FUTURE PROSPECTS FOR RENEWABLE ENERGY IN COLOMBIA

This paper introduces the reader to the energy sector in Colombia, the current status of renewable energy and policies. Renewable energies will be analysed to their competitiveness in the future and suggestions for policy changes and adaptions are given.

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Abstract

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1. Introduction

We have to accept that resources of our planet becoming scarcer. The crude oil price shows high volatility and rose to a level above many forecasts. For a long time questioned, now it shows to be proven than GHG (Greenhouse Gas) emissions are the source of global warning. Governments need to act now in order to lower GHG emissions and keep a clean environment for our future generations. Sources of renewable energies do not just have the advantage of producing clean energy, as we will see later. Hopefully in the future those technologies can compete with traditional technology on a cost basis. This is exactly the aim of this paper. We will analyse the future competitiveness of different renewable technologies in Colombia and show which ones will be most important. For conducting this Analysis, we will use a similar framework as Caspary (2009) described. Before coming to this analysis, we will also evaluate important current energy policies and their possible effect on renewable energies.

1.1. Energy sector in Colombia

The energy sector in Colombia was completely restructured in 1994 (Ministry of Mines and Energy – IADB, 2010). What was before a state-owned company, now got split up in four parts and different companies. The Generation, transmission, distribution and commercialization are now strictly apart. For the transmission and distribution, public-private companies are responsible to provide Colombia with a reliable electricity grid. Private companies investing in new generation capacity, where vertical integration is forbidden.

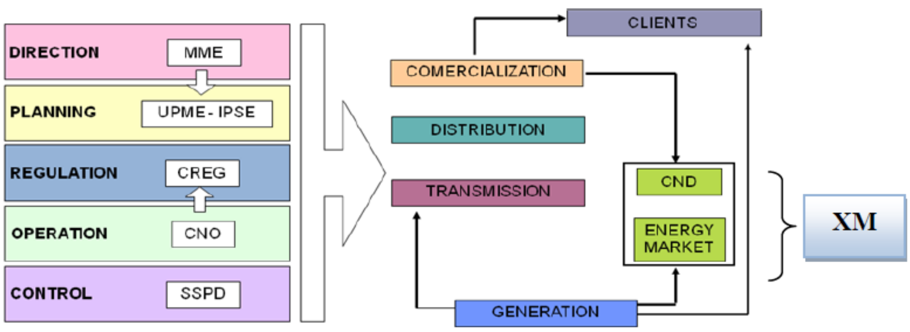


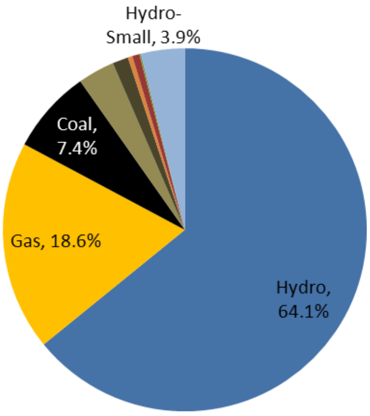
Figure 1. Structure of electricity sector (Ministry of Mines and Energy – IADB, 2010)

The system is supervised by the Ministry of Mines and Energy (Ministerio de minas y energia – MME) and prices regulated by the Energy Regulation Commission (Comisión de Regulación de Energia y Gas – CREG). Planning of capacity is conducted by the Planning Office of Mining and Energy

(Unidad de Planeación Minero Energética – UPME). Further institutions, namely CND and CNO are responsible for the operation. The SSPD (Superintendencia de Servicios Públicos) is responsible of supervising and XM is the system operator.

1.2. Energy mix and renewable energies

Colombia relies highly on hydroelectric power, namely 68% or 9000MW, including large and small hydroelectric installations. Furthermore it relies with around 30% on fossil fuels. Gas as most important input factor, followed by coal. As a response of a prospected higher future demand in Colombia and Latin America, many new projects are in the planning phase (UPME, 2009). 57.5% of these projects will be hydropower and 42.3% powered with fossil fuel. Just one wind energy project is registered with 20MW accounting for 0.0014% of all planned projects.



Effective installed Capacity per December 31, 2010

	MW	%
Hydro	8525	64.1%
Gas	2478	18.6%
Coal	990	7.4%
Fuel - Oil	434	3.3%
Residual Fuel	187	1.4%
Cogeneration plant	54.9	0.4%
Thermo	83.4	0.6%
Wind	18.4	0.1%
Hydro-Small	518.8	3.9%
TOTAL	13289.5	100

Figure 2: Energy mix per December 31, 2010 Source of Data: XM

Colombia is rich of resources. Its vast gas reserves of 7.3 TCF (Trillion Cubic Feet) in 2008 will last 23 years with the current exploitation (ANH 2009 cited in ESMAP 2009). Coal reserves are rated up to 7 billion tons which corresponds to 100 years of exploitation at current level (ANH 2009 cited in ESMAP 2009). Oil reserves are much scarcer.

Looking at the possibilities for generation of electricity with wind, the potential is huge. Just the potential in the northern region of Colombia where winds have been classified as class 7 (over 10 m/s) are rated to meet twice the demand of Colombia (Pérez and Osorio, 2002 cited in Caspary, 2009). However at the time of writing just 18.4MW of wind power is installed. Photovoltaic installation are not mentioned which are connected with the national grid. The estimated average potential for solar is 4.5 kWh/m2 radiation, where the Guajira peninsula has the potential of up to 6 kWh/m2 radiation (UK Trade & Investment, 2011). In the southern region of Colombia, volcanic activity makes the potential for geothermal power interesting. Temperatures around 220°C can be found, optimal for geothermal energy generation (UK Trade & Investment, 2011). With the huge banana and coffee plantations, huge amounts of residues occur. Using this potential and using the residues for generating energy from biomass would be a further opportunity. Studies estimate yearly productions of up to 190 million m3 of biogas which would be equivalent to 995 GWh of energy (UK Trade & Investment, 2011). Further potential consist of existing landfills in the major cities, accounting to a potential of 47MW of production. Major sugar mills already started investment for generating electricity from residues and 268MW of production should be installed in the near future.

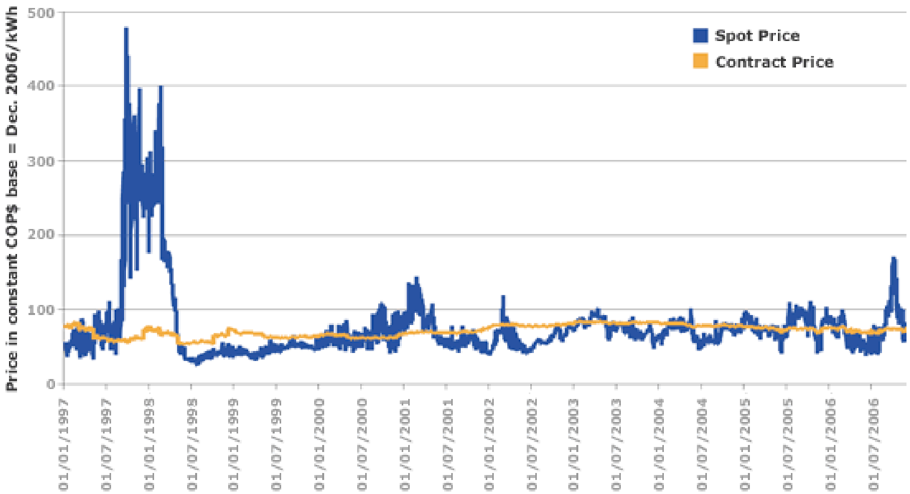


Figure 3: Spot price of electricity in Colombia: Effect of the ENSO in the years 1997 and 1998 (CREG Website)

Colombia's energy mix compared to others in Latin America, shows that Colombia has one of the most GHG friendly energy mixes with almost up to 70% hydro generated electricity. However hydro generated electricity has also its downside. Colombia suffers highly on the El Niño Southern Oscillation (ENSO) effect. Try periods brings Colombia's electricity production into problems. In the period of April 1991 to July 1992, strict energy rationing had to be implemented, due to the lack of water. From April 1997 to May 1998 electricity pool prices reached extremely high levels. During such periods, the energy mix looks different and fossil fuel generated electricity can take overhand. According to Vergara et al. (2010), wind and hydro energy resources are complementary. During the mentioned dry periods the mean average of wind was well above average. Also can be seen, that wind power is available in the early evening when the demand peaks. The authors analysed the four most important hydro installations and found out that there is a huge potential running wind and hydro generation in a joint operation system. They were able to proof that the summed up firm power of both generation surpasses the firm power of each single production. To which extent firm power is important in the Colombian system will be explained in the next section. The current regulatory system in Colombia has not yet recognized this complementary factor of joint operation between wind and hydropower.

Colombia is interconnected with two of its neighbouring countries, Ecuador and Venezuela and is a purely net exporter. Marginal cost for electricity production is lower than from their neighbouring country and electricity export is thus interesting. Plans for a connection with Panama / Central America are underway and completion of the project is estimated for 2013 (UPME, 2009).

2. Policies impacting the future prospects of renewable energies

2.1. Goals of the government

The intention of the government is to increase the share of renewable energies to 3.5% by 2015 and to 6.5% by 2020 (Ministry of Mines and Energy – IADB, 2010). Currently Colombia's renewable energy consists mainly of small hydro plants, biomass cogeneration (from sugarcane bagasse) and wind farms. According to local regulations only hydropower plants with a capacity under 10MW are counted as renewable energy. With these figures, the actual part of renewable energy accounts for 1.4% of the whole electricity production.

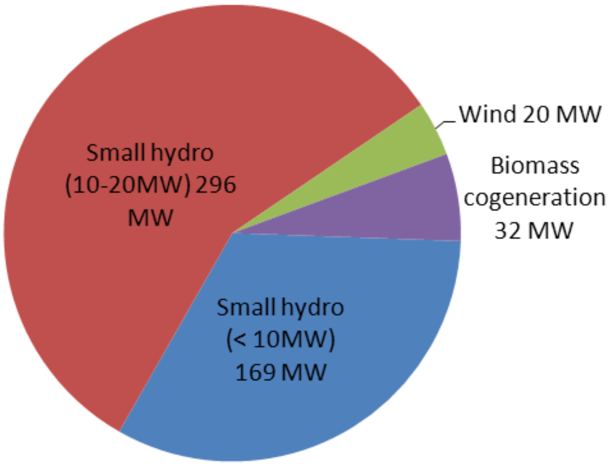


Figure 4: Renewable Energy in Colombia – Current situation Data from: Ministry of Mines and Energy and IADB (2010)

Colombia has still many remote areas, which are not connected to the national grid. Those capacities and demands are not accounted in the numbers in this paper. Energy production in those remote areas is expensive, relies mostly on fossil fuel and is subsidized by the government. In those areas the amount of renewable energies amounts to 8% and is planned to increase to 20% by 2015 and 30% by 2020 (Ministry of Mines and Energy – IADB, 2010).

2.2. Energy efficiency

Looking at the legal framework and policies, the government is supporting much more efforts in energy efficiency than expanding the renewable energy production. Many programs have been started in the last years. New regulations for reducing consumption in public buildings, commercial and residential sectors and implementing of a more efficient street lightning have been set. From January 1, 2011 not efficient light bulbs should be banned for import. According to a resolution signed in 2010 (MME, N°180919), the electricity savings target is 14.8% for 2015 on a nationwide basis.

2.3. Reliability charge (Cargo por confiabilidad)

With the high dependence of hydropower a mechanism had to be introduced for reliable firm power production. In order to prevent future shortages of energy supply and to keep the spot price stable, CREG implemented a mechanism called "reliability charge". Basically it consists of so called firm energy obligations which are bought in auctions by generating companies which can ensure firm power to a fixed price in dry periods. In order to participate in such an auction, a project needs to meet certain requirements. Studies and schemes of feasibility, financial and management environmental alternatives and fuel acquisition need to be submitted. In a second phase, companies will bid for the firm energy options. Starting prices is a level with an excess supply and above the equilibrium of aggregated supply and demand. Consecutively in each round, the price will be lowered until reaching the clearing price. All companies offering at a price below this level will win the firm energy options. Those obligations have a maximum commitment of maximum 20 years. According to CREG, this mechanism has two main goals. First to attract investors to invest in firm energy projects and giving them the opportunity to sign contracts before the construction of a facility even starts. Second, to ensure stable prices and electricity supply in periods with scarce resources. With a firm energy obligation (FEO), the generating company has the right to receive a reliability charge even if the FEO is not required at that time. They have the obligation to own a generation asset to back the FEO and have enough fuel to generate. Finally they need to provide the energy when the spot price will be higher than the scarcity price. At the moment of writing (April 15, 2011), the spot price is 65.12 $/kWh and scarcity price is set by the regulator to 409.96 $/kWh.

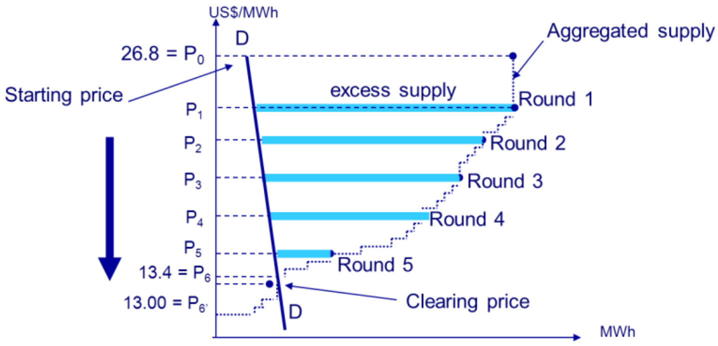


Figure 5: Auction Process (CREG Website)

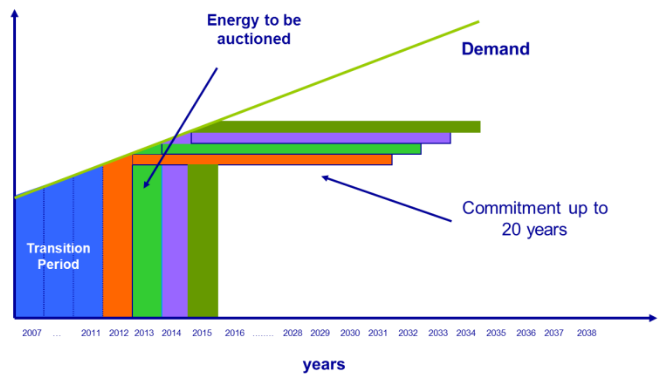


Figure 6: Commitment period (CREG Website)

Unquestionable, this brings certain stability to the Colombian electricity market as well as incentives for investors. As the price will be set by auction, prices will be set by a competitive scheme and resulting in more efficient prices. As mentioned in Ministry of Mines and Energy and IADB (2010), this mechanism has also its downsides which I assess as highly important in the discussion of renewable power. Through these obligations, the energy source cannot be chosen freely. According to this paper, agents are able to manipulate the scarcity price as only a few companies own most of the generation assets. It is obvious that only firm electricity generations can participate in this scheme. Unfortunately this excludes most of the renewable energies such as solar and wind as they don't deliver stable (firm) energy. Through this mechanism the regulator favours fossil fuel generation plants over small hydro and renewable sources.

2.4. Other policies

Regulatory decrees, laws and resolutions have been created in the past years. Many of them in order to promote energy efficiency and renewable energies. In 2002, a law has been created so that generation companies can be exempted for the first 15 years of income taxes. The law just mentions generation by biomass, wind and agricultural waste. In order to be eligible, the electricity generating company needs to sell CO2 emission reduction certificates and spend at least 50% from this revenue in the social development where the company produces. Other means of renewable energies are not included in this law.

2.5. Suggestions to improve renewable energy incentives

A feed-in tariff could be imposed in the Colombian Energy system. This gives generators a guaranteed grid access and the possibility for long-term contracts for their produced electricity. The tariff structures differ in every country, but are normally adapted to the type of the renewable energy. Investors receive incentives to invest and receive an acceptable rate of return.

Another maybe more competitive strategy would be to implement a Renewable Portfolio Standard (RPS). Electricity suppliers are obligated to produce a part of their electricity from renewable energy sources. Certified renewable energy suppliers will sell their electricity and emit a certificate to the buying company. The buying company in turn will submit their certificates to the regulating organization for controlling. This strategy seems favourable to a feed-in tariff as market mechanisms will still work for renewable energies and there will be a competition between renewable energy producing companies. The quota imposed can start low and then rise in the future depending on its impact on the global spot price, as the regulator normally tries to keep the spot price stable.

As an addition to the existing reliability charge and its auction for firm electricity for conventional energies, a national renewable energy auction could be added (Ministry of Mines and Energy – IADB, 2010). As for the RPS, generators would be required to produce part of their electricity from renewable resources. If not produced themselves, they could acquire the required energy in such an auction. The auction process could be similar and divided in two parts. One part where renewable energy sources can actually produce firm power (geothermal and biomass) and the other part with wind and solar power. Also this mechanism would provide generators with long term contracts and would keep the price competition. The administrator for these auctions could be the system operator XM as well.

Net Metering could be an additional mechanism for small installations at the customer side. Electric meters can count the consumption and the excess electricity given back to the grid. The customer then only pays the net consumption. Net Metering assumes the same price for consumed and excess electricity. It is assumed that this method would only be applicable to bagasse cogeneration in connection with sugar mills and small PV installations (Ministry of Mines and Energy – IADB, 2010).

Also changes in the current laws need to be considered (Ministry of Mines and Energy – IADB, 2010). For companies serving both, generation and distribution, a limit of maximum 60% of providing their own electricity is imposed. Renewable Power could be exempted from this limit. This modification would give the incentive to the companies to increase their share of renewable electricity generation.

Self-generation of electricity is permitted in Colombia (Vergara, 2010), but not if generation is located off-site. This might be problematic in respect to renewable energy production. Companies should be allowed to produce their electricity elsewhere, where the site properties are appropriate for electricity generation, and paying a fee for using the national electricity grid.

Another problem is financing renewable technology projects. Investors will not take the risk to invest in a new technology never built in Colombia or will demand a higher interest rate. A financial institution could be created to issue loans for such projects in the starting phase.

3. Analysis

3.1. Input factors and description of analysis

Investment cost will decline in the coming years for most of the renewable energy technologies as they become mature and more efficient. On the other hand, we might also think about increasing cost in the future because of an upcoming saturation, as the best sites will already be developed. However in the case of Colombia this seems unlikely to happen as renewable resources are high. In this analysis the most important cost figure is the development of production prices for renewable energy over the next years. General estimates for Colombia don't exist and we need to use global estimates shown in Table 1.

US$/MWh	2010	2020	2030	2050	2100
Large Hydro	70	70	80	120	150
Large Hydro - L	20	20	20	30	40
Small Hydro	150	120	100	100	120
Small Hydro - L	40	30	30	30	30
Wind	70	60	50	60	70
Wind - L	30	30	20	20	30
Modern biomass	140	120	100	100	120
Modern biomass - L	50	50	30	30	30
Geothermal	180	140	120	100	100
Geothermal - L	30	40	30	30	30
Solar PV	600	350	100	100	80
Solar PV - L	100	60	40	30	30

Table 1: Low and High Cost estimates for the coming years in 2000
Data quoted in UNEP (2006)

In Table 1 we can see that for each technology two different cost scenarios are assumed. One scenario where costs will be highly improved (L) and the more pessimistic alternative where we can expect low cost improvement.

US$/MWh	2010	2015	2020	2025
Geothermal 50MW UPME	48	46	45	45
Geothermal 20MW UPME	75	72	70	70
Wind 100MW UPME	65	57	52	52
Wind 10MW UPME	76	68	61	61
Biomass 50MW UPME	66	64	63	63
Biomass 20MW UPME	79	75	73	73
PV 30MW UPME	128	109	93	93
Small Hydro 5W UPME	77	75	74	74

Table 2: Estimates from UPME for different projects 2011 (UPME, 2011)

In addition, actual estimations for electricity generation projects from renewable resources Colombia could be found, shown in table 2.

The second important figure will be the long run marginal cost for energy production in Colombia. When a technology is able to produce electricity under the long run marginal cost, investors are most likely to select this

technology for expanding. This we can find out by equating the long run marginal cost with the cost of production by microeconomic principles. On the other hand, when a technology produces electricity over the long run marginal price, investor's most likely refrain to invest or public policies need to intervene.
There are different scenarios for the long run marginal cost of electricity, but we will select a medium price scenario of 40 US$/ MWh (UPME, 2009).

As already described in section 2, we need to consider the reliability charge for this analysis. According to Caspary (2009) this charge has been set to 13.9 US$ / MWh until 2013 and assumes the charge in the long run to be 7 US$ / MWh. Thus large hydro, geothermal energy and modern biomass will profit of a payment of 7 US$ / MWh. For modelling this impact, the marginal cost will be augmented by 7 US$ / MWh to yield 47 US$/ MWh. For electricity generation which are not able to provide firm power, the marginal cost will be reduced by 7 US$ / MWh to finally yield 33 US$ / MWh. This concerning small hydro, wind and solar PV plants.

As we know, thermal power plants produce GHG emissions. To have a complete analysis we need to account for these negative externalities in this analysis. This has not been done yet in Colombia and cost from negative externalities should be internalized with regulations of the electricity framework in Colombia. In order to quantify the negative externalities, we divide them in global and local externalities.

In order to simplify this study we will internalize global externalities only for CO2 as data is available. The damage is normally stated as US$/ tCO2 and many studies with a broad range of results can be found. For this model, we will take the values stated in the Stern Review (HM UK Treasury Office, 2006 cited in Barker 2007). Three values are stated:

- 25 US$/tCO2 along a trajectory to 450 ppm CO2e
- 30 US$/tCO2 along a trajectory to 550 ppm CO2e
- 85 US$/tCO2 for the "business-as-usual" case (no abatement)

In order to use this data in our analysis we need to know the CO2 emission factor of the electricity system in Colombia. In a resolution from 2010 this factor is set to 0.2849 kg CO2/kwh for every electricity power plant connected to the Colombian grid. This factor is low compared to other Latin American countries due to the high level of hydropower (Ministry of Mines and Energy – IADB, 2010). Using this number for our analysis we will denominate the internalizations as:

- *IG1*: 7.1 US$ / MWh along a trajectory to 450 ppm CO2e
- *IG2*: 8.5 US$ / MWh along a trajectory to 550 ppm CO2e
- *IG3*: 24.2 US$ / MWh for the "business-as-usual" case (no abatement)

Further we need to estimate local negative externalities and find an approximate value in order to internalize them. This seems to be much more challenging as exact data is missing for Latin America and many studies are not transferable for the Colombian case due to other geographical and density occurrences. Costs of morbidity in Colombia are found in table 3.

	Annual cost	
Categories	*Billion pesos*	*Percentage*
Cost of medical treatments (doctors, hospitals, and clinics)	80	16
Cost of time lost to illness	245	47
DALYs (valued at GDP per capita)	195	37
Total	520	100

Table 3: Estimated Annual Costs of Morbidity from Urban Air Pollution. From (World Bank, 2007)

Next, these numbers account for the whole urban air pollution of Colombia. According to the International Energy Association (cited in Countryside Energy Co-operative Inc.), 37% of the world's carbon dioxide emissions result from electricity generation. We think that this factor suffices for this study. Applying this factor and using an exchange rate of 2000 Pesos / US$, we receive a value of 1.9 US$ / MWh in order to internalize the local negative externalities. Thus for our analysis we use the denomination:

- IL: 1.9 US$ / MWh

We will show and discuss findings from this analysis in the following section.

3.2. Results and interpretation

3.2.1. Large hydro

The cost of large hydro power projects are mostly connected with the existence of appropriate sites. This is also the reason why costs are expected to rise in the future. Large Hydro plants can provide firm power and thus profit from the reliability charge scheme. Many future projects are already underway and the government doesn't need to impose new incentives.

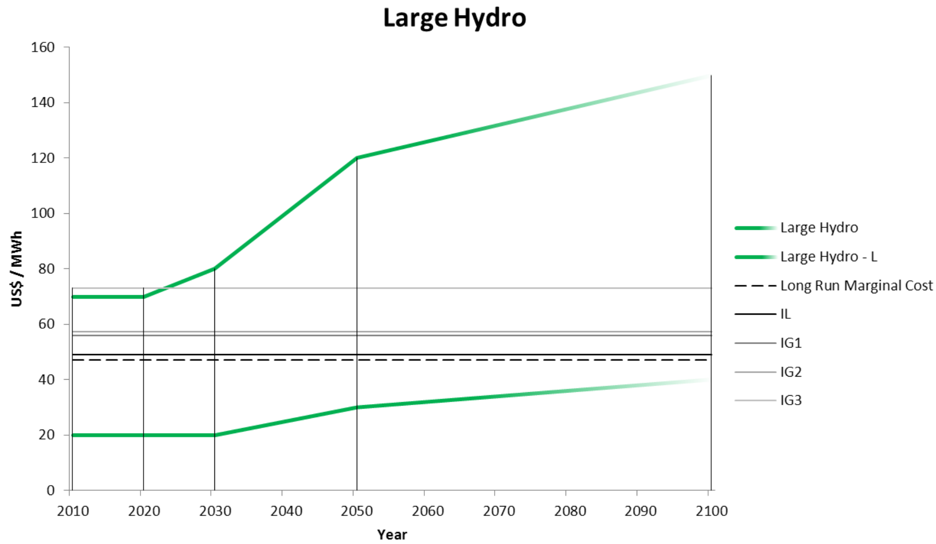


Figure 7: Analysis for Large Hydro

3.2.2. Small hydro

Small Hydro electricity production is already a financially attractive technology and many projects are underway as well. The broad range with costs is coming from the properties of different suitable sites. Internalization of externalities would help to promote small hydro projects even more. Extremely small hydro power projects, like the UNEP estimation for a 5MW plant would still be unattractive. We can assume that plants over 10MW are competitive, looking at the future expansion plans in Colombia.

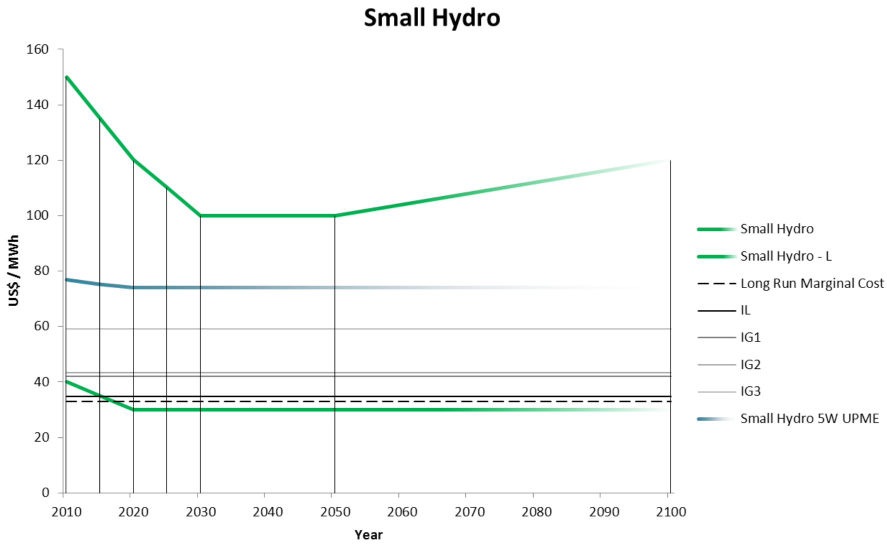


Figure 8: Analysis for Small Hydro

3.2.3. Wind power

It seems that wind power can become important in the near future. Looking at the low cost scenario, wind energy is already competitive and regulations internalizing carbon emissions would definitely help to make this technology even more competitive. The estimates from UPME are surprisingly high and follow the high cost scenario. Although the only real installed renewable energy source is wind, it doesn't seem to be too profitable at the moment, looking at both UPME estimations. Many studies show that opportunities for wind energy are extraordinary in Colombia, due to the good wind conditions in the north. Another source states the generation cost at 38.35 US/MWh for the Jepirachi project (Caspary, 2008). These figures are somehow contradictory. Generation cost of 38.35 US/MWh would follow the low cost scenario and be competitive.

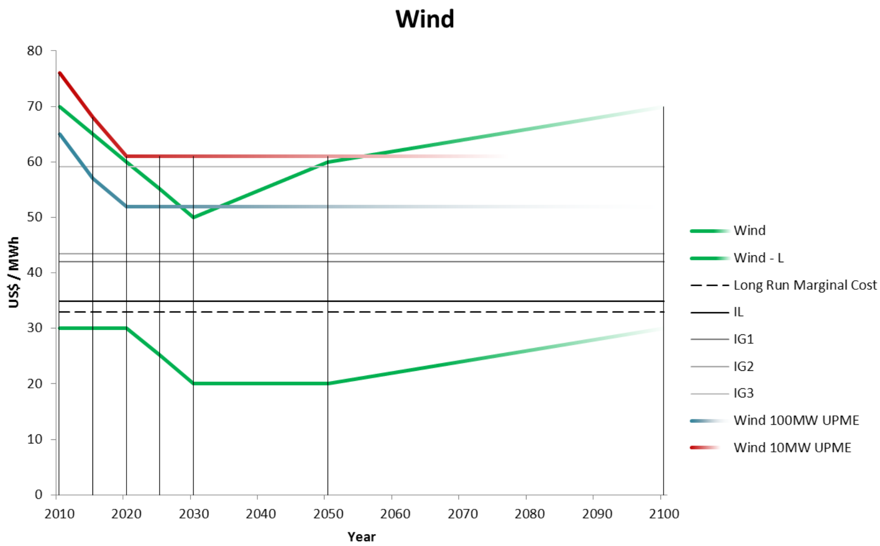


Figure 9: Analysis for Wind Energy

3.2.4. Modern biomass

When comparing the graph of modern biomass with the graph of small hydro we can see many similarities. We can see that modern biomass become competitive in the near future. Electricity generation from biomass can also profit from the reliability charge as they can provide firm power and they are not depending on fossil fuel. Electricity from biomass already exists in the Colombian energy mix. There are important opportunities as organic waste accrues in the banana, coffee and sugarcane production.

The assumptions from UPME actually show, that Biomass might become even more attractive in the near future and that prices find themselves in the middle between the low and high cost scenario.

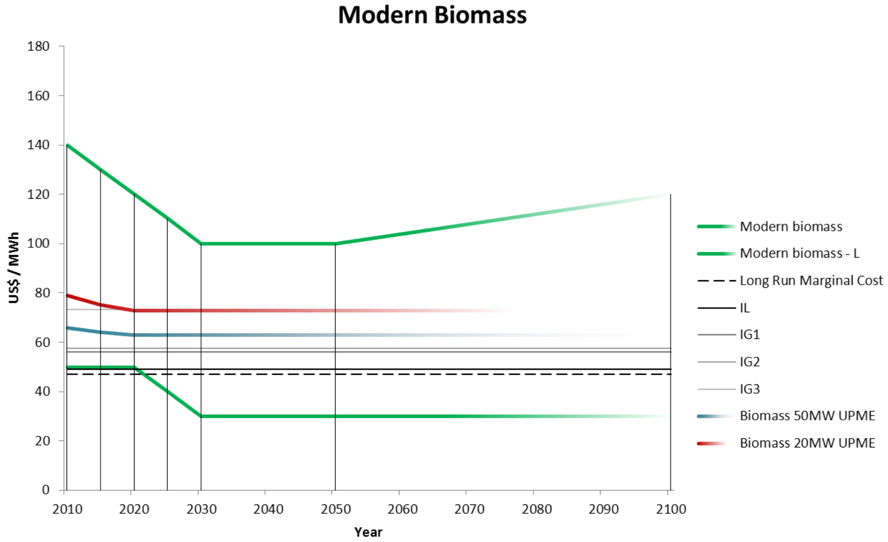


Figure 10: Analysis for Modern Biomass

3.2.5. Solar PV

Photovoltaic installations seem to be far away from competitive. Production and installation of PV Cells are still expensive and efficiency of energy conversion is still low. According to this analysis, it doesn't seem that Solar PV Projects will be financially interesting in the near future. Also the UPME scenario shows the same trend.

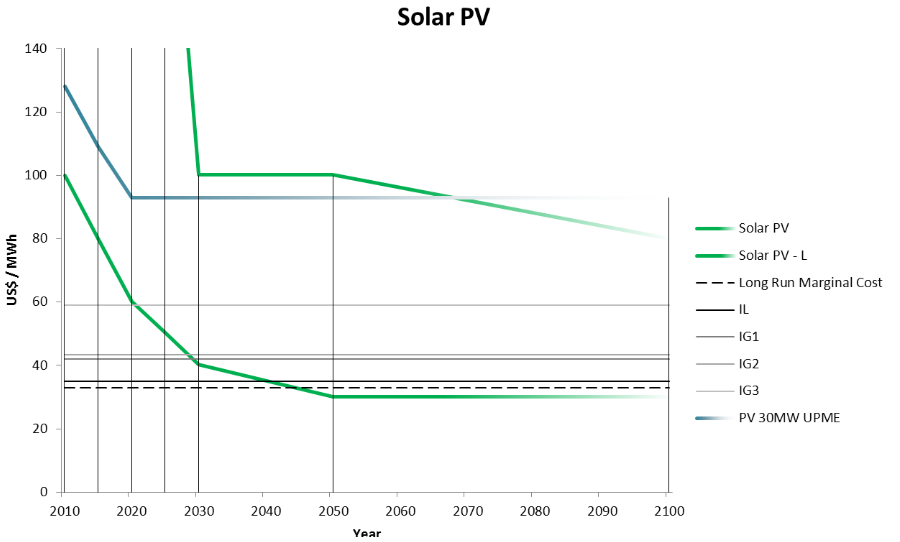


Figure 11: Solar PV

3.2.6. Geothermal

According to this analysis, geothermal power plants can be competitive, depending of the scenario. Cost of electricity finally depends on a lot of factors and also on technology development. As Colombia has areas with volcanic activities, this technology might become interesting and financially attractive in the near future. Looking at the UPME calculations show this fact and bigger geothermal plants would already be competitive.

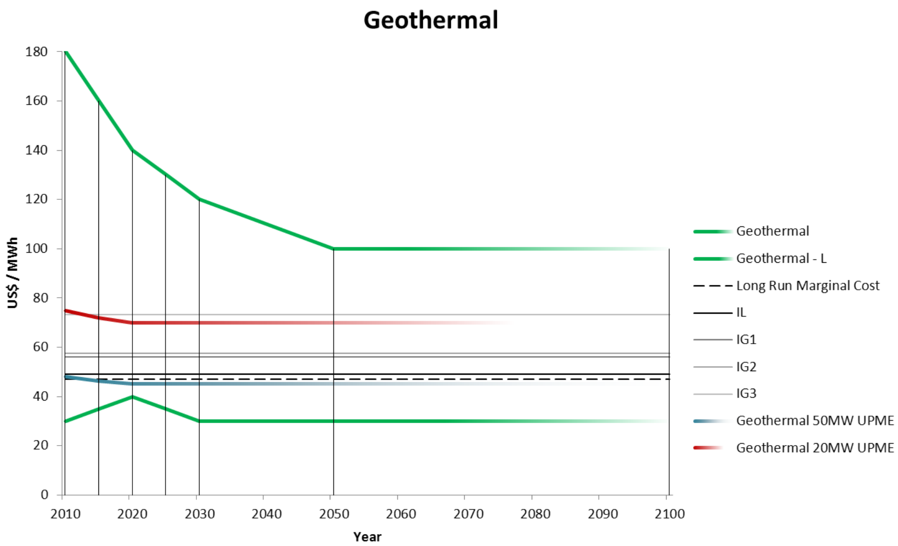


Figure 12: Geothermal

4. Conclusions and limitations

We can see that the differences of the high and low cost scenarios are high in all of the cases. The question arises, which of these scenarios Colombia follows. With the actual estimations from UPME, we were able to answer this question. For every renewable technology, the assumptions from UPME are in the middle of the two scenarios, apart from the wind power, where extremely high prices are expected. The data from the UNEP report, which has been published already some years ago and which figures global estimates, still seem to be correct when comparing them with the actual estimates from 2011 of UPME.

Internalizing externalities is extremely challenging. Many reports have been written about cost of CO_2 emissions and findings differ with factors up to five. Even more difficult are to identify local impacts from emissions and to which extent these impacts originate from the electricity production. Many assumptions had to be made for the calculations and analysis. These calculations show how a technology would become competitive if emissions of GHG would be accounted for, which is by far not the case in Colombia and even internationally.

We were able to see that there are some particularities which need to be accounted for, like the impact of the ENSO on electricity production stability. Also particular is the promotion of firm power, which might be a barrier for renewable energies not able to provide firm power.

We can conclude that biomass and geothermal energy production will become important and competitive in Colombia. A capacity of 32MW of bagasse cogeneration is already running. For geothermal energy only some pre-studies have been launched. Hydro power is already broadly established in the energy mix and seems to be competitive for projects above a certain size. In the case of wind power, we come to contrary results. On one side the high cost estimation of UPME and on the other side the already running wind park with a capacity of 20MW with a generation cost of just 38.35 US/MWh. Solar photovoltaic power will definitely not be competitive in the future and only be suitable for small off-grid installations.

It seems that Colombia started many efforts in the middle of 2010 to promote renewable energy and energy efficiency. Funding of such projects and programmes still seem to be problematical. The regulatory authorities of Colombia would have many tools at hand for promoting renewable energy, many of them described in this paper. Numerous countries already implemented such mechanisms with success. We shouldn't forget that Colombia needs to invest a lot of capital for fighting against the poverty and money is scarce. Nevertheless, Colombia's economy seems to catch up and prospects look good. Colombia is rich of resources and can profit from them also in terms of renewable energies.

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