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An enabling framework for wind power in Colombia: what are the lessons from Latin America?

Abstract

This article discusses the existing framework for enabling wind power in Colombia. Although the Colombian framework does not specifically target wind power, it provides tax reductions for renewables. So far, such policy has favoured conventional technologies (including hydro), at the expense of renewable energy technologies. Other Latin American countries including Brazil, Mexico, Chile and Costa Rica have achieved fast deployment of wind energy technologies by combining feed in tariffs with other incentives such as portfolio standards and tax reduction. The Brazilian case is an example of how adequate incentives can add wind energy technologies to a power system that relies mostly on hydro sources. Based on this evidence, we propose a policy for promoting renewables in Colombia by using schemes that combine feed-in tariffs and portfolio standards to make initial progress by 2020.

Introduction

This article examines the existing environment for power generation in Colombia and identifies policy requirements for increasing the share of Renewable Energy Technologies (RETs), specifically wind power. As high capital costs are one of the main barriers to investing in wind power, we focus on the regulatory incentives for investment in power generation.

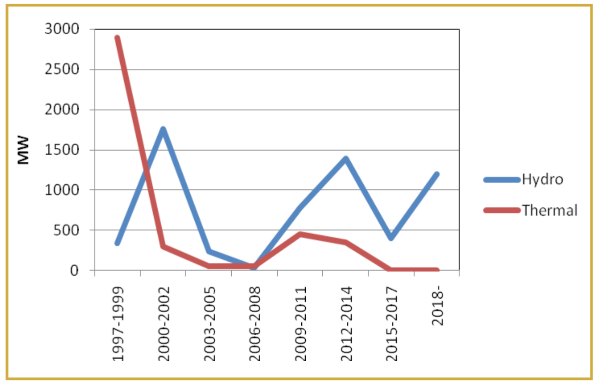
Colombia's hydroelectricity potential is among the highest in the world (WEC, 2004). Energy policy in Colombia has aimed at developing these resources: by 2010, hydro power's share of total generation capacity was 63%, and it supplied between 70% and 80% of the demand connected to the transmission grid (XM, 2010). Although this policy has had positive results in terms of costs and efficiency of supply (Larsen et al., 2004), the high dependence on hydro power makes the system vulnerable to climatic variations (UPME, 2009; Larsen et al., 2004). Thermal generation, with a 33% share of total installed capacity, balances the fluctuations of hydropower generation. In a dry year, when hydropower cannot operate at full capacity, thermal power plants generate up to 50% of total demand, whereas in average rainy conditions, thermoelectricity dispatch might be as low as 15-20% of the total (UPME, 2009; XM, 2010).

During the last fifteen years, gas-powered plants have been the preferred option to back up power generation during periods of peak demand and during the dry season in Colombia. More than 1400 MW of gas-fired generation capacity has been built since 1994, making up 28% of installed generation capacity in 2010, and accounting for 84% of thermal capacity (UPME, 2009). Combined-cycle gas turbines (CCGT) have shorter lead times and lower capital costs than large hydro plants; this, along with the incentives given to thermal plants between 1997 and 2005, made CCGT a commercially attractive option for increasing the reliability of power supply in Colombia.

Regulatory incentives for remunerating capacity expansions that increase security of supply and the reliability of the interconnected system date from 1994. These incentives have been modified and adjusted to the changing conditions of the Colombian market (Larsen et al., 2004; Dyner et al., 2007). By definition, this mechanism is technology-neutral, meaning that any technology that ensures 'firm' (i.e. stable) energy supplies can receive monetary payments. As Figure 1 shows, between 1997 and 2007, the incentives initially favoured thermal technologies for increasing generation capacity, but ever since 2000 these have favoured hydro technologies. Note that the only wind farm in place did not receive capacity payments and was built using different incentives.

To summarise, hydroelectricity forms the basis of power generation in Colombia, and because water inflows are variable, CCGTs provide security of supply. However, as Figure 1 shows, incentives for firm capacity have favoured hydro-based power, a seasonally-dependent technology. The dominance of hydro power has a direct impact on the profitability of thermal plants, whose high operating costs make thermal generation economically infeasible during periods with high availability of water. With this structure, the electricity sector in Colombia has a relatively low carbon footprint, and the main reason for seeking a larger share of RETs is technology diversification and, as discussed above, security of supply.

Figure 1. New generation capacity between 1997 and 2010 and expected additions to 2018 (results from auctions).



The potential for RETs deployment in Colombia is high but has not been fully estimated. Water sources suitable for small hydro plants (less than 20 MW) are abundant, as is solar radiation. More research is needed to assess the wind potential of the whole country, but the coastal region of La Guajira, where Jepírachi, the only wind farm, is located, has proven potential for generating commercial wind power as high as 18 GW, according to Vergara et al. (2010). Because the capital costs of wind power are relatively high compared to other options, policy-makers in Colombia tend to consider it a viable option to generate energy in off-grid zones, rather than a technology that can contribute to power supply in the interconnected power sector (UPME, 2009). Nevertheless, evidence from the only wind power project in Colombia suggests that wind power technology can increase the reliability of power supply in the dry seasons. In particular, wind flow variations in La Guajira, Colombia, balance seasonal and hourly variations of water flows, and effectively increase the availability of energy (ESMAP, 2009).

Experiences from around the world indicate that wind power can be successfully added to the primary energy mix, provided that there is an enabling framework that lowers entry barriers, especially the high capital costs (IEA, 2009). In 2002 Colombia created a general framework for promoting Renewable Energy Technologies (RETs). This framework includes incentives for research on RETs and tax exemptions for suppliers that use RETs and obtain carbon certificates. Between 2004 and 2010, the Colombian enabling framework promoted only one wind farm with a capacity of 19.5 MW (0.015% of total 13440 MW capacity). This is a poor result compared to other countries in Latin America.

The existing framework for promoting renewable and wind power generation consists of the following initiatives:

- Law 697 of 2001 and Decree 3683 of 2003, which:
    1. Incorporate renewables and energy efficiency as part of the goals to be met by energy policy and create institutions to support their development,
    2. Propose research funding for energy efficiency, and
    3. Include renewable options for non-interconnected regions.
- Law 788 of 2002, which establishes:

  A fifteen-year tax-exemption period for power generated from wind or biomass energy. To benefit from this tax-exemption scheme, generators must obtain carbon emission certificates, which are an additional source of income, and 50% of this income must be invested locally in social benefit programs.

This policy for RETs has been insufficient to trigger a large-scale development of wind power in Colombia. By 2010, the only wind farm in place was Jepírachi. Despite the significant potential for developing renewable energy sources, only 1.2% (105 MW) of proposed new generation projects are non-hydro renewable. Although other wind projects are under consideration, the indicative plan for power generation and transmission expansion registers only the 20MW Jouktai wind farm, which is to be located in La Guajira (ESMAP, 2009; UPME, 2009).

The Colombian framework fails to promote wind power mainly because the incentives it provides (tax cuts) are not targeted at lowering entry barriers for renewables. The high capital costs of wind power, a market structure based on hydro technologies and high industry concentration (four utilities account for 82.39% of hydro capacity; UPME, 2009) create a negative environment for investing in wind farms.

As discussed earlier, regulatory incentives (capacity and reliability charges) have favoured expansion based on medium to large-scale hydro plants at the expense of other technologies, particularly renewables (Larsen et al. 2004). Reliability charges can be allocated regardless of technology and could in principle remunerate the capital costs of wind energy. In their current form, however, reliability charges do not provide a method of forecasting the power generated by intermittent sources other than that available for hydro sources. The contribution of hydroelectricity to power supply can be forecast from long historic time series which are not available for wind, solar or other renewable energy technologies. Thus, it is not possible to make a reliable estimate of the contribution of wind power technologies to total energy supply during years of extreme weather conditions. A lack of wind generation data is common to many wind farms, but average assessments of capacity can be used for remunerating immature wind farms, as the New York Independent System Operator (NYISO), the Pennsylvania-Jersey-Maryland market (PJM) and Spain do. (Botero et al., 2010).

As there are limited incentives for technological innovation, utilities are reluctant to diversify their technology portfolios. Barriers to renewable energy technologies are likely to persist in the short to medium term. Wind power costs, however, are expected to decrease, which will provide an opportunity to develop Colombia's wind resources. From the 1980s to the 2000s worldwide, wind power capacity grew at annual rates above 20% (IEA, 2004); turbine sizes increased and capacity costs generally decreased (Wiser and Bolinger, 2009). Capital and equipment shortages in the 2000s put pressure on wind capacity costs, but in the long term it is expected that the industry will move along a learning curve, thus reducing its capital costs (Wiser and Bolinger, 2009).

The case of the Jepírachi wind farm, which this article discusses in detail, illustrates the challenges of Colombia's renewables, and also shows the potential for the deployment of wind power technologies on a larger scale. Having examined the Colombian framework for promoting RETs, we then look at policies in Latin American countries, focusing on those whose power sector structure is similar to that of Colombia's. Based on this analysis, we examine the potential for the Ministry of Mines to set wind generation goals of 3% for 2015 and 6% by 2019. Finally, this proposal is contrasted with the current proposal by Vergara et al. (2010) to make reliability payments to intermittent sources by calculating their contribution to the ability of the interconnected system to meet demand during extremely dry seasons (firmness).

Assessment and development of wind resources in Colombia

As of 2010, the only wind farm operating in Colombia is located in La Guajira province, a region in the north-east of the country. This onshore wind farm has fifteen units of 1.3 MW each for a total nominal power of 19.5 MW. This farm, the first one built in Colombia, was commissioned in 2004 and it is connected to the national grid by a 110 kV transmission line. Minimum wind speed for the windmills is 4 m/s and the average wind speed is 9.25 m/s (EPM, 2008; Pinilla and Trujillo, 2009). This wind regime is rated among the best in South America, comparable only to the Patagonia region (ESMAP, 2010). The farm was built by Empresas Públicas de Medellín (EPM), a public utility, the second largest power generator of the country and the only vertically integrated utility. Jepírachi is part of EPM's R&D program on wind energy, whose purpose is to learn about the operation of wind farms in Colombia, and which includes:

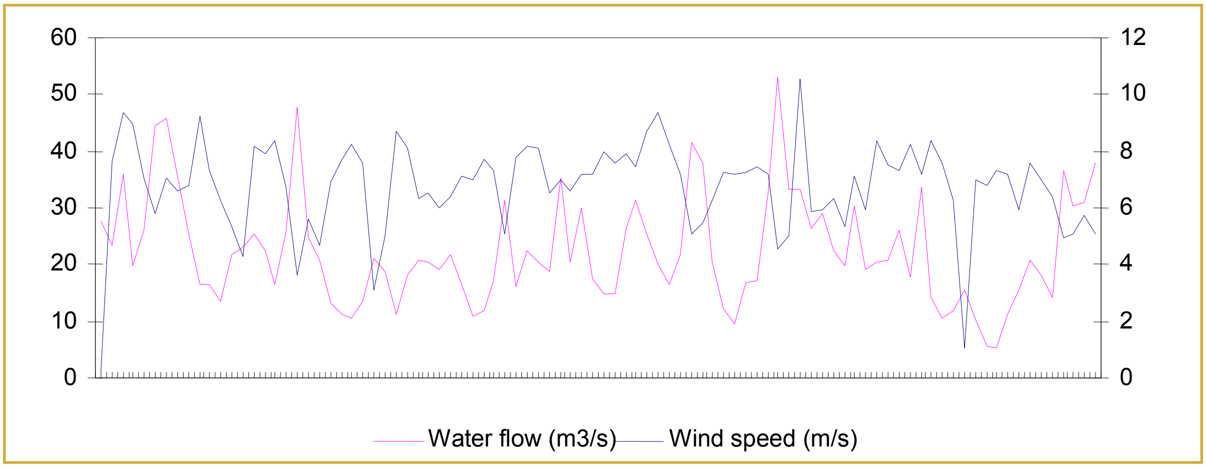
1. Evaluation of wind regimes
2. Study of tax incentives and the enabling framework for RETs, and
3. A pilot plant to transfer and innovate wind energy technology

EPM started this R&D program after examining medium to long-term trends for power generation in Colombia. The Guajira is a semi-tropical desert, and the operating challenges of the pilot plant have shown the need to adapt wind power technology to the Caribbean conditions (Pinilla and Trujillo, 2009).

GTZ, the World Bank and the Universidad Nacional de Colombia advised EPM during the formulation of the project, whose capital investment was $21 million dollars (EPM, 2004). The plant is located in the Uribia municipality, in the territory of the indigenous Wayúu community. This is an arid area, with long summers, frequent droughts and no surface water. Water comes from wells and desalination plants. As a part of its social and environmental plant, EPM built a desalination plant that provides the Wayúu community with clean water. Carbon credits are 10% of the Jepírachi's revenues, the rest coming from energy sales.

The output and performance data for the Jepírachi plant confirm that year-round winds in the Guajira region confirm the high potential for energy generation (see Figure 2). However, as winds speeds do vary, the performance of wind power is evaluated in terms of its capacity factor and availability. Capacity, or plant factors, are a measure of the productivity of a power plant, calculated as the amount of energy that the plant produces over a given time period divided by the amount of energy that would have been produced if the plant had been running at full capacity during the same time period (DOE, 2008). Availability is defined as the number of hours of energy production divided by the number of hours that wind speed is between the operating limits of the turbine (Pinilla and Trujillo 2009). Pinilla and Trujillo (2009) report that capacity factors for turbines in Jepírachi are similar to those for other turbines, averaging 38% with 96% availability, whereas production is higher than typical values in the literature (1750kWh/m2-year per turbine).

Figure 2. Complementarities between water regimes in the northwest of Colombia and wind regimes in La Guajira, Colombia.



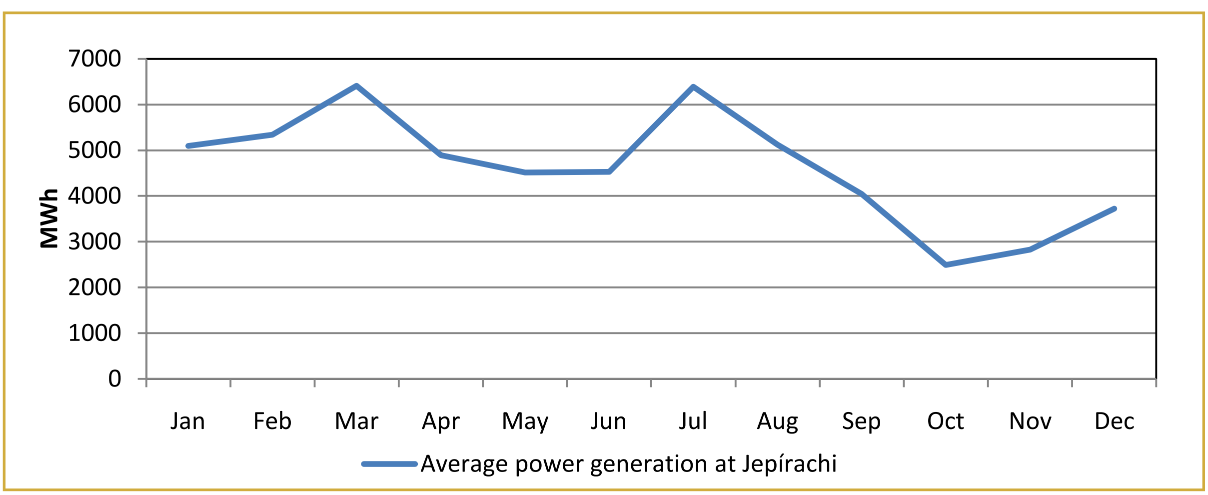
Source: COLCIENCIAS-EPM-Universidad Nacional de Colombia, 2003.

As Figure 2 shows, wind peaks in La Guajira coincide with low water flows in the northwest of Colombia. To a large extent, wind resources complement water resources and the complementarities between water flow and wind speed are higher during the first months of the year, when water is scarce. Figure 2 shows how energy produced in Jepírachi is higher during the first six months of the year, and it is lower during the second semester.

In addition to the complementarities between water and wind regimes, daily variability of wind can also improve the performance of the interconnected system because wind power could displace some water resources in the low-demand hours (Vergara et al., 2010).

Being the first operational wind farm in Colombia, Jepírachi has provided valuable data and knowledge

Figure 3. Average power generation at Jepírachi. Adapted from Vergara et al., 2010



that may support efforts to expand wind power generation in Colombia. In particular, and unlike other projects, this has been well accepted by the Wayúu community and is a reference for the future of wind power in La Guajira (Valencia, 2009). There are technical challenges in adapting wind generation technology to the conditions of the Caribbean (Pinilla and Trujillo), but the plant's performance is likely to improve as EPM learns to operate the technology in the harsh climate of La Guajira. Current performance data prove that the high-speed, low-turbulence winds of Guajira province could generate more than 100GWh per year (Pérez and Osorio, 2002), and a couple of projects have been proposed to develop such potential, as shown in Table 1.

From this policy perspective, during the early stages of technology adoption, innovation and learning are the main benefits of adopting RETs. In the long run, these technologies increase the robustness of Colombia's power system by complementing its hydro energy sources. As the previous discussion shows, the Colombian power market needs clear, direct and effective regulation of renewables to promote wind power. This becomes even more evident if one examines the policies for renewables in similar countries. The next section analyses the enabling frameworks for wind energy in Latin America and relates these frameworks to the Colombian case in order to propose changes to the existing policy.

Table 1. Wind power capacity expansions built and under construction in Colombia as of 2010

Project	Capacity (MW)	Location	Company	Stage
Jouktai	20	Uribia, Guajira	Wayuu S.A. / ISAGEN	Advised by the Netherlands. Environmental license issued in 2010*
Ipapure**	200	Ipapure (Uribia, Guajira)	N.A.	In 2008 EPM asked for bids for a pre-feasibility study for a 200MW plant in Ipapure (Uribia) and Bahía Hondita (Maicao)***.

** Source: ISAGEN (2010)*
*** Source: ESMAP (2009)*
**** Source EPM (2008)*

Against this background, the main challenges in expanding wind power in Colombia have less to do with technology or with resources than with policy and the regulatory framework. In this sense, in a market dominated by hydropower technologies, investors are unlikely to pursue individual RET projects unless there is a comprehensive enabling framework, set at the national level, which provides clear incentives targeted at specific technologies. As hydropower has a low carbon footprint and low operating costs, the main reason for creating such a comprehensive RET policy is to enable a variety of technologies to enter the market, thus diversifying primary energy supply.

Wind power policy in Latin America

The initially slow penetration of renewable power in Latin America (LA) has changed since the mid-2000s, and for many countries, including Brazil, Mexico, Chile and Costa Rica, wind power capacity is growing at average rates higher than 25%. Policies to promote RETs in LA are diverse. Mexico and Brazil have devised comprehensive programs to increase their share of renewables, including wind power, on both small and large scales. These programs rely on incentives such as tax breaks and feed-in tariffs for wind power plants operating in a competitive power market. Feed-in tariffs guarantee a minimum price for renewable energy which is usually higher than the retail electricity price, and which is sustained over a long time frame. With small markets and a centralized market structure with vertical integration, Costa Rica and Nicaragua have reached the highest shares of wind power in the region (5 and 4.5% respectively; see Table 2). Chile is now implementing a different strategy through a RET portfolio standard. A renewable energy portfolio standard mandates electricity retailers to source a portion of their supply from renewable facilities (IEA, 2010). Because all suppliers must comply with the mandate, this policy internalizes environmental costs, without targeting a specific renewable energy technology (Kydes, 2007).

As shown in Table 2, for some countries surveyed in LA wind power capacity is already higher than 1%, and many countries are committed to ambitious expansion plans. We now discuss some of these cases in detail. Note that, in most of these countries, carbon emissions from power generation are low.

Mexico

Mexico's installed electricity generation capacity is nearly 75% thermal and 19% hydro (SENER, 2009). In 2007, Mexico approved a plan for developing the use of large-scale renewable energy (PERGE plan). The World Bank supports the PERGE plan, which includes an assessment of wind power potential and the building of the La Venta III wind power farm (101.4 MW). This initiative was complemented by the enactment of the Law for Renewable Energy Use and Financing of Energy Transition (LAERFTE) in 2008. LAERFTE defines the programs and strategies for promoting RETs. The current goal for wind power is to reach 4.34% of installed capacity by 2012 and to generate between 1.74 and 2.91% of power from wind (SENER, 2009). The construction of transmission lines connecting the wind-rich Isthmus of Tehuantepec to the national grid is also one of the programs created by LAERFTE. To address the intermittence of wind energy and to integrate wind power technologies with the grid, the regulatory

Table 2. Wind power capacity in Latin America, 2009 or 2010

	Installed capacity, MW	Approved and planned expansion, MW	Potential wind power capacity, GW	Percentage of total generating capacity
Argentina*	60	794	200	0.23%
Brazil*	931	3140	143	0.89%
Chile*	172	2000	40	1.29%
Colombia*	19,5	27,5	18	0,15%
Costa Rica*	120,1	100,5	0.6	5,34%
Cuba	7,2		N.A.	0,14%
Curazao	9	24	N.A.	5,17%
Ecuador	2,4	15	N.A.	0,06%
Mexico*	519	2300	71	1.03%
Nicaragua	40	215	2	4,53%
Uruguay*	20,5	150	2	0,93%

Sources: Programa de Energía Eólica en Uruguay http://www.energiaeolica.gub.uy/index.php and LAWEA http://www.lawea.org/YearBook/2009-2010/EspanolFinal/index.html

** data for 2010*

commission has drawn up interconnection and transmission contracts for renewables (Reglamento ley energías renovables, 2009; Contrato de interconexión, 2010), aimed at stabilizing wind producers' income.

In addition, other laws provide incentives like deducting 100% of capital investment in equipment and machinery for renewable generation from taxes (Ley del Impuesto sobre la Renta Art. 40 Fracción XII, 2008). Finally, small-scale wind power generation is one of the technologies included in the program for rural electrification (Proyecto de Servicios Integrales de Energía), which is funded by the World Bank and which aims to reach 2500 rural communities by 2012.

Brazil

Brazil's installed capacity is 79% hydro and 18.5% thermal. In 2002 Brazil created the PROINFA program, aiming to reach a 20% share of renewable energy sources in power generation by 2020 (Lei 10.438, 2002; Lei 10.762, 2003). This comprehensive policy has provisions for technology transfer and for developing domestic technology, as well as incentives for small producers. In the case of Brazil, electricity generated by wind, small hydro, and biomass plants is sold to Eletrobrás, the state-owned electricity utilitiy, in twenty-year contracts at a regulated price. In the first stage of the program (until 2013), a renewable energy price is set to reflect technology costs, and for wind power, the price is guaranteed to be at least 90% of the average end-use tariff. For the second stage of the program, renewable energy is to be paid at the average cost of new hydro plants, which is lower than the average cost of new wind plants (Lei 10.438, 2002). To increase the competitiveness of wind energy, in 2009 regulators held separate capacity auctions for wind power, approving more than seventy wind projects with a combined capacity of 1.8 GW (ANEEL, 2010).

Uruguay

Uruguay's wind energy program is financed by the Global Environmental Facility (GEF) through UNDP and it is executed by the energy and nuclear technology division of the Ministry of Mines and Energy. The objective of this program is to develop a policy framework for wind power, to acquire relevant information for wind projects and to remove technological barriers through technology transfer and development (MIEM, 2008).

Hydroelectricity accounts for 70% of total power generation capacity in Uruguay, the remaining capacity being thermal. However, renewables are making progress in this country: a) by 2009, two 10 MW wind farms were already in place; and b) Decrees 77/2006, and 397/2007 mandate the state-owned utility UTE to award contracts for building 60MW of non-conventional renewable sources, while 28.45 MW of wind power were awarded to three different projects currently under development (DNTN, 2009).

Decree 77 of 2006 and Decree 397 of 2007 allow UTE to buy at least 50% of generated power if the installed capacity is greater than 10 MW, and 100% if there are long-term contracts for renewable energy. Wind power is always dispatched, as it has low marginal costs and is exempt from transmission charges. Wind power generators have long-term power sales agreements with UTE, which do not allow generators to sell to third parties, though they can sell excess generation in the spot market. To increase the share of wind energy and to diversify the primary energy matrix, UTE is authorized to contract up to 150 MW of wind power capacity. New generators enjoy corporate tax breaks, and domestic equipment makers are exempt from other taxes.

Chile

Chile's installed capacity is 62% thermal and 37% hydro. Three companies, Endesa, Colbun and AES, have a 53% share of generation capacity. Chile's renewable energy law (20.257), enacted in 2008, mandates generators with a capacity larger than 200 MW to include sales of at least 5% of their total from renewable sources. This fraction is to increase by 0.5% annually between 2015 and 2024 until 10% of energy demand is supplied from renewables. Generators that do not meet the renewables' requirement pay a monetary penalty. To date, this policy has promoted 170 MW of wind power (LAWEA, 2009).

Costa Rica

The Instituto Costarricense de Electricidad (ICE) is a public monopoly that controls power generation, transmission and distribution in Costa Rica. Laws 7200 of 1990 and 7508 of 1995 allow private investment in the generation of up to 15% of installed capacity and set incentives for renewables. Building, Operation and Transfer (BOT) contracts and power sales agreements to ICE are the main incentives used to promote investment in renewable, mostly wind and geothermal energy. These mechanisms have successfully increased wind power capacity in Costa Rica from 16.5 MW in 1996 to about 120 MW in 2010. Approximately 80% of this capacity belongs to private concessionaires and 20% to ICE (ICE, 2010). The existing wind projects have support from the Clean Development Mechanism (CDM), and two of them (Chorotega and Vera Blanca) are part of World Bank's Prototype Carbon Funds. About 100 MW of wind power is due to be auctioned in the near future under BOT contracts.

Nicaragua

Law 532 of 2005 aimed to increase the share of renewables in the predominantly thermal energy system. This law sets tax incentives for renewable energy, and it also mandates distribution companies to contract a portion of their energy from new RETs. These contracts are for a minimum of ten years and subject to a regulated price. Generators that do not have contracts with distributors may sell their energy in the market place at prices initially set between 5.5 and 6.5 USD ¢/kWh. In addition to these incentives (portfolio standard and feed-in tariff), wind power generators in Nicaragua receive CDM support.

In general, RET policies in Latin America emulate the success of those developed in the EU and the US, and there are no noticeable innovations. As in most of the world, Latin American wind power policies combine tax incentives with feed-in tariffs and in some cases portfolio standards. Although wind power policies in Latin America are relatively new, they have produced good results, particularly in Brazil, Mexico, Chile and Costa Rica. Relevant lessons for Colombia and may be summarized as follows:

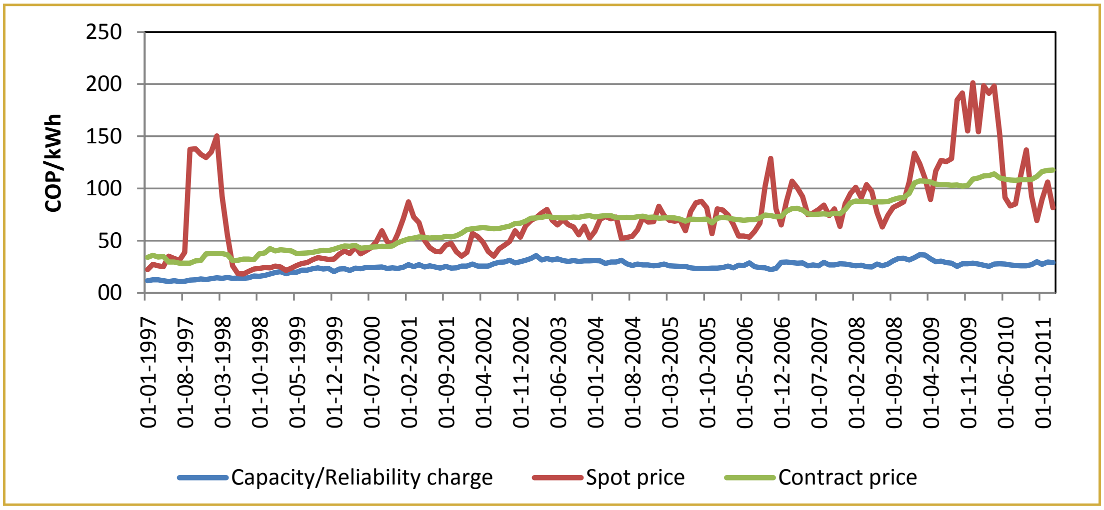
- RET policies need clear goals, targets and dates to achieve them.
- If hydroelectricity dominates power generation, enabling frameworks for RETs should provide incentives targeted at specific technologies, such as the separate wind auctions held in Brazil, as well as feed-in tariffs
- Carbon funds and other international financial mechanisms are useful for increasing the Internal Rate of Return of wind power projects. However, to reach a higher share of wind power generation, countries need to integrate these technologies with the grid. The Mexican interconnection contracts for wind energy are a good example of how to achieve such integration.

The next section examines and compares different policy alternatives to increase wind power share in Colombia. We propose and discuss a goal of reaching a wind share of 3% of generation capacity by 2015 and 6% by 2019.

An enabling framework for wind power in Colombia

In the absence of a feed-in tariff, CDM and energy sales are the main sources of revenue for wind power in Colombia. Unlike thermo- and hydro-electricity, wind power technologies have no access to the capacity and reliability charges paid in Colombia. Between 1997 and 2006 these charges contributed 49% to the average generator's income, and although they are decreasing, they still represent 28% of its revenues (Figure 4).

Figure 4. Evolution of income sources for power generators in Colombia between 1997 and 2011. In 2010 1 USD = 1887 COP.



Successful wind energy policies set generation targets and dates, along with the mechanisms to meet them. Targets in developing countries range from 3% to 10% of renewable energy share in generation. From experiences in comparable countries, a 3% share of wind generation capacity by 2015 and 6% by 2019 are attainable goals, and would have an almost negligible effect on the system's finances. Many countries combine financial and production incentives to reduce market and capital risks for new wind power capacity (Zuluaga and Dyner, 2007). This article next compares feed-in tariffs, portfolio standards, reliability charges and subsidies mechanisms in terms of their information needs, costs and fiscal impact, effectiveness in lifting market barriers, ease of monitoring and enforcing, and flexibility within changing economic and market conditions (Table 3).

A recent analysis of market barriers for wind power in Colombia identifies three main instruments to lowering entry barriers for renewable energy (Vergara et al., 2010): 1) strengthening access to and increasing participation in the CDM; 2) targeting subsidies such as exemptions to income tax as well as to systems' charges; and 3) introducing reliability charges (Table 3) and taxes on polluting technologies. As we discuss next, although these three instruments enable the development of wind power, a more comprehensive policy is required to increase its market share in Colombia.

Two of the three instruments proposed by Vergara et al. (2010), CDM and tax exemptions, are already in place in Colombia. CDM forms part of Colombia's national environmental policy and is a source of revenue for the Jepírachi wind farm, which also enjoyed tax exemptions on capital. However, these are completely insufficient revenues compare with the capacity charge mechanism that is available to hydro and thermo electricity, making clean technologies uncompetitive. Two of the main utilities in Colombia, EPM and ISAGEN, have shown an interest in investing in wind power, but only as part of their R&D initiatives aimed at making progress along their learning curves regarding diversification, with a specific focus on its adaptation to local and Colombian market conditions (ISAGEN, 2010).

Taxing polluting technologies and modifying current market rules to include wind power have not been tried yet, but their usefulness within the Colombian context is unclear. Carbon taxing, for instance, would have little effect on energy prices because the base load power is hydro, which is enough to satisfy demand in

Table 3. Comparison of policy instruments for promoting renewable energy

Policy Instrument	Information needs	Costs	Effectiveness	Ease of monitoring and enforcing	Flexibility
Feed-in tariffs	Low	Shared with customers	High. Decrease levelized energy costs from 2% to 30%*	High, established by regulatory commission	High, tariffs can be periodically reviewed and modified
Portfolio Standard	Low	Shared with customers	High. Used by 9 of 20 IEA – wind members*	Established by regulator. Needs a market for green certificates	Low, targets are set for a given period of time
Subsidies	Low	Fiscal impact, need to be included in government budget	Decrease levelized cost of energy from 2% to 20%*	Allocation and targeting of subsidies is difficult, often causing inefficiencies	Low, subsidies set for a fixed period of time
Reliability / capacity charges	High	High costs of auctions. Costs shared with customers	N/A	Low, need additional investment for metering	Periodically reviewed and modified, according to performance. Revisions are expensive.

* *www.iea-retd.org*

most periods. This suggests that, with a large hydro baseline, a more direct mechanism is needed to stimulate investment in renewable energy technologies.

According to Vergara et al. (2010), the reliability charge previously discussed can be modified to include wind projects in the corresponding auctions. Vergara et al. (2010) argue that a capacity charge designed for wind power might be as effective as direct incentives such as the renewable portfolio standard. In the short term, however, this mechanism is difficult to implement because there is no information for calculating the firm energy contribution from wind power.

Furthermore, regardless of how these capacity and reliability charges are implemented, the Colombian experience suggests that market mechanisms alone are insufficient to promote alternative power because of the existing entry barriers. More importantly, incentives and instruments are means to reach the goals of policy, and should be designed and implemented after these goals have clearly been set. Note that, even though reliability and capacity charges might be periodically reviewed and modified, this may be relatively costly to achieve. However, previous arguments, particularly the one relating to the unavailability of long time series on wind flows, clearly reject this alternative.

It is clear that electricity regulators and policy-makers need relevant data when considering increasing investment in clean energy. Not every policy has the same information requirements. Information availability influences the ease of monitoring and enforcing policy. These leave room for considering all the options in Table 3, except for the changes to the Colombian reliability charges, which have already been rejected.

Unlike other instruments in Table 3, feed-in tariffs can directly target specific technologies and are effective mechanisms for recovering the high capital costs of wind power technology. In addition, feed-in tariffs are flexible. A flexible instrument can easily be adapted to changing market and economic conditions. Feed-in tariffs, for instance, might be in line with wholesale market prices and may only need to be adjusted by a producer price index.

By definition, portfolio standards are less flexible than feed-in tariffs and must be sustained over longer periods of time. Changes in portfolio standards need to be discussed and announced in advance, to avoid regulatory uncertainty. Portfolio standards, however, are highly effective, and because utilities are overseen and regulated, they can be monitored and enforced with ease.

The previous section indicates that the most successful Latin American policies for increasing the share of RETs in power generation make use of feed-in tariffs. By far, feed-in tariffs have been the most widely used and successful regulatory option to promote renewables and wind energy worldwide, as nearly 45% of global wind generation capacity (53 GW in 2008) has been installed using this mechanism (REN21, 2010; IEA, 2010).

Renewable portfolio standards have also been successfully applied in LA to increase the market share of renewable energy. This mechanism promotes renewable generation and internalizes the environmental costs, while allowing the market to develop and utilize the most economic technologies (Kydes, 2007). Portfolio standards are a part of the renewables policy in Australia, Canada, Italy, Japan, Korea, Portugal, Sweden, the UK and the US (IEA, 2009), and they are usually combined with other environmental policies.

Based on lessons learned from Latin America and elsewhere, we propose an effective framework for promoting RETs in Colombia by combining feed-in tariffs with renewable portfolio standards. The first step in this direction is to define a policy with both measurable goals and the mechanisms to reach them. A target of 3% of renewables would add about 400 MW of wind power capacity by 2015, and to reach a 6% by 2020, an extra 450 MW would be needed. An effective mechanism to achieve this goal is to mandate generators with capacities larger than 500 MW to source 3% of their dispatch from renewable energy in exchange of a feed-in tariff, while other generators can participate voluntarily. For other independent producers, new renewable power capacity can be allocated by auctioning 20 MW modules to be remunerated through a feed-in tariff. This scheme would complement existing instruments, namely supply subsidies and CDM support, while providing stronger incentives for investment.

Conclusions

To a large extent, Colombia's limited success in promoting wind power reflects the absence of a policy program specifically targeted to increasing the share of renewable energy within the portfolio of power generation. The World Bank (Vergara et al., 2010) proposes to adjust the current reliability charge to increase investment in wind power generation. Although appealing, this approach is not adequate, as: a) it places high requirements on wind power for information, which is currently not available; and b) it is not as effective as other proven mechanisms around the world. The experience in other countries is that, independently of the market structure and size, the early adoption of wind power benefits from two basic mechanisms: feed-in tariffs and portfolio standards (Zuluaga and Dyner, 2007). Moreover, policies that seek to accelerate learning by doing and technology adoption, like the Brazilian PROINFA program, are adequate to lower entry barriers in countries with a large hydroelectricity component, such as Colombia.

Latin America, and particularly Colombia, has a good opportunity to deploy wind power technologies that now offer relatively cheap and modular generation units. From the perspective of regional integration, this is a strategic opportunity for Colombia, which needs a much higher electricity supply to contribute to the requirements of Central American countries and to complement Ecuador's and Peru's supply.

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