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Rethinking Our Energy Future

A White Paper on Renewable Energy for the 3GFLAC Regional Forum

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Preface

The Global Green Growth Forum (3GF) was initiated in 2011 with the aim of supporting a global transition to inclusive green growth through global alliance making and the promotion of public-private partnerships. This forum is a unique platform to catalyze partnerships that can rapidly bring to scale green growth opportunities bringing together governments from developed, developing and emerging economies along with the private sector. Realizing the potentials of green growth requires the effective mobilization at scale of financial, technological and human capital. This will only be possible if governments and the private sector collaborate at the local, national and the international levels to overcome barriers, and create the right incentives for actors to innovate and invest.

The global 3GF is hosted by the Danish government and supported by five partner countries China, Kenya, Mexico, Qatar and the Republic of Korea. During the October 2012 Global Green Growth Forum (3GF) in Copenhagen,[1] the Government of Denmark and the Inter-American Development Bank (IDB) agreed to undertake an effort, under the umbrella of the 3GF, to promote a follow up discussion on the topic of energy and climate in Latin America and the Caribbean.

The 3GF Latin America and the Caribbean (3GFLAC) Forum is held in Bogota on June 18th, 2013 under the auspices of the IDB and the governments of Denmark and Colombia. 3GFLAC builds on results from the Rio+20 conference that raised important questions about the future of growth. It called the Latin America and Caribbean (LAC) countries to embrace growth models that are clean, efficient, resilient, and socially inclusive.[2] It will be the first regional meeting of 3GF, and will seek to provide a platform for dialogue among high-level stakeholders, to share the latest knowledge and best practice in public policy, and to discuss ways to promote innovative technology and investment in renewable energy. The meeting will focus on how to make use of the substantial endowment for renewable energy to meet the region's growing energy demand.

This document is oriented towards stimulating the discussions, commitments and partnership building between governments and the private sector at the Forum. The commitments and insights derived from this first regional 3GF meeting will both benefit the LAC region and feed into the global 3GF meeting in Copenhagen on October 21-22, 2013.

A number of individuals led by Walter Vergara, Claudio Alatorre and Leandro Alves, assisted in drafting and reviewing this document including Wilson Rickerson (Meister Consultants Group); Mauricio Solano Peralta and Xavier Vallve (Trama TecnoAmbiental); Chris Flavin and Michael Weber (Worldwatch Institute); Juan Pablo Carvallo and Dan Kammen (University of California at Berkeley); Rajendra K. Pachauri (TERI); Jason Eis (Global Green Growth Institute); David McCauley, Tabaré Arroyo, and Santiago Lorenzo (WWF); Lisbeth Jespersen (Ministry of Foreign Affairs, Denmark); Karen Schutt (Mines and Energy Ministry, Colombia); Paul Isbell (Johns Hopkins University); Hilen Meirovich, Ana R. Rios, Juan Roberto Paredes, Jose Ramón Gomez, Verónica Valencia and Emiliano Detta (Inter-American Development Bank).

Executive Summary

In Latin America, as a result of population growth combined with improvements in quality of life, a 3% annual growth in economic output is expected during the foreseeable future. This will require the region to almost double its installed power capacity to about 600 GW by 2030, at a cost of close to 430 billion dollars,[3] posing a challenge but also an opportunity to redefine the energy model for the region.

LAC already has a low carbon power sector, anchored through a substantial hydrological resource. However, the anticipated energy demand will require major additions to the existing power matrix. Fortunately, the region could produce over 78 PWh[4] from solar, wind, marine, geothermal and biomass energy. The corresponding nominal peak capacity would be about 34 TW[5] (world installed capacity is 5 TW) well above any foreseeable demand. The cost of use of these Non-Traditional Renewable Energy Technologies (NRETs) is falling and in some cases is already competitive with fossil alternatives.

These resources constitute a near zero carbon option. They also constitute an indigenous energy resource without an expiration date and with substantial societal benefits,[6] including energy security, resilience, local environmental benefits, domestic job creation, and improved balance of payments, amongst others. According to one estimate, the value of these societal benefits could amount to about $50 per MWh delivered which, if considered, places many of these options in a very competitive position.

By and large, the rules of the power sector in LAC and elsewhere, despite being in theory "technology-blind", were tailor-made to suit conventional power generation technologies, and have therefore intrinsic biases against renewable energy. NRETs differ from conventional generation in their cost structures, revenue and costs stream, generation profiles, geographical distribution, and the wider range of societal benefits they deliver. Therefore, scaling up NRETs will require a recasting of this framework.

In order to accommodate these differences, countries can implement mechanisms to compensate for the current biases, or reform the electricity market regulatory and institutional framework so that they provide a truly level playing field, especially by accommodating variable generation and by developing new pricing mechanisms. Public policies have an important role to reduce risks associated with NRETs and increase the profit potential of these investments. Countries and regions that take the lead in developing these new energy sources will have first-mover advantage in one of the world's fastest growing economic sectors—reaping the economic growth and job creation that will flow from it.

Introduction

In Latin America and the Caribbean (LAC), economic output is projected to grow by about 3% annually into the foreseeable future, supported by population growth and improvements in quality of life. This will require the region to nearly double its installed power capacity to about 600 GW by 2030, at a cost of close to 430 billion dollars.[7] This represents a challenge to the region's energy model but also an opportunity to redefine and transform it.

Current plans in some countries in the region consider that a substantial share of the new demand could be met with fossil fuels, with hydropower providing much of the remainder. However, fossil fuels -the main source of energy worldwide- are driving climate change toward dangerous thresholds.[8] A sustainable future ("the future we want", as posited by the United Nations Conference in Sustainable Development -UNCSD) requires an urgent change of path possible only if a major departure from the business as usual (BaU) scenario is achieved, capable of preventing global temperature from escalating much further than 2 degrees Celsius (°C) this century.

A global climate stabilization goal of this magnitude would require of no more than 20 gigatons (Gt) of CO_2 to be emitted by 2050 (a significant deviation from the current projection of 45 Gt of CO_2) and no more than 10 Gt of CO_2 by the end of the century. Under current population growth projections, this implies an average annual per capita emission of 2 tons by mid-century equivalent to less than 40% of current emission levels.[9]

For the region, fortunately, an alternative energy path is available that is consistent with these goals. Starting from a relatively clean supply base (LAC's installed power capacity is estimated at about 280 GW, the majority of which, 52%, is already provided through renewable energy resources, including hydropower[10]), non-traditional renewable energy technologies (NRETs) —solar, wind, geothermal, ocean, small-scale hydropower, and advanced bio-energy—together with improvements in energy efficiency—are now ready to play a major role alongside hydropower in meeting LAC countries' energy needs.

The costs of these technologies are falling rapidly, and in many cases are competitive with fossil fuels. LAC's unusually rich renewable resource base may place the region's renewable energy (RE) generation costs at the lower end of the global cost spectrum, a fact particularly significant given that these sources are currently providing electricity that is less expensive than that generated by fossil fuels in other parts of the world.[11] And this can be done with additional and substantial economic, social and environmental benefits (societal) benefits.

Globally, the scale of recent developments in renewable energy suggests that a historic energy transformation is underway. NRETs —assembled in large power plants as well as widely decentralized small systems— are rapidly diversifying the energy economies of many nations. Some industrial nations, including Germany and Denmark and others such as Mexico, Uruguay, Costa Rica and China, are well on the way to make renewable energy and energy efficiency the centerpieces of their energy futures. Countries and regions that take the lead in developing these new energy sources will have first-mover advantage in one of the world's fastest growing economic sectors—reaping the economic growth and job creation that will flow from it.

This discussion today is more relevant than ever as the region faces *macro trends reshaping power system evolution*,[12] including: the need to mitigate greenhouse gas emissions; the impacts of climate change, calling for a higher resilience of power systems; an increasing impact of fossil fuel price volatility; the advent of new information and communication technologies for grid monitoring and control (smart grids); the emergence of new clean energy business models for both large and small-scale generation; and an increased vehicle fleet electrification.

While there have been some non-traditional renewable energy investments across the region, the use of these resources has not nearly reached its potential as some barriers to their implementation and myths remain. First of all, NRETs are perceived as a luxury that the region cannot afford without subsidies or external support. Many also believe that NRET can cover only a minor part of the power demand. Furthermore, there is a perception that intermittent resources such as wind or solar impose a hefty burden on power systems. Finally, there is an implicit perception that policy recipes to promote renewables necessarily come at high economic cost for the countries that implement them. Since successful policies cannot be simply transferred across borders, there is little clarity on how to accelerate the deployment of NRETs.

This document focuses on the region's need to define its future energy model and meet the increasing energy demand by addressing three questions: What is the magnitude of the available renewable sources? What are the associated societal benefits?[13] And, what are the policy options for adopting renewable energy?

These issues are presented and the stage is set for broader discussions about a new energy future in which new, resilient, and renewable energy sources meet most of the electricity requirements in the LAC region as a complement to its substantial hydropower base. To reach this goal, the report focuses on NRETs for grid-connected electricity generation. There are equally compelling discussions –beyond the scope of the analysis- regarding new paradigms for increasing energy efficiency, use of renewable energy in transportation and heat applications, and for expanding energy access through off-grid systems.

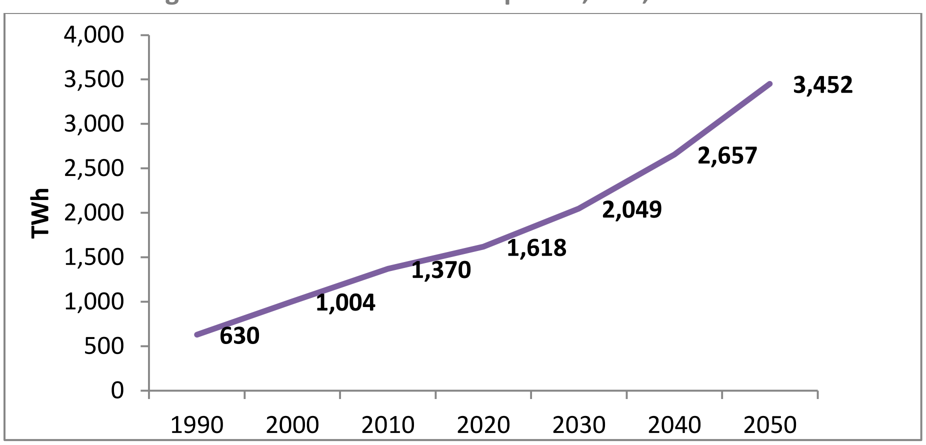
Resource Endowment for NRETs for Power Generation in LAC

Power demand

LAC generated 1.3 PWh[14] in 2010, close to 7% of the world's total electricity production (20.2 PWh)[15], representing an increase of about 50% since 2000 (Figure 1). Meanwhile, the region had 325 GW of installed capacity in 2010, or 6.4% of total global installed electric capacity (5.07 TW).[16] However, the demand for electricity in the region is projected to increase to 3.5 PWh by 2050.[17]

Using data from the GEA Model of the International Institute for Applied Systems Analysis (IIASA), the IDB estimates that, under a business-as-usual scenario, LAC power demand will nearly triple to about 3.5 PWh (Figure 1) while the carbon emissions of the power sector are expected to double from current levels by 2050 (from 0.25 $GtCO_2e$/yr to 0.54 $GtCO_2e$/yr).[18] This implies a continuing high share for the use of non-fossil based power generation as well as substantial improvements in energy efficiency but still places the region under a projected net increase in emissions.

Figure 1. Demand for electric power, LAC, 1990-2050

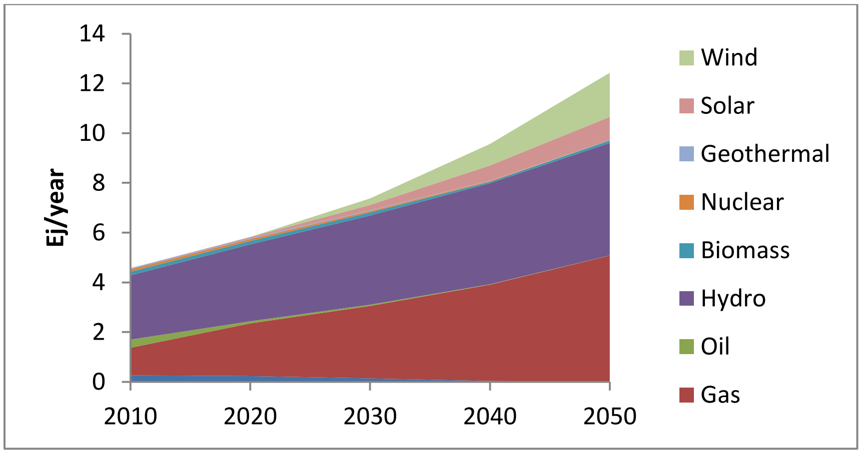


Source: Historical data from British Petroleum Annual Statistical Review of World Energy 2012. Projections to 2050 from IIASA's GEA Model Database. Data for 2010 is the average of BP (1,373 TWh) and IIASA (1,269.8 TWh). One thousand (1,000) TWh equals 1 petawatt hour (PWh).

While coal and oil currently have only minor roles in the LAC power matrix, both of these fossil fuels are projected to disappear completely by 2050, even under the IIASA business-as-usual scenario. The share of fossil fuels in the generation mix is nevertheless expected to increase from 37% to 40% (peaking at 42% in 2030), mainly because the share of natural gas is expected to rise from 24% to 41% by 2050. Indeed, beyond 2030, expanded natural gas begins to compete with NRETs and large hydropower within the generation mix. This significant expansion of natural gas within the LAC power mix, expected under the BaU trajectory, is what accounts for the projected doubling in LAC power sector emissions. Indeed, hydropower's share of the LAC electricity mix is also projected to fall from 56% in 2010 to 36% in 2050.

Meanwhile, the share of NRETs in the LAC power mix is projected to rise from less than 1% presently to 22% in 2050 (see Figure 2).

Figure 2. Projected Evolution of LAC Power Mix to 2050

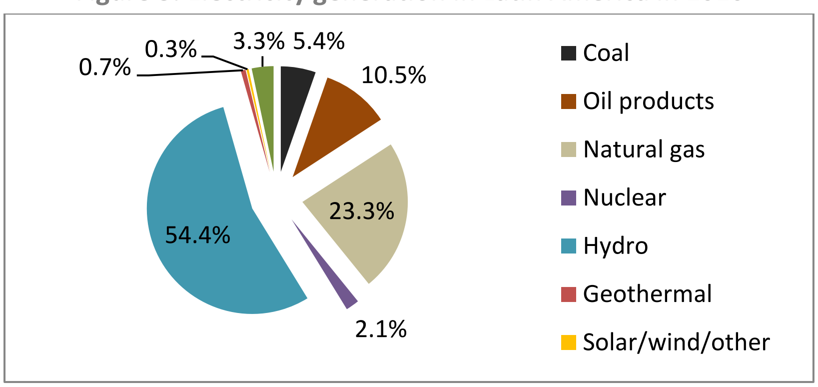


Source: IIASA's GEA Model Database.

Power supply

A distinctive feature of the power supply matrix in LAC is its heavy reliance on hydropower (Figure 3). Overall in the region, NRETs and hydropower provide 52% of current installed capacity and generate around 59% of the region's electricity[19].

Figure 3. Electricity generation in Latin America in 2010



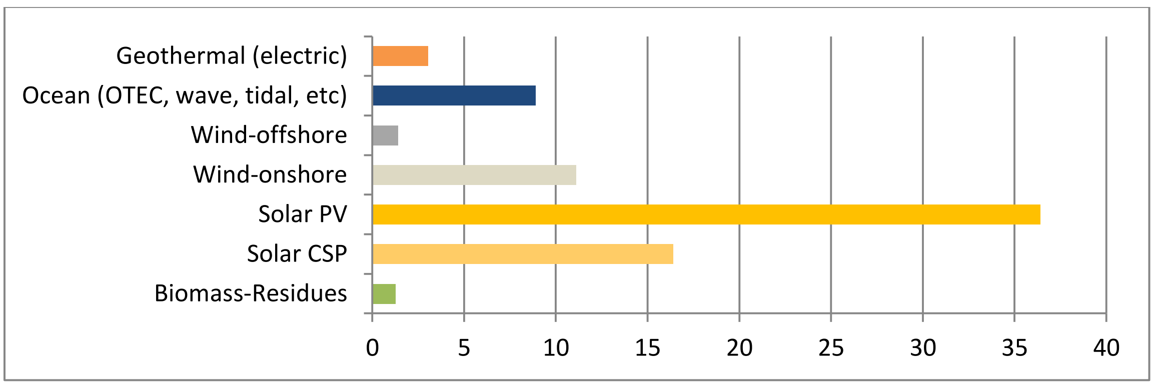
Source: IEA 2010, World Energy Balances

While this large contribution to power generation brings substantial global and local benefits, it does on the other hand increase the region's exposure to changes in the stability of hydrological cycles projected under current climate change scenarios. In this context, and in order to maintain a diversified power supply while limiting its carbon emissions, the region would need to access other renewable energy resources.

Fortunately,[20] the non-hydro renewable energy resources of LAC are also substantial. These are indeed world-class and could easily provide the required complement to hydropower to meet regional demand to 2030 and beyond, even assuming aggressive demand growth rates, and considering a range of technical constraints. Recent assessments[21] show that the region could produce over 78 PWh from solar, wind, marine, geothermal and biomass energy (Figure 4). The corresponding nominal peak capacity would be about 33 TW[22] (500 GW for geothermal; 3,400 GW for marine –ocean- power; 450 GW for offshore wind; 4,200 GW for onshore wind; 17,000 GW for PV; 7,500 GW for solar CSP, and 255 GW for biomass residues), well above foreseeable demand and enough to power the entire region, indeed the entire global demand, several times over.

Considering that current consumption is 1.3 PWh, this means that by exploiting 1.6% of the available technical potential the full current electricity demand could be met. Moreover, the projected 2050 demand growth of 3.5 PWh would only amount to 4% of total available technical potential. In a global context, the renewable energy potential of the region could theoretically meet a major share of global power demand. The availability of this resource in the face of the sustainability challenge in the provision of power and the potential benefits that its deployment could bring to the region, calls for further review and exploration of possible ways to maximize its use.

Figure 4. Renewable energy resource technical potential for electricity generation in LAC (PWh)

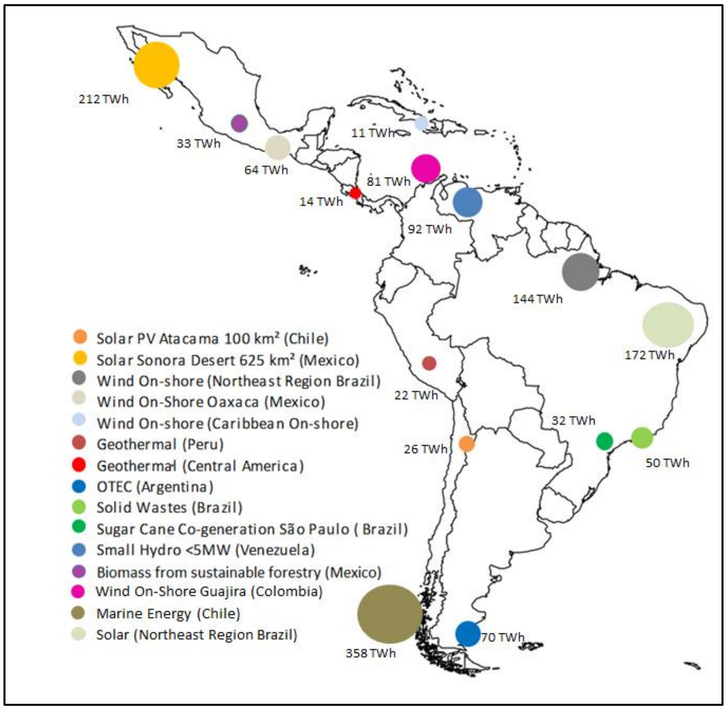


Source: REN21.[23] Solar is in practice a limitless resource. However, in this study, the potential solar resource was bounded based on limited by space availability (assuming 269 million hectares for Mexico and Central America and 1,761 for South America) with an average land use factor of 0.6, average solar irradiation of 152.4 to 175.9 W/m², 25% conversion of efficiency, and a performance factor of 90%.

Some of the renewable energy resources are broadly distributed, and others are concentrated in specific sites. Figure 5 shows specific regional renewable energy resources that have been drawn from different country studies. Developing just these illustrative resources would meet more than 100% of current electricity demand. These figures do not necessarily represent the full resource of a given area. In the case of Atacama Desert, for example, the land area that would be required to generate 26 TWh would be just 100 km^2, or 0.01% of the desert's area.

Globally, the amount of new investment in NRETs is growing rapidly. In 2012 investment in NRETs and hydropower reached $244 billion - an increase of over 600% from 2004 - and, projections for 2012-2035 estimate a cumulative total of $6 trillion out of a total power system investment of $16.9 trillion.[24] However, LAC's share of global investment in NRETs and hydropower is modest (5.4% of the total).[25]

Figure 5. Examples of specific RE-rich sites for electricity generation



Estimated Site Specific Technical Potential: Mexico (Solar) [26]; Wind On-shore (Brazil)[27]; Venezuela[28]; Argentina[29]; Mexico (Wind On-Shore)[30]; Brazil (Solid Wastes) [31]; Brazil (Sugar Cane Co-generation) [32]; Chile (Solar PV) [33]; Peru [34]; Central America [35]; Mexico (Biomass) [36]; Caribbean [37]; Colombia [38]; Chile (Marine)[39] , and Brazil (Solar).[40]

Despite this small share of total investment, major new developments underway in NRETs in the region include:

- **Photovoltaic (PV).** There has been a sharp increase in PV project development activity in the region, driven by dramatic cost reductions during the past few years. Multiple large-scale PV systems have been completed, or have started development, and some industry forecasts predict that over 2 GW could be installed across the region by 2016.[41]
- **Concentrated solar power (CSP).** The first CSP power plant in the region is under construction in Mexico, a hybrid solar/gas plant with a solar generating capacity of 14 MW.[42] In Chile, the government has released a competitive tender for CSP power, anticipated to be in the range of 50 to 100 MW, offering a public subsidy and access to concessional finance and grants.[43]
- **Wind.** Wind power generation costs have also fallen rapidly, and the entry of more efficient designs, and larger tower capacities have contributed to this cost reduction.[44] Wind is the fastest growing NRET in the region. Cumulative installed capacity in Latin America reached 3.5 GW in 2012, an increase of 53% compared to the 2.3 GW[45] installed in 2011. The majority of these additions came from Brazil, which installed more than 1 GW,[46] and from Mexico, which added more than 800 MW in 2012.
- **Geothermal.** Mexico is the world's 5th largest producer of geothermal electricity with almost 1 GW of installed capacity. This country is now seeking to complement the utility's activity with private sector projects, and has requested resources from the Clean Technology Fund.[47] Central America has almost 500 MW of installed capacity in Costa Rica, El Salvador, Guatemala, Honduras, and

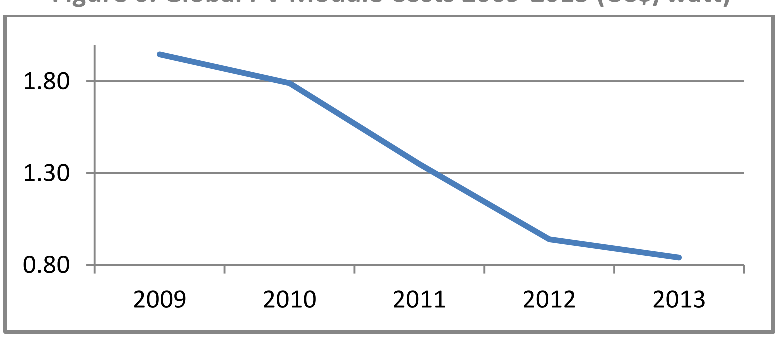
Nicaragua. More recently Caribbean countries (St. Kitts and Nevis, Grenada, Dominica, Montserrat, and St. Lucia) have developed plans to exploit their geothermal resources. There have been no geothermal projects to date in South America, although Argentina is planning a 100 MW plant in Neuquén,[48] and Colombia, Ecuador and Panama are actively exploring their resource.[49]

- **Biomass-based generation.** Biomass, including energy from waste sources, is the primary source of electricity from NRETs in LAC. Most of it comes from sugarcane or wood from Brazil (7,800 MW), followed by Mexico (496 MW), Guatemala (300 MW), Argentina (300 MW) and Chile (526 MW).[50] There continues to be interest in developing biomass and waste resources across the region.
- **Marine energy.** There is no wave, tidal, or ocean thermal energy project operating in LAC, but interest is emerging as a result of significant resource potential. Chile is assessing the possibility of publishing a tender for prototype wave and tidal projects in the South, with support of the IDB, to take advantage of the substantial endowment along its coast line.
- **Small hydro:**[51] There is an installed capacity of approximately 1.6 GW[52] in the region.

Costs

The costs of NRETs are dropping, following a market entry and maturation curve. The case of photovoltaic power is particularly remarkable as it is closer now to the fully commercial phase. The LCOE of PV has historically been higher than those of other generation technologies. During the past several years, however, PV prices have dropped dramatically as module prices have declined to $0.80/watt and below in 2013 (Figure 6). This has translated into dramatically lower PV LCOEs and steep decreases in the incentives required. Above all, most NRET auctions carried out in LAC are showing declining prices (see Table 1), particularly for larger markets and the lower rungs of the LCOEs.

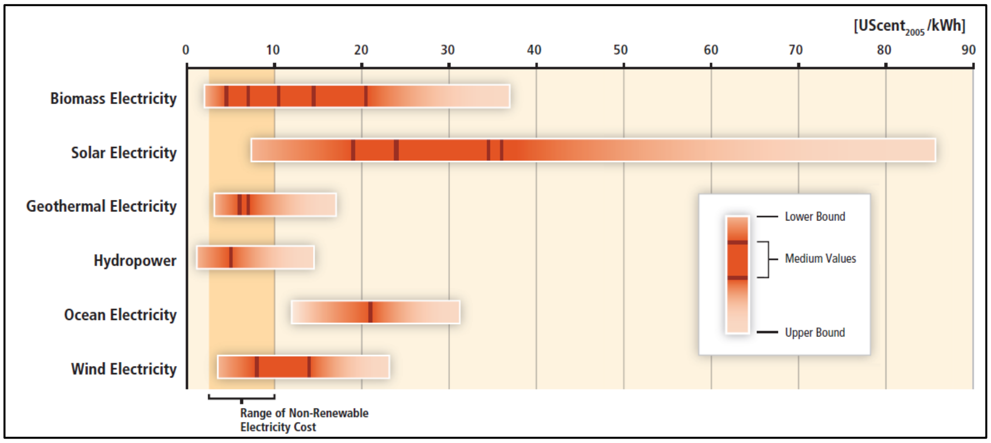
Figure 6. Global PV Module Costs 2009-2013 (US$/watt)



Source: Adapted from Bloomberg New Energy Finance (2013).

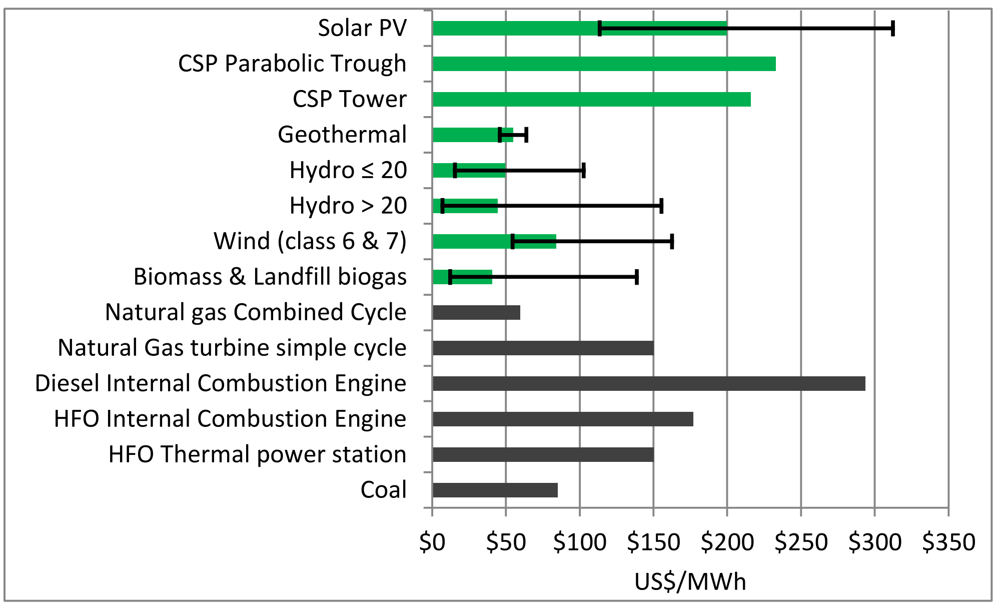
The Special Report on Renewable Energy Sources and Climate Change Mitigation published by the International Panel on Climate Change provides levelized costs of energy (LCOE) for different technologies (Figure 7) around the globe. In addition, the International Renewable Energy Agency (IRENA) has recently compiled a dataset of LCOEs for different technologies in LAC (see Figure 8).[53] Although LCOE calculations exclude overall system costs, NRETs can be a cost effective option in many cases (nonetheless, further analysis is needed to make comparisons for each individual electricity system). It is anticipated that the LCOE will be further reduced for most of NRETs as they move along the maturity curve (see Figure 9).

Figure 7. Levelized Cost of electricity generation, IPCC



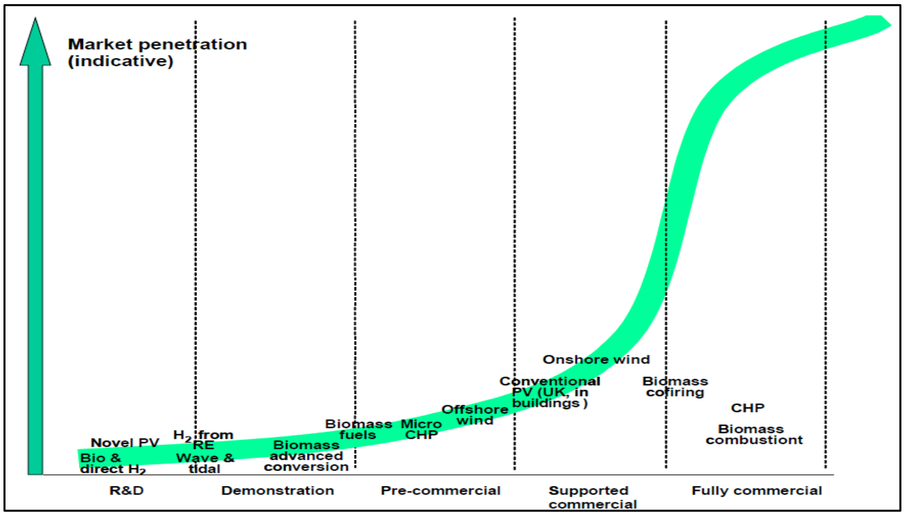
Adapted from Figure SPM5, SRREN.[54] Medium values are shown for the following subcategories, sorted in the order as they appear in the respective ranges (from left to right): **Biomass**: 1. Cofiring; 2. Small scale combined heat and power, CHP (Gasification internal combustion engine); 3. Direct dedicated stoker & CHP; 4. Small scale CHP (steam turbine); 5. Small scale CHP (organic Rankine cycle). **Solar Electricity**: 1. Concentrating solar power; 2. Utility-scale PV (1-axis and fixed tilt); 3. Commercial rooftop PV; 4. Residential rooftop PV. **Geothermal Electricity**: 1. Condensing flash plant; 2. Binary cycle plant. **Hydropower**: 1. All types. **Ocean Electricity**: 1. Tidal barrage. **Wind Electricity**: 1. Onshore; 2. Offshore.

Figure 8. Levelized cost of electricity generation in LAC, IRENA



NRET LCOE data from a database by IRENA[55] based on actual LAC project data, excluding Government incentives and subsidies. Green bars show the median values, and error bars show minimum and maximum values. Data for the two CSP technologies, as well as for fossil fuel technologies, are based on a study by IMCO,[56] using fuel price data from Mexico's public utility CFE. Hydro ≤ 20 refers to hydropower under 20 MW.

Figure 9. Degree of maturity of the different renewable energy technologies



Source: Foxon et al. (2005).[57]

Table 1. Results for publicly available NRET auctions and contracts in LAC countries

Country	Average Tariffs in $/MWh (Size in MW)				Year	Type
	Wind	Biomass	Small hydro	Solar		
Argentina	127 (754)	0	0	572 (30)	2009	Auction
Brazil	150 (1,000)	70 (N/A)	96 (N/A)	0	2006	Public
Brazil	77 (1,800)	80 (2,400)	0	0	2009	Auction
Brazil	75 (2,050)	82 (713)	81 (N/A)	0	2010	Auction
Chile	102 (78)	0	0	0	2009	Private
Honduras	120 (102)	0	0	0	2009	Public
Honduras	148 (94)	0	0	0	2010	Public
Mexico	66 (304)	0	0	0	2009	Auction
Panama	91 (121)	0	0	0	2011	Auction
Peru	80 (140)	63 (27)	60 (160)	220 (90)	2010	Auction
Uruguay	85 (150)	0	0	0	2010	Auction

Source: Carvallo (2013).[58] “Public” stands for direct procurement, “Auction” means an international auction regardless of who called it, and “Private” refers to a private project not deployed through auctions nor procurement.

Societal Benefits from NRE for Power Generation in LAC

NRETs deliver *more than energy*.[59] While these resources constitute a near zero carbon option, they also constitute, as a group, an indigenous energy resource without an expiration date and with several societal benefits.[60] To guide the decision process on the use of these resources, a synthesis of key societal benefits follows:

- **NRETs contribute to de-carbonization of regional economies**. Although by global standards greenhouse gas emissions from the power sector are low in LAC, current projections predict that these will increase as more fossil-fuel based, mostly natural gas plants are built to meet regional demand.[61] Scaling up NRETs is one of the most effective strategies to reduce the emissions of greenhouse gases in the region as it would also facilitate the de-carbonization of the transport and industrial sectors. The adoption of bold renewable energy deployment targets will also strengthen the position of countries that take proactive action in the international climate change arena.
- **NRETs can contribute to long-term energy security.** Energy security can be defined as a country's control over its energy sources (i.e. sovereignty) and the ability of the energy system to respond to fuel supply disruptions (i.e. resiliency).[62]
  - Given the inexhaustible nature of renewable energy supplies, the security of supply spans generations . The recent Global Energy Assessment from IIASA concludes that LAC in particular could capture energy security benefits from a shift toward renewable energy.[63]
  - Volatile fuel prices can complicate and disrupt energy planning and broader economic initiatives, directly affecting inflation and therefore affecting macroeconomic stability[64]. As a diverse stock portfolio can decrease the impact of volatile individual commodities, an energy portfolio diversified through NRETs helps insulate LAC economies from oil and natural gas price fluctuations.
- **Diversification of power supply can help reduce vulnerability of hydro-based power systems to unstable hydrological cycles.** In the case of a hydro-dependent power matrix, other renewables can help address the impact of extreme events in hydrological cycles, or changes over time in firm capacity, while maintaining a low carbon footprint in the sector.[65] Glacial retreat, for example, is already affecting hydropower output in the Andean nations.[66] Non-hydro renewable electricity can serve as an insurance policy against the risk of an unstable hydropower outputs.[67]
- **Low operation and maintenance (O&M) costs typically associated to renewables can help redirect budgetary resources to other development priorities.** A 10% increased share of renewable electricity would decrease regional oil consumption by 20 million barrels per year, or about to 2% of region's 2009 gross domestic product (GDP).[68] This would lead to additional resources readily available to be invested in social needs. This is particularly relevant for Haiti where 3% of the GDP could be saved by a shift towards renewables.
- **NRETs have a positive impact on job creation.** Generally, it is estimated that NRETs create more jobs per dollar invested than conventional electricity generation technologies. According to a study in the United States, jobs created by employment of renewable energy are three times those

generated by the same level of spending on fossil fuels.[69] Additional reports have also shown that the deployment of NRETs contributes positively to employment as compared to other technologies - both regarding the number of jobs generated in the renewable energy sector as well as economy-wide.[70]

- **NRETs reduce the local health and environmental impacts of fossil fuel technologies**. The generation of electricity from fossil fuels, and in particular from fuel oil, diesel oil and coal produces negative impacts on the environment and on human health due to air pollution from nitrogen oxides, sulfur oxides, and particulate matter.[71] Extraction processes of fossil fuels can have high on-site environmental impacts. Moreover, the trend towards using fracking technologies to extract natural gas will likely increase environmental risks of extraction. The use of renewable energy helps mitigate these impacts.[72]
- **Non-hydro renewable electricity production can reduce power plant siting concerns.** There has been sharp criticism related to the impacts of large hydropower plants in the LAC region[73] exemplified –for instance- by resistance to projects in Brazil (Belo Monte)[74] and in Chile (Hydro-Aysen).[75] High profile efforts to halt oil and gas exploration have been reported in regions such as Yasuní in Ecuador[76] and the Camisea gas project in Peru's Kugapakori-Nahua-Nanti Reserve.[77] Certain types of NRETs can be sited more easily and flexibly than conventional generation and therefore reduce many of these social and environmental concerns.
- **The renewable electricity industry represents a significant opportunity to attract new investment**. LAC currently accounts for just 4% of the global investment on NRETs, but has the potential to capture a much larger share of global investment on NRETs, estimated at $6 trillion during 2012-2035.

Societal costs and benefits are difficult to generalize because they are location-sensitive: they depend on the geographical context, the utility, the technology, and ultimately the project itself. Some of these benefits may be quantified into a dollar figure using established methodologies.[78] Others may be quantified but only partially. In particular, the hedge value of NRETs against fossil fuel price volatility, which is one of their most relevant benefits, is hard to fully quantify, simply because there are no 25-year hedges for fossil fuels available in the market against which NRET costs could be compared on a like-for-like basis.[79] Finally, some benefits may only be considered in a qualitative way as their impact is hard to measure, such as siting concerns and investment attraction.

For purposes of illustration, Table 2 summarizes avoided costs and societal benefits of grid-connected PV electricity generation provided by a range of studies, mainly in the context of the United States.[80] The value of fossil price hedge appears relatively small due to the lack of available methodologies to quantify this benefit over the long term. Some of these benefits would apply as well to other technologies. The consideration of avoided costs and societal benefits are important. For instance, societal benefits that apply to all NRETs (avoided costs due to GHG emissions, pollutant emissions, and fossil fuel price hedge) represent about 47 $/MWh. Reducing this amount from the NRET LCOE values on (or by adding them to the fossil fuel-fired LCOE values), shows that most NRETs are societally cheaper (on a LCOE basis) than even the most inexpensive fossil fuel technologies.

Table 2. Avoided costs and societal benefits of PV electricity generation

Value	Range ($/MWh)
Value of avoided GHG emissions	3.3 – 19.3
Value of avoided criteria pollutant emissions	0.1 – 18.8
Avoided generation capacity cost (relevant if peak demand occurs in daytime)	29.2 – 230.6
Avoided cost of additional transmission infrastructure	0.4 – 100.0
Avoided distribution cost	1.9 – 29.5
Avoided cost of fuel (natural gas)	32.4 – 97.1
Avoided generation and T&D losses (system losses)	1.5 – 43.0
Value of grid Support (ancillary services)	0.5 – 2.8
Value of fossil fuel price hedge (risk premium)	4.1 – 9.5
TOTAL	***77.5 – 513.1***

Source: Adapted from NREL (2008) and other sources.[81]

Policies for NRET for Power Generation in LAC

Justification

Although the policies and regulations that define the electricity markets are by and large supposed to be "technology-blind", the reality is that this framework and implementing institutions were designed on the basis of conventional generation technologies available a few decades ago. Therefore, an inherent bias in favor of such conventional technologies exists. NRETs require rethinking this framework given their particularities; among others (see also Table 3):

Table 3. Differences between conventional and renewable energy technologies

	Conventional technologies	Renewable technologies
Cost pattern	Lower capital costs and higher fuel costs emphasize short term market operation, particularly spot market.	Higher capital costs and lower fuel costs require long-term bankable contracts instead of direct market participation. High penetration of zero variable cost capacity changes the dynamics of marginal cost-based electricity markets.
Generation pattern	Predictable short term generation puts focus on following demand through a mix of peak gas turbines and large hydropower. Ancillary services are relevant, but not critical.	Unpredictable short term generation require devoting more resources to follow variation, particularly setting up a market for short term demand response. Ancillary services are critical.
Geographic pattern	Large fossil fuel plants are generally more flexible in terms of location, which eases joint transmission-generation planning and rate setting for the former.	Distributed and remote locations may require the need of specific transmission planning and rate setting mechanisms. The geographic pattern may also imply that the scale of projects is smaller.
Societal benefits	Besides energy, power (in some cases) and ancillary services, there are no more products in a conventional electricity market.	NRETs require redesign of electricity markets to incorporate new "products", such as climate change resilience, price hedging, and lower environmental footprint, among others.

- **NRETs have a different cost structure**. Whereas most of the long-term costs of fossil-fuel fired generation are linked to their operation (fuel costs), upfront investment makes for most of the cost for NRETs. This capital-intensive nature of NRETs can be a hurdle to project development and has consequences in terms of the risks investors are willing to take.
- **NRETs have a different generation pattern over time**. Many NRETs depend on the availability of natural resources which do not necessarily match demand. Therefore, they can generate electricity only when such resource is available. This is the case in particular of technologies such as wind, solar and marine. Accordingly, market rules, distribution network design, and transmission interconnectivity need to accommodate variable generation.
- **NRETs have a different geographical pattern**. Some NRETs such as PV are widespread; others are available only in specific sites. This particularity of NRETs has consequences in several areas of policy and regulation, including land-use considerations, transmission network design and specifications, and adequate rules for integration of small scale power plants.

- **NRETs provide a number of societal benefits**. NRETs deliver social and environmental benefits that are usually unrecognized and un-priced in the market. Policies and regulations need to be designed so that these benefits are internalized in investment decisions.

In order to accommodate these differences, mechanisms can be implemented to compensate for the current biases, and/or the market rules can be changed altogether so that they provide a truly evened playing field.

Entry mechanisms

Renewable energy policy is rapidly evolving. New policies have been introduced every year and many existing policies have been continuously revised. There have been numerous studies devoted to describing and analyzing these different policy types and enumerating best practices, including several recent studies focusing specifically on policy models in LAC.[82] Recent studies have identified over 100 different categories of policy support mechanisms[83].

National renewable energy **targets** have usually been a key building block for market entry of non-traditional renewables. In 2005, 45 countries had national renewable energy targets in place.[84] By 2012, the number had increased to close to 120.[85] Although many of these targets are not accompanied by mechanisms to penalize stakeholders for non-compliance, they are nevertheless very useful in providing a political direction and driving policy change.

The primary drivers for accelerating large-scale, on-grid renewable energy market growth and for meeting renewable energy targets at the international level, have been feed-in tariffs (FITs) and renewable portfolio standards (RPS) supported by tradable credits. Both policies compel utilities to procure renewable electricity by fixing either the price or the amount of energy, respectively. Auctions represent a third model in which a specific capacity or energy is competitively procured. FIT rates are set administratively, auctions set rates through periodic competition, and short-term credit markets set rates based on spot market trading. In some cases policymakers combine these **procurement policies** in new and innovative hybrids. Some RPS policies utilize a combination of fixed prices, auctions, and short-term credit trading – or use the mechanisms in parallel.[86] Of these three, the use of short-term credit trading alone has receded in favor of alternative (or hybrid) models because projects supported by variable revenues from credit trading are difficult and expensive to finance.[87]

Significant time and effort has been devoted to describing FITs[88] and auction designs[89] as well as discussing the comparative merits of each.[90] The practical differences between these two policy types, however, are fairly limited. Beyond the rate setting mechanism, both polices can be designed to be similar in terms of long-term and standard contracts, capacity caps, technology eligibility, priority and guaranteed interconnection, priority dispatch, etc. Incentive levels that are too high create excess profits for generators, whereas incentives that are too low may not support market growth and may not achieve policy objectives. In practice, both policy types can be (and have been) designed to be efficient and effective and to meet a broad range of different policy objectives.

FITs are the most prevalent national policy mechanism internationally and have supported the majority of global wind and PV capacity.[91] Although FITs were initially used in Europe, the majority of FIT policies are now in emerging economies and developing counties. A number of countries in the LAC region adopted FITs (or policies closely related to FITs) during the last decade, including Argentina, Brazil, Dominican Republic, Ecuador, Honduras and Nicaragua.[92] More recently, however, there has been a strong trend toward competitive bidding in the region with Argentina, Brazil, Costa Rica, El Salvador, Honduras, Jamaica, Mexico, Panama, Peru, and Uruguay introducing auctions. Chile and Nicaragua are the only countries in the region whose policies resemble a RPS, mandating generators and distributors to comply with specific quotas of NRET in their sales or purchases, respectively.

FITs and auctions were originally designed to achieve incremental - rather than structural - change in the electricity markets, but in some cases they have been refurbished to enable scaled-up renewable energy penetrations by putting in place sophisticated mechanisms to manage growth such as cost control and ratepayer protection.[93] These procurement policies coupled with broader electricity market reforms attempted to steer structural change in the countries they were implemented.

An alternative or complementary approach to procurement policies previously presented is onsite or offsite **self-supply regulations** that enable and encourage consumers to generate their own electricity from renewable energy sources. In the Caribbean, countries such as Barbados, Grenada, Jamaica, and St. Lucia have introduced different versions of net metering and net billing policies that allow onsite generation to be credited against customer electricity bills at (or below) the retail electricity rate.[94] Additional Caribbean countries may introduce similar policies since CARICOM members recently agreed to "draft and implement regulatory and legislative reforms to … allow for self-generation and feed-in of excess electricity for small renewable power producers…".[95] Onsite generation is also being encouraged in countries such as Uruguay where onsite generators have the option to credit their output at the retail rate for up to 10 years. Generation that exceeds onsite demand can also be reimbursed, but this must be negotiated on a case-by-case basis.

Mexico offers a unique case of offsite self-supply regulations that are driving the development of NRETs, and notably that of wind power in the Isthmus of Tehuantepec (with more than 770 MW of installed capacity[96]). Mexican regulations include an energy bank, post-stamp wheeling (transmission) charges, and capacity recognition to offset demand charges.[97] In many of these projects consumers and generators have created self-supply associations through cross-sharing agreements.

In addition to procurement or self-supply policies, a set of **complementary policies** are used that strengthen the enabling environment for renewable energy (e.g. streamlined permitting, property tax exemptions, import tax exemptions), provide market support (outreach, education, capacity building, and institutional strengthening), and enhance the contribution of NRETs to local development.

New Energy Market

The energy market regulation is already technologically biased in favor of fossil fuel technologies and neglects their negative societal impacts. Repairing these two missing pieces is what the "new" energy market needs to do in order to efficiently allocate scarce resources. This involves changes in market rules, network design and enabling policies. As the current generation of policies enacted in the LAC region continues to mature and policy makers continue to strive toward national targets, a set of best practices for addressing the upfront costs of renewable resources and scaling up regional markets is likely to emerge. LAC has the opportunity of *leapfrogging* towards innovative frameworks to anticipate and then manage high penetrations of renewable generation, and in particular of variable generation.

Variable generation

In order to incorporate variable generation in the region there is a need to understand both the electricity markets structure and the types of technologies available in each electricity grid. Electricity market structures vary widely across the LAC region, and include vertically integrated monopolies in many Caribbean countries, single-buyer markets in several Central American countries, and wholesale electricity markets in many other countries in the region (see Figure 10). The commonality among these structures is that these were designed around large, centralized power plants that provide steady "base load" power and peaking plants that supplement the base load generators when demand rises.

An electricity grid with a high penetration of renewable energy, however, would require a different mix of generator types. Given the technical difficulties to store power, electricity systems can accommodate some share of *inflexible technologies* ("must-take" technologies that cannot be dispatched, i.e. turned on and off at will), but require as well *flexible technologies* that can ensure that the generation matches the load at any instant.

In conventional power systems base load technologies such as nuclear or coal occupy the *inflexible (*i.e. *non-dispatchable)* niche, whereas peak technologies such as hydropower (with seasonal or hourly storage reservoirs) or gas turbines occupy the *flexible* niche, with other technologies with limited flexibility occupying intermediate positions. In contrast, in renewable energy systems, non-controllable (*non-dispatchable*) technologies such as wind, solar, marine, and also geothermal power occupy the *inflexible* niche. NRETs such as hydropower and some biomass technologies are available to occupy the *flexible* niche. Other options are available as well to achieve the flexibility that renewable electricity systems include (for instance) regional integration, energy storage, and demand control.[98]

The LAC region is well-positioned in terms of **flexible generation technologies:** With the highest penetration of hydropower in the world, it has the ability to absorb significant penetrations of variable renewable energy. However, current policies and regulations hamper, rather than foster, synergies between hydropower and NRETs. New mechanisms are required to enhance the value of hydropower as a technology that compensates the short-term variability of NRETs.

Figure 10. Electricity Market Structures in LAC

Gencos = generation companies; discos = distribution companies; transco = transmission company; ISO = independent system operator; IPP = independent power producer.

Power systems integration

Around the world, regional connections have evolved from bilateral relationships based on trading surplus power and providing mutual support in case of system emergencies to formal legal entities that span multiple states and countries and have formal regulatory power and centralized control over electricity dispatch. In LAC, a regional electricity system has been pursued as a key element for economic integration. Interconnection projects have been proposed for South America, Central America, and the Caribbean. Today, the objective of scaling up NRETs provides a further powerful reason to implement these projects.

As compared to large countries such as Brazil, which clearly have the land area and the renewable resources to take advantage of geographic diversity, smaller countries such as those in Central America and the Caribbean will benefit more from greater regional transmission interconnection.[99] Regional integration would permit variable generation to be balanced across international borders. Generally, regional power pools can:

- improve system reliability and unlock investments by creating opportunities to capture greater economies of scale;
- enable the integration of variable renewable energy by complementing greater geographic and resource diversity;
- allow operating reserves to be shared and coordinated (in the Nordic power pool, for example, it has been estimated that reserve requirements would need to be twice as high if each country operated in isolation given the high regional penetrations of wind);[100] and,
- higher penetration of variable renewable generation, providing additional incentives to harness resource-rich areas such as the Patagonia (tidal and wave resource) or the Atacama and Sonora deserts (solar radiation).

Wind and solar output may be variable at a single site, but the overall variability to the system can be smoothed out by geographically dispersed resources. In other words, while wind speeds may be low at one wind farm, they may be high at another at the same time. Similarly, clouds may temporarily reduce output at one solar plant, but the skies may be sunny over another on the system many kilometers away. Larger power systems can more readily incorporate variable renewables because the output from geographically dispersed renewable energy systems is less correlated. Wind forecast errors, for example, can be reduced by as much as 30% - 50% when wind is aggregated over a broad geographic area.[101] Since generation is less variable in aggregate, it reduces the need for operating reserves and lowers integration costs.

Progress in regional integration is limited, however. The Central American Electrical Interconnection System (SIEPAC for its Spanish acronym) has created new opportunities for power trade – and variable generation integration – among nations. It has been estimated that the interconnection on its own will result in a 3% reduction in energy cost and 4% fuel savings for the connected countries.[102] Nonetheless, differences in electricity market structures and regulations have constrained efforts to integrate the markets. These same challenges are mirrored across the continent. For example, the Andean region countries are currently intending to ease electricity exchange through the Andean Electrical

Interconnection System (SINEA). Likewise, Uruguay has been vocal with respect to the relevance of the interconnection with Brazil to transmit surplus wind power and import in low wind times[103]. Although there are an increasing number of plans and proposals to connect across international borders, artificial barriers created by mismatched regulations currently constrain trade and will likely continue to do so in the near to mid-term.[104]

An integrated power system, could be made even more effective through the adoption of complementary measures, including:

- **Demand response,** which consists of mechanisms to incentivize end-use customers to adopt measures or technologies leading to changes in their real-time electricity consumption to match available supply. It can be used as a cost-effective resource to balance variable renewable energy generation, by adjusting in real-time the load curve in response to resource availability.[105]
- **Storage technologies,** to provide further system flexibility and thus enable a higher penetration of variable NRETs. Technologies currently being deployed[106] include pumped hydro and lithium-ion batteries. Both technologies are already present in the region (the Rio Grande pumped hydro 700 MW plant in Argentina,[107] and the two Battery Energy Storage Systems of Angamos and Los Andes in Chile, with a combined capacity of 32 MW).[108] Most pumped hydro systems in the world use freshwater, but there is one that uses seawater[109] - a technology that could be applied in LAC. Small-scale battery storage systems are another promising technology for the medium term. In particular, electric vehicles will have in the near future the capacity to soak up generation at times of low demand to address two problems at once. Storage technologies serve other purposes in addition to scaling up NRETs (as in the case of the above mentioned systems in LAC), and NRET deployment provides additional reasons to implement them. Water hydrolysis for hydrogen synthesis could also be used to store energy during wet, rainy periods.
- **Shorter scheduling and dispatch intervals**. In wholesale markets, generation dispatch is typically scheduled on an hourly basis. Once generation is scheduled, it is required to hold its output at a fixed level until the top of the next hour. Since wind and solar are more likely to vary within the course of an hour than other resources, this means that they may require higher operating reserves. This type of regulation draws from the most expensive ancillary service resources introducing a further cost barrier for the integration of variable renewable energy into wholesale markets. In order to address this, markets can be designed to schedule generation at sub-hourly intervals, such as 5, 15, or 30 minutes. Shorter scheduling intervals reduce the probability that variable renewable generation will diverge from scheduled output, reduce the need for operating reserves, and therefore reduce integration costs. Market gate closure[110] times that occur closer to actual generation delivery time can also help reduce forecast error.

Depending on the electricity sector structure, challenges related to the use of market mechanisms to integrate variable renewable energy and introduce analogous ancillary service and regulation functions into electricity systems might differ between countries. In particular, there are not yet well-established demand response markets in the LAC region that could be used to support variable renewable generation, although Chile's market is perhaps the furthest along.[111]

Expanding Transmission Infrastructure

Transmission expansion is an issue closely related to regional integration. Countries in the LAC region are already seeking to expand their transmission networks in order to strengthen existing connections, extend service to new locations within their borders, and interconnect with neighboring countries. Higher penetrations of renewable energy might require additional layers of planning for the transmission system. New transmission capacity may be needed to integrate and balance variable renewable energy resources as well as access many of the best renewable resources (such as those shown on Figure 5) often located far from population centers.

Transmission planning methodologies are in place throughout the region to accommodate the growth of conventional centralized generation, but the expansion of smaller-scale power plants may call for new approaches to transmission planning and implementation. New transmission can be difficult to finance and build because of the upfront capital cost, planning and development risks, and timing challenges. Since transmission and generation are generally not built simultaneously, generators face the risk that sufficient transmission capacity might not be built if it is not already in place, whereas transmission developers bear uncertainty related to the probability that the line might not be fully utilized due to insufficient generation. To address the challenges, several countries and states[112] have enabled the construction of dedicated transmission lines to renewable resource-rich areas, supported by special regulations and cost recovery provisions. The *open seasons* implemented in Mexico provide a good example.[113] The options available will depend on each country's electricity market structure.

Large concentrations of renewable energy resources exist that could meet significant proportions of regional demand if they could be developed. Near-term opportunities could be unlocked, for example, renewable energy scale-up in Mexico and Brazil could be enabled with a $660 billion investment in immediate transmission.[114] To realize such opportunities, regional policymakers will need to identify innovative models for transmission capacity planning, cost allocation, and financing.

Energy prices

Although many regulatory frameworks are leaned to leave electricity prices to be set through a market or market-alike dynamic aiming towards efficiency, market agents clearly play according to a set of rules that in some cases explicitly deters or keep NRETs from participating in such market dynamic. The way in which biddings for the expansion of the power system are designed determines the incentives for the different technologies.

Market rules in generally lack mechanisms to value the benefit of RETs in terms of long-term price stability -one of the benefits that NRETs provide is to stabilize electricity prices in single-buyer markets. In order to achieve a truly level playing field between NRETs and conventional technologies, all generators would need to be asked to offer a constant electricity price over the long term (which would then be included in their Power Purchase Agreements). This would mean that fossil fuel generators would need to get long-term fuel hedge contracts.

In reality, fossil fuel-fired generators are almost always allowed to pass through the fuel price volatility to the consumers or to the government, and this becomes a further bias against NRETs. Innovative mechanisms need to be designed in this respect

Energy subsidies also have a direct connection with the deployment of NRETs. LAC made up over 7.5% of global energy subsidies. Pre-tax subsidies[115] accounted for approximately 0.5% of regional GDP or 2% of total government revenues (although in some countries energy subsidies account for over 5% of GDP).[116] NRETs need to compete in unfavorable terms when fossil fuels used for electricity generation are subsidized while subsidized energy leads to consumers lacking the appropriate incentives to implement self-supply alternatives. Some countries that rely heavily on fossil fuels for electricity generation have set up subsidies to dampen the effect of fuel price volatility on the consumers. The challenge in these cases is to ensure a transparent subsidy mechanism (well-targeted subsidies that benefit the most needed population) without jeopardizing the creditworthiness of utilities and thus their ability to scale up NRETs.

Looking forward

The region can meet its future energy needs in a cost-effective manner through renewable sources, leading the way globally, and building a strong green economy. Regardless of the view that each country has on the long-term future of its electricity system, increasing the penetration of NRETs today makes sense from all perspectives. These issues lie at the heart of current debates about the role that different generation technologies can and should play in the short and long term, with some stakeholders claiming that 100% renewable electricity systems are both technical and economically possible and desirable.[117]

Notes

[1] 3GF, 2012. Report. Global Green Growth Forum, 8-9 October 2012, Copenhagen. "Resource Efficiency and Growth". http://bit.ly/3GF2012

[2] Schwartz, J., Darmania, R., Oliver, C., & Ullman, M. Inclusive green growth in Latin America and the Caribbean. Washington, DC: The World Bank.

[3] Yépez-García, R. A., Johnson, T. M., & Andrés, L. A. (2010). Meeting the electricity supply/demand balance in Latin America & the Caribbean. Washington, DC: The World Bank.

[4] Hoogwijk, M. and Graus, W. (2008). Global potential of renewable energy sources: a literature assessment. Background Report by order of REN21 – Renewable Energy Policy Network for the 21st Century. Ecofys. Poole, A.D. (2009). The Potential of Renewable Energy Resources for Electricity Generation in Latin America; International Copper Association Ltd. – ICA Latinoamérica. (2010). Renewable Energy for Electricity Generation in Latin America: the Market, Technologies and Outlook. Chile. Meisen, P. and Krumper, S. (2009). Renewable energy potential of Latin America. Global Energy Network Institute.

[5] Capacity factor values taken from assumptions made by Hoogwijk et al (2008) and NREL. (2010). Energy Technology Cost and Performance Data. Available at: http://www.nrel.gov/analysis/capfactor.html

[6] See note 13.

[7] Yépez-García et al., 2010 (See reference in note 3).

[8] On May 9th, 2013 in Mauna Loa CO_2 concentration levels of 400ppm were recorded, which is a substantial increase over the level that existed in the pre-industrial period at 280ppm.

[9] Vergara, W., Rios, A. R., Galindo, L. M., Gutman, P., Isbell, P., Suding, Samaniego, J.L. (2013). The climate and development challenge for Latin America and the Caribbean: Options for climate-resilient, low-carbon development *Washington, DC*. Inter-American Development Bank.

[10] 30% of the global hydro capacity is in LAC (although a significant portion is in Brazil) while the region only accounts for 7% of the total global electricity generation.

[11] International Renewable Energy Agency. (2013). Renewable power generation costs in 2012: An overview. Abu Dhabi, United Arab Emirates. http://bit.ly/IrenaCosts.

[12] Clean energy Ministerial. (2013). 21st Century Power Partnership: An overview and key activities. Washington, DC.

[13] For the purposes of this document, the term "societal benefits" or "externalities" refers to the positive or negative impacts generated by the provision of goods or services and that have an effect on a third party. Societal costs or benefits occur when the costs or benefits of those that produce or buy the goods or services are different to the total social costs or benefits that their production and consumption involve.

[14] 1 petawatt-hour (PWh) is equal to 1,000 terawatts-hour (TWh), or 1,000,000 gigawatts-hour (GWh).

[15] Own elaboration based on data from EIA energy database: http://www.eia.gov/countries/

[16] According to the US Energy Information Agency (EIA): http://1.usa.gov/160W3wH

[17] Other sources estimate a growth in demand between 2.5 PWh to 3.3 PWh by 2030. Yéepez-García et al., R. A., Johnson, T. M., & Andrés, L. A. (2010). Meeting the electricity supply/demand balance in Latin America & the Caribbean. Washington, DC: The World Bank. (See reference in note 3). Luna, N., García, F., & Garcés, P. (2012). Energía sostenible para América Latina y el Caribe. *ENERLAC, 4*, 83-100.

[18] Vergara et al., 2013. (See reference in note 9).

[19] Although this varies by sub-region: Mexico and the Caribbean depend heavily on fossil fuels, Brazil and the countries of the Andean-Amazon sub-region rely heavily on hydropower, whereas the generation parks of Central America and the countries of the South Cone are fairly evenly divided between hydropower and fossil fuel-fired generation

[20] At present, 92% of all on-grid renewable electricity generation is from hydropower, but the penetration of non-hydro technologies has been growing steadily, often with public support. Biomass and waste comprise the largest share, with almost 6%, and the remaining 2% are shared among geothermal (1.3%), wind (0.6%), and solar (0.004%).

[21] See references in note 4.

[22] Capacity factor values taken from assumptions made by Hoogwijk et al (2008) and NREL. (2010). Energy Technology Cost and Performance Data. Available at: http://www.nrel.gov/analysis/capfactor.html

[23] Hoogwijk, M. and Graus, W., 2008. (See reference in note 4). This report includes as well a potential of 2.8 PWh for hydropower (800 GW), and 2.8 PWh for energy crops (580GW). Energy residues capacities reported in this study were in thermal capacity. Therefore this capacity was multiplied by a 30% thermal to electric conversion factor. One reason to exclude energy crops is the anticipated continuous demand for food, feed and fiber from the region to balance global demand. Energy crops would exert an additional pressure on land resources possibly leading to a net loss of regional carbon sinks.

[24] The New Policies Scenario. *See* International Energy Agency. (2012). World energy outlook 2012. Paris, France.

[25] Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance, & Bloomberg New Energy Finance. (2012). Global trends in renewable energy investment 2012. Frankfurt, Germany: Frankfurt School of Finance and Management.

[26] WWF, 2012. Solar PV Atlas: Solar Power in Harmony with Nature. Towards 100% renewable energy. WWF in collaboration with First Solar, 3TIER, and Fresh Generation.

[27] Antonio Leite de Sá, Electric Energy Research Center – CEPEL, 2001. Brazilian Wind Atlas available at: http://bit.ly/WindData

[28] ICA, 2010. (See reference in note 4)

[29] Available at: http://bit.ly/Armereom

[30] Available at: http://bit.ly/Morelosmx

[31] Basto Oliveira, L. and Pinguelli Rosa, L., 2003. Brazilian waste potential: energy, environmental, social and economic benefits. Energy Policy.

[32] WADE, 2004. Bagasse Cogeneration – Global Review and Potential. World Alliance for Decentralized Energy.

[33] Corporación para la Competitividad e Innovación de la Región de Atacama; news available at: http://bit.ly/AtacamaCSP

[34] Ibid 57

[35] Ibid 11

[36] T. Johnson, C. Alatorre, Z. Romo and F. Liu, 2010. Low-Carbon Development for Mexico. http://bit.ly/lcdmex

[37] Ibid 11

[38] Corpoema – UPME (2010). Plan de desarrollo para las fuentes no Convencionales de energía en Colombia

[39] Garrad Hassan for the IDB (2009) Preliminary Site Selection: Chilean Marine Energy Resources.

[40]Calvalcanti and Petti (2007) Assessment of SEGS-Like Power Plants for the Brazilian Northeast Region and assuming a 21% capacity factor. Available at: http://bit.ly/solarBrazil

[41] e.g. Masson, G., Latour, M., & Biancardi, D. (2012). Global market outlook for photovoltaics until 2016. Brussels, Belgium: European Photovoltaic Industry Association.

[42] NREL. (2013). Concentrated Solar Power Projects Database. Agua Prieta II, Mexico. Information retrieved and available at: http://bit.ly/AguaPrieta

[43] See Concurso Planta de Concentración Solar de Potencia (CSP) http://bit.ly/CSPChile. Concessional finance is offered by the IDB (with resources from the Clean Technology Fund) and the German Development Bank KfW. A grant from the European Union's Latin-American Investment Facility (LAIF) is also available.

[44] Overcapacity in manufacturing due to market decline in some countries and Chinese competitions are also important factors that have driven wind power prices down.

[45] In the case of solar nominal power capacities normally noted as W are also described as Wp.

[46] GWEC. (2013). Global Wind Statistics 2012. Global Wind Energy Council. Retrieved and available at: http://bit.ly/GWEC2012

[47] Revised CTF Investment Plan for Mexico. http://bit.ly/ctfMXrev

[48] Ministry of Environment of Argentina: http://bit.ly/EnvArg

[49] Chile passed a Geothermal Law in 2000 to foster exploration and expects first deployments in 2015. Valenzuela F, 2011. "Energía Geotérmica y su Implementación en Chile", Revista Interamericana de Ambiente y Turismo. Vol. 7, Nº 1, pp. 1-9. http://bit.ly/RIAT7Chile

[50] EIA energy database: http://www.eia.gov/countries/ Other countries such as Colombia and Nicaragua have some power plants installed. Note that the biomass capacity figures may not reflect actual renewable energy capacity, as many power plants are co-fired by biomass and fossil fuels.

[51] The definition of small hydro varies from country to country. It is commonly defined as projects with installed capacity of up to 20 MW but for Brazil it includes projects of up to 30MW.

[52] Estimated as the 2.7% of the global installed capacity. Global installed capacity is reported by IRENA 2012 (see reference in note 11).

[53] International Renewable Energy Agency, 2013 (see reference in note 11).

[54] See http://bit.ly/SRRENfr.

[55] In some cases, the study in Mexico did not consider some of the technologies for which data is available in the rest of the region. In other cases, the Mexico study presented LCOEs for which comparable data was not available in the IRENA database.

[56] Instituto Mexicano para la Competitividad A.C. - IMCO. (2013). Externalidades asociadas a la generación de electricidad. Medio Ambiente / Cambio Climático. Available at: http://bit.ly/IMCompet

[57] T.J. Foxon, R. Gross, A. Chase, J. Howes, A. Arnall, D. Anderson, 2005. UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. Energy Policy v33(16). http://bit.ly/barriersRE

[58] : Carvallo, J.P., 2013. "Explaining Renewable Energy Adoption in Latin America." Master's Project. Berkeley, CA: Energy and Resources Group - University of California, Berkeley.

[59] "More than Energy" was the motto of the International Grid-connected Renewable Energy Policy Forum held in Mexico in 2006. See http://bit.ly/gridre.

[60] See note 13.

[61] Yépez-García et al., 2010. (See reference in note 3).

[62] A standard methodology for quantifying energy security benefit has not yet emerged. One recent analysis in Asia used the cost of stockpiling fossil fuels to hedge against supply disruptions as a proxy for energy security benefits. Another recent analysis from a US utility attempted to use the national security benefits of reduced oil reduction as an argument for justifying energy efficiency programs.

[63] Riahi, K., Dentener, F., Gielen, D., Grubler, A., Jewell, J., Klimont, Z., Krey, V., McCollum, D., Pachauri, S., Rao, S., van Ruijven, B., van Vuuren, D. P., & Wilson, C. (2011). Energy pathways for sustainable development. In L. Gomez-Echeverri, T. B. Johansson, N. Nakicenovic & A. Patwardhan

(Eds.), *Global Energy Assessment: Toward a Sustainable Future*. Cambridge and New York: Cambridge University Press.

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[87] It is important to note that the fact that the credits tradable – i.e. that they are a separable commodity from electricity – has not been problematic. However, markets that have relied exclusively on short-term or spot market trading for credits as the only compliance mechanism have faced challenges with high credit price volatility coupled with uneven market growth. Under the original RPS designs from the US in the mid- to late-1990s, short-term credit trading was envisioned as the primary mechanism for policy compliance. As RPS has evolved across the United States and internationally during the last twenty years, however, many short-term tradable credit markets now also include some type of price floor mechanism, or parallel procurement pathways that allow auctions for long-term contracts, standard offers, or bilateral negotiations for long-term contracts. This trend is also evident internationally.

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