Challenges and Opportunities for the biomass fueled distributed generation power market in Brazil

by

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Abstract

This paper evaluates challenges and opportunities for biomass fueled distributed generation (DG) power systems in Brazil. We were particularly interested in biomass because of its enormous technical potential and co-location with electricity load centers, and the DG model because it is emerging as a means to achieve regional grid stability. Brazil has long been an advocate of renewable energy, yet has failed to develop a more robust biomass market, and its electric grid is highly dependent on long-distance transmission from large-scale hydro stations.

We assessed the macroeconomic condition of the country, business environment, energy markets, energy regulations, and logistics of biomass fuel procurement. We interviewed energy regulators, industry trade associations, energy consultants, stakeholders in the biomass segment, and companies developing biomass power projects. Additionally, we comprehensively researched recent open source materials in order to get a clear picture of the current market dynamics.

Our findings suggest three primary reasons for the poor utilization of biomass power in Brazil: failure to acknowledge critical vulnerabilities in hydro capacity factors, deficient transportation infrastructure, and price supports that artificially improve the competitiveness of other power sources. Nevertheless, it appears that ***eucalyptus*** is emerging as a viable fuel for industrial DG applications.

Finally, we conclude that excessive development in the Amazonia region has increased the probability that Brazil experiences a phenomenon called 'Dieback', wherein the rainforest ecosystem will transform from a global *sink* to a global *source* of Carbon. This could exacerbate warming trends that have compromised the country's hydro-reservoirs, and consequently stands to jeopardize Brazil's entire electric grid. The recent drought conditions and the electricity blackouts confirm our findings.

Neither biomass power nor DG systems can address looming energy shortages, but they do present an opportunity to insulate electricity consumers from the costs incurred by intermittency. Moreover, leveraging biomass power is in line with the country's high prioritization of renewable energy, and it has the potential to make-up for stubborn pre-sal natural resources that remain locked undersea. We recommend that Brazil recognize the systemic risks posed by further hydro development, and support biomass DG as a means to shave electricity load demand from already compromised hydro reservoirs.

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Luiz helped us understand the interaction of federal, state, and local government in energy planning, competitive bid processes, and project execution.

Executive Summary

Our research explored opportunities for biomass fueled distributed generation (DG) power systems in Brazil. DG is defined as an electric power source connected directly to the distribution network on the customer side of the meter.[1] The biomass fuels we examined were sugarcane bagasse, the leftover stalk from sugar production, and eucalyptus, which is used for paper, pulp and fiberboard production. Legislation, investment subsidies, and tax incentives for DG power are confined to the sub 30MW range. Despite these incentives and technical potential, the cost of fuel procurement combined with the lack of scale efficiencies by small-scale power stations render biomass power in the DG range to be uneconomical under most circumstances. Hydropower projects bidding electricity for $0.045/kWh in auctions, high transport costs, a risk-averse investment environment, and energy auction supports for other renewables are contributing factors. Nevertheless, we anticipate that accounting for the combined costs incurred by seasonal intermittency from climate compromised hydro reservoirs and burdensome electricity taxes, industrial users will find sub-30 MW biomass fueled systems more economical despite the initial capital costs.

Biomass fuel made from sugarcane bagasse is, and will remain, the predominant feedstock for the universe of biomass fueled systems. We believe verticalization of eucalyptus production into industrial supply chains will become the dominant business model specifically for the *industrial* biomass DG market. We expect this market to be primarily populated by petrochemicals companies, iron and steel mills, agribusiness, and food and beverage businesses.

There are four notable drivers of this market growth. First, biomass is a process efficient option. Both fuels have impressive heating values, are good feedstock for charcoal production, and can be used to produce process steam and cooling. Second, it facilitates a tangible and

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defensible transition towards sustainable energy development, which is increasingly considered valuable by energy intensive businesses. Third, having a biomass system on-site can insulate an electricity user from the extraordinarily high cost of electricity delivery, rated the third most expensive for industrial consumers. Lastly, it provides a critical back up to grid electricity, which is significantly compromised by climate-induced drought conditions.

Deforestation in the Amazon is accelerating aridity in the eastern portion of the country. The past three years have experienced persistent drought conditions. Brazil's hydro reservoir system, which supplies 76% of the country's electricity, is at 20-year lows. Permitting and approval of planned hydro projects is taking much longer than expected, wind development is running into difficulty, and the stubbornness of pre-sal development has cast doubt on the feasibility of complementing hydro deficiencies with thermal power. These circumstances combined with the fact that Brazil's ambitious energy expansion plan barely meets annual growth projections, suggests anyone who can, ought to develop electricity self-sufficiency. Even under an ideal scenario, where climate trends reverse and pre-sal production becomes prolific, the inability of the government and its utilities to keep pace with much needed transmission system improvements leaves the whole grid worrisomely fragile.

The industrial segment, which is heavily reliant on hydropower, is particularly vulnerable to un-planned intermittency. Industrial facilities that augment power needs with DG systems are effectively insuring themselves against climate induced hydro reservoir depletion. Unless pre-sal oil production expedites miraculously, there aren't many alternative fuel options. Fortunately, both eucalyptus and sugar production are co-located with industrial hubs. Unfortunately, the roads between them are terrible.

To help reduce the economic costs and development problems incurred from large-scale hydro intermittency, the government would be well advised to facilitate support to the biomass for power market through its existing infrastructure development plans and by accounting for benefits of biomass such as being seasonally complementary to hydro low levels, not requiring transmission systems, and being carbon neutral. Support should be offered to the industrial segment in the form of tax incentives and write downs for the capital costs of biomass turbine systems, and also to sugar mills and eucalyptus plantations that seek to provide feedstock fuel for these systems. The business environment already resembles an oligopoly, so our recommendation of interventionist, top-down economic manipulation to achieve these ends is realistic and achievable. We believe that the net benefits of these manipulations include maintaining a low carbon, high output electric grid, and addressing the industrial segment's outright criticism of transmission and distribution taxes.

1 Macro-economic picture in Brazil

Figure 1 ***Source: Economic Intelligence Unit***

Brazil is the seventh richest economy in the world with a GDP of $2.2 trillion in 2011, and the largest in terms of area and population in Latin America. The country's economy is heavily dependent on commodities export and with cooling demand from some of its largest trading partners (China, US etc.) the country is experiencing a widespread economic slowdown after witnessing years of robust growth. The slowdown has exacerbated already complex challenges facing the businesses and critical infrastructure that facilitate economic growth. There are three main factors that have contributed to this current state of worrying economic activity for the country, in the face of cooling demand for its exports.

First and foremost is the country's aging and inadequate infrastructure. Brazil's quality of infrastructure is ranked 104th out of 142 countries, behind China (69th), India (86th) and Russia (100th), per a survey conducted by the World Economic Forum.[1] There is consensus amongst economists and investment banks that Brazil must invest 4% of GDP for 20 years to be at par with Chile, the current benchmark in Latin America, and 6-8% of GDP to be at par with South Korea, the benchmark in Asia.[2] In contrast, the government is slated to spend just 1% of GDP on infrastructure in the period 2011-2014. Under normal circumstances this level of spending is insufficient to galvanize an economy teetering on the brink of recession, let alone to showcase its economic prowess to the world during the fast approaching Football world cup in 2014 or Olympic Games in 2016.[3]

The *second* factor contributing to the slowdown, similar to what other emerging economies are facing, is the crippling bureaucracy and red tape that inflate transaction costs and prevent expedient transaction completion. For instance, the average number of procedures (paperwork, filings, and registrations) needed to start a new business in Brazil is 17 versus an average of 8 in the US. Furthermore, setting up a new business typically takes an average of 166 days, compared to an average of 11 days in the US.[4] Even at large, government sponsored and supported projects, red tape, endless paperwork, and redundant bureaucratic procedures inhibit the country's cost competitiveness. At ports, for instance, it can cost almost twice as much to load or unload a single container than it does in Rotterdam, Amsterdam, and almost three times as much as it does in Asia. In some cases, six different agencies require paperwork on individual shipments.[5]

Figure 2 World Rankings of Ease of Doing Business in Brazil[6]

The *third* factor that is stifling the economy is the extremely complex and costly tax structure that businesses have to deal with. Morgan Stanley estimates that companies spend 2600 hours a year preparing, filing, and paying taxes. Furthermore, these taxes consume 36-38% of GDP, a European sized chunk, but Brazilians get nowhere near the public services that Europeans get.[7,8]

These three factors combined have been affecting business for so long that they have their own name in Portuguese, *custo Brasil*[9] or the cost of doing business in Brazil. The government is working hard to address these concerns by enacting policies and measures designed to reduce bureaucracy, improve infrastructure, attract private investment, and rein in taxes. Now in its second phase, the Growth Acceleration Program (or PAC), first launched in 2007, helped Brazil weather the financial storm better than most countries. Under the second phase, $527 Billion will be spent during the period 2011-14 on logistics, power generation and transmission, and social and urban infrastructure projects.[10]

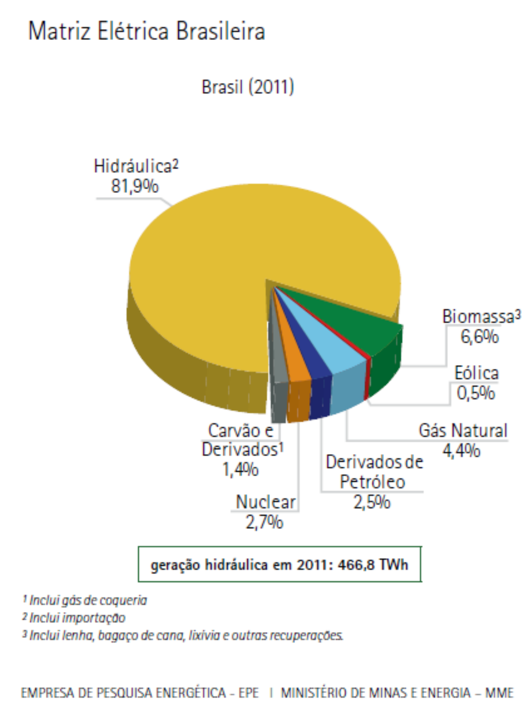
Additionally, there are ongoing efforts to attract private sector investment to finance major infrastructure projects because rising revenues (including those earmarked for the PAC projects) due to strong growth and falling tax evasion have dried up.[11] However, investors are not interested due to the poor yields, lack of long term stable cash flows, and *custo Brasil*.

2 Current Power Situation

Brazil has some very complex economic issues to tackle in the next few years. Foremost among them is energy, a vital enabler of economic growth and social stability. Unfortunately, nowhere is *custo Brasil* more evident than in the power sector. Inadequate infrastructure, supply gaps, bureaucratic inefficiencies, exceptionally high taxes, and insufficient diversification of generation sources continue to undermine competitiveness of domestic industries and stifles economic growth.

2.1 Grid Composition

Brazil is among the top five countries in the world in terms of technical potential for hydro-electricity generation.[12] Additionally, the country has good solar and wind resource potential, not to mention the excellent soil conditions that make it the largest sugar producer, largest beef exporter, and second largest ethanol producer in the world (though with the best energy balance) and a major producer and exporter of other agricultural commodities.[13]



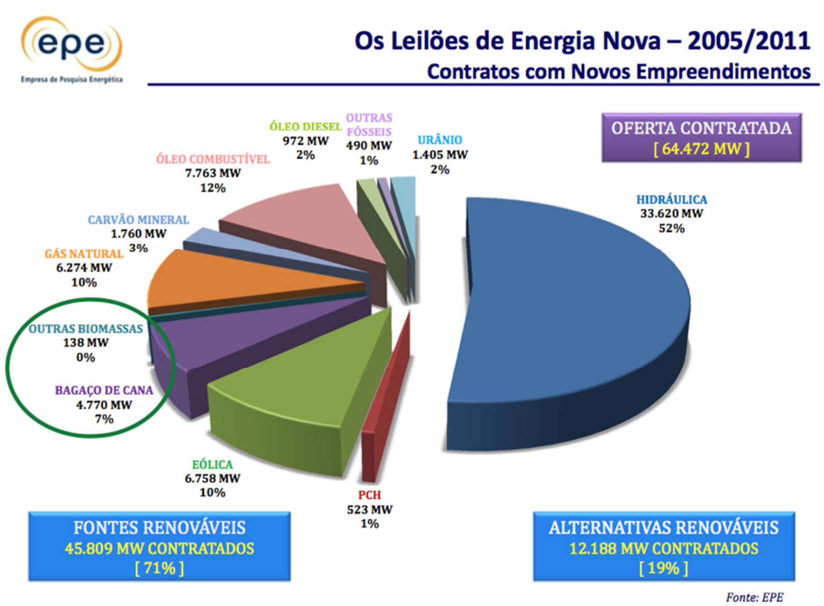
In 2011, Brazil consumed 527.38 TWh[14] of electricity, of which 81.9% or 466.8 TWh was generated from 929 operational hydro-electric plants that together accounted for 71% of

Brazil's installed generation capacity of 115 GW[15]. 40% of the total hydropower generation was from large hydro dams located in north or north-east regions of the country[16]. These dams, located far away from the consumption centers in the southern part of the country, necessitate long transmission lines that result in substantial transmission and distribution losses and require major maintenance expenditure. In fact, transmission is one of the key challenges facing the power sector considering the additional hydropower capacity planned in the coming years. The next largest sources of electricity are biomass with 6.6%, natural gas with 4.4% and nuclear energy with 2.7% of the share.

2.2 New Generation

In the aftermath of the 2001 power crisis, Brazil has consciously focused on diversifying its energy supplies by overhauling its electricity auction and spot market system, introducing private participation in the provision of electricity services, expanding its net non-hydro generation capacity with other renewables, and backstopping potential intermittency from wind and hydro with thermal generation, mostly from natural gas (according to plans). Unprecedented discovery of oil and natural gas in the 'Pre-Salt' (or *Pre-Sal*) basin off the coast of South-East Brazil in 2007 has been integral to Brazil's long-term energy strategy. Pre-Sal reserves could eventually unlock between 70-100 billion barrels of oil equivalent (BOE), which could place Brazil among the top five oil producers in the world.[17] However, political meddling with Petrobras has significantly hampered progress. Since 2006, the government has capped petrol prices to protect the competitiveness of ethanol and combat inflation. To meet rising demand, Petrobras has been forced to top up what it produces with imports, which it must then sell at a loss. Moreover, legal requirements to hire and buy parts locally have played havoc with budgets and schedules. As a result, production has consistently missed targets since then, the company recently posted its first quarterly loss in 13 years, and had to reduce it's projected 2020 production target by 11%.[18]

Competitive electricity auctions since 2005 have done much to diversify the country's grid mix, (see below), with large portions of new generation capacity coming from oil (12%), natural gas (10%), wind (10%), and biomass (7%). However, its longstanding priority of hydro development remains, with plans to build another 48 new dams totaling 38,000 MW by 2021.[19,20] Most notably, wind (eolica) and the discovered, but yet to be economically extracted, pre-salt natural gas based power is widely expected to assume a larger share of the new generation capacity being planned.



2.3 Challenges

In order to keep pace with growth, Brazil needs to bring an average of 4.5% additional electricity supply per year. Government electricity supply projections assert that this demand growth will be met, but are premised on efficient infrastructure and optimistic capacity factors for power supplies that come online. The three biggest obstacles to Brazil meeting the 4.5% per annum are that hydro capacity factors do not take into account the possibility of drought, transmission infrastructure projects are behind schedule, and the cost of electricity delivery is so heavily taxed that electricity consumers are dis-incentivized to grow.

2.3.1 Supply Gaps due to Inadequate Infrastructure

In spite of government's ambitious plans to grow electricity generation, Brazil continues to face supply gaps due to inadequate generation infrastructure. Electricity consumption is expected to grow at the rate of 4.5% per annum until 2021, as per a study by EPE, the energy research arm of the Brazilian government.[21] While there are ambitious plans to establish new assets to meet the projected rising electricity demand, as of now, generation continues to fall short of consumption. Last year, Brazil imported 7.8% of its electricity consumption, while losing 16.4% of the total electricity generated domestically (including imports net of exports) to transmission and distribution losses.[22] The large losses are a function of high reliance on large-scale hydro power plants located in the Northern and Northeastern part of the country, thousands of miles away from the load centers in the South and Southeast.

The latest in a string of massive blackouts last year affected 53 million people and put the spotlight squarely on the country's aging and inadequate infrastructure and its level of preparation for the upcoming FIFA World Cup and Olympic Games.[23] While government attributed the blackouts to unforeseen circumstances, there is consensus among industry analysts for the need for urgent investment in maintaining and upgrading the massive, aging transmission lines that connect large dams in the north to load centers in the south.

2.3.2 Taxes and High Cost of Electricity

The cost of electricity is exceptionally high in Brazil. Different sources claim average industrial rates to be between $160 and $183 per MWh. Firjan, a Rio based metals and mining industry association claims that the average cost per kilowatt-hour in Brazil is 50% more than the world average and 134% more than other BRIC countries (Russia, India, and China).[24] Countrywide, an astonishing ***45%*** of the average electricity bill goes towards transmission and distribution taxes. [25,26] These high costs make neighboring countries like Paraguay look more attractive for energy intensive industries to consider for expansion or even relocation.[27] In August, the government gave a *temporary* 28% electricity rate cut to industrial users (bringing the rate down to around $128/MWh), which is expected to reduce material and manufacturing costs by 4%. This move reduced an estimated $6.4 Billion in revenues to electric utilities, but improved the positions of metals and mining companies, who cite the cost of electricity to be one their greatest expenditures. Alcoa, the aluminum producer claims the cost of electricity to amount to 40% of total costs.[28]

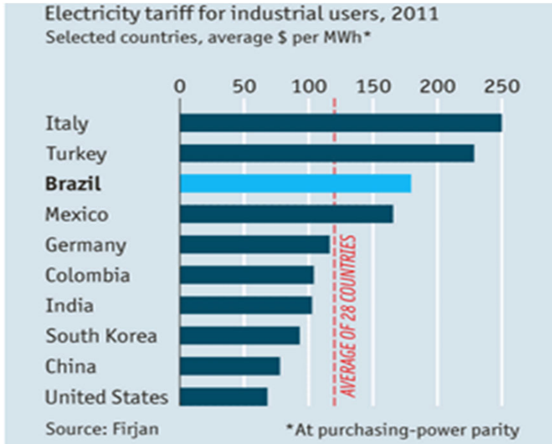


Figure 3 "Sparking Recovery" The Economist, 15 Sept. 2012

Critics contend that such cuts deplete much needed revenue for reinvestment in electricity T&D infrastructure. This concern is affirmed, at least in part, by the fact, when Ms. Roussef approved the rate cut, she also renewed contracts for 85,000 km of transmission lines that were due to expire. Without this renewal, Eletrobras and major state owned utilities would have had to re-bid their contracts in auction. If this had happened, they might have lost out to international companies with more cash to invest in the transmission system.[29] While this would be a benefit to the grid, Brazil is very protective of its monopoly on energy management.

2.3.3 Insufficient Diversification

Brazil faced an unprecedented drop in water levels at its large hydroelectric facilities in 2001 that led to widespread economic slowdown, hardship for people, and rationing of electricity by the government.[30] Over the years, the country has diversified its generation to include significant thermal capacity. However, with 81.9% of its generation still coming from hydropower[31], the last rainless summer has once again brought the country's energy supply into question. Another 26.5 GW of large-scale hydro dams are under construction in the northern region of the country[32]. Overall, another 48 dams are slated to come online by 2020[33]. This will only increase the risk that the country faces due to fluctuations in water levels due to many reasons including, large scale deforestation in Amazonian rainforest, climate change, and over exploitation of Amazon river.

3 Case for Biomass

The Brazilian energy research institute, EPE, anticipates that biomass will generate 5.5% of the country's electricity in 2020, and 11% by 2030.[34] In order to do that, 450 MW/year in additional capacity is required between now and then, which we do not believe is practically achievable, particularly considering the low cost of hydro and wind power. Most of this growth is expected to come from sugar cane bagasse, which currently generates 78% of biomass-fueled electricity.[35] Since the financial crisis, sugar and ethanol mills are heavily debt burdened, and recent draught conditions have left them struggling to keep pace with production demand.[36] This circumstance has made the sugar sector uninterested in getting involved in the business of fuel supply, especially for small-scale power systems. Based on electricity auction results, it appears that utility-scale biomass power plants are able to broker fuel supply contracts.

Eucalyptus is emerging as an attractive renewable fuel source of choice for DG customers, particularly in the industrial sector. Almost 2.5 million hectares of eucalyptus already grow in the South-Central region, with another 800,000 hectares in the Northeast.[37] Petrochemical companies, iron and steel mills, the food and beverage industry, and grain processing facilities are all starting to explore the possibility of eucalyptus pellet fueled DG systems. According to biomass energy consultants, when their electricity consumption profile, steam/cooling demand are high, and the logistics of fuel transport are ideal, self-generation from eucalyptus makes economic sense. Although bagasse will always remain the greatest net contributor to the biomass fuel market, we believe that eucalyptus 'fuel' plantations will become the predominant source of fuel feedstock for industrial DG.

3.1.1 Sugarcane bagasse

Sugarcane bagasse, the leftover stalk and residue from sugar production (approx. 30% of the harvest mass[38]) commands most of the attention for biomass power applications in Brazil. Bagasse has an impressive heating value (17-19 MJ/kg, just under half that of natural gas), constitutes 78% of the biomass market, currently generates about 2,200 MW of power (or 6.6% of net electricity generated) and has the technical potential to generate between 9,000 and 12,000 MW of power by 2020.[39,40] However, despite its abundance and relative proximity to electricity load centers (especially compared to hydro and wind), sugar mills remain poorly positioned to supply biomass as fuel for power applications or electricity generation. For starters, the main driver of the sugar business is ethanol production, and international sugar

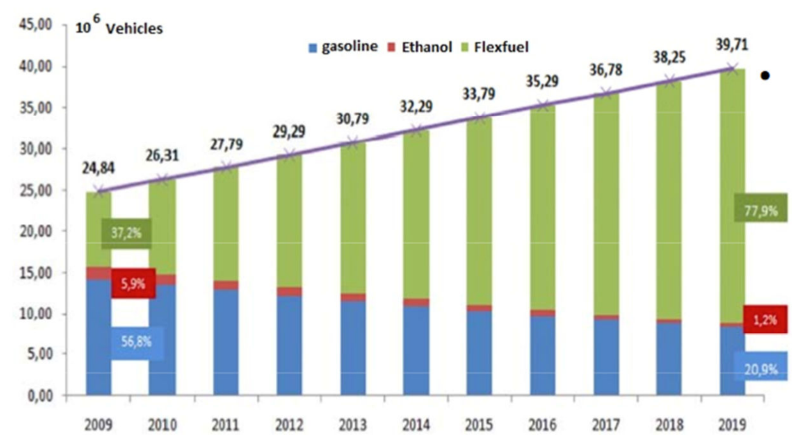
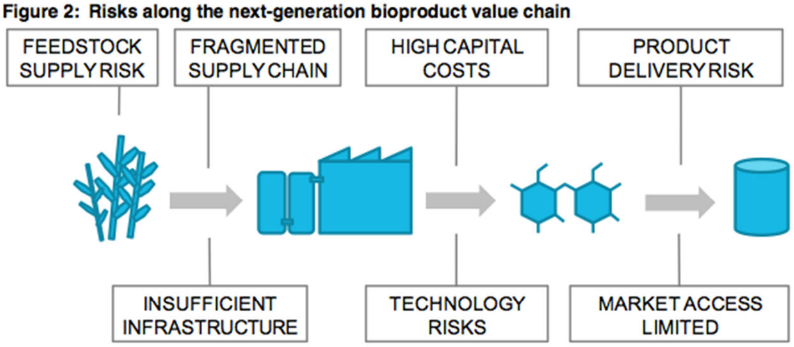


Figure 4 Analysis of combustive uses of bio-combustibles *Source EPE 2012*

demand is a close second. Delivering or supplying waste products from sugar harvest is a distant third.

Brazil's 433 sugar mills and 440 bioethanol refineries have their hands full with keeping pace with the investment required to meet market demand for sugar exports and domestic ethanol for transport fuel, estimated at $490 billion by 2030.[41] The situation is further complicated by the logistics of fuel procurement from a fragmented (albeit consolidating) sector, transportation across poor roads, only 14% of which are paved, some risk that fuel supply contracts will not be honored, and an incipient domestic fuel consumption market.[42]

Figure 2: Risks along the next-generation bioproduct value chain



Source: Bloomberg New Energy Finance

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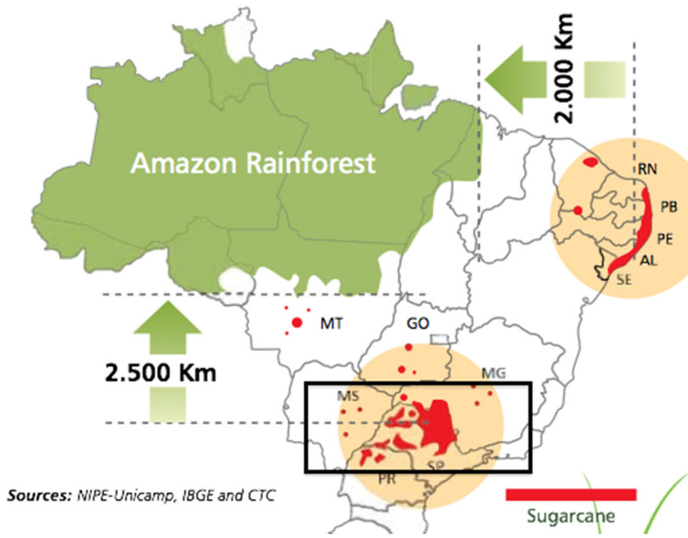
Despite these barriers, bagasse fueled power plants have successfully competed in energy auctions with a *produced* price (the price of electricity leaving the generating station, prior to transmission) of $.07/kWh[43]. Most of these projects have been in the states of Mato Grasso and Sao Paulo, which make up the country's South-Central region and crush more than half of the country's sugar crop. Unfortunately for biomass interests, since 2009 wind and hydro projects have been consistently bidding projects estimated to produce electricity for between $.062/kWh and $.045/kWh respectively.[44] Currently, it is only possible for a biomass fueled system to beat the $.07/kWh threshold for specific projects where factors such as logistics, availability of biomass, and the energy consumption profile of the client are ideal.[45]



90% of Brazilian sugarcane is produced within black box, not far from the country's most prominent industrial and municipal electric load centers

All of Brazil's 433 sugar mills are energy self sufficient, and about 100 sell electricity back to the grid. Sugar mills, however, are not likely to become significantly more invested in contributing to either regional or distributed electricity generation markets. Augmenting the amount of electricity imputed to the grid requires tens of millions of dollars per retrofit, which presents a risky investment for an enterprise that doesn't see direct benefit from being a player in the electricity market. Without support to finance power system retrofits, or a guarantee from state or federal governments that they will purchase produced electricity on the spot-market, greater participation in this market is far too expensive, particularly considering market demands for sugar and ethanol and the financial woes of the industry.[46] New boilers would be needed to generate steam at higher pressure, along with controls equipment, and expensive monitoring and safety devices that the government requires for net generator's in order to document and respond to electricity supply-demand dynamics.[47]

A 2012 survey by the International Sugar Organization found that half of all sugar mills were facing money problems.[48] Meanwhile, C. Czarnikow Futures Ltd, a sugar and ethanol trading and advisory firm, estimates that the Brazilian sugar industry may need as much as $490 billion in investment by 2030 to keep pace with sugar and ethanol demand.[49] This is largely a result of the combined effects of a credit and commodities boom in the years preceding the 2008 economic meltdown.[50] The worst drought in 50 years is not helping.[51] Deviating business models to include fuel procurement under such conditions does not make business sense despite the technical potential of the millions of tons of waste product from every sugar harvest.

Nevertheless, the industrial segment is well aware of the technical potential of biomass and has taken notice of the fuel opportunities presented by bagasse and other biomass residues, notably eucalyptus. Presently, an entire industry is developing to export bagasse pellets to Europe, where they are eligible for CDM credits, and utility scale biomass plants are the only viable option for achieving the government's ambitious 2020 biomass power goals. In the meantime, Industry is making headway procuring fuel from the country's second largest source of biomass, eucalyptus.

3.1.2 Eucalyptus Market

Historically, eucalyptus growth has mostly been confined to Brazil's paper and pulp segment, consisting of about 220 mills, as well as fiberboard and other wood products manufacturing companies.[52] Like their counterparts in sugar and ethanol, paper and pulp mills are entirely energy self-sufficient, fueled mostly by wood residues leftover from paper production, known as black liquor.

In terms of business model, the biggest difference between bagasse and eucalyptus is that bagasse is collected or contracted from a sugar mill whereas eucalyptus is essentially harvested from a 'fuel plantation'. Recent trends suggest that plantations will either be vertically integrated into the self-generator's operation, or maintained by a long-term management and fuel supply contract. We have confirmed this assertion with bioenergy consultants Energia Renovais do Brazil, Thermopyla Bioenergia SA, POYRY, and ABIB. DOW Chemicals is pioneering this model with their Aratinga wood-to-energy plant in Bahia state, which will replace a natural gas-fired steam system at a petrochemical facility with a eucalyptus fueled cogeneration unit.[53]

The Brazilian Industrial Biomass and Renewable Energy Association predicts that the current technical potential of eucalyptus fuel to be equivalent to 896 MW of power, and that about half of that is economically recoverable, suggesting around 450 MW is available from this source to generate facility electricity and process steam.[54]

In 2011, ERB was reported to be completing three biomass projects in addition to the DOW one, and reviewing an additional three. When we contacted ERB, POYRY, and Thermopyla Sustainability throughout the fall of 2012 and early winter 2013, our correspondence suggested a similar amount of activity, all based on eucalyptus fueled systems, and each attempting to be eligible for DG incentives.[55] The level of discretion that characterized our conversations gives us reason to believe that this space is n fact growing, but is extremely competitive and that achieving acceptable levelized costs of electricity remains challenging.

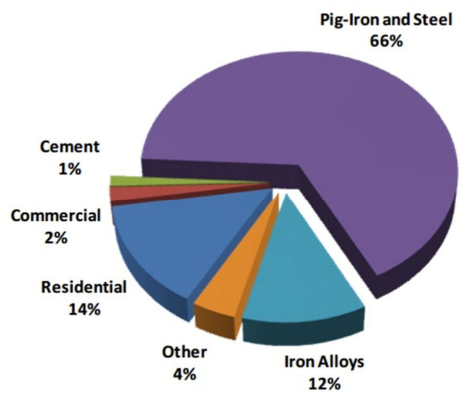
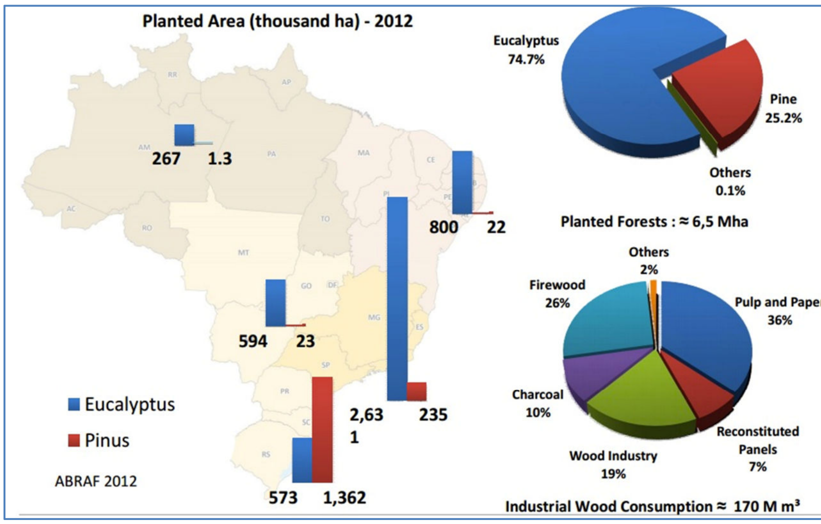


Figure 5 Industrial consumption of Charcoal by sector[56]

Like bagasse, most eucalyptus plantations are located in the industrial, South-Central region, predominately in the states of Minas Gerais (1.4 million hectares) and Sao Paulo (1.04 million hectares), with large quantities spread across the Northeast region (Paraiba, Pernambuco, Alagoas), a burgeoning industrial area. Minas Gerais also has the greatest concentration of iron and steel mills, which are being incentivized by regulators to reduce the volume of native wood consumed to fuel their charcoal furnaces in exchange for renewable feedstocks such as eucalyptus. The consultancy POYRY estimates that this charcoal market, which consumes 88% of domestic coal production, is the greatest opportunity area for eucalyptus fuel providers and brokers.[57] While this does not necessarily correspond with the DG market, in terms of measures to reduce industrial driven deforestation and enhance the use of renewable fuels, it is significant.



UF	Eucalyptus (ha)
MG	1.400.000
SP	1.044.813
PR	161.422
BA	631.464
SC	102.399
RS	273.042
MS	378.195
ES	203.885
PA	148.656
MA	151.403
GO	58.519
AP	49.369
MT	61.950
TO	47.542
PI	37.025
Outros	4.650
Total	**4.754.334**

Figure 6 - Eucalyptus production by State[58]

Brazilian iron and steel companies already own more than 1 million ha of eucalyptus plantations. Industry trade associations and energy consultants assert that iron and steel mills will increase their eucalyptus land holdings by a factor of two in order to match furnace-fuel demand to keep pace with anticipated resumptions in iron and steel. Additionally, government legislation aimed at restricting timber products, such as charcoal, from being harvested from native forests has been acknowledged by industry as a regulatory driver as well as a common ‘sustainability’ goal.[59] The trouble, like with bagasse, remains transport cost, which can account for 40-50% of the cost of electricity produced by a biomass plant.[60]

Companies like Vale, Anglo American, Gerdau, Usiminas, and others all have made concerted efforts to improve the non-hydro renewable component of their energy mix.[61] Vale has it's own renewable energy division, Rio Tinto has joined a partnership with GE Energy to explore renewables, and Anglo has already replaced 30% of the hydro capacity for one of its iron ore plants with wood pellets.[62,63,64] They perceive hydro intermittency and high taxes for grid electricity to be unacceptable expenditures. For instance, Vale reported that energy and fuel amounts to 13% of the cost of goods sold in 2011.[65] With the global materials and metals market still reeling from the lingering effects of the 2007 financial crisis, incurring such costs for basic services like electricity suggest alternatives ought to be explored.

3.2 Complementarity of Biomass with long term energy security

Importantly, supporting industrial self-generation of biomass-fueled power is complementary to existing energy and infrastructure policy objectives. Bagasse fueled power is a natural hedge against the grid's hydro system; it is cheapest during the dry season, when reservoir levels are at their lowest. As we have mentioned earlier, despite this logic, a robust bagasse power market remain a few years away.

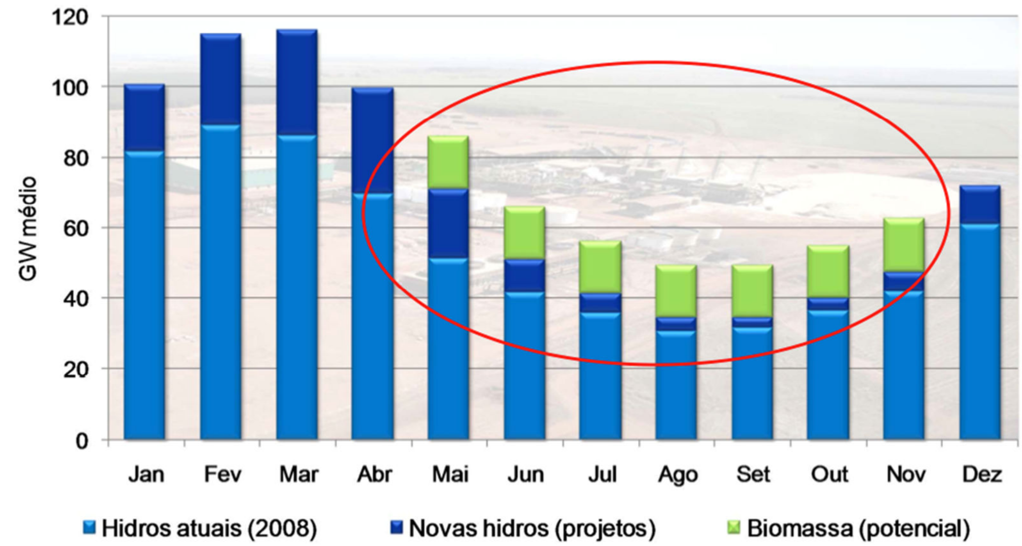


Figure 7 Zilmar, Jose de Souza. (September, 2012) ***Bagasse Cogeneration in the Brazilian Ethanol Industry*****, slide 6**

Inside of the next five years, however, Brazil is set to invest $66 billion in roads, which will reduce the most significant cost of biomass fuel procurement- transportation, which can account for 40-60% of the levelized cost of electricity (the cost of electricity produced, including capital, O&M, depreciation, and fuel costs) generated from a biomass system. As road conditions are improved, traffic, accidents, and travel time will be reduced, and it can be reasonably expected that biomass fuel prices will decrease.   The cost of electricity, especially in the form of transmission and distribution (T&D) taxes on industrial consumers, has significantly prevented industrial companies from investing in other forms of capacity management, IT, and personnel training.[66] Self-generation of any form will allow companies to re-allocate capital from tax expenses to investments that enhance operational efficiencies. Lastly, grid stability is critical for sustained economic growth, and long distance transmission of electricity from drought affected hydro reservoirs continually threatens to plunge large regions of the country (especially the Northeast) into darkness. By generating their own steam and electricity on site, not only will self-generators (DG or larger scale) achieve security of supply, but also will shave the amount of future electricity growth demanded. The government ought to see the industrial sector as an opportunity area in this regard, as industrial electricity use is expected to increase from 26% of net electricity consumed to 50% by 2020.[67]

Last, but not least, the cost of electricity is a long-standing and well-documented point of contention between Brazil's strategic industries (iron, steel, aluminum, and paper/pulp) and the government. The average cost of electricity is the third highest in the world, at $160/MW, with peak rates as high as $500/MW. Under the right conditions, when factoring in the invariable cost of electricity produced, generating power from biomass can be much less than from the grid when factoring in peak charges.

These factors, among others, make the case for biomass power applications more than just a 'cause célèbre' for renewable energy advocates. When logistics and the power profile of an energy consumer align, the economics of biomass-fueled self-generation are favorable to delivered electricity. Perhaps more importantly, by doing so, the industrial segment will reduce electricity demand for which the governments projections of hydro and wind power capacity factors may not be prepared to supply.

3.3 Economics of Biomass Power

Estimates on the Levelized Cost of Electricity (LCOE) from a biomass plant range from $.06/kWh-$29/kWh. The two most prominent factors affecting the large price range are the cost of collecting the biomass, and the cost of transporting it.[68] *Thompson Reuters* calculated that the transportation costs account for 40% of truck delivered commodity costs,[69] which corresponds with our observation that fuel delivery costs are a major barrier to biomass power playing a more prominent role in the electricity grid.

For sugarcane bagasse, the price is seasonally variable. During the fall and spring sugar harvest, the price of biomass approaches the higher end when sugar mills are preoccupied with sugar production. In the winter, which corresponds to the dry season and when sugar plantations are fallow, sugar mills sometimes have to pay someone to haul bagasse away at cost or burn it. This circumstance makes mill owners more receptive to selling this resource for profit.

The cost eucalyptus is more affected by the costs of plantation management, including equipment, seeding, maintenance, and production. Industrial companies that we have observed making inroads to eucalyptus production typically have no expertise in the agriculture business, so they have been developing joint ventures or signing long-term contracts to consultants like ERB, Green Energy Group, Brazil Bioenergy SA, and others who can manage the plantations and fuel production. The up-front costs of such an arrangement can be considerable, but this business model is premised on the assumption that over time, electricity produced from eucalyptus fuel produced in this manner can be cheaper than grid electricity when accounting for peak charges and production lost due to intermittency.[70]

3.3.1 Analysis – LCOE

Based on our assumptions and analysis for a typical 30 MW Eucalyptus fueled Biomass based Distributed Generation power system, electricity could be produced at a cost of \$0.0625/kwh. At this rate, biomass could prove to be competitive with hydropower (\$0.045/kwh) and wind energy (\$0.065/kwh), provided fuel could be provided at a cost of \$27/ton. LCOE of a typical biomass fuel plant (keeping all else equal) is highly sensitive to the cost of fuel. With the right infrastructure and transportation costs, partnernships similar to ERB and DOW cogeneration contract could be replicated across the country and thus lead to higher uptake in Biomass based self-generation. For more detailed assumption, please refer to Exhibits in the Appendix section.

4 Future Scenario

Brazil's economic future is highly dependent on its ability to successfully meet its energy and power needs. As discussed earlier, this is in turn critically dependent on its ability to operate its mega dams at capacity. That in turn in dependent on sufficient rainfall in the Amazon basin, home to most of the large dams that supply most of Brazil's electricity needs. However, Brazil's economic development has resulted in an alarming deterioration in the Amazonian region. The large deforestation over the last 50 years to clear land for farming agricultural commodities and rearing cattle, is now reaching a scale that threatens to set off what scientists have termed the great Amazonian dieback. In such a scenario Amazon, one of single richest ecosystems left in the world, will witness a massive biomass destruction that will turn it from a net sink to a net source of carbon, drastically accelerating the effects of anthropogenic climate change.

The Amazon region is larger than the European Union combined with a size of around 7 million square kilometers[71]. 40.5 % of the hydropower potential for Brazil is located in Amazon. The region produced 20% of the world's flow of fresh water into the oceans and has the potential to generate 260 GW of electricity, more than twice the current installed capacity of 115 GW of Brazil[72]. While it is important to harness this massive potential, the rate at which development can take place needs to be urgently slowed or regulated. World Wildlife Fund (WWF) estimates that 17% of the forest in the Amazon has been cleared to develop cattle ranches over the last 50 years. At least 30 more dams are being planned in the region and the government is planning to generate as much as 50% of the country's electricity needs through these mega dams. However, it is imperative that the large scale deforestation, fire and destruction is stopped before it reaches calamitous proportions and starts an irreversible decline of the ecosystem. Described below are the *three reasons* why this needs to be stemmed at the earliest.

4.1 Water Cycle

All the major dams that supply electricity to the country are located in the Amazonian region. One of the largest, most expensive, intensely opposed, and over budget dams, Belo Monte, is being built in the Amazonian region. The dam threatens to destroy 120,000 acres of Amazonian Rainforest and displace thousands of people. The estimates from number of dams planned by Brazilian government range from 30 to 150. Far from being a shining example of development, the project threatens to worsen the water cycle of the region. According to numerous studies, further deterioration in the Amazonian ecosystem will lead to a more extreme water cycle, making rainy season wetter and summers drier. The ongoing extreme drought is clearly an example of such a phenomenon. These extremes will inundate the dams with excess water in one season and not enough in the others, leading to alarming shortages and possibility of more blackouts in the country.

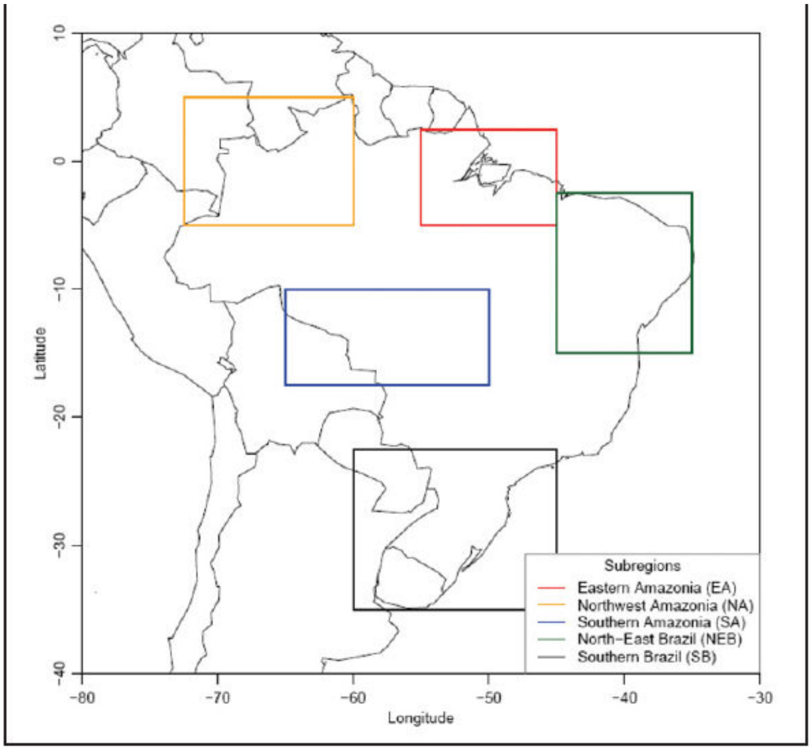
4.2 Carbon Sink

The Amazonian region absorbs close to a *billion tons* of carbon every year, cleaning the environment in the process and slowing down our march towards a scenario of 450ppm of carbon dioxide in the air, widely believed to be the point of no return for the climate system. If the deforestation continues at the present rate, the region will soon become a net source of carbon, releasing carbon in the air, further accelerating the point of no return. Every dam that is built leads to diversion of rivers and flooding of the forest area. This in turn leads to rotting of vegetation and release of more potent greenhouse gases such as methane. Brazil cannot continue to reap the benefits of hydropower, touting the country's low carbon emissions due to a renewable energy based grid, while ignoring the externalities of building dams and diverting rivers and destroying forests.

4.3 Dieback

As discussed earlier, if the decline continues, there is a very real risk that we will witness what the scientists are calling the great Amazon Dieback, wherein the forest biomass will enter into precipitous and irreversible decline and will ultimately cease to exist, in turn releasing billions of tons of carbon in the air. This frightening phenomenon will have ramification for the entire planet and not just for Brazil or the South American region. This has been confirmed by numerous studies, one of the most notable amongst them being the World Bank Study titled “Assessment of the Risk of Amazon Dieback”. According to it, the probability of the dieback varies between the different part of the Amazon but its overall severity increases over time. The study further warns that there is not only a need to slow the large scale destruction of Amazon but also to slow down anthropogenic emission so as not to severely accelerate this phenomenon. Ultimately, “Amazon dieback should be considered a threshold for dangerous climate change”.

Marked (Figure 8) below are the five major Geographical Domains in the Amazon Basin. The region of Southern Amazonia is liable to be the one most affected by strong land use change drivers. Northwestern Amazonia is not likely to be impacted by the changes in Amazon. However, Eastern and Northeaster Amazonia are already experience drier conditions and witnessing the effects of direct anthropogenic impact.



Source: Figure generated for the report by Cox and Jupp 2009.
Note: Eastern Amazonia (EA; 2.5°N-5°S; 45°W-55°W); Northwestern Amazonia (NA; 5°N-5°S; 60°W-72.5° W); Southern Amazonia (SAz; 10°S-17.5°S; 50°W-65°W; Northeastern Brazil (NEB; 2.5°S-15°S; 35°W-45° W; Southern Brazil (SB; 22.5°S-35°S; 45°W-60°W).

Figure 8 Geographical Domains in Amazon

Unfortunately, as depicted below (Figure 9) these are the dams are unfortunately planned in exactly the same regions, where the effects of Amazon dieback are bound to be felt the most, leading to a devastating scenario that will drastically affect Southern Brazil.

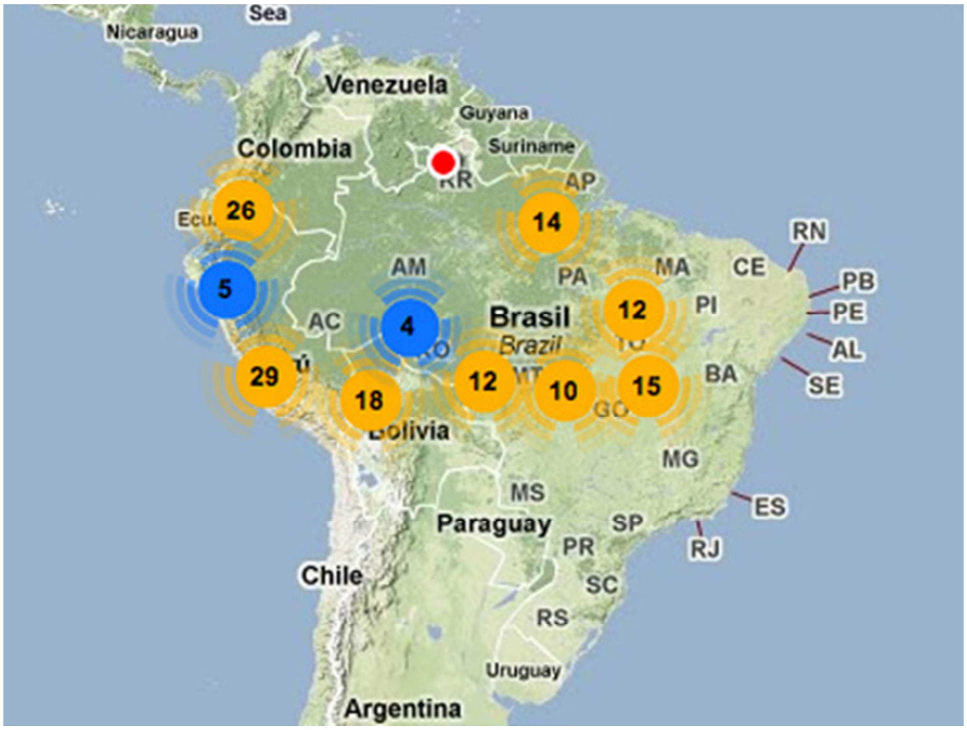


Figure 9 Dams planned in Amazon

4.4 Scenarios

Cost of Energy HIGH

Climate Change HIGH (low rainfall)	Climate Change LOW (High rainfall)
High-High Reasons Reservoirs low, hydropower low, supply less than demand Pre-Salt doesn't produce Investment unavailable Results Economy is low because of high cost of electricity Industrial production becomes uncompetitive Investment flows out to neighbouring countries Solution Biomass is not as viable since agricultural productivity drops Biomas power is not competitive Biomass based DG is not attractive	**High - Low** Reasons Delays in transmission infrastructure expansion Pre-Salt doesn't produce Investment unavailable Results Economy is low because of high cost of electricity Industrial production becomes uncompetitive Investment flows out to neighbouring countries Solution Biomass is more abundant due to high agricultural productivity Biomas power is more competitive Biomass based DG is most attractive
High-Low Reasons Pre-Salt economically extracted and not exported Results Economy is humming, petrochemical companies do well Industrial production becomes competitive Investment in to Brazil Solution Biomass is not viable since natural gas becomes cheap	**Low - Low** Reasons Hydropower max capacity Transmission is built and maitained Results Economy is humming Industrial production becomes competitive Investment in to Brazil Solution Biomass is not viable since natural gas becomes cheap

Cost of Energy LOW

Low-Low is the most optimum scenario for Brazil to be in. However, to keep the economy humming, Brazil will have to keep its cost of energy low. This will not be possible with the continued focus on building expensive mega dams. The destruction in Amazon is bound to further increase climate change risk, which will in turn make capacity factors for dams even lower and making the electricity even costlier.

We believe that Brazil has reached a negative equilibrium where even small disturbances can push the system away from the stable state into a self-perpetrating loop that could prove to be catastrophic for the country. Brazil should do everything to remain in the **Low-Low** region to maintain a healthy economy and environment.

5 Conclusions

Considering the observed effects of climate trends in Brazil, the country's dependence on hydro presents near-term and long-term problems for electricity consumers. In 2001, low reservoirs levels resulted in costly and embarrassing blackouts. This energy 'crisis' galvanized the government to overhaul its electricity regulatory regime, privatize much of the energy industry, implement a sophisticated electricity auction system, and develop a comprehensive long-term energy strategy. Despite reducing the proportion of hydro in the grid matrix from 88% in 2001 to 70% in 2012 and projections of reaching 67% in the next few years, persistent drought, which is being exacerbated by continued deforestation, suggests that the grid is susceptible to blackouts during the dry season, and that future hydro outputs are overly optimistic.[73] Electricity auctions have been successful at diversifying the grid composition, but price dynamics favoring hydro and wind render other sources, such as biomass, uncompetitive. This restricts opportunity to further diversify. Importantly, the country's energy expansion plans *barely* meet the country's electricity growth demand, and is premised on hydro capacity factor projections that do not account for the probability of drought. Weather over the past three years and climate models suggest otherwise.

Even if the government were to offer unprecedented support for biomass power development, it would be unlikely to resolve the country's looming energy shortfalls. To insulate themselves from the risks presented by electricity intermittency, electricity intensive industrial operations should become more energy self-sufficient. Objectively, natural gas is probably the preferred fuel, but the likelihood of pre-sal[74] production and requisite distribution infrastructure to come online in time is slim. Meanwhile, thousands of megawatts worth of biomass fuel happen to grow in states that are co-located with Brazil's industrial centers. The number of industrial DG systems in Brazil is few right *now*, but we expect businesses with high electricity, steam, and cooling needs to explore meeting these energy demands with biomass over the next couple of years.

Our evaluation of the biomass market concluded that, despite the enormous technical potential of sugarcane bagasse (estimated at 9,500 MW by 2020), eucalyptus is the more economical fuel source. In terms of net electricity generated, sugarcane bagasse is, and will continue to be, the predominant feedstock for biomass power systems, but the variable cost of bagasse fuel procurement for a sub-30 MW power system make it a less attractive fuel source than eucalyptus.

Metals and mining, petrochemical, and grain processing companies are starting to explore opportunities for eucalyptus fueled power systems. The logistics of long-term fuel supply contracts from a eucalyptus plantation are much more straightforward than from a sugar plantation, which is primarily interested in keeping pace with sugar and ethanol demand.

The greatest challenge for biomass power projects is competing with the cost of grid electricity. Hydro and wind developers submit project bids to electricity auctions based on produced power prices between $.045 and $.065/kWh, which is substantially less than what is produced by a biomass system and do not necessarily include the capital costs. When logistics and the electricity needs of an electricity consumer are ideal, the cost of electricity produced from a DG biomass system can break the $.07/kWh threshold, at which point it makes economic sense to pursue, but until road infrastructure improves, these scenarios will be more the exception than the rule. We did not model the potential costs of grid intermittency, the possibility of higher peak charges, and increases in transmission and distribution taxes, but have been told that avoiding these costs are a major incentive for electricity consumers to explore generating electricity on-site from biomass.

The greatest opportunity for biomass power rests in the fact that it is a non-hydro, carbon neutral fuel source. Companies like Vale, Alcoa, Anglo American, and DOW Chemical have all gone on record, in both annual reports and interviews with executives, about their interest in reducing their environmental footprint by developing non-hydro renewable power resources. With climate change posing a great threat to the viability of hydro based system, the government would be prescient to enable industrial electricity consumers to take advantage of DG incentives by allowing for write-offs of these investments, and supporting producers of biomass, who currently see little opportunity in this market because auction price dynamics favor other power projects, notably hydro, but also wind, neither of which are safe bets in the event that the climate continues to warm.

5.1 Policy Recommendations

Electricity growth and infrastructure improvement is central to the Brazilian government's development strategy over the next ten years. Regulators ought to consider investments in biomass power complementary to these goals; a hedge against hydro vulnerabilities, an additional source of revenue for struggling sugar mills, and reduced cost of commodity transport. More explicit support for biomass power for industrial self-generation will have positive ripple effects across the economy. By facilitating a linkage between agribusiness and electricity production, domestic companies in the power segment stand to capture billions of dollars of market share. Unlike for other applications, like wind and solar systems, domestic manufacturers can actually outcompete international firms in this space, which parlay's well with existing policies to support domestic manufacturing. Of equal importance, every megawatt produced on site is one that does not need to be developed from another resource and transmitted long distances, incurring losses.

Harnessing more biomass energy will commoditize a waste product and generate revenue for sugar and ethanol mills that are in great need of cash. A glance at Brazil's electricity growth plans suggests that regulators are cutting it close in terms of delivering sufficient electricity to meet projected growth. For this reason, we support any efforts to augment electricity supply, but the low carbon nature of biomass and its preponderance in areas co-located with electricity load demand makes the case for biomass particularly compelling. An especially creative means to this end is to incentivize industrial companies to build on-site power systems. Our research suggests that eucalyptus is the most economical fuel type.

To achieve these goals, we recommend the following policy provisions.

1. The Ministry of Mines & Environment (MME) develop contingency plans to include biomass baseload in addition to thermal complementarity to wind and hydro starting in 2016

2. Establish regular working group consisting of relevant trade associations and leading companies with interests in biomass power (UNICA, ABIB, COGEN, ORPLANO, ERB, Brazil Biomass Energy SA) to coordinate dialogue to inform policy craft for biomass fueled renewable power
3. Offer incentives, such as tax write-offs, to industrial electricity consumers that reduce their reliance on the grid through biomass power systems
4. Focus road infrastructure improvements on areas that will reduce the transport costs between centers of sugar production (South-Central and Northeast regions) and concentrations of industrial activity
5. Introduce geographic considerations into auction price dynamics to account for the cost of transmission and distribution infrastructure and the associated losses from distant sources of power generation

Rationale

Recommendation # 1 is in line with existing policy goals to ensure that Brazil's electric grid is not subjected to brown-outs or black outs. A cursory glance at the country's electricity expansion plans shows that Brazil will just barely meet power demand. Based on recent drought, it is fair to assume that hydro capacity factors will be compromised in the summer during the dry season, which will invariably cause electricity intermittency similar to the shortages in 2001 and this past December 2012.

Recommendation #2 aims to ensure that the government has a platform to leverage expertise directly from industry. Currently, there is a gap between federal government rhetoric and local government capabilities. The private sector acknowledges the potential of biomass power, and agrees that national plans to augment supplies from this source are mutually beneficial, but also recognizes the limitations of state and local governments in achieving those goals. A workgroup of this sort will give direct line of sight between federal policy initiatives and local project viability.

Recommendation #3 would make the substantial investments in on-site power/steam systems more attractive. The industrial sector accounts for a quarter of electricity use in Brazil, and this proportion is due to double by 2021[75], which puts great stress on the grid. Every megawatt that is generated onsite is a megawatt that no longer needs to be delivered by aging transmission infrastructure. The technical expertise to become self-generators is already mature; what remains absent is the financial incentive to reduce risks associated with such investments. If industrial electricity consumers transition towards a self-generation model, electricity demand that might otherwise increase the probability of blackouts can be reduced.

Recommendation #4 could be an addendum to existing PAC 2 road infrastructure investments. Presently, it costs twice as much to get commodities from farm to port as it does to ship them from port to China, which significantly compromises Brazil's global competitiveness.[76] Fortunately, the sugar producing south-central and northeast regions are also the country's major economic centers, therefore improvements to road networks used between concentrations of sugar mills industrial centers will reduce transaction times and costs, which are estimated to account for 40% of the cost of delivered products.

Our *final recommendation*, that auction price dynamics account for the transmission distance between the site of generation and electricity load centers, will internalize the associated cost of T&D infrastructure required for hydro and wind projects. These costs are currently not reflected in the cost of delivered electricity, but will eventually be passed on to consumers through electricity taxes. If auctions were able to capture these costs, the playing field between biomass and other forms will level out.

Appendix

	Installed Capacity Evolution per Power Source (MW)										
SOURCE	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Hydro	82,939	84,736	86,741	88,966	89,856	94,053	98,946	104,415	109,412	111,624	115,123
Uranium	2,007	2,007	2,007	2,007	2,007	2,007	3,412	3,412	3,412	3,412	3,412
Natural Gas	9,180	9,384	10,184	11,309	11,659	11,659	11,659	11,659	11,659	11,659	11,659
Coal	1,765	2,485	3,205	3,205	3,205	3,205	3,205	3,205	3,205	3,205	3,205
Fuel Oil	2,371	3,744	5,172	8,790	8,790	8,790	8,790	8,790	8,790	8,790	8,790
Diesel Oil	1,497	1,497	1,471	1,471	1,121	1,121	1,121	1,121	1,121	1,121	1,121
Process Gas Tec	686	686	686	686	686	686	686	686	686	686	686
Small Hydro	3,806	4,201	4,230	4,376	4,633	4,957	5,187	5,457	5,737	6,047	6,447
Biomass	4,496	5,444	6,272	6,681	7,053	7,353	7,653	8,003	8,333	8,703	9,163
Wind	831	1,283	3,224	5,272	6,172	7,022	7,782	8,682	9,532	10,532	11,532
Total	109,578	115,467	123,192	132,763	135,182	140,853	148,441	155,430	161,887	165,779	171,138

Ministry of Mines and Energy -MME, Company of Energy Research - EPE, ‗Plano Decenal de Expansão de Energia 2020‗. Brasilia; MME/EPE, 2011.

Figure 10 Ministry of Mines and Energy -MME, Company of Energy Research - EPE, ‗Plano Decenal de Expansão de Energia 2020‗. Brasilia; MME/EPE, 2011.

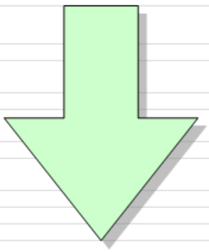
Biomass Based Power Plant Model Screenshots -

Generalized Revenue Requirements Model
Example: Biomass Power Plant--Power Only

This simplified model computes both the current $ and constant $ level annual cost for a model biomass power plant.

The spreadsheet cells highlighted in green are input cells:	Input Cell
Principal results are highlighted in blue:	Result

This example assumes a 20 year economic life with no salvage value and gives cash flows for each year.



Unit Conversions:

Conventional		SI Units
Enter Btu/lb	⇨	Conversion to kJ/kg
8,169	=	19,000
Conversion to tons/hr	⇦	Enter t/h
26.5	=	24.0
Enter $/ton	⇨	Conversion to $/t
20.00	=	22.05

Capital Cost			Capital costs shown are for example only. Actual costs may vary.
Capital Cost ($)	90,000,000		
Electrical and Fuel--base year			
Net Plant Capacity (kW)	30,000		Net Plant Capacity: Size of plant based on net power output to grid
Capacity Factor (%)	85		Capacity Factor: Annual fraction that rated capacity is available from plant
Annual Hours	7,446		
Net Station Efficiency (%)	20		Net Station Efficiency: Ratio of net energy output from plant to fuel energy input to plant
Fuel Heating Value (kJ/kg)	19,000		Fuel Heating Value: Higher heating value (heat of combustion) of fuel expressed on a dry basis input in SI units. To convert from Btu/lb, see
Fuel Consumption Rate (t/h)	28		Fuel Consumption Rate: Fuel rate in dry metric tons per hour, to compare short tons per hour, see calculator above.
Fuel Ash Concentration (%)	1		Fuel Ash Concentration: Fraction of ash in fuel, percent dry basis
Annual Generation (kWh)	223,380,000		
Capital cost per net electrical capacity ($/kWe)	3,000		Capital Cost: Total installed cost of plant per unit capacity
Annual Fuel Consumption (t/y)	211,623	5713825.26	Annual fuel consumption in dry metric tons per year
Annual Ash Disposal (t/y)	2,116		

		($/kWh-net electrical)	
Expenses--base year			
Fuel Cost ($/t)	27.00	0.0256	Fuel Cost: Cost of fuel in $/dry metric ton, to convert from $/short ton, see calculator above
Labor Cost ($/y)	2,000,000	0.0090	Labor Cost: Cost of labor to operate facility
Maintenance Cost ($/y)	1,500,000	0.0067	Maintenance Cost: Cost of maintaining the plant
Insurance/Property Tax ($/y)	1,200,000	0.0054	Insurance/Property Tax: Cost of insurance for the plant plus any property or other local taxes
Utilities ($/y)	200,000	0.0009	Utilities: Purchased utilities including power, gas, water, waste disposal
Ash Disposal ($/y)--use negative value for sales	20,000	0.0001	Ash Disposal: Cost of ash disposal from plant, use negative value when ash is sold at value
Management/Administration ($/y)	200,000	0.0009	Management/Administration: Cost for administrative personnel and other administration
Other Operating Expenses ($/y)	400,000	0.0018	Other Operating Expenses: All other expenses for operating the plant, for example natural gas not included in utilities, chemicals, or additives
Total Non-Fuel Expenses ($/kWh)	5,520,000	0.0247	
Total Expenses Including Fuel ($/y)	11,233,825	0.0503	
Taxes			
Federal Tax Rate (%)	34.00		Federal Tax Rate: For federal tax calculations
State Tax Rate (%)	0.00	9.6	State Tax Rate: For state tax calculations
Production Tax Credit ($/kWh)	0.000		Production Tax Credit
Combined Tax Rate (%)	34.00		Combined Tax Rate: combined federal and state tax rate to which project is subject
Income other than energy			
Capacity Payment ($/kW-y)	166		Capacity Payment: Payment made from power purchaser if plant can guarantee capacity (depends on contract)
Interest Rate on Debt Reserve (%/y)	5.00		Interest Rate on Debt Reserve: Interest income earned on reserve account if financing institution requires security deposit
Annual Capacity Payment ($/y)	4,980,000		
Annual Debt Reserve Interest ($/y)	343,751		
Escalation/Inflation			
General Inflation (%/y)	6.00		General Inflation: Overall inflation rate used to adjust current dollar result to constant dollars.
Escalation--Fuel (%/y)	5.00		Escalation--Fuel: Rate at which fuel cost escalates over time
Escalation for Production Tax Credit	0.00		Escalation--PTC: Specified index for production tax credit
Escalation--Other (%/y)	2.10		Escalation--Other: Rate at which other expenses escalate over time

Financing		
Debt ratio (%)	75.00	Debt ratio: Fraction of financing covered by debt borrowing
Equity ratio (%)	25.00	Equity ratio: Fraction of financing covered by corporate investment
Interest Rate on Debt (%/y)	8.00	5 Interest Rate on Debt: Interest rate applied to debt portion of investment
Economic Life (y)	20	Life of Loan: Example assumes 20 year economic life
Cost of equity (%/y)	15.00	Cost of Equity: Rate of return on equity portion of investment
Cost of Money (%/y)	9.75	Cost of Money: Weighted cost of investment for full investment including both debt and equity
Total Cost of Plant ($)	90,000,000	
Total Equity Cost ($)	22,500,000	
Total Debt Cost ($)	67,500,000	
Capital Recovery Factor (Equity)	0.1598	Capital Recovery Factor: Factor used to compute level annual cost from present worth
Capital Recovery Factor (Debt)	0.1019	
Annual Equity Recovery ($/y)	3,594,633	Annual Equity Recovery: Uniform annual revenue required to earn stipulated rate of return on equity
Annual Debt Payment ($/y)	6,875,024	Annual Debt Payment: Uniform annual payment needed to pay off debt
Debt Reserve ($)	6,875,024	Debt Reserve: Funds placed in reserve account as security deposit. Sometimes required by financing institution to ensure debt repayment if p

Depreciation Schedule: Fraction of capital asset depreciated in each year

Depreciation Schedule	Fraction	MACRS--5 year	MACRS--10 year	Straight Line--20 year
Year 1	0.0500	0.2000	0.1000	0.0500
Year 2	0.0500	0.3200	0.1800	0.0500
Year 3	0.0500	0.1920	0.1440	0.0500
Year 4	0.0500	0.1152	0.1152	0.0500
Year 5	0.0500	0.1152	0.0922	0.0500
Year 6	0.0500	0.0576	0.0737	0.0500
Year 7	0.0500	0.0000	0.0655	0.0500
Year 8	0.0500	0.0000	0.0655	0.0500
Year 9	0.0500	0.0000	0.0655	0.0500
Year 10	0.0500	0.0000	0.0655	0.0500
Year 11	0.0500	0.0000	0.0329	0.0500
Year 12	0.0500	0.0000	0.0000	0.0500
Year 13	0.0500	0.0000	0.0000	0.0500
Year 14	0.0500	0.0000	0.0000	0.0500
Year 15	0.0500	0.0000	0.0000	0.0500
Year 16	0.0500	0.0000	0.0000	0.0500
Year 17	0.0500	0.0000	0.0000	0.0500
Year 18	0.0500	0.0000	0.0000	0.0500
Year 19	0.0500	0.0000	0.0000	0.0500
Year 20	0.0500	0.0000	0.0000	0.0500
Total	1.0000	1.0000	1.0000	1.0000

Tax Credit Schedule: Fraction = 1 if received in year, 0 if not

Tax Credit Schedule	Fraction in Year
Year 1	1
Year 2	1
Year 3	1
Year 4	1
Year 5	1
Year 6	0
Year 7	0
Year 8	0
Year 9	0
Year 10	0
Year 11	0
Year 12	0
Year 13	0
Year 14	0
Year 15	0
Year 16	0
Year 17	0
Year 18	0
Year 19	0
Year 20	0

Annual Cash Flows

Year	1	2	3	4	5	6	7	8	9	10	11	12	
Equity Recovery	3,594,633	3,594,633	3,594,633	3,594,633	3,594,633	3,594,633	3,594,633	3,594,633	3,594,633	3,594,633	3,594,633	3,594,633	3,5
Equity Interest	3,375,000	3,342,055	3,304,168	3,260,599	3,210,493	3,152,873	3,086,608	3,010,405	2,922,770	2,821,991	2,706,095	2,572,814	2,
Equity Principal Paid	219,633	252,578	290,465	334,034	384,140	441,761	508,025	584,228	671,863	772,642	888,538	1,021,819	1,
Equity Principal Remaining	22,280,367	22,027,789	21,737,324	21,403,290	21,019,150	20,577,389	20,069,365	19,485,136	18,813,274	18,040,632	17,152,093	16,130,274	14,
Debt Recovery	6,875,024	6,875,024	6,875,024	6,875,024	6,875,024	6,875,024	6,875,024	6,875,024	6,875,024	6,875,024	6,875,024	6,875,024	6,8
Debt Interest	5,400,000	5,281,998	5,154,556	5,016,919	4,868,270	4,707,730	4,534,346	4,347,092	4,144,857	3,926,444	3,690,558	3,435,800	3,
Debt Principal Paid	1,475,024	1,593,026	1,720,468	1,858,106	2,006,754	2,167,294	2,340,678	2,527,932	2,730,167	2,948,580	3,184,466	3,439,224	3,
Debt Principal Remaining	66,024,976	64,431,950	62,711,482	60,853,376	58,846,622	56,679,328	54,338,650	51,810,718	49,080,551	46,131,971	42,947,505	39,508,281	35,
Fuel Cost	5,713,825	5,999,517	6,299,492	6,614,467	6,945,190	7,292,450	7,657,072	8,039,926	8,441,922	8,864,018	9,307,219	9,772,580	10,
Non-fuel Expenses	5,520,000	5,635,920	5,754,274	5,875,114	5,998,491	6,124,460	6,253,073	6,384,388	6,518,460	6,655,348	6,795,110	6,937,807	7,
Debt Reserve	6,875,024	0	0	0	0	0	0	0	0	0	0	0	
Depreciation	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000	4,500,000	4,5
Capacity Income	4,980,000	4,980,000	4,980,000	4,980,000	4,980,000	4,980,000	4,980,000	4,980,000	4,980,000	4,980,000	4,980,000	4,980,000	4,9
Interest on Debt Reserve	343,751	343,751	343,751	343,751	343,751	343,751	343,751	343,751	343,751	343,751	343,751	343,751	
Taxes w/o credit	3,835,139	354,249	419,901	490,805	567,381	650,084	739,403	835,867	940,048	1,052,564	1,174,082	1,305,320	1,4
Tax Credit	0	0	0	0	0	0	0	0	0	0	0	0	
Taxes	3,835,139	354,249	419,901	490,805	567,381	650,084	739,403	835,867	940,048	1,052,564	1,174,082	1,305,320	1,4
Energy Revenue Required	27,089,894	17,135,591	17,619,573	18,126,292	18,656,969	19,212,899	19,795,454	########	21,046,337	21,717,836	22,422,317	23,161,614	23,9

Current $ Level Annual Cost (LAC)

Cost of Money	0.1500												
Present Worth (time 0)	23,556,430	12,956,969	11,585,155	10,363,766	9,275,811	8,306,267	7,441,845	6,670,786	5,982,682	5,368,317	4,819,525	4,329,071	3,8
Total Present Worth	132,179,792												
Capital Recovery Factor (current)	0.1598												
Current $ Level Annual Revenue Requirements ($/y)	21,117,238												
Current $ LAC of Energy ($/kWh)	**0.0945**												

Constant $ Level Annual Cost (LAC)

Real Cost of Money (inflation adjusted)	0.0849
Capital Recovery Factor (constant)	0.1056
Constant $ Level Annual Revenue Requirements ($/y)	13,957,973
Constant $ LAC of Energy ($/kWh)	**0.0625**

Sensitivity Analysis

Enter base, minimum, and maximum values in input cells

Capital Cost

Case	Relative Change (%)	Capital Cost ($)	LAC Current ($/kWh)	LAC Constant ($/kWh)	Relative Change in COE (%)
Formula Values	→		0.0945	0.0625	
-10	-100	0	0.0397	0.0263	-32
-9	-90	3,000,000	0.0415	0.0275	-28
-8	-80	6,000,000	0.0434	0.0287	-25
-7	-70	9,000,000	0.0452	0.0299	-22
-6	-60	12,000,000	0.0470	0.0311	-19
-5	-50	15,000,000	0.0489	0.0323	-16
-4	-40	18,000,000	0.0507	0.0335	-13
-3	-30	21,000,000	0.0525	0.0347	-9
-2	-20	24,000,000	0.0543	0.0359	-6
-1	-10	27,000,000	0.0562	0.0371	-3
Base	0	30,000,000	0.0580	0.0383	0
1	57	47,000,000	0.0683	0.0452	18
2	113	64,000,000	0.0787	0.0520	36

Fuel Cost

Case	Relative Change (%)	Fuel Cost ($/t)	LAC Current ($/kWh)	LAC Constant ($/kWh)	Re Cha C
Formula Values	→		0.0945	0.0625	
-10	-100	0.00	0.0603	0.0399	
-9	-90	2.21	0.0631	0.0417	
-8	-80	4.41	0.0659	0.0435	
-7	-70	6.62	0.0687	0.0454	
-6	-60	8.82	0.0715	0.0472	
-5	-50	11.03	0.0743	0.0491	
-4	-40	13.23	0.0771	0.0509	
-3	-30	15.44	0.0799	0.0528	
-2	-20	17.64	0.0827	0.0546	
-1	-10	19.85	0.0855	0.0565	
Base	0	22.05	0.0883	0.0583	
1	35	29.85	0.0981	0.0649	
2	71	37.64	0.1080	0.0714	

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