectively. For Chile, Galetovic *et al*. (2001) estimate the price elasticity of electricity demand by commercial and residential users, finding the short-run values at -0.33 and -0.19 for residential and commercial consumers, respectively, while the long-term values are estimated at -0.41 and -0.21. Lastly, the research on the topic focusing on Colombia, such as the Study by Maddock *et al.* (1992), estimate the short-run price and income elasticity of residential electricity demand in the range between -0.17 and -0.47 and between 0.30 and 0.36, respectively. Interestingly, the authors also find a consistent pattern whereby richer consumers have absolutely larger price and income elasticities than do the poor ones.

Figure 42. Comparison of Estimates of Price and Income Elasticity of Demand for Electricity

Short- and Long-Run **(a)** Price **(b)** Income Elasticity Estimates





Irffi et al. (2006)
Schmidt and Lima (2004)
Holtedahl and Joutz (2004)
Espey and Espey (2004)
Chang and Martinez-Combo (2003)
Silk and Joutz (1997)
Maddock et al. (1992)
Shin (1985)
Modiano (1984)
Barnes et al. (1981)
Houthakker (1980)
Murray et al. (1978)
Taylor et al. (1977)
McFadden et al. (1977)
Acton et al. (1976)
Wilder and Willenborg (1975)
Halvorsen (1975)
Mount, Chapman, & Tyrrell (1973)
Houthakker et al. (1973)
Anderson (1973)
Houthakker and Taylor (1970)
Fisher and Kaysen (1962)
0
0.25
0.5
0.75
1
1.25
1.5
1.75
Long-Run
Short-Run

ANNEX 3: ELECTRICITY SUPPLY MODEL AND FUEL PRICE ASSUMPTIONS

I. Description of Electricity Supply Model

1. After the total annual demand is calculated, OLADE's SUPER model is then used to determine the optimal, cost-minimizing generation mix to meet the demand. The SUPER model was developed by OLADE and is aimed at the prioritization, scaling and selection of electricity projects to meet the growth in electricity demand. In each phase, the system determines generation targets for each of the system's power plants, minimizes the expected value of the operating and capital costs throughout the period, and evaluates the financial and environmental impacts caused by the future development of the electricity sector.

2. In addition to the demand scenario as an input to the model, various data is also inputted into the SUPER model, including hydrology, reference prices for fuels, existing plants with their operational features, projects under construction or bidding, which are fixed, and their entry dates, as well as eligible projects with their earlier entry dates and operational features, investment costs and operational variables, among other inputs.

3. The modeling of demand curves is done on the basis of historical demand records, which form the starting point for the load curves. Thus, based on annual estimates of the long-term demand scenario obtained from the detailed analysis performed using the electricity demand model and based on historical demand records, the SUPER model generates energy and power demands of each year of the prospective horizon.

4. The model uses country-specific information on hydrology, when available. This information includes the time series of volumes of flow in different sites, which preserves the most important time and space parameters estimated on the basis of historical records. Its objective is to supply hydrological information for optimization and simulation. The model produces the available and minimal energy, maximum capacity and storable energy for each hydroelectric project, period of time and hydrological condition.

5. To produce these results and utilize SUPER, hydrological data for different measurement stations must be inputted, and these data must be related to each basin with operational or eligible projects in that basin.

6. The problem of expansion planning can be divided into two sub-problems: investment and operation. These problems are due to the nature the two-stage decision-making process of first making expansion decisions, and then evaluating those decisions once in operation. Based on operating costs and other factors, the expansion strategy is reformulated, which in turn impacts the operations side once again.

7. The analysis of system expansion under the SUPER model is conducted selecting a path of capacity expansion, selecting hydroelectric projects and the expansion of the so-called thermal

classes (grouping thermal plants with similar technological and operational features, such as steam plants that use coal). This expansion path is obtained by minimizing the total costs of investment and operation throughout the Study period. The expansion plans for hydroelectric capacity considers the country expansion plans.

8. As a result, the capacity expansion plan is thus obtained, with the addition of individual hydroelectric projects and of thermoelectric projects grouped in thermal classes, with the installed capacities in each case and the start-up dates. Based on these data, a power balance is calculated to verify that the system's power demand or maximum demand is covered and the gross margin of reserve. The investments required for this plan are also calculated.

9. The expected generation for each period of each hydroelectric plant and of each thermal class is obtained from the model. Annual generation by plant and type of plant and the system's energy balance must be calculated separately using text files transferred to Excel. In addition, the analysis and verification of results are conducted separately from the SUPER model.

i. Supply Assumptions

10. **Plant Specification Assumptions by Technology.** Given the current available information on costs, plant dependability and state of development, the model considers the technologies shown in Table 16.

11. In order to simplify the assumptions, plant specifications are assumed to be constant across the region. The unitary investment cost for each technology, except hydroelectricity based generation, is constant for every Country.[61] Other technologies, including solar power (both concentrated solar thermal and photovoltaic), were not considered in this analysis.

Table 16. Levelized costs by Technology

	Levelized cost US$/MWh		
CRUDE price	**50**	**100**	**150**
Combined cycle (Gas)	44	64	78
Hydro	39	39	39
Coal	41	49	52
Geothermal	77	77	77
Nuclear	78	78	78
Wind	93	93	93
Diesel/FO	140	207	273

[61] For the case of hydro-based generation, the investment cost assumptions for Central America, Ecuador, Peru and Colombia were a specific unitary cost for each project based on the information contained in each country's expansion plan. For other countries, the average unitary cost was assumed to be a function of the marginal availability of hydrologic resources. Hence, the average unitary cost of installed capacity for Brazil was US$1,800/KW, for Mexico & Paraguay US$2,500/KW, and for all other countries: US$2,000/KW.

12. **Carbon tax assumptions.** Two carbon tax scenarios were used for 20 and 50 US$ per ton of CO_2 respectively. The assumed additional cost per fuel type is as follows:

	Diesel (US$/Barrel)	**Fuel Oil** (US$/Barrel)	**Natural Gas** (US$/mmbtu)	**Coal** (US$/Ton)
20 US$/Ton CO_2	7.95	9.9	1.0	78.36
50 US$/Ton CO_2	19.87	24.7	2.4	195.9

ii. Fuel price assumptions

13. The crude oil price is a key parameter for the cost of electricity across the generation technologies. In order to produce the oil price sensitivity analysis it is important to define the associated prices for natural gas, coal and oil derivatives.

14. Concerning the price of fuel at the plant door the model assumes transport and handling costs only for coal and natural gas (related to pipeline transport cost) Accordingly, for these fuels the final cost of fuel is computed as the sum of spot price and transport/handling cost. On the other hand, for diesel and heavy fuel oil the fuel cost is computed only as the spot price. It is then worth emphasizing an implicit assumptions made by the model: there is no cost to use wind and water62 . The spot prices – for natural gas, fuel oil, diesel and coal - used throughout this report for the 20 years time analysis are based on the projections provided assuming fix prices for each fuel along the study period. We considered a price for oil of 100 dollars per barrel. To simplify our exercise and the assumptions around fuel prices we estimate a price for coal, gas and oil derivatives considering the equations below.[63] These equations result from least square regressions of price of each fuel against oil price (as an average of crude oil WTI). The equations used are following listed[64].

Coal Price: $CP_t=30.4 +0.611xOilP_t$

Gas: $GasP_t=2.5+0.058xOilP_t$

Heavy Fuel Oil: $HFOP_t=0.4+0.818OilP_t$

Diesel Price: $DP_t =0.57+1.194x\ OilP_t$

[62] It must be stressed that this assumption of zero cost for water is just an average premise for all the countries of Latin American and the Caribbean region.

[63] The team is fully aware of the simplification of this analysis. Prices for oil, gas and coal are not fully correlated. Furthermore the economics explaining prices for these fuels consider factors such as demand, relative scarcity and substitutability among other factors. The fundamentals of these fuels market are quite complex and a deeper analysis of the future tendencies of the prices of these fuels is out of the scope of this study. Hence we simplify the exercise by considering a simple regression analysis approach .

[64] The equations refer to: coal price in US$/ton, diesel price in US$/barrel, heavy fuel oil in US$/barrel, Gas in US$/MMBTU and crude oil in US$/barrel.

ANNEX 4: COMPARISON OF ICEPAC RESULTS WITH COUNTRY EXPANSION PLANS

ARGENTINA

Document name	Balance Energético Nacional *(Presentation: La Política Energética Argentina: Elementos para el Planeamiento Energético)*	ICEPAC Scenario
Publication date	2008	2010
Period covered	2008-2025	2008-2030
Electricity demand	216.4 TWhr in 2025	168 TWhr in 2025
Electricity demand annual % growth	3.2% (average annual growth 2008-2025)	2.7% (average annual growth 2008-2030)
GDP growth assumptions	2008-2014: 4.0% 2014-2018: 3.0% 2018-2025: 2.5%	2.9% (average annual growth 2008-2030)
Conclusion	The generation mix trends are roughly consistent except for natural gas. But even natural gas shows same direction (decline), just not as sharp a decline as the Argentina Balance Energético Nacional projects.	

BOLIVIA

Document name	*Actualization del Plan Referncial del Sistema Interconectado Nacional Boliviano*	ICEPAC Scenario
Publication date	2005	2010
Period covered	2005-2014	2008-2030
Electricity demand	6.136 TWhr in 2014	9.03TWhr in 2014
Electricity demand annual % growth	5.2% (average annual growth 2005-2014)	6.5% (average annual growth 2008-2030)
GDP growth assumptions	4.0% average annual GDP growth 2005-2014 in the base case. (Pessimistic case = 2.6%; Optimistic case = 5.4%)	3.2% (average annual growth 2008-2030)
Conclusion	Bolivia's country expansion plan estimates a lower annual % growth in demand than the ICEPAC Scenario. In the ICEPAC Scenario, the share of natural gas in the generation mix slightly increases by 2030 and the expense of hydro.	

BRAZIL

Document name	*Plano Nacional de Energia*	ICEPAC Scenario
Publication date	2007	2010
Period covered	2005-2030	2008-2030
Electricity demand	859-1,245 TWhr in 2030 (range of values within four different growth scenarios	1,087 TWhr in 2030
Electricity demand annual % growth	3.5%-5.1% (range of values within four different growth scenarios)	4.4% (average annual growth 2008-2030)
GDP growth assumptions	2.2% - 5.1% (range of values within four different growth scenarios)	3.0% (average annual growth 2008-2030)
Conclusion	There is consistency between the ICEPAC Scenario and Brazil's *Plano Nacional de Energía*. This is largely because Brazil's government projections span the entire ICEPAC projection period (through 2030), thus the ICEPAC scenario was able to more accurately take into account the government's long-term projections.	

COLOMBIA

Document name	*"Plan de Espansion de Referencia Generacion - Transmision 2009-2023." Republica de Colombia, Ministerio de Minas y Energia.*	ICEPAC Scenario
Publication date	2008	2010
Period covered	2009-2025)	2008-2030
Electricity demand	89.0– 111.6 TWhr in 2025	82.1 TWhr in 2025
Electricity demand annual % growth	3.3% (average annual growth 2009-2025)	3.6% (average annual growth 2008-2030)
GDP growth assumptions	6.0% (sustained annuall GDP growth, 2009-2025)	3.1% (average annual growth 2008-2030)
Conclusion	Although the Colombia Expansion Plan's GDP assumption (6.0%) is significantly higher than ICEPAC's GDP assumption	

COSTA RICA

Document name	"Plan de Expansion de la Generacion Electrica, Periodo 2008-2021." Instituto Costarricense de Electricidad (ICE)	ICEPAC Scenario
Publication date	2007	2010
Period covered	2008-2021 (although demand projections go through 2030)	2008-2030
Electricity demand	21.2 GWhr (escenario bajo)-24.9 GWhr (escenario alto) in 2030	21.8TWhr in 2030
Electricity demand annual % growth	4.2% - 6.6% (average annual growth 2008-2030)	3.4% (average annual growth 2008-2030)
GDP growth assumptions	3.0% (average annual growth 2008-2030)	3.1% (average annual growth 2008-2030)
Conclusion	Electricity annual % growth is similar in the government expansion plan: in 2030 under ICEPAC (21.8 TWhr) is slightly higher than the lowest (21.2 TWhr) of Costa Rica's three electricity demand scenarios.	

ECUADOR

Document name	*CONELEC, "Plan Maestro de Electrificación del Ecuador 2007-2016"*	ICEPAC Scenario
Publication date	2007	2010
Period covered	2007-2016	2008-2030
Electricity demand	22.82 TWhr in 2017 (medio crecimiento escenario)	22.1 TWhr in 2017
Electricity demand annual % growth	3.56% (average annual growth 2008-2017)	4.8% (average annual growth 2008-2030)
GDP growth assumptions	2008-2017, by year: 5.5%, 5.3%, 5.1%, 5.0%, 4.9%, 4.8%, 4.7%, 4.7%, 4.6%, 4.6%	2.7% (average annual growth 2008-2030)
Conclusion	Electricity demand numbers are roughly on par	

EL SALVADOR

Document name	National Expansion Plan *(data provided by Salvador, Fernando Lecaros's colleague)*	ICEPAC Scenario
Publication date	2003	2010
Period covered	2003-2020	2008-2030
Electricity demand	9.383 TWhr in 2020	8.5TWhr in 2020
Electricity demand annual % growth	4.7% (average annual growth 2003-2020)	4.1% (average annual growth 2008-2030)
GDP growth assumptions	4.8% (average annual growth)	2.8% (average annual growth 2008-2030)
Conclusion	The country data is from 2003, which likely explains the discrepancies in GDP growth assumptions and electricity demand growth.	

GUATEMALA

Document name	*Plan de Expansión Indicativo del Sistema de Generación, CNEE*	ICEPAC Scenario
Publication date	2008	2010
Period covered	2008-2022	2008-2030
Electricity demand	13.4-19.3 TWhr in 2022 (range of values within four different scenarios – NOTE for energy as a whole)	17.3 in 2022
Electricity demand annual % growth	4.6%-6.8% (range of values within four different scenarios – NOTE for energy as a whole)	6.6% (average annual growth 2008-2030)
GDP growth assumptions	3.3% (escenario bajo) – 5.5% (escenario alto)	3.1% (average annual growth 2008-2030)
Conclusion	Note that discrepancies could result from the fact that the Guatemala National Expansion Plan only provides projections for the energy sector as a whole, rather than specifically the electricity sector. Still, the electricity demand values are comparable.	

HONDURAS

Document name	*Proyección de Demanda de Energía Eléctrica*, Escenario Base, ENEE	ICEPAC Scenario
Publication date	2010	2010
Period covered	2010-2025	2008-2030
Electricity demand	14.473TWhr in 2025	11.5 TWhr in 2025
Electricity demand annual % growth	6.41% (average annual growth)	5.3% (average annual growth 2010-2025)
GDP growth assumptions	(no data available)	2.9% (average annual growth 2008-2030)
Conclusion	Average annual growth is 1% lower in ICEPAC when compared to national plan	

MEXICO

Document name	*Prospectiva del Sector Eléctrico*	ICEPAC Scenario
Publication date	2009	2010
Period covered	2009-2024	2008-2030
Electricity demand	365 TWhr in 2024	373 TWhr in 2024
Electricity demand annual % growth	3.6%	3.1% (average annual growth 2008-2030)
GDP growth assumptions	2.7% (annual growth)	2.9% (average annual growth 2008-2030)
Conclusion	Overall satisfactory match on electricity demand, electricity demand annual % growth, and GDP growth assumptions. In terms of the generation matrix, the match is acceptable if it is assumed the “undecided” portion of the expansion plan goes to gas	

NICARAGUA

Document name	*Plan Indicativo de Generación 2008-2014 (Excenarios Refernciales). Ministerio de Energía y Minas*	ICEPAC Scenario
Publication date	2008	2010
Period covered	2008-2014	2008-2030
Electricity demand	4.201 TWhr in 2014	4.3 TWhr in 2014
Electricity demand annual % growth	5.0%	5.0% (average annual growth 2008-2030)
GDP growth assumptions	3.6% (average annual growth 2008-2014)	2.8% (average annual growth 2008-2030)
Conclusion	Electricity demand numbers are roughly on par	

PANAMA

Document name	*Empresa de Transmisión Eléctrica S.A., "Plan de Expansión del Sistema Interconectado Nacional 2007-2021."*	ICEPAC Scenario
Publication date	2007	2010
Period covered	2007-2021	2008-2030
Electricity demand	12.29 TWhr in 2021	13.6 TWhr in 2021
Electricity demand annual % growth	5.4%	4.6% (average annual growth 2008-2030)
GDP growth assumptions	2.7% (annual growth)	4.0% (average annual growth 2008-2030)
Conclusion	The ICEPAC scenario calls for a higher annual GDP growth compared to the country expansion plan.	

PERU

Document name	*"Peru Plan Referencial de Electricidad"* Ministry of Energy & Mining	ICEPAC Scenario
Publication date	2006	2010
Period covered	2006-2015	2008-2030
Electricity demand	43.74 TWhr in 2015 (escenario medio)	38.5 TWhr in 2015
Electricity demand annual % growth	6.6% (average annual growth 2006-2015, escenario medio)	4.2% (average annual growth 2008-2030)
GDP growth assumptions	Escenario Bajo: 5.6% Escenario Medio: 6.5% Scenario Alto: 7.3%	3.9% (average annual growth 2008-2030)
Conclusion	Although there are discrepancies in the GDP growth assumptions and the electricity demand growth assumptions, the comparison between the absolute electricity demand numbers are very similar (43.74 TWhr in 2015 vs. 38.5 TWhr in 2015)	

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