UNIVERSITY OF CALCARY

Determining the Viability of Rice Husk Bioenergy in Ecuador

by

Steven Aurelio Ottoni

A Masters Degree Project submitted to the Faculty of Graduate Studies in Partial
Fulfillment of the Requirements for the Degree of

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CERTIFICATE OF COMPLETION OF INDIVIDUAL PROJECT

FOR THE UNIVERSITY OF CALGARY

MASTER OF SCIENCE DEGREE IN SUSTAINABLE ENEGY DEVELOPMENT

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, the individual Project Report entitled “Determining the Viability of Rice Husk Bioenergy in Ecuador” submitted by Steven Aurelio Ottoni in partial fulfillment of the requirements for the degree of Master of Science in Sustainable Energy Development.

Supervisor: Ph.D. Ximena Córdova-Vallejo

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Abstract

Ecuador's national electricity plan faces major challenges in the upcoming years: current oil derivative subsidies are economically unsustainable; and an increasing reliance on hydroelectric power can cause nationwide energy shortages, as shown 2009. It is for these reasons that this study proposes the use of decentralized forms of energy, like bioenergy, to help meet the country's future energy needs. Bioenergy is an attractive option because: (1) it monetizes various forms of waste (e.g. agro-waste); (2) its technology is tried and tested; (3) it reduces transition losses because energy output is used locally; and (4) it stimulates local economies. Because rice is one of Ecuador's largest agro-industries, its residue, rice husk, was selected as the bioenergy fuel in this analysis. Results indicate that the county of Daule- the highest rice producing region- has the theoretical capacity to generate roughly 4MWe per annum; produce moderate financial returns; and provide more than 43 jobs to the region.

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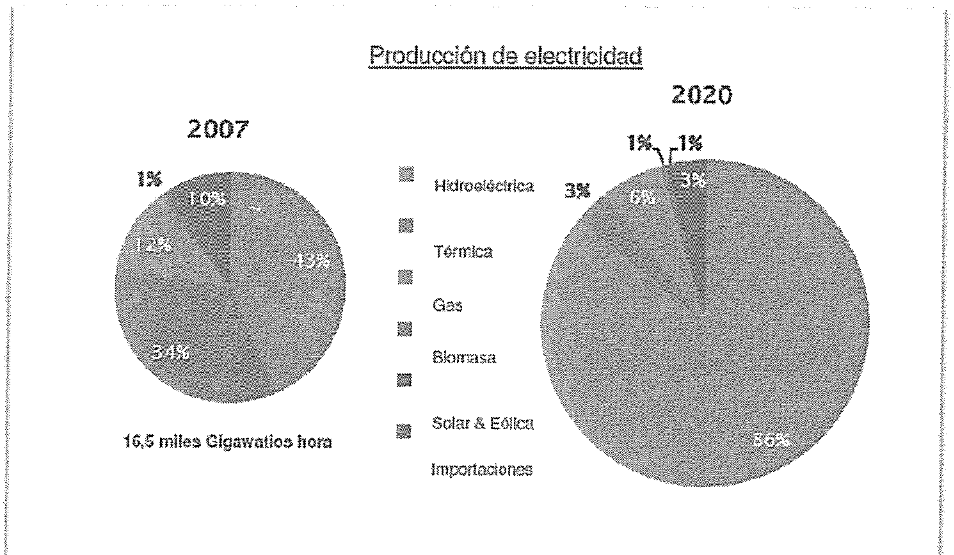
ECUADORS'S ENERGY PROFILE AND PROJECT RELEVANCE

A quick look at Ecuador's energy mix (figure 1) reveals a heavy reliance on hydro and thermal power for electricity generation; which is problematic for several reasons. Thermal power, which is comprised primarily of diesel and fuel oil, is uneconomical as Ecuador lacks the refining capacity to produce these lighter fuels. As thermal power equals roughly 40% of the electricity mix, Ecuador must import oil deficits to meet demand; which increases the cost per kilowatt substantially. While balancing the energy mix with hydropower appears to be a viable solution, the climactic conditions (i.e. the seasonal dry months) can seriously affect the output of hydro-plants, as shown in 2009. Resulting shortages force electricity importations from Peru and Columbia, at high premiums. Further exacerbating the problem is Ecuador's electricity goals for the near future. By 2020, the plan is to double hydropower to 86% of the total electricity portfolio (Tech4CDM). This endeavor is not only costly and time consuming, but it increases the vulnerability to seasonal dry spells. Moreover, under the best case scenario, the new hydro-plants will only be able maintain electricity demand till 2030 (CONELEC, June, 2007); which means the current strategy is shortsighted. Finally, if centralized sources of energy like hydro continue to grow, so will the electrical losses associated with distribution. These factors combined necessitate the rethinking of the future energy mix. Decentralized sources of electricity, like biomass, offer great promise yet they only comprise roughly 2% of the current, and future, energy mix. This paper attempts to highlight the potential of one such biomass, rice husk.



Goal of change in the energy matrix of 2020 (Source: MEER).

Figure 1- Ecuador Energy Mix (Tech4CDM)

Diesel & Oil

Despite being the fifth-largest oil producer in South America, Ecuador is a net importer of refined products oil products (EIA, 2009). This is due to the fact that Ecuador lacks the ability to refine its crude oil, making the country susceptible to volatile oil prices and energy shortages. For example, in 2009, Ecuador imported 14.2 million barrels of oil derivatives, with a cost of 858 million USD; but in 2008, the import cost of 12.5 million barrels was 1.3 billion USD (Hoy, 2009). This volatility from one year to the next makes it difficult to plan and budget, and affects the quantity of oil the country can afford to import; which, in turn, affects the price of electricity. Moreover, Ecuador's subsidizing policy reveals more inefficiency: “The costs of importing oil-derived fuels increase every year, for example, while Ecuador sells at less than 60USD the barrel of crude oil, it imports diesel at 90.78 USD/barrel” (Pelaez-Samaniego, M., L.A.B., J, & G, 2007). In fact, for 2010, the total cost of oil derivative subsidies will reach roughly 3 billion USD; and more specially, 256 million for the electric sector (El Comercio, 2009). To put these numbers into perspective, 3 billion USD represents roughly 10% of the country’s total GDP.

Given the historical trend of increasing oil prices, at which point will subsidizing become unsustainable? Also, we need to include the environmental costs of oil production. Recently, in July of 2010, the Esmeraldas refinery (in the province of Esmeraldas) was the culprit of an oil spill of 1,300 barrels; which leaked into two rivers, Teaone and Esmeraldas, and will take four months to remediate. Diversifying the energy mix to renewable sources, therefore, makes economic and environmental sense. If we consider the rice sector, the bulk of the millers are situated in the province of Guayas (look for the city of Guayaquil on figure 2); coincidentally, the province also happens to have the largest concentration of thermal power sources. The focus of this paper is to determine if the residue from rice production, rice husk, can be viable option to generate renewable, decentralized, energy in the region.

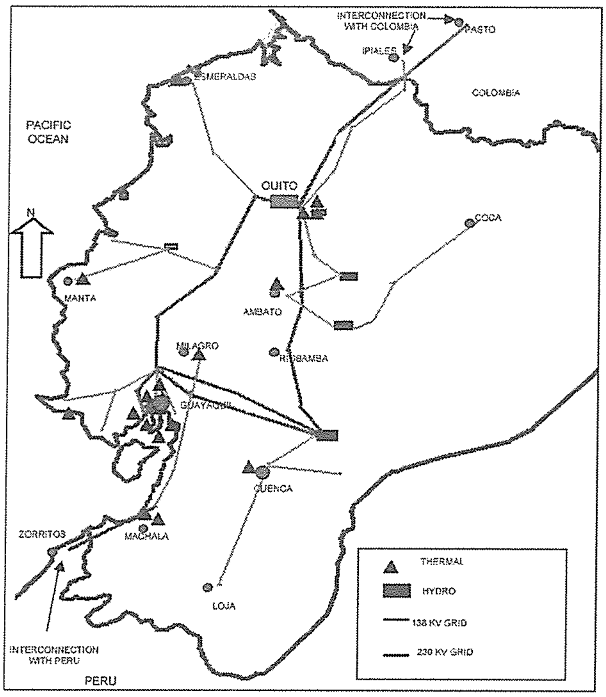


Figure 2- Ecuador electricity generation and transmission network, in 2005. Source: CONELEC (2006b)

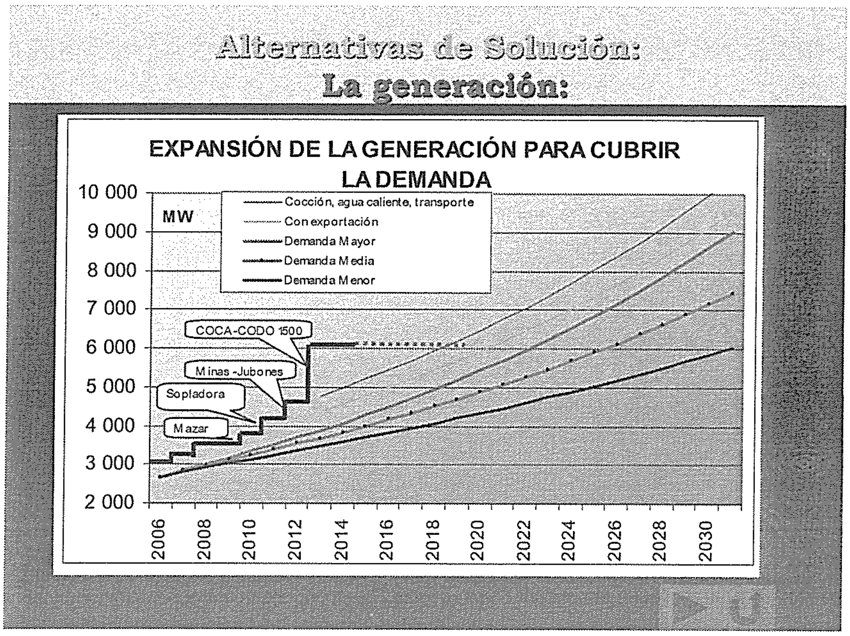
Hydropower

According to the Consejo Nacional De Electricidad (CONELEC), hydroelectric power accounted for 53.72% of the total electricity generation in 2009 (CONELEC, 2009). While an increasing reliance on hydropower as a means to reduce fossil fuels is a positive step, it is not without its problems.

Firstly, due to the severe dry spell between October 2009 and March 2010, output from Ecuador's largest hydro plant, Paute, dropped drastically. Paute, which produces 1,075 MW, saw its reservoir drop 20 meters below optimal level, rendering eight of its ten turbines inactive. "Paute can supply up to 20,000 MW per hour under normal conditions", but because critically low water levels were unable to sustain production, output was just 4,000-5,000 MW per hour (LAHT, 2010). Consequently, energy rationing was put into effect; and blackout periods were assigned throughout the country, which included the nation's capital Quito. Because commercial output slowed during this period, the resulting economic losses are estimated in the tens of millions of dollars (UPI, 2009).

The 2009 energy crisis had other significant consequences. Shortages forced the country to spend an additional 300 million USD to purchase 22 million gallons of fuel oil and diesel in order to satisfy electricity demand (El Comercio, 2009). Keep in mind that during this period, Ecuador was importing diesel at 82.7 USD/barrel, and sold to the market for 39.4 USD/barrel; which represents a high national cost for the country. For example, this increased use of thermal electric generation, raised the price per kilowatt/hour from 0.08 USD to 0.12 cents (El Comercio, 2009) . Moreover, aside from fossil fuel imports, the energy crisis increased electricity imports from Columbia and Peru to 3,000 MW/h and 1,200 MW/h respectively. In 2009, imports represented almost 7% of electricity mix, with a price tag of 52.86 million USD (CONELEC, 2009).

Looking forward, plans are currently underway to build 1,500 MW capacity hydroelectric plant, called Coca-Codo-Sinclair, by 2013. The project comes at a cost of around two billion dollars (Skinner, 2010). However, even with this investment, hydro power will only be able satisfy electricity demand till about 2030 under conservative estimates; and till 2023 if we consider high-growth demand (see figure 3). What will happen beyond these dates? Will the country require more fossil fuel imports? And what if severe droughts were to hit again? Looking at Ecuador's future energy mix once more, a heavy reliance on hydropower is not a silver bullet in solving their energy needs. Diversifying the energy portfolio to include other renewable energy projects, like biomass cogeneration, reduces the strain on hydro plants, and also helps to ensure more consistent energy supply.



Alternativas de Solución:
La generación:

Figure 3- Hydropower increase (CONELEC, June, 2007)

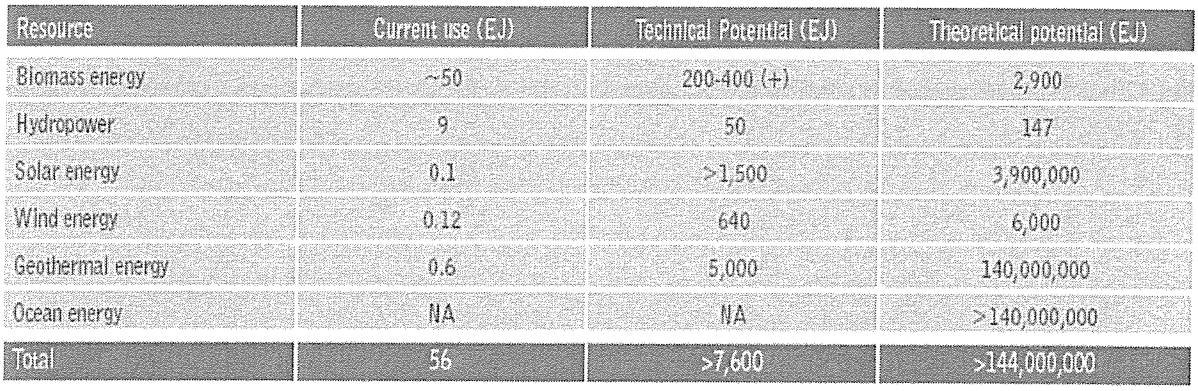
Distribution Losses

Expanding large-scale central energy sources, like the Coca-Codo-Sinclair hydro project, will ultimately result in distribution losses. According to CONELEC, 1,404.05 GWh of energy was lost in the distribution system in 2009; which represents 17.55% of the country's total available energy (CONELEC, 2009). One can easily discern that with the addition of another large energy facility, and increased distribution lines, more losses will occur- especially since the new project is situated deep in the Amazon, near the Coca y Quijos Rivers. Moreover, one also must consider the economic and social cost of losing almost one fifth of the total available energy. It is for this reason that this paper proposes exploiting decentralized forms of energy, like biomass. One such example in Ecuador is the use of bagasse (biomass residue from sugarcane production) to produce electricity. Ecoelectric S.A., who runs and operates the project, produced 69.37 GWh in 2009 (CONELEC, 2009). While a project of this size only accounts for a small fraction of the total energy production- less than 1%- it produces its own electricity and supplies the grid with surplus. A combination of such projects around the country can have a considerable impact. The next section will look at another promising biomass, rice husk, and examine its potential for electricity.

CHAPTER 2-
BIOMASS, ECUADOR'S RICE INDUSTRY & DAULE COUNTY

Biomass as Fuel Source

Biomass is defined as "the energy stored in non-fossil organic materials such as wood, straw, vegetable oils and wastes from the forest, agricultural and industrial sectors" (The Canadian Encyclopedia). When biomass is used as energy, through a bioconversion process, it is referred to as bioenergy. This form of energy is anything but new: it has been employed for thousands of years, especially in early civilizations for cooking and warmth. The energy contained within biomass is developed through the process of photosynthesis, via solar energy; and unlike fossil fuels which requires thousands of years to transform into useful energy, bioenergy is converted on much shorter timescales and on a continuous, renewable basis (The Canadian Encyclopedia); for example, organic residue resulting from rice production. With technological improvements in biofuels, biodiesel, and biomass electricity generation; the potential growth for the bioenergy market appears promising; a recent report from the International Energy Agency (IEA) claims that under moderate estimates, bioenergy may represent 20-50% of total energy supply by 2050 (Biopact, 2007). This is primarily due to the fact that biomass has many sources, for example: agricultural waste, forest residue, dung, and energy crops. Furthermore, as biomass provides roughly 10% of the world's total energy supply (45 exajoules), it is "by far the most important renewable energy source being used (Biopact, 2007) (see table 1). This reaffirms the importance of biomass as a means of replacing fossil fuels to help meet future energy demands.



Resource	Current use (EJ)	Technical Potential (EJ)	Theoretical potential (EJ)
Biomass energy	~50	200-400 (+)	2,900
Hydropower	9	50	147
Solar energy	0.1	>1,500	3,900,000
Wind energy	0.12	640	6,000
Geothermal energy	0.6	5,000	140,000,000
Ocean energy	NA	NA	>140,000,000
Total	56	>7,600	>144,000,000

Table 1- Overview of current use, and the technical and theoretical potentials of different renewable energies (Biopact, 2007)

The potential benefits of using biomass as a primary fuel source are significant. (1) When biomass is produced and consumed on a sustainable basis, "it is a carbon-neutral carrier and can make a large contribution to reducing greenhouse gas emissions" (Biopact, 2007). In other words, as plants grow they absorb CO_2 from the atmosphere, and when burned to create bioenergy, they release the same CO_2, completing the carbon cycle. As long as the same amount of biomass being burned is being grown, we can say the process is carbon neutral. (2) Biomass increases energy independence by diversifying a countries energy matrix, and by exploiting local resources (UNEP and Energy Efficiency). (3) It also helps reduce environmental issues related to waste management; that is, the disposal of biomass wastes. (4) Lastly, bioenergy can provide an additional source of revenue for the agricultural and forestry sectors (UNEP and Energy Efficiency).

These four factors can be especially beneficial in the case of Ecuador: CO_2 reductions can lead to carbon credits to help finance bioenergy projects; biomass can help wean off the country's dependence on fossil fuels; it also helps manage current disposal problems of agricultural waste, which creates harmful Green House Gas emissions (GHG) like methane (CH_4); and as Ecuador has a poverty rate of 35.1% (Index Mundi), developing bio-industries can certainly provide an economic boost.

The rest of this paper is devoted to a particular biomass residue with tremendous potential in Ecuador: rice husk. Before we define the usefulness and application of rice husk in relation to the aforementioned factors, we begin by outlining its source: the rice industry.

Ecuadorian Rice Industry

Agriculture has long been a major component of the Ecuadorian economy; in fact, still today it remains the second most important source of overall revenue (Borja & Williams, 2004). This sector constitutes roughly 17% of the country's total real Gross Domestic Product (GDP), and employs 23% of the national work force; agriculture has also been the only economic sector with positive growth rates since 1994 (Borja & Williams, 2004). Therefore, the national importance of agriculture cannot be understated. Throughout the 1960's, '70, '80 and even the early '90's, traditional crops like: bananas, cocoa, sugar cane, and palm oil have dominated the sector (Borja & Williams, 2004). However, in more recent times, cereal production, primarily rice and corn, has been steadily growing at 10-15% per annum; and now represents roughly 15% of the agriculture sector. Rice crops, after cocoa crops, represent the "largest of any single crops in Ecuador" as of 2004 (Borja & Williams, 2004).

Rice production in Ecuador has been growning in earnest since the 1970's: an average of 7% per year (Borja & Williams, 2004). Two major events during the 1990's created annomalies that consierably affected the industry. The first was between 1990 and 1994, where the annual rice production rate soared to average of 19%, due to the free trade aggreement among the Andean Nations (known as the Andean Pact), and also to a growing rice deficit in the Andean region, mainly in Columbia (Borja & Williams, 2004). The second occurred in 1994, when a climactic event known as *El Nino* dropped production rates by an average of 14% per year till 1999. Unstable economic conditions (i.e. exchange rate, increase in interest rates, a decline in credit for farmers to purchase seeds), worsened matters (Borja & Williams, 2004). But since 2000, the rice market has rebounded, growing from 1.1 million tonnes to 1.34 million tonnes in 2008 (MAGAP, 2008). Given that world rice production was about 595 million tonnes in 2001 (Maps of World, 2006), Ecuador's contribution might be considered minimal; however, when you consider the country's size and population, production rates are modest.

The Ecuadorian rice sector can be best described as fragmented. Small farmers, who have an average farm size of 10 hectares (ha), account for 35% of total rice production (Borja & Williams, 2004). The remaining two thirds of production come from mid-sized to large-sized farmers, averaging 300 ha and 1,500 ha respectively (Borja & Williams, 2004). While a national rice association does exist (National Federation of Rice

Producers- FENARROZ), this organization only manages about 10% of the total planted area of rice in Ecuador; and therefore FENARROZ "has limited financial, administrative, and analytical capacity and little influence on national policy decisions affecting rice sector" (Borja & Williams, 2004). The Sugar Cane industry by contrast has fewer small-plant owners, and a higher concentration of large scale owners; which means owners have greater financial resources, access to up-dated industry information, and therefore more willing and able to expand into newer technologies, like bagasse cogeneration. This is pertinent for several reasons: the rice sector lacks industry leaders to explore emerging technologies; because the industry is fragmented it makes it difficult to get rice owners to cooperate and pool their resources; and since most rice owners are small to medium-sized, they lack financial capability. In sum, these factors present a major challenge for implementing a new technology, like biomass cogeneration, within rice mills. Overcoming such challenges will be discussed in further detail below.

The County of Daule

It is no secret that the majority of rice production in Ecuador is derived from the coastal region. In fact, the provinces of Guayas and Los Rios represented roughly 90% of the total national rice production in 2008, with the edge given to Guayas (MAGAP, 2008). In selecting a suitable site for a biomass cogeneration system, one of the most critical factors is the supply of the biomass. In this case, the biomass being considered is a rice residue from production, known as rice husk. Given that Guayas is the leading province for rice production, choosing one of its county's will ensure more stable biomass input. According to the rice statistics provided by the Ecuadorian government (MAGAP, 2008), the county of Daule had the highest production rates between 2003 and 2008; representing an average of 16.33% of total production during this period. In 2008 alone, Daule produced about 200 thousand tonnes of rice.

With regards to biomass cogeneration, what may complicate matters is the industry structure in Daule. In this county alone, there exist over 80 different rice millers (Appendix A). This alludes to the fragmented nature of the industry discussed above, and Daule being a classic example. Given the high concentration of millers, and in order for a cogeneration system to have a sufficient supply of biomass, it may require the cooperation of various rice millers, or of the county as a whole. These concerns are addressed in another section. We now turn our attention to the biomass itself, rice husk, and the technology required to convert it into energy.

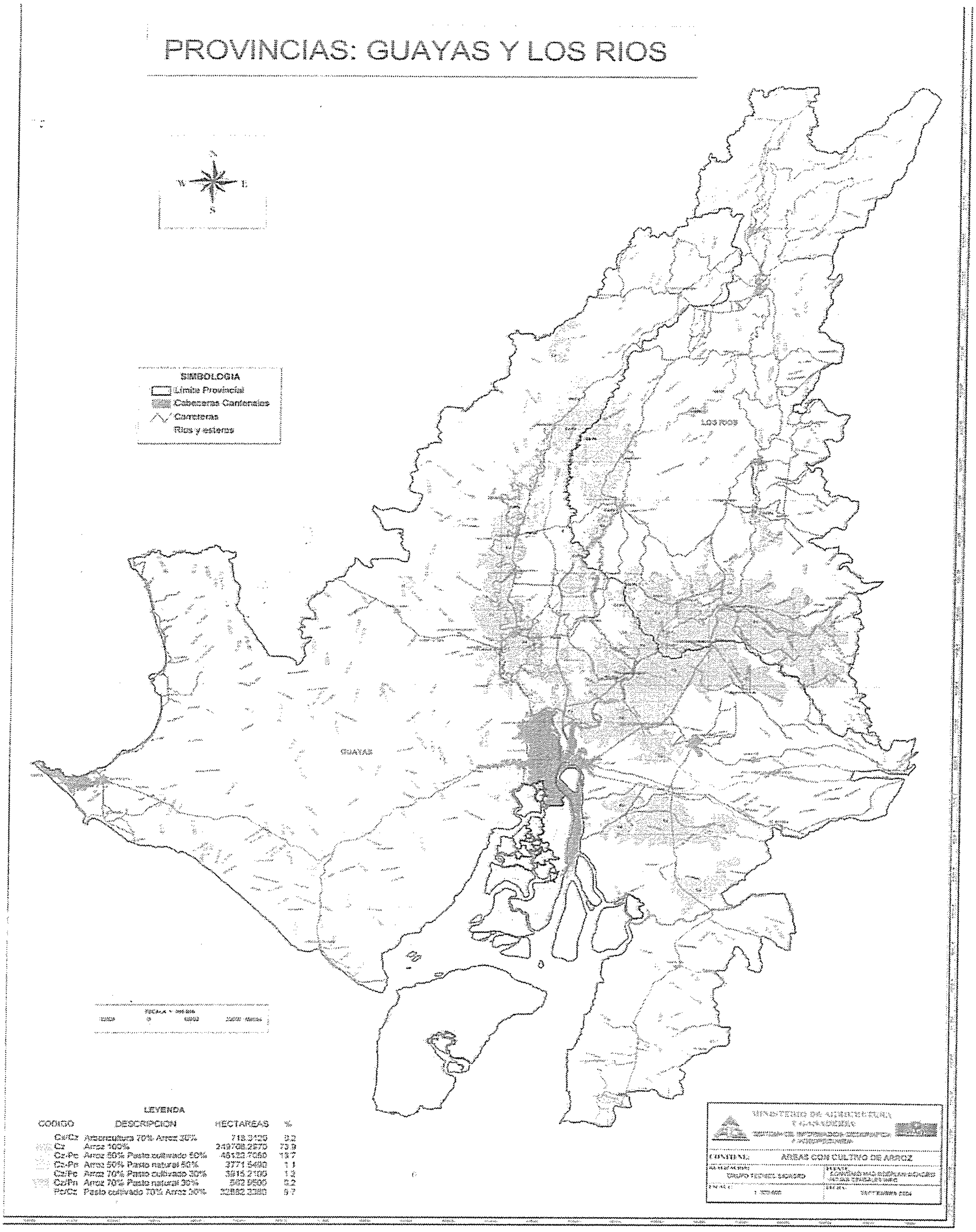


Figure 4: A look at the amount hectares devoted to rice production (in yellow) in the provinces of Guayas and Los Rios

CHAPTER 3-
RICE MILLING AND RICE HUSK

Before exploring the potential of rice husk as bioenergy, this report first examines its origin. Rice husk, or rice hull as it commonly referred to, is a by-product of the rice production process; we therefore begin this section with a brief description of the rice milling process, along with some important terminology.

Basic Terminology

The following terminology is essential in understanding the rice milling process (Rice Knoweldge Bank, 2009):

a) Rough rice paddy (or paddy rice): This is rice in its original form. Rice kernels are embedded within a protective hull.

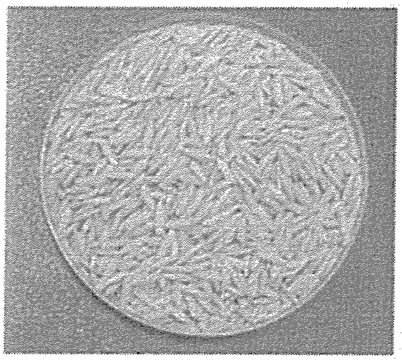


Figure 5- Rough Rice (Rice Knoweldge Bank, 2009)

b) Brown rice (or husked rice): The most basic form of processed rice, whereby the outer protective hull is removed, but the bran layers are still retained giving it a tan color and nut-like flavour.

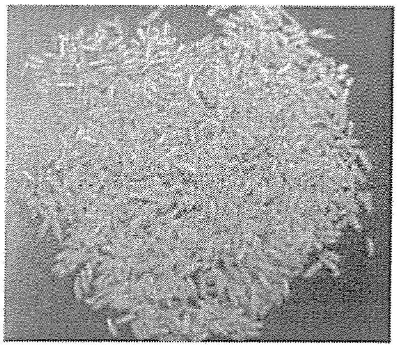


Figure 6- Brown Rice (Rice Knoweldge Bank, 2009)

c) Milled Rice (or white rice): Is the product resulting from the removal of all or part of the bran, and germ from the rough rice.

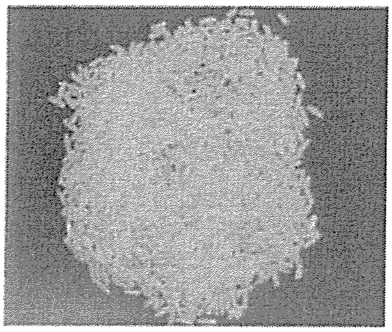


Figure 7- White Rice (Rice Knoweldge Bank, 2009)

d) Impurities: Includes things like stones, husk, chaff, weed, seeds; which are not part milled rice.

e) Milling recovery: This is “total milled rice obtained out of paddy; expressed as weight percentage of milled rice (including broken kernels) obtained from a sample of paddy. The maximum milling recovery is 69-70% depending on rice variety, but because of grain imperfections and the presence of unfilled grains, commercial millers are happy when they achieve 65% milling recovery. Some village type rice mills have 55% or lower milling recovery” (Rice Knoweldge Bank, 2009).

f) Milling degree: Is a measurement of the amount of bran removed from the husked rice.

e) Rice kernel composition: The general composition is as follows: 20% rice husk, 11% bran layers, and 69% starchy endosperm (Rice Knoweldge Bank, 2009). The typical by-products from the milling process include: rice hull, rice germ and bran layers, among other things (Rice Knoweldge Bank, 2009).

g) Whole and Broken kernels: Whole kernels are milled rice without any broken parts; whereas broken parts are only a certain fraction of the kernel, and brake down into large (50%-75% of the kernel), medium (25-50% of the kernel) and small (less than 25% of the kernel size) (Rice Knoweldge Bank, 2009).

h) Bran: Located between the hull and the kernel, bran protects the seed Fibre, contains B vitamins and trace minerals.

i) Head rice: It is "milled rice with length greater or equal to three quarters of the average length of the whole kernel. It is often expressed on a % paddy or rough rice basis (on 14% Moisture content basis)" (Rice Knoweldge Bank, 2009).

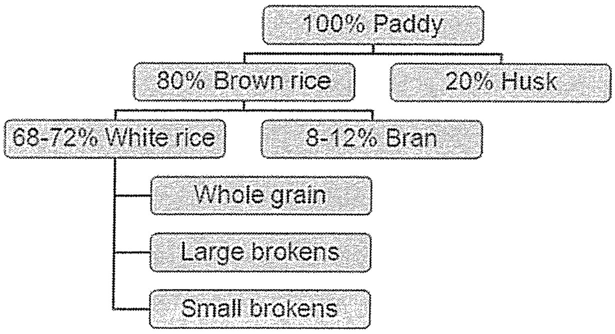


Figure 9 - Rice Fraction (Rice Knoweldge Bank, 2009)

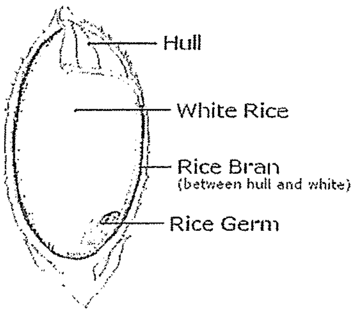


Figure 8- Rice Grain Diagram (Britton, Duran, & Sanchez, 2006)

The Rice Milling Process

The milling process is designed to remove husk and bran layers of the paddy, along with any impurities that may be present (Rice Knoweldge Bank, 2009). The end result is an edible, white rice kernel.

The focus here will be on the commercial sized mills, and not the smaller, village rice mills that also exist in Ecuador, because cogeneration projects require a generous amount of biomass input. In other words, larger rice mills will produce more rice husk by-product.

In commercial mills, the rice paddy is milled in various stages to reduce the mechanical stresses and heat build-up in the grain; which minimizes grain breakage and renders a polished grain (Rice Knoweldge Bank, 2009). Although rice mills vary in size, technology, and configuration, they all generally follow three basic stages (Rice Knoweldge Bank, 2009):

- The Husking stage: This entails removing the rice husk from the paddy;
- The whitening/polishing stage: This involves stripping the bran and germ from the brown rice; and polishing the exterior of the kernel and removing particle remnants, thereby improving the rice's appearance;
- The grading, blending, and packaging stage: Starts with the separation of the broken kernels from the head rice; following by a blending of desired broken kernels with head rice; and finally, packaging the final product for transport.

A more detailed stepwise process for commercial milling is given in table 1.

Modern rice milling processes consist of (Rice Knoweldge Bank, 2009):

Stage	Function
Pre-cleaning	Removing all impurities and unfilled grains from the paddy
Husking	Removing the husk from the paddy
Husk aspiration	Separating the husk from the brown rice/unhusked paddy
Paddy separation	Separating the unhusked paddy from the brown rice
De-stoning	Separating small stones from the brown rice
Whitening	Removing all or part of the bran layer and germ from the brown rice
Polishing	Improving the appearance of milled rice by removing remaining ran particles and by polishing the exterior of the milled kernel
Sifting	Separating small impurities or chips from the milled rice
Length grading	Separating small and large brokens from the head rice
Blending	Mix head rice with predetermined amount of brokens, as required by the customer
Weighing and bagging	Preparing milled rice for transport to the customer

Table 2- Rice Milling Process (Rice Knoweldge Bank, 2009)

There are several critical steps prior to milling that are relevant to rice husk cogeneration. (1) Pre-drying the paddy: Often times the rice paddy contains high levels of moisture that are not suitable for milling. In such cases, farmers dry the paddy using various techniques, e.g. sun drying, which requires considerable time and space. As we will see in the next chapter, cogeneration produces electricity, so perhaps the additional heating can be used in the pre-drying stage. (2) Parboiling: is a process by which the rice paddy goes through a hydrothermal treatment before milling (Rice Knoweldge Bank, 2009). It involves an extensive soaking, steaming and drying process, which almost doubles the total processing cost (Rice Knoweldge Bank, 2009). However, parboiled rice has been shown to have added nutritional benefits, fewer broken kernels, and increased total rice output- thus raising its value in comparison to regular rice. Because the parboiling process requires additional energy, for example, hot water needed in the soaking process; in some parts of India, millers are using rice husk to accomplish this (Rice Knoweldge Bank, 2009). These two factors will be considered when applying the technology to Ecuador. The parboiling process is further explained below.

According to the Rice Knowledge Bank, the three steps of parboiling are (Rice Knoweldge Bank, 2009):

- Soaking (sometimes called steeping) paddy in water to increase its moisture content to about 30%.
- Heat-treating wet paddy, usually by steaming, to complete the physical-chemical changes.

- Drying paddy to a safe moisture level for milling.

Rice Husk

We now arrive at the main focus of this study: rice husk. As figure 9 illustrates, rice husk (or “rice hull” as shown in the picture) is the outermost layer of the paddy. It is removed from the paddy grain to produce edible white rice during the husking and husk aspiration stages of the milling process, as indicated above. Needless to say, rice an agricultural stable worldwide, and for many developing nations, it constitutes a major component of their diet; for Ecuador, rice is no less important (see chapter 2). An important fact about rice husk is that accounts for roughly 20% of the paddy weight (Rice Knoweldge Bank, 2009). If in 2008 Ecuador produced 1.3 million tons of rice, there would have been 260,000 thousand tons of rice husk by-product resulting from the production. While this organic waste has many uses; for example, as flooring in livestock pens in farms, or burned to help reduce moisture content; the vast majority gets discarded where it is left to degrade by natural processes according to the former Minister of Agriculture in Ecuador, Walter Poveda Ricaurte. Furthermore, rice millers selling their rice husk to farmers are earning negligible amounts; farmers can also easily substitute this biomass with another.

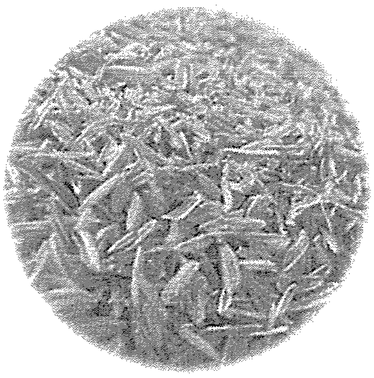
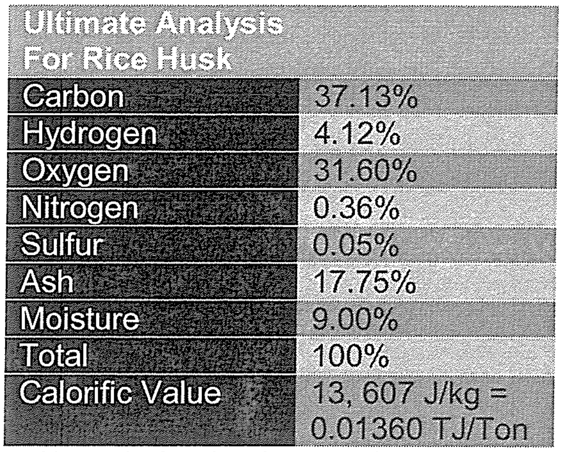


Figure 10 - Rice Husk (Rice Knoweldge Bank, 2009)

The idea is then to utilize this biomass more efficiently. Converting biomass to bioenergy is suggested for the following reasons: (1) it is widely available; (2) it has a reasonable calorific value; (3) and has relatively low moisture content. In the first case, we already know that there is a considerable amount of unused rice husk that can be used. Secondly, in relation to the other commonly used biomasses' to produce energy (see figure 14 below), rice husk has a high average calorific value, which makes it a "good, renewable source of energy" (Rice Knoweldge Bank, 2009). Calorific value essentially defines the energy content of a biomass fuel; it refers to the energy released as heat when the biomass undergoes combustion, and is expressed as "energy/mass of fuel" in both figures 13 and 14. It is considered as one the most important parameters when designing thermal system. The elemental composition of a biomass is integral in determining its calorific value; figure 13 shows the ultimate analysis for rice husk for a Clean Development Mechanism (CDM) project for the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC - A.T. Biopower Rice Husk Power Project). Thirdly, moisture content can considerable impact the performance (combustion efficiency) of the thermal plant if the percentage is too high, and, thus, it must be carefully controlled; for example, in *suspension combustion* moisture content should be below 15% (UNEP and Energy Efficiency). Because rice husk has an inherently low moisture level- for example, compared to bagasse (see figure 14) - it can be used in wide variety bioconversion technologies. Lastly, the ash content is also an important consideration. If we refer to figure once more, we can see the high level of ash content within rice husk. When rice husk undergoes combustion, the ash content is typically around 17%, however, it can be as high 26%; which means "when used for energy generation large amounts of ash need to be handled" (Rice Knoweldge Bank, 2009). If not handled accordingly, the thermal performance may be affected. On the other hand, rice husk ash may be used in industrial applications like concrete production and/or as an oil spill absorbent; mainly due to the high content of amorphous silica (Ricehuskash.com, 2008). The quality of the ash is contingent on the type of technology (see chapter 5); and, consequently, additional profit may be generated for project owners.

Environmental concerns

An important issue regarding rice husk is disposal practices. As previously stated, common practice in Ecuador is to either burn the rice husk in open areas, or to simply discard it. Burning the husk creates carbon dioxide (CO_2) emissions, while decaying husk leads to greater methane (CH_4) emissions; and both are known GHGs that contribute to global climate change. Furthermore, Mr. Ricaurte explained that it is not uncommon to find rice husk blowing into roads (mainly in the Coastal regions) or into neighboring farms, causing problems for locals; therefore, using rice husk for cogeneration provides a plausible solution to these problems. As will be shown in a latter chapter, by reducing (or avoiding) GHG emissions from disposal practices, project developers can also earn Carbon Credits which they can sell through the Kyoto Protocol's CDM to earn funding.



Ultimate Analysis For Rice Husk	
Carbon	37.13%
Hydrogen	4.12%
Oxygen	31.60%
Nitrogen	0.36%
Sulfur	0.05%
Ash	17.75%
Moisture	9.00%
Total	100%
Calorific Value	13, 607 J/kg = 0.01360 TJ/Ton

Table 3- Calorific Value of Rice Husk (UNFCCC - A.T. Biopower Rice Husk Power Project)

No.	Fuel	Calorific Value (Kcal/Kg)	Moisture Content (%)	Ash (%)
1	Rice Husk	3100	8.92	19.40
2	Bagasse	3550	10.53	7.03
3	Straw	3050	15	4
4	Nuts and Shells	4100	10	6
5	Wood	4400	9.83	3.14

Table 4- Rice Husk Properties (UNEP and Energy Efficiency). * 1kcal = 0.0041868MJ

Existing Rice Husk Power Generation Projects

Rice husk cogeneration projects are certainly not uncommon. In Villa Sara, Uruguay, a 10MW installed capacity is currently being developed using 110,000 tones of biomass/year, provided by nine rice millers (UNFCCC - Galofer). The purpose of this project is to improve environmental conditions by utilizing the rice husk waste; and also to supply electricity to the national grid through the co-gen process (UNFCCC - Galofer). The co-gen will work as follows: "rice husk will be used as fuel in a specially designed boiler…this boiler will generate water steam by burning large amounts of rice husk at high temperatures. This high-pressure and high-temperature steam produced will pass through a turbine and will activate the electrical generator, from which energy will be obtained. This energy will finally be connected to the public grid" (UNFCCC - Galofer). Furthermore, this plant will reduce the amount of CO_2 by roughly 50,000 tonnes annually (UNFCCC - Galofer).

On a smaller scale, a project in Kandal, Cambodia operates a 2MW rice husk power generation plant. Under this set-up, Angkor Bio Cogen (ABC) will sell the resulting electricity to Angkor Rice Mill under a power purchasing agreement; and any surplus electricity will be sold to neighboring mills and communities (UNFCCC - Angkor). The purpose of this project is once again to manage unused rice husk; and to replace the diesel oil currently being used for power generation. Moreover, the project needs 47,520 tons/year of rice husk for power generation; and the initial investment for this project is estimated at 4.74 million Euros (UNFCCC - Angkor). ABC will also use a travelling grate boiler, due to its "reasonable efficiency rate at 76%" and the high quality ash it produces; the ash can be sold for additional profit (UNFCCC - Angkor). On the social font, ABC will hire a co-gen plant manager and local_engineers to manage the project, leading to job creation. Finally, the project is said to reduce 51,620 tons of CO_2 equivalent annually (UNFCCC - Angkor).

The Villa Sara and Kandal projects are two examples from literature that illustrate the viability of rice husk co-gen plants of varying sizes. The challenge is then to design a tailored cogeneration project for Ecuador, which includes: appropriate site location, technology, and financial consideration. The next chapter examines the multiple available cogeneration technologies.

CHAPTER 4-
FROM BIOMASS TO BIOENERGY

Introduction to Bioconversion

As stated in chapter 2, bioconversion is the process by which organic material is converted into useful energy sources. Generating electricity from biomass is becoming an attractive option for industrialists because it uses the very same technology employed in the power generation industry; that is, "furnaces to burn coal, boilers to raise steam from the heat produced and steam turbines to turn the steam into electricity" (UNEP and Energy Efficiency). In fact, it is probably for this reason that heat and electricity production currently dominate bioenergy use (IEA Bioenergy , 2007). In a recent report by IEA Bioenergy, they state that "...traditional use of biomass, in particular, is for production of heat for cooking and space heating... It is not expected that this traditional use will diminish in coming decades... Nevertheless, modernising bioenergy use for poorer populations is an essential component of sustainable development schemes in many countries..." (IEA Bioenergy , 2007). This statement captures the very essence of this study. While the main growth markets for bioenergy originate from the European Union, North America, and, Central and Eastern Europe (IEA Bioenergy , 2007); much of its potential lies in developing countries where agriculture still plays a prominent role in the overall economy, like Ecuador.

In the year 2000, biomass contributed roughly 1% of the total global electricity generation- a negligible amount (see figure 15). However, it should be noted that during this same period biomass was the biggest contributor among all available renewable energies for electricity generation, after hydro (UNEP and Energy Efficiency); and its contribution is expected to continue growing through to 2030 and beyond. As a result, we can expect more resources being allocated to bioconversion technologies, thus increasing efficiency and making them more cost competitive with non-renewable energies.

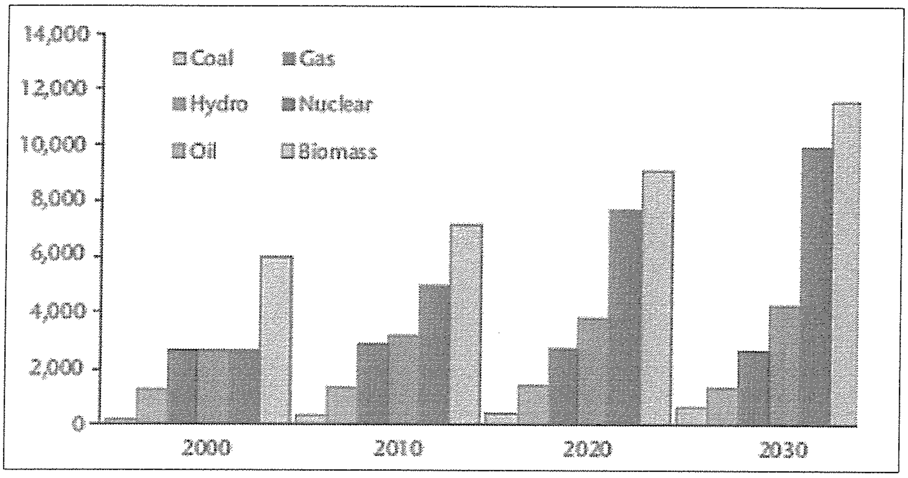


Figure 11 - Global Electricity Generation by Source in the year 2000 (IEA Bioenergy , 2007)

Bioconversion Technologies

Bioconversion is process of converting the energy stored within biomass into useful energy. As the below schematic indicates (figure 16), many options, or technologies, exist; and much depends on the desired outcome; i.e. heat, electricity, and/or fuels. While figure 16 groups the major technologies into two main categories: thermochemical and biochemical conversion, for the sake of clarification, direct combustion will be explained as a form of technology in itself. We now turn to a brief and simplified discussion of each technology.

1) Direct Combustion: It is the oldest and most established form of conversion technology. Essentially it entails burning the biomass in a furnace to generate heat to produce steam, which in turn is used to drive a steam turbine (UNEP and Energy Efficiency). More specifically, it is the oxidation of biomass through excess air, producing hot flue gases which in turn produce steam in a heat exchanger (IEA Bioenergy , 2007). The outcome is the production of heat and/or electricity.

The two main types of systems consist of:

- Condensing steam cycle: produces electricity only;
- Extraction steam cycle: produces both heat and electricity.

Simplicity is one the hallmarks of this technology. Generally speaking, it has a lower efficiency in comparison to the other two conversion forms. However, in a co-fired system, biomass is mixed with coal in a coal fired power station; which improves conversion efficiency considerably, and as is a more economical alternative (UNEP and Energy Efficiency).

2) Thermochemical Conversion: This form of conversion includes gasification and pyrolysis. Both are considered more advanced and expensive approaches to bioconversion. (1) Gasification uses a partial combustion process to transform biomass into combustible gas (UNEP and Energy Efficiency). Through a controlled amount of oxygen and/or steam, the biomass is converted into carbon monoxide and hydrogen when it reacts with high temperatures. The product of the gasification is called synthetic gas (syngas). The resulting gas can be used in a gas turbine to produce heat and/or electricity, or into methanol to produce biofuel. According to a report from UNEP, while many aspects of gasification are in the development stage, it offers great the prospect of high efficiency and may be the best option for converting biomass in the near future (UNEP and Energy Efficiency). (2) Pyrolysis decomposes wastes through the heating in the absence of air. The reaction in the chamber splits the molecules into gaseous, liquid and solid fractions. In doing so, the result creates a gas, oil and charcoal; which can be used in a variety of applications, including the production of heat, electricity and biofuel.

3) Biochemical Conversion: Through a process of both aerobic and anaerobic degradation; whereby bacteria in a first stage deplete oxygen in an air tight chamber (aerobic), and then facultative bacteria in a secondary stage lead the creation of methane gas. The result is a biogas that can be used to produce biofuel and electricity.

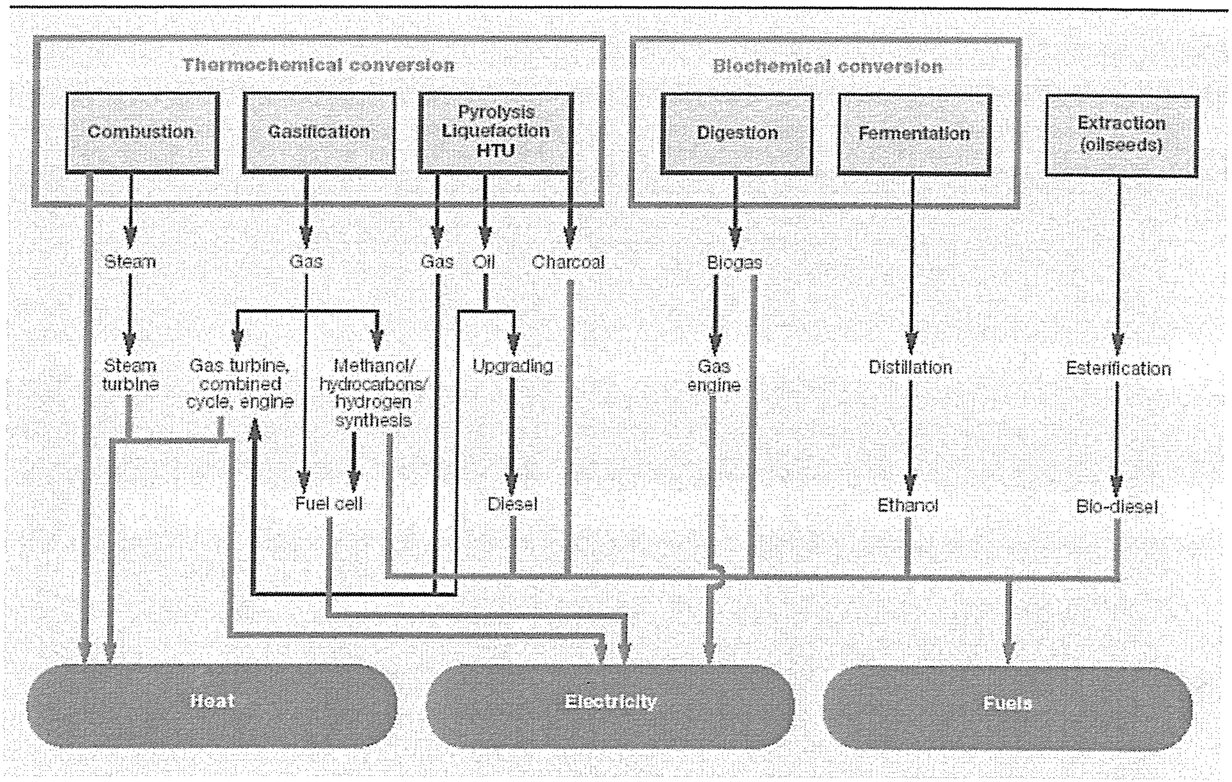


Figure 12 - The Main Conversion Options for Biomass (IEA Bioenergy , 2007)

Discussion and Conclusion: Direct Combustion

After examining the three bioconversion options presented above, it appears that for the purpose of this study, that is to produce electricity from rice husk, option one is the best fit. Firstly, given that direct combustion is a proven technology with simpler functionality than the other options; this may be an easier sell to rice millers. Avoiding malfunctions (which cost rice millers profit) and extensive learning programs (on how to operate and maintain the equipment), might persuade millers who come from an industry that is set it its ways; in other words, direct combustion offers more certainty. Secondly, newer forms of direct combustion systems have improved efficiency (which will be discussed below); and this ensures higher output, and in turn, higher returns on investment. Thirdly, other options produce several by-products, like biofuel and charcoal, which are not necessary in this context. Fully benefiting from such systems probably requires exploiting these by-products. Fourthly, given that most of the rice industry is made up of small to medium sized millers, financial considerations are important. Rice millers do not have easy access to credit, nor do they have much liquid capital available; therefore it is reasonable to assume that will most likely select a cost effective alternative like direct combustion. Lastly, rice husk power projects officially registered as CDM's are using direct combustion technology; choosing a similar technology allows us to follow a similar methodology to receive carbon credits.

Choosing a Bioconversion System

The task now becomes picking a suitable bioconversion system within the direct combustion technology. Taken from literature, the four most commonly used technologies are: pile combustion, stoker combustion, suspension combustion, and fluidized bed combustion (UNEP and Energy Efficiency).

a) Pile Combustion: Is the simplest form of direct combustion. Essentially, biomass is piled on a fixed grate inside a furnace (combustion chamber) where it is burned in air. The air passes up through the grate in a process called under-fire air (UNEP and Energy Efficiency). Because the combustion process is incomplete at this point (i.e. some unburned carbon and carbon monoxide remain), a secondary combustion is used atop the first, whereby more air in introduced to complete the process; this is called over fire air (UNEP and Energy Efficiency). Next, a boiler placed atop the second chamber absorbs the heat created during combustion, which then boils the water inside the boiler tubes (UNEP and Energy Efficiency). The water eventually turns into steam that drives a steam turbine. The steam from the turbine is then condensed and then returned to the boiler, completing the cycle. Although pile burners can handle wet and dry fuels (high moisture content), its efficiency is very low: 50-60%. Because there is no mechanism in place to remove ash, the furnace needs to be shut down which halts production temporarily (UNEP and Energy Efficiency). Furthermore, most pile-burner systems typically use a single pass steam turbine generator, which operates at relatively low steam temperature and pressure; consequently, overall power plant efficiency may be as low as 20% (UNEP and Energy Efficiency)

b) Stoker Combustion: A major limitation of the pile combustion is that it needs to be shut down in order to remove the ash; the stoker combustion overcomes this limitation. A stoker is basically a moving grate that continuously removes the ash, which also allows the plant to operate continuously. Another benefit to this process is that biomass can be spread out more across the grate, which increases combustion efficiency (UNEP and Energy Efficiency). Despite improvements to the basic stoker process, like inclined grates and water-cooled grates, efficiency is still low at 65-75%, especially with overall efficiency slated at 20-25%.

c) Suspension Combustion: There is no grate system in suspension combustion. Instead, biomass is finely ground and blown in a specially designed combustion chamber where it mixes with air. Biomass then burns in a flame inside the chamber, creating heat. Efficiency from this process can be as high as 80%, and reduces physical space as it requires only a small sized furnace (UNEP and Energy Efficiency). However, this system is not without its limitations. First, the size of the biomass most be less than 15mm, and moisture content should be around 15% or less; this requires special monitoring. Secondly, extensive biomass drying and processing facilities are needed so that the input is of the right consistency (UNEP and Energy Efficiency). As it stands, very few biomass projects using this technology are in place.

d) Fluidized Bed Combustion (FBC): This is the fourth and last direct combustion option. Like suspension combustion, its efficiency is quite high; and given that it can handle a heterogeneous mix of biomass, with varying levels of moisture, it certainly the most versatile of the four technologies (UNEP and Energy Efficiency). Inside this technology lies a sand (or limestone) bed supported by a grid plate which contains an air injection nozzle. Air is pumped from below the grid and fluidizes the bed material (which also contains the biomass) and expands it to twice its volume. This fluidization promotes mixing and turbulence, and increases heat transfer within the chamber. For this reason, bed temperature is lower than other technologies (see figure 17). Once the bed becomes hot enough, the biomass burns and produces heat. In a typical FBC setting, a cyclone filter separates the solid material from the resulting flue gases; and then the solids from the filter are re-circulated into the bed (UNEP and Energy Efficiency). Flue gas is the combustion exhaust gas which may contain a small amount of pollutants, like: particulate matter, carbon monoxide, nitrogen oxides and sulphur oxides.

FBC has two very important advantages. (1) As mentioned above, it can burn a variety of biomass without compromising efficiency; (2) when certain chemical reactants are introduced, like calcium carbonate (CaCO3), pollutants like sulphur are reduced, which can then be removed from the ash. FBC can burn biomass with a moisture content of up to 55%, and efficiency rate can be as high as 82% (UNEP and Energy Efficiency).

A direct comparison chart of the four technologies is provided below: (UNEP and Energy Efficiency)

Parameter	Pile Combustion	Stoker Combustion	Suspension Combustion	Fluidized Bed Combustion
Grate	Fixed / Stationary Grate	Fixed or moving grate	No grate or moving grate	No grate
Fuel Size	Uniform size of the fuel in the range of range 60 to 75 mm is desired & % fines should not be more than 20%	Uneven fuel size can be used	Preferable for high % of fins in the fuel	Uniform size fuel in the range of 1 to 10 mm.
Combustion	Difficult to maintain good combustion due to : ❖ Air fuel mixing is not proper ❖ Bed height is in stationary condition resulting in clinker formation ❖ Difficult to avoid air channeling ❖ Due to intermittent ash removal system it is difficult to maintain good combustion	The combustion is better & an improved version of pile combustion. Since most of the fuel is burnt in suspension the heavier size mass falls on the grate. If the system has a moving grate the ash is removed on a continuous basis & therefore the chances of clinker formation are less.	It is similar to stoker combustion, but since the fuel sizes is small & even the combustion efficiency is improved as maximum amount of fuel is combusted during suspension.	Best combustion takes place in comparison with the other types since the fuel particles are in fluidized state & there is adequate mixing of fuel & air.
Bed temperature	1250- 1350 °C	1000- 1200 °C	1250- 1350 °C	800- 850 °C
Moisture	High moisture leads to bed choking & difficult combustion conditions	Combustion condition not very much disturbed with 4-5 % increase in moisture	Same as Stoker Combustion	It can handle fuels with high moisture condition up to 45-50% but high moisture in the fuels is not desirable, & adequate precautions are to be taken up in the design stage itself.

Table 5- Comparison of the Various Combustion Technologies (UNEP and Energy Efficiency)

Discussion and Conclusion: Fluidized Bed Combustion Boiler

Based on the above analysis of the four direct combustion technologies, Fluidized Bed Combustion is chosen as the bioconversion that will be used in this study. The decision was based on the following criteria:

I. Biomass Flexibility: As shown in 1994 with the El Nino event, the rice industry is not immune to climactic events. In the event of a force majeure that results in a drastic decrease in production, less rice husk will be available; and, this in turn, will affect the output of the power plant, more specifically profitability. To hedge against this, FBC systems can operate efficiently with a variety of fuels (UNEP and Energy Efficiency), whereby rice millers can supplement input with other biomass waste, like agro waste. In fact, rice millers may even be able to boost output by utilizing local biomass waste; and this is possible because FBC can burn low grade fuels.

II. Pollution control: Because project developers expect to receive financing in the form of carbon credits under the Kyoto Protocol (discussed in more detail in chapter 6). Using the FBC, sulphur emissions can be significantly reduced with the aid of chemical reactants; and because FBC operates at lower temperatures, Nitrous Oxides are reduced (UNEP and Energy Efficiency). In lowering the amount of harmful pollutants resulting from production, it not only assures that the general environment is cleaner, but it increases the amount of carbon credits.

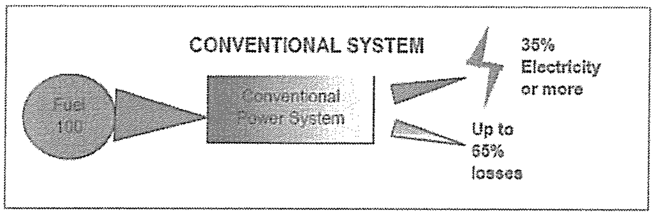
III. Operation and maintenance: As with other combustion technology, FBC allows for easy start-up and shut-down; and as mentioned above, is an important consideration. Of times when the technology is passed from installers to rice millers (or project developer's) problems arise. The ease of use helps overcome this. Due to the inherent equipment design, ash handling is simplified and requires less man power (UNEP and Energy Efficiency). Furthermore, FBC has higher degree of durability and reliability, for the following reasons: (1) absence of moving internal parts, (2) longer periods between maintenance schedules; (3) better system control and less supervision because of micro-processors and automatic ignition. Finally, because FBC operates at lower temperatures, corrosion and erosion effects are lessened (UNEP and Energy Efficiency).

IV. Efficiency: FBC offers considerably high efficiency: combustion efficiency of about 95%, and overall system efficiency of about 84% (UNEP and Energy Efficiency). This of course yields longer term profits because higher output generates greater savings (by replacing grid-tied fuel sources), and/or increased profits if excess power is produced (from the FBC system) and sold to the national grid. While FBC may be a more expensive alternative among the direct combustion options, the four aforementioned factors make it sound investment.

Comparatively speaking, FBC efficiency is very high, and yet it can be even greater through the process of cogeneration; which is discussed below.

Cogeneration – Combined Heat and Power (CHP)

By definition, cogeneration refers to “the sequential generation of two different forms of useful energy from a single primary energy source” (UNEP and Energy Efficiency). The two useful forms of energy resulting from the FBC process are heat and electricity; and for this reason cogeneration is also called CHP, *Combined Heat and Power*. Going back to our direct combustion process, whereby electricity is created, we explained that the steam used in driving the turbine is condensed and returned to the boiler, which creates a recycling system. However, in a CHP system, useful steam is taken (for example, by vacuum) from the turbine before it is condensed, to use its Heat energy. In our case, Heat energy can be used in many applications, for instance: rice husk drying, or meeting the hot water needs in rice mils. Figure 18 summarizes this principle.



Cogeneration System (CHP):

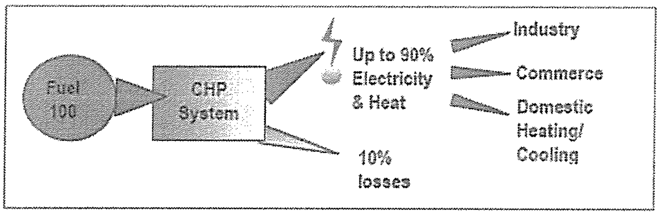


Figure 13 - Basic Cogeneration Schematic (COGEN europe, 2009)

So what is the main advantage of cogeneration systems? When steam from the bioconversion is utilized, overall efficiency can reach 90%; and because this heat can replace other fuels, energy cost savings are realized (COGEN europe, 2009). In a typical thermal power plant, only one third of "primary energy fed into the power plant is actually made available to the user in the form of electricity" (UNEP and Energy Efficiency); which represents a tremendous amount of energy loss. The majority of the losses are in the form of heat, and another small percentage (10-15%) result from transmission lines (as discussed in chapter 1). Cogeneration helps to overcome these issues by utilizing the wasted Heat, and because the electricity will be used locally, transmission losses are minimized.

Biomass cogeneration has macro-level benefits like reducing the strain from the national grid; and micro- level benefits from reducing the energy costs of millers, and also capitalizing off local resources. Furthermore, the environmental and social benefits are significant: captured heat can be used to replace fossil fuels; higher efficiency implies lower harmful emissions to the environment, like carbon dioxide (CO_2); and CHP also leads to increased employment from the development of CHP systems (COGEN europe, 2009). Also, CHP is considered as one the most promising solutions in meeting emission targets outlined in the Kyoto Protocol (COGEN europe, 2009). It is important to mention that CHP is a mature technology; meaning that performance outcomes are well documented and understood.

The Cogeneration System

The CHP system has four main considerations: boiler, generator, heat-to-power ratio, and the steam turbine. In our case, the FBC boiler will be employed; and its process, efficiency and benefits were explained earlier. Generators convert the mechanical energy (motion energy produced from the steam) into electrical energy; and two types exist: synchronous, and asynchronous. The synchronous system has the ability to operate independently from the grid- and usually more expensive; conversely, the asynchronous can only function with the grid, or other generators (COGEN europe, 2009).

A very important factor in determining the type of CHP system to implement is the *heat-to-power ratio*. It is defined as "the ratio of thermal energy to electricity required by the energy consuming facility...and the heat-to-power ratio of a facility should match with the characteristics of the cogeneration system to be installed" (UNEP and Energy Efficiency). In other words, different industries require varying degrees of heat and electricity loads; and establishing this ratio helps determine the necessary steam turbine to yield favorable levels of each. Heat-to-power ratio parameters are provided in figure 19.

The steam turbine (prime mover) is what drives the electricity generator, whereby the steam pressure from the FBC boiler moves the turbine blades; which then turns the generator. Steam turbines fall into two general categories (UNEP and Energy Efficiency): Back-Pressure turbine and Extraction condensing turbine. Their key differences are illustrated in figure 19.

Cogeneration System	*Heat-to-power ratio* (kWth / kWe)	*Power output* (as per cent of fuel input)	*Overall efficiency* (per cent)
Back-pressure steam turbine	4.0-14.3	14 - 28	84 – 92
Extraction- Condensing Turbine	2.0- 10.0	22 – 40	60 - 80

Table 6- Heat-to-power ratio parameters (UNEP and Energy Efficiency)

The cogeneration process and its corresponding elements are depicted in figure 20. We can see that the biomass (rice husk) enters the system, and first goes through a process to ensure that it meets the system requirements (e.g. sizing: to ensure the proper grain size, mixing: to ensure that there sufficient quantity). Next, the biomass is fed into the FBC boiler where high pressure steam is produced, and also the flue gas containing harmful pollutants. The flue gas may be treated by various methods: particle filtration, baghouse filters, and/or electrostatic precipitators. From there, the high pressure steam enters the steam turbine, and the resulting output is electricity (by way of the generator "G"), and steam. The low pressure steam is condensed to form water, which is recycled back to the boiler; and the medium pressure steam is captured to be used as Heat energy (e.g. for heating water). With the above information in hand, we now turn to chapter five to establish a suitable cogeneration scenario for Ecuador.

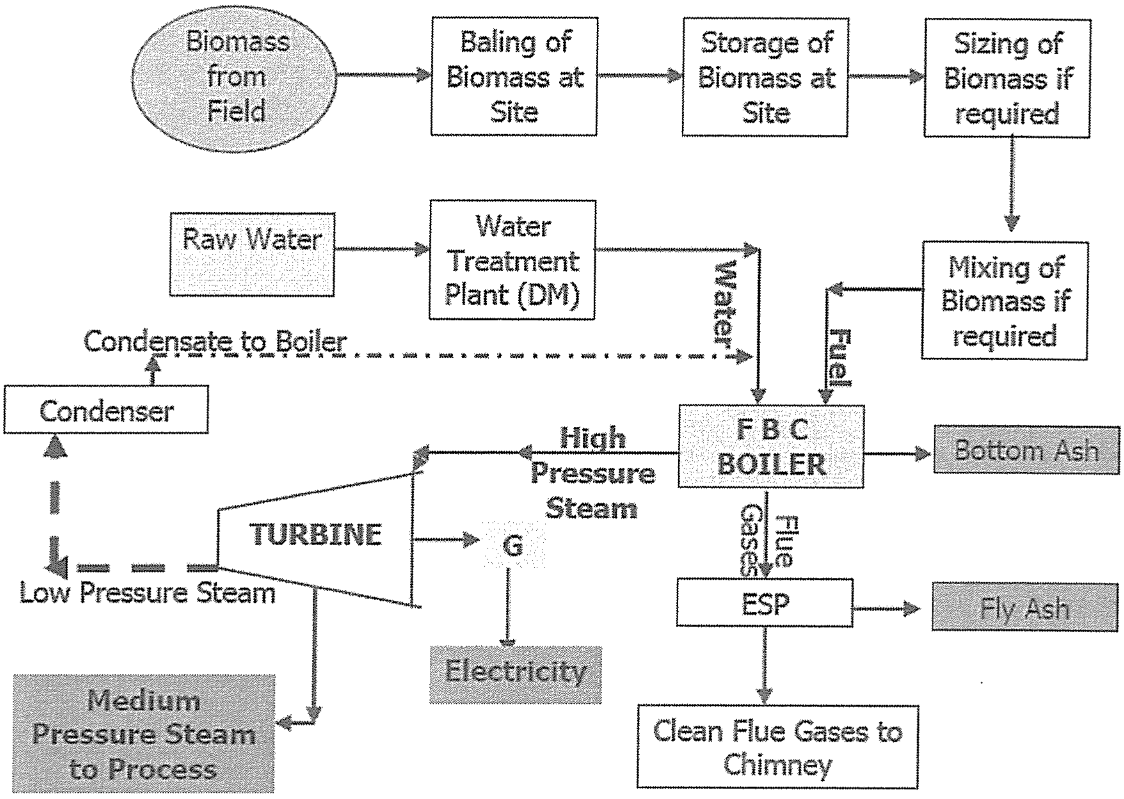


Figure 14 - Cogeneration Flow Chart

CHAPTER 5-
PROJECT DESIGN

Availability of Biomass

As previously stated, a very important consideration in designing a bioconversion system is the amount of available biomass, in this case, rice husk. In chapter 2 we discussed how the county of Daule in Ecuador has the highest production of rice countrywide; and therefore, the highest output of rice husk. However, because rice production varies from one year to the next, it is important to know the yearly average production rate, along with the standard deviation. The standard deviation tells us how much production varies from the average- a crucial detail in estimating potential input levels for the FBC system. Using information provided by the Ministry of Agriculture on rice production (MAGAP, 2008), the following statistical information was established:

Year	Yearly Rice Production (in tons)	Total Production Average (total rice production divided by the number years)	Yearly rice production minus Total Production Average	(Yearly production minus total production average), squared
2002	199, 045.00		-20, 883.25	436,110,130.60
2003	193, 912.00		-26, 016.25	676,845,264.10
2004	214, 513.50		-5, 414.75	29,319,517.56
2005	226, 372.50		6, 444.25	41,528,358.06
2006	236, 900.20		16, 971.95	288,047,086.80
2007	243, 473. 00		23, 544.75	554,355,252.60
2008	225, 281.55		5, 353.30	28,657,820.89
Total	**1,539,497.75**	1,539,497.75 / 7 = **219,928.25**		**2,054,863,430.61**

Table 7- Statistical Information for Daule

The value "2,054,863,430.61" (total production average) is needed to calculate the variance. The variance is used to get the standard deviation, and is calculated by dividing the total production average by the total number of years (7), minus one.

Therefore:

Variance= (2,054,863,430.61)/ (7-1)
Variance= 342,477,238.40

To get the standard deviation, we take the square root of the variance:
Standard deviation= √342,477,238.40
Standard deviation= 18,506.14

With the standard deviation in hand, we can now estimate the expected annual rice production more accurately. Given that the annual production average between 2002 and 2008 is 219,928.25, and using the standard deviation of 18, 506.14 tons, production is expected to fall somewhere in the range of 201,422.11 tons and 238,434.39 tons. In order to be conservative, the lower value will be used to determine the amount of input in the FBC system. Furthermore, because rice husk represents 20% of the actual rice, we can now determine how much of it is available.

Rice Husk (input) = (20%) * (201,422.11 tons of rice)

Rice Husk = 40,284.42 tons/year

In sum, the amount of available rice husk for the county of Daule is estimated at 40,284.42 tons per year.

Project Setup

Given the fragmented nature of the Ecuadorian rice industry (as described in chapter 2), no one rice mill in Daule produces enough husk to generate a significant amount of electricity. Since the purpose of this study is to offer a viable alternative to Ecuador's existing electricity matrix, the amount of electricity generated from a biomass project should be maximized. In order to maximize the amount of electricity output, the total available rice husk should be utilized in the bioconversion process. Similar projects are already in place: the most notable is the Galofer CDM project in Uruguay. The Galofer project is setup to gather rice husk from 9 different mills situated in the Villa Sara community- as this area accounts for 65% of national production (UNFCCC - Galofer)- and the husk is then processed and converted at a central facility. In other words, while implementing a bioconversion system may be unfeasible for individual millers, a community approach not only improves economies of scale, but minimizes risk and increases power output. In our case, project developers must choose a suitable location where there is sufficient storage space for the husk, and also for the bioconversion equipment; locations may include larger sized rice mills, like the one used in the Galofer project.

That being said, designing a community-style project poses two obvious challenges: (1) rice husk collection (road access, transport costs etc); and (2) cooperation amongst rice mills (to ensure perennial supply of husk). Both points are addressed in greater detail in chapter 6 and 7 respectively.

Theoretical Electrical Output from the Bioconversion Process

Consider the following conversion information:
MWe (Mega Watt electrical)

1 Joule (J) = 1 Watt Second

Since, there are 60 seconds in one minute, and 60 minutes in an hour: 60 x 60=3600

Therefore: 3600 Joule = 1 Watt hour (Wh)

From this, we can derive the following:

3600 Joule= 1 Watt hour

3600 Mega Joules (MJ) = 1 Mega Watt hour (MWh)

3600 Tera Joules (TJ) = 1 Tera Watt hour (TWh)

Also,
MJ = 10^6 J
TJ = 10^{12} J
Therefore:
1,000,000 MJ= 1 TJ

Rice Husk as Fuel

-Step 1: Determining the Energy from the Available Rice Husk

Biomass Availability = 40,284.42 tons of rice husk/year

Calorific value of rice husk = 13, 607 J/kg = 0.01360 TJ/tons (from chapter 4)

Energy= (40, 284.42 tons) * (0.01360TJ/tons)

Energy= 550.688 TJ/year

-Step 2: Electricity Output from the Bioconversion Process

Because we do not have specific details, such as: the heat requirements of the proposed central facility, and/or neighboring mills; we are unable to calculate the heat to power ratio (HTO) - a key figure in deciding the type of cogeneration system to implement. However, from literature we know that the HTO of food industries generally fall between 0.8 and 2.5 (UNEP and Energy Efficiency); and, according to figure 19, this range is most suitable for the Extracting-Condensing Turbine system. The power output for this cogeneration system ranges from 22% to 44%; and in keeping a conservative approach, 22% will be used to calculate the annual electricity production.

From step 1, we know that the energy from the available rice husk equals 550.688 TJ/year.

Therefore, since the power output is 22%:

Electricity output= (550.688 TJ/year) * (22%)
Electricity output= 121.151 TJ/year

From the conversion information above:
= (121.151 TJ/year) / 3600
= 0.337 TWh
= 0.337 * 1,000,000
= 33,653.0556 MWh/year

Next, to determine the yearly electrical power of the central plant:

= (33,653.0556 MWh per year) / ((24*365) hrs per year))
= (33,653.0556 MWh per year) / (8760 hrs per year)
= 3.842 MWe

-Step 3: Energy Requirements of the Co-gen System

Biomass, or rice husk in our case, is not the only important form of input when designing the cogeneration system; in fact, the electricity required by the system components needs to be considered. The co-gen components, known as auxiliaries, comprise mainly of: boiler feed water pumps, air supply fans, (induced & force drafts) compressed air, water treatment plant, ash handling system, cooling towers for condenser etc. (UNEP and Energy Efficiency). As a general rule, the auxiliary power consumption is estimated at 15% of the total power generated from the system (UNEP and Energy Efficiency); this of course may vary depending on the fuel mix and the type of turbine system setup used.

Therefore, the estimated energy load for the auxiliaries is:

= (33,653.0556 MWh/year) * (15%)
= 5047.958 MWh/year

-Step 4: Net Energy Production of the Co-gen System

= (33,653.0556 MWh) – (5047.958 MWh)
= 28,605.098 MWh

In conclusion, the total amount of electricity that will be sent to the national grid is 28,605.098 MWh (see figure 15 below). Because this electricity will be used be locally, it will reduce some of the distribution losses discussed in chapter 1, and also the replace the fossil fuel used in power generation.

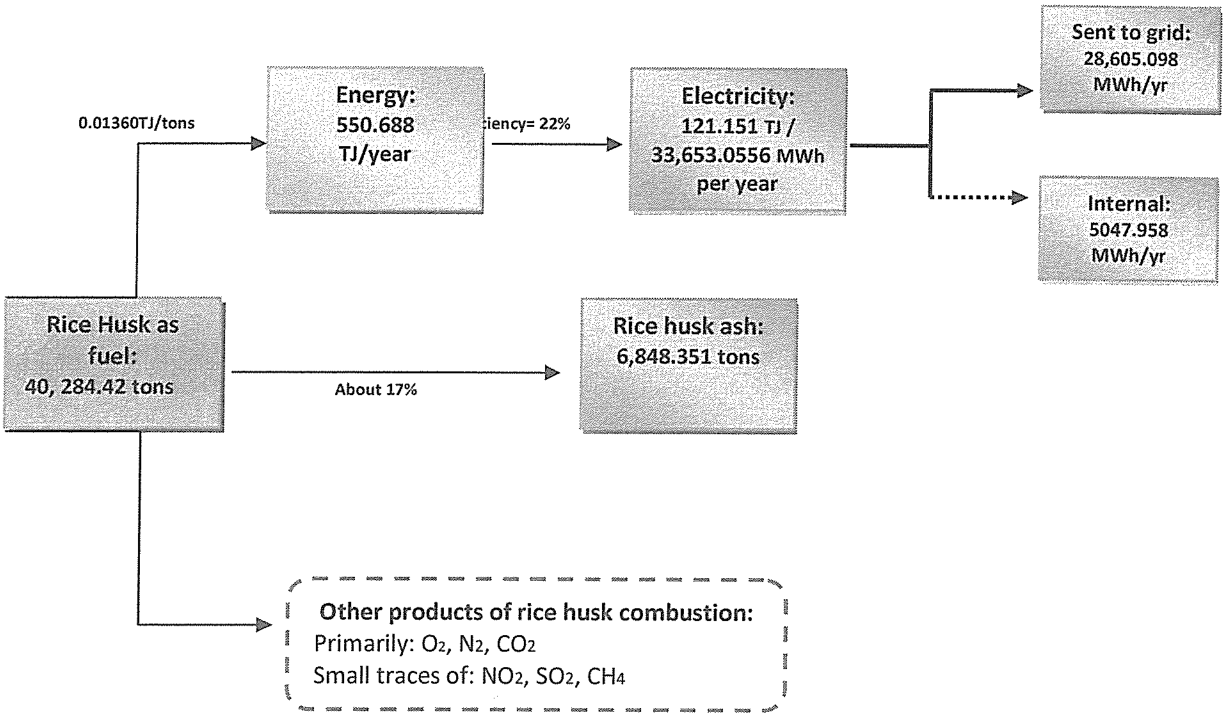


Figure 15 - Theoretical Electrical Output

CHAPTER 6-
FINANCIAL PERSPECTIVE & CLEAN DEVELOPMENT MECHANISM

The following section examines the feasibility of implementing a cogeneration system by analysing the general costs and potential revenue streams. It also considers the possibility of earning carbon credits under the Kyoto Protocol, more specifically, the Clean Development Mechanism- which is specifically designed to assist developing nations implement projects such as this.

System Costs & Related Costs

1) Equipment Costs

Because we do not know specifically what FBC system, or equipment manufacturer, will be used in the project design; the equipment costs will have to be estimated. According to the United Nations Environmental Programme (UNEP), as a general rule, "the capital cost is approximately US 300,000 per MW…This includes the FBC boiler, turbine, and all other accessories…This capital cost is somewhat high for the small and medium enterprises to invest, more so in the absence of government subsidies or an encouraging mechanisms" (UNEP and Energy Efficiency). One particular encouraging mechanism, the CDM, is discussed in detail below.

From this information, the estimated cost of the FBC cogeneration system is:

= (3.842 MWe) * (USD $300,000)
= USD $1,152,600

2) Procurement and Transportation Costs

A major concern when using the rice husk as biomass fuel is transportation. This is due to its high bulk density, which, consequently, "results in lower tonnage per vehicle" when transporting it to the central facility (UNEP and Energy Efficiency); and this in turn, will require more loading trips, and ultimately higher transportation costs. Costs associated with transportation include: transport fuel; and loading and unloading costs.

According to a study done in India, transportation costs for rice husk include (UNEP and Energy Efficiency):

Rice husk procurement: USD $20/per ton

Transportation costs: USD $10/per ton

While transportation prices vary from one project to another- mainly due fluctuating fuel costs- the above estimates provide project developers with a reliable reference.

Therefore, the estimated transportation costs are:

Rice Husk = 40, 284.42 tons of rice husk/year

Procurement costs: (USD $20/per ton) * (40, 284.42 tons)
Procurement costs: USD $805,688.40/year

Transportation costs: (USD $10/per ton) * (40, 284.42 tons)
Transportation costs: USD $402,844.20/year

Therefore, the total transportation cost is:

= (USD $805,688.40) + (USD $402,844.20)
= USD $1,208,532.60 /year

3) Maintenance Costs

An important financial consideration when implementing a bioconversion system is the annual operating cost, i.e. maintenance and labour costs. According to a report issued by the PREGA National Technical Experts from Institute of Energy, "annual maintenance costs are assumed at 3% of the total equipment cost" (PREGA , 2004). As for labour costs, a regional analysis will need to be conducted in order to determine the local wage rates for various job positions; and therefore, labour costs are not considered.

Equipment costs= USD $1,152,600

Maintenance cost= (USD $1,152,600) * (3%)

Maintenance cost= USD 34,578.00/year

Apart from the foregoing costs, project developers need to consider the following additional expenses: land cost (buying/renting); site preparation cost; tools and spare parts costs; grid connection cost; bank fees and/or loans; training cost; insurance during construction cost. Such costs are project specific, which means they vary considerably from one location to the next; and thus they cannot be generalized. Once these costs are obtained, they can be added to list above to give a more accurate projection of the total system costs.

Revenue from Electricity Production

1) Electricity Revenue

According to 'Regulacion No. CONELEC – 009/06', the profit for selling electricity to the national grid from a biomass source is USD 0.0967 /kWh (see Appendix B). With this information in hand, we can determine the profit from the electricity production.

Net Energy Production of the Co-gen System/year: 28,605.098 MWh

1,000 kWh = 1 MWh

Therefore:

28,605.098MWh = 28,605,098.00 kWh

The profit for selling electricity to the national grid= 9.67centsUSD/kWh

Profit= (9.67cUSD/kWh) * (28,605,098.00 kWh)

Profit= 276,611,297.7cUSD/year

Profit= (276,611,297.7cUSD) / (100c/dollar)
Profit= USD $2,766,112.98/year

2) Potential Revenue from Rice Husk Ash

As described in chapter 3, rice husk ash is a by-product of the combustion process, and because of its physical properties, it can be used in a variety of industrial applications. While rice husk ash is not currently used in Ecuador, a similar study suggests that "a modest estimate of the profit from ash sale is about 50 US$ (USD or US$, at the start or at the end? - be consistent throughout) per ton" (PREGA , 2004). Using this estimate, we can determine the potential profit from the ash.

Rice husk ash= 6,848.351 tons/year (from chapter 5)

Profit from ash sale= (6,848.351 tons) * (USD $50/ton)
Profit from ash sale= USD $342,417.55/year

Clean Development Mechanism

The Kyoto Protocol was established in December 1997 as an international response to climate change concerns. Kyoto was officially put into effect February 16, 2005, and has been ratified by 141 countries (CBC News, 2007), with the goal of reducing GHG emissions below 1990 levels. GHGs (namely: Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_20)) are the main contributors to the *Green House Gas effect*, which causes an increase in the earth's temperature. The Kyoto Protocol contains legally binding emission targets for Annex 1 countries (developed nations) for the post-2000 period, along with "measures to assess performance and progress...and Countries that fail to meet their emissions targets by the end of the first commitment period (2012) must make up the difference plus a penalty of 30 per cent in the second commitment period...Their ability to sell credits under emissions trading will also be suspended" (CBC News, 2007). The Kyoto Protocol is administered by the United Nations Framework Convention on Climate Change (UNFCCC), which uses three mechanisms to achieve emission targets: (1) Emissions trading, (2) Joint implementation, (3) Clean Development Mechanism (CDM).

The "CDM is a mechanism that allows an industrialized nation listed in Annex I of the UNFCCC to buy emission reductions which arise from sustainable development projects that are in non-Annex I (developing) nations...The carbon credits that are generated by a CDM project are termed CERs (Carbon Emission Reductions), expressed in tonnes of CO_2 equivalent (tCO_2e)" (McLaughlin, 2010). The CDM process is depicted below in figure 21. According to the UNFCCC, there is a total of 2,396 registered CDM projects; and 439,220,261 issued CER's (UNFCCC, 2010). Since each CER represents one tonne of CO_2 equivalent, roughly 439 thousand tCO_2e emissions have been avoided- clearly illustrating the effectiveness of the CDM to help achieve Kyoto Protocol targets.

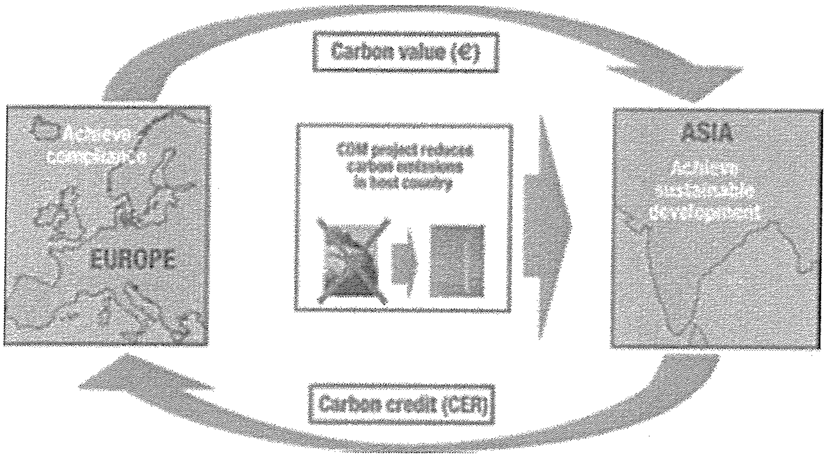


Figure 16 - CDM Flow Diagram (McLaughlin, Can CDM help CHP projects develop?, 2010)

Biomass energy plays an important role in the CDM: not only are there 277 officially registered projects, but of all the CDM projects currently in the pipeline, 13.6% are biomass energy (UNEP Risoe, 2010). As discussed in chapter 3, CDM projects using rice husk are already in place- even in neighbouring South American countries, like Brazil. These existing projects make it easier to develop rice husk projects in Ecuador because their approved CDM methodologies can be used as a guide. Moreover, CDM methodologies are publicly available on the UNFCCC website.

Ecuador currently has twelve registered CDM projects, with another eight pending validation; which means that the government has the necessary departments in place to develop CDM's (UNEP, 2008). Government support is an important consideration for project developers.

The cogeneration project proposed in this study can earn carbon credits through the following *accepted CDM activities*:

"Type I, Category I.C. Thermal energy for the user with or without electricity. The project activity will displace the use of fossil fuels in the electric connected system and cause GHG emission reductions through this" (UNFCCC - Galofer).

"Type III, Category III.E. Avoidance of methane production from biomass decay through controlled combustion. This will avoid the emissions from fermentation of the rice husks" (UNFCCC - Galofer).

The following CER calculations are based on the methodology used in the A.T. Biopower Rice Husk CDM Project (UNFCCC - A.T. Biopower Rice Husk Power Project).

1) Carbon Credits from Methane Avoidance

Using rice husk as bioenergy not only leads to electricity generation, but it also manages the environmental concerns of current disposal practices: (1) burning the husk in open-air; and (2) letting the husk decay naturally; and both cases cause GHG emissions. Because no accurate data exists on which practice is more common in Daule, we will assume that all the husk is burned in open-air. This is because when the husk is left to decay, "it will release more of a carbon content as methane than when it is burned in the open air" (UNFCCC - A.T. Biopower Rice Husk Power Project); and because methane has a higher global warming potential, it generates a greater amount of CER's. Therefore, assuming that all the husk is burned in open-air maintains a conservative estimate.

-Step 1:

Rice husk used as fuel tons/year * carbon content of rice husk = Annual Carbon Released (tons/year)

Rice Husk= 40,284.42 tons/year

Caron Content= 37.13% (from chapter 3)
40,284.42 tons/year * 37.13% = 14,957.605 tons of carbon released/year

-Step 2:

Carbon released per year * **Carbon released as CH_4 in open-air burning (1)** * **Conversion Factor: Molecular weight CH_4 vs. Carbon (2)** * **Global warming potential of CH_4 (3)** = **Annual CH_4 released (tons CO_2 equivalent**

Therefore:

(14,957.605 tons) * (0.5%) * (16/12) * 21 = the annual CH_4 released in tCO_2e
= 209,406.47 tCO_2e

(1) Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual, Table 4-16 (UNFCCC - A.T. Biopower Rice Husk Power Project)
(2) Molecular Weight: Carbon (C) =12, Hydrogen (H) = 1
CH_4= (12) + (4 *1)
CH_4= 16
(3) Taken from current IPCC guidelines (UNFCCC - A.T. Biopower Rice Husk Power Project)

2) Carbon Credits from Displacing Fossil Fuels from the National Grid

The World Bank's EM Model will be used to estimate Carbon Emission Factors (CEFs) for the various types of electricity generation within the national grid. The CEF (see table 2) is the weighted average for each type of fuel of power generation (UNFCCC - A.T. Biopower Rice Husk Power Project).

Type	CEF in $KgCO_2/kWh$
Hydro	0.000
Natural Gas	0.610
Diesel Oil	0.717
Oil	0.613
Renewables	0.000

Table 8- CEF for various types of fuels (UNFCCC - A.T. Biopower Rice Husk Power Project)

Ecuador's electricity matrix is as follows (from chapter 1):

Hydroelectric: 43%
Thermal (primarily diesel): 34%
Gas: 12%
Import (oil): 10%
Other (solar and biomass): 1%

-Step 1:

(Weight of generation type in national grid (%)) * (CEF for every generation type in the national grid ($kgCO_2/kWh$))

Type of generation	(1) Weight of grid	(2) CEF (tCO_{2e}/MWh)	(1) * (2)
Hydroelectric	43%	0.000	0.000
Natural Gas	12%	0.610	0.073
Diesel Oil	34%	0.717	0.244
Oil	10%	0.613	0.061
Other	1%	0.000	0.000
Total Grid CEF for 2007			**0.378**

Table 9- CEF Factor for Ecuador National's Grid

-Step 2: Grid-based Emissions

Known variables:

(a) Total grid CEF = 0.378 tCO_2e/MWh

(b) In chapter five we determined that this project will send 28,605.098 MWh/yr to the national grid

Therefore, the amount of GHG emissions displaced from the grid (in 2007):

tCO_2e = (Annual Grid electricity replaced by the project (MWh)) * (Annual Grid CEF's)
= (28,605.098 MWh/yr) * (0.378 tCO_2e/MWh)
= 10,812.727 tCO_2e

Discussion: As discussed in chapter 1, the Ecuadorian government is actively expanding the use of hydropower with the intent of making it 86% of the total electricity generation by 2020. This implies that carbon credits derived from displacing fossil fuels from the national grid will diminish considerably over the next thirteen years- perhaps as early as 2013. Therefore, calculating grid based CERs will have to done on a year-to-year basis to adapt to the changing energy matrix. In other words, because grid based CERs cannot be accurately forecasted, it will not be taken into account in the financial summary below.

3) GHG Emissions from Rice Husk Combustion

Bioenergy from controlled combustion does release small quantities of GHGs that need to be considered when determining CER credits. The Intergovernmental Panel on Climate Change (IPCCC) provides a default factor of 30kg/TJ for estimating methane emissions resulting from combustion in energy industries (UNFCCC - A.T. Biopower Rice Husk Power Project).

Default factor for methane= 30kg/TJ

Rice husk quantity= 40, 284.42 tons of rice husk/year

Calorific value of rice husk = 13, 607 J/kg = 0.01360 TJ/tons

Energy= (40, 284.42 tons) * (0.01360TJ/tons)
Energy= 550.688 TJ/year

Therefore:

= (550.688 TJ/year) * (30kg/TJ) * (1 ton/1,000 kg)
=16.521 tons CH_4/year

Global Warming Potential of methane= 21

= (16.521 tons CH_4/year) * 21
= 346.94 tCO_2e

4) Carbon Credits Revenue

Because CDMs are a market based system, CER prices fluctuate from one year to the next. Factors that influence the CER price for developing nations include: project risk, host Country, and overall economic conditions. According to the IDEAcarbon pCER Index, "forward prices in the primary market currently range from €7.50 to €10.00 for a flow of CERs delivered across 2009-2012" (Carbon Positive, 2009). Assuming that this project will be developed within that period, the bottom price of €7.50 will be used to estimate the value of the carbon credits.

CERs from Methane Avoidance = 209,406.47 tCO_2e

CER deductions from Combustion Emissions = (346.94 tCO_2e)

Therefore:

Total tCO_2e = (209, 406.47) – (346.94)
Total tCO_2e = 209, 059.53

-Total Revenue from CERs:
Price of CERs = €7.50
As September 27, 2010: €7.50 (Euro) = 10.11 USD (XE, 2010).
= (Total tCO_2e) * (price of CER)
= (209, 059.53 tCO_2e) * (10.11 USD)

= USD 2,113,591.85/year

It is important to note that CER deductions from rice husk transport are not accounted for because specific details, like the exact distance between rice mills and the central facility, are currently not available. Moreover, potential CER credits from displacing fossil fuels from cement productions (using rice ash) are also not considered, as more information from the cement industry in Ecuador is needed.

Financial Summary & Discussion

A summary of the aforementioned costs and revenues are provided in the table 4. While the numbers appear overwhelmingly favourable, we must keep in mind that some important costs are excluded, e.g. land and labour expenses. The summary is simply meant to give project developers an overview of the general financials associated with developing a biomass cogeneration project; and additional costs, like land, can be added to the summary once they are determined. Furthermore, if a market for rice husk ash can be established, it represents a promising additional stream of revenue, as shown in the table. Also, it should be noted that the revenues and costs were calculated using conservative estimates, for example CER price; which means that project developers can probably expect higher returns.

	Financial Summary
Costs (USD):	
Equipment purchase	$1,152,600.00
Procurement & transport costs	$1,208,532.60
Maintenance costs	$34,578.00
Total Costs	**$2,395,710.60**
Revenue (USD):	
Electricity Sales	$2,766,112.98
CER Revenue	$2,113,591.85
Total Revenue (USD)	**$4,879,704.83**
Potential ash sales	$342,417.55
Revised Total Revenue	**$5,222,122.38**

Table 10- Financial Summary for Biomass Cogeneration

CHAPTER 7-
BUSINESS STRATEGY AND STAKEHOLDER ANALYSIS

Stakeholder Analysis

The benefits of stakeholder involvement are significant. Benefits include: access to local and traditional knowledge; enhanced legitimacy of proposed projects; helps avoid costly and time-consuming litigation; and ensure that projects meet the needs of the public in terms of both purpose and design (Hanna, 2009). Failure to identify key stakeholders can be costly, as seen in the Brent Spar incident in 1994, where Royal Dutch's failure to engage dialogue with Greenpeace had serious impacts on their operations (Stanford University, 1995). That being said, this chapter will identify the key stakeholders that are involved, or potentially involved, in the development of rice husk cogeneration projects.

Before continuing, we must first make the distinction between primary and secondary stakeholders. "Primary stakeholders are those essential to the survival of a company; therefore, continual interaction with them is important" (Ronald Mitchell, 1997). "Secondary stakeholders are those who are affected by, or can affect, an organization's operations, but are not involved in regular transactions with the organization" (Ronald Mitchell, 1997). Secondary stakeholders are often overlooked as they are not essential to the organizations survival, but doing so is risky because these stakeholders can become primary stakeholders, and their influence can impact operations.

Introducing cogeneration technology to the rice industry in Ecuador is certainly no easy task. One important consideration is the *procurement* phase of the value chain from Michael E. Porter's article *Competitive Advantage: Creating and Sustaining Superior Performance* (see Figure-1 below). This implies acquiring the following: co-gen equipment (i.e. FBC steam boilers); sufficient rice husk biomass from various rice millers (biomass input); the service of professionals who can install the new equipment; and establishing connection to the national electricity grid. The task is then to determine who are the primary and secondary stakeholders associated with this phase of the value chain.

The following table outlines the relevant stakeholders. For the aforementioned reasons, each stakeholder group should be engaged early on in the project design process.

Primary Stakeholders	Secondary Stakeholders
• Rice Mill Operators: To obtain sufficient rice husk (biomass input) • Suppliers of co-gen equipment • Companies capable of installing co-gen equipment • Truck companies- They are needed to transport the rice husk to the central facility • Energy utilities- They need to provide access to the distribution network • Government: Import taxes may cause financial problems in acquiring foreign cogeneration equipment	• Farmers who currently use the rice husk as flooring for livestock. They might oppose the alternate use of the husk • Municipalities of co-gen projects: Citizens may oppose commercial transport of rice husk for various reasons, e.g. pollution, noise,traffic issues etc. • Rice Association: Their inclusion may encourage rice millers to provide rice husk

Table 11- Relevant Stakeholders for Cogeneration Projects

Business Strategy

The intent behind this study is not simply to propose a theoretical model for rice husk cogeneration. The hope is to provide a realistic scenario from which the rice industry can benefit; and, doing so will necessitate developing a business strategy for project developers. Therefore, this section will focus on the critical steps toward strategy formation by applying the SWOT model proposed by authors Learned, Christensen, Andrews, and Guth, of *The Design School.* This model of strategy will be used to evaluate the *strengths & weaknesses* (internal appraisal of the rice millers), and the *threats & opportunities* (external appraisal of the environment in which rice millers operate) (Mintzberg, Ahlstrand, & Lampel, 2005). More specifically, the SWOT will reveal if rice husk cogeneration is a viable option for rice millers by establishing whether there is *fit* between the aforementioned internal capabilities, and external possibilities. In sum, given that rice husk cogeneration is new endeavor in Ecuador, a SWOT analysis will be a very useful starting point.

Applying SWOT to Rice Husk Cogeneration

1) External Analysis

We begin the SWOT analysis with the external environment, that is, *the threats* and *opportunities*. It is at this step that opportunities for profit and growth (opportunities), and the potential threats to rice husk cogeneration projects (threats) are uncovered

(QuickMBA). According to the *Design School*, this entails a six-step environmental variables checklist (Mintzberg, Ahlstrand, & Lampel, 2005):

1) *Societal Changes:* This refers to "changing customer preferences", and "population trends"; which may impact distribution, and/or product demand and design (Mintzberg, Ahlstrand, & Lampel, 2005). In the case of rice husk cogeneration, rice is a stable for the country; in fact, according to the Ministry of Agriculture, rice consumption is steadily on the rise (MAGAP, 2008). That being said, we can safely assume product demand in not a concern. This is important because in order for rice husk co-gen to be economical, there needs to be a constant supply of the husk; and as the husk only represents 20% of the actual rice paddy, steady input is essential.

2) *Governmental Change:* This implies any new legislation impacting product costs; or new enforcement priorities impacting investments, products or demand. According to the CONELEC- the national body responsible for enforcing electricity policies- determining the price per kilowatt hour (kWh) for private energy projects is a complicated matter. In other words, rice millers who install co-gen equipment to produce electricity will have trouble obtaining the price per/kW for selling electricity back to the national grid. This is troublesome because the rate is needed to calculate pay-back periods and internal rate of returns on projects. CONELEC explained that the current government administration has cancelled the previous buyback (price per/kWh) rates; and that now rates need to be negotiated- which creates uncertainty for project

developers. The price per/kWh referenced in chapter 6, was obtained through the Ministry of Renewables in Ecuador; and is therefore not the official rate.

3) *Economic Changes:* This refers to the typical economic indicators: interest rates, exchange rates, and real personal income changes. Interest rates need to be considered because rice husk cogeneration projects are capital intensive, and may cost in millions of dollars as shown earlier. If rice millers are unable to get favourable lending rates, projects may be unattractive. Further information (e.g. local bank rates) is required to make reasonable assumptions or conclusions on the matter.

4) *Competitive Advantage:* This implies the following: the adoption of new technologies, new competitors, price changes, and new products. Given that the rice sector in Ecuador is already highly competitive, the arrival of new competitors is unlikely; however, where change is most likely to occur is the adoption of new technologies. This assumption is derived from the fact that nearby countries, like Brazil and Uruguay, are making significant technological changes with promising results. These co-gen projects are using state-of-the-art equipment, such as traveling grate boilers, due to higher operational efficiencies and outputs. The rice sector in Ecuador is starting to take notice- this according former Minister of Agriculture Walter Poveda Ricaurte; and those millers who invest early in co-gen technologies, will gain a competitive edge.

5) *Supplier Changes*: Suppliers are an important consideration for any industry. As industries evolve, the number of suppliers may change, along with the supply of certain

products and services. As indicated above, co-gen projects will require new technologies. Moreover, this equipment currently must be imported from Europe, as the number of these suppliers is limited. Consequently, rice millers considering exploring co-gen projects, should start by establishing a positive relationship with suppliers, as their options for importing equipment are few.

6) *Market Changes*: If rice milling companies implement co-gen technology, they are in effect opening up new markets to their business; in other words, where before they were solely rice producers, they would now be utility providers (of electricity). This represents a sizable opportunity for millers as the rice industry is highly competitive, and gaining new market share is difficult. Therefore, using the waste from current operations to gain additional income (through selling electricity) is a market worth exploring.

2) Internal Analysis

It is here that we examine the internal environment of the rice mills; more specifically, with the application of co-gen technology. We focus on the *strengths* and *weaknesses*, which means: analyzing the resources and capabilities of rice operators; and, conversely, the absence of certain, necessary strengths (QuickMBA). This will be determined by using the *strength and weakness checklist*, borrowed from the *Design School* (Mintzberg, Ahlstrand, & Lampel, 2005):

1) *Research and Development (R&D):* The rice industry in Ecuador is characterized by the following: it is highly concentrated, whereby most operators are located in the province of Guayas; and there are many companies of the same size, meaning that

there are no market leaders. How does this apply to *R&D*? Well because most firms are medium sized, they lack the financial capital to invest in new technologies. And because there are no market leaders, most firms simply follow a pathway dependency, where they won't change unless they have to, or unless others set a positive example. Moreover, mills are often owned by the same family for several generations, and changing the culture (e.g. investing in newer technologies) is not an easy task- especially if business is already profitable.

2) *Management Information Systems:* Most rice operators lack quality, updated information on new technologies and innovations in the industry. In fact, most of operators contacted for this project were unaware of CDM projects using rice husk, and of the many technological advancements in the industry. This gap of information slows the progress within individual rice mills, and more importantly, the motivation for owners to adopt or take advantage of emerging industry innovations.

3) *Operations:* Typical operations inside rice mills can be described as rudimentary; mainly due to the older equipment. This, however, may be seen as an opportunity to stimulate the interest of owners in co-gen. For example, newer equipment can improve energy efficiency, which cut costs; and also improves production capacity, which increases profit. On the flip side, installing new co-gen technology does require a minimum amount of rice husk input. This is problematic on two fronts: (1) the average mill is medium sized, meaning that there is probably insufficient rice production for co-gen; and (2) rice production is seasonal, therefore rice husk input will drop-off during

certain periods of the year, and in turn, reduces the electricity production of the equipment. To resolve these issues, owners will have to coordinate with other millers to obtain sufficient rice husk throughout the year; which greatly increases the complexity of their operations.

4) *Finance:* As mentioned earlier, the rice industry is highly competitive and is comprised of many medium-sized owners. Because of this, businesses operate on modest profit margins, and, as a result, have low financial and operating leverage. This may prove to be a major obstacle in implementing costly technology that does not guarantee short-term financial returns. In other words, the risk associated with such a project may be unrealistic or unsettling for the rice operators.

5) *Human Resource (HR) and Management Team:* Here we examine the managerial capabilities and expertise of the rice mill workforce, in relation to rice husk co-gen. The implementation of co-gen technology is no simple task. Given that the technology is new and foreign- as it needs to be imported and is currently not being used in the industry- specialized workers will need to be recruited. As most mills have limited *HR* resources, finding adequate engineers may (or may not be) a problem. Also, one can assume that these workers will come at a higher price tag, which may increase costs of the project. Furthermore, in order for this type of project to be initiated, it will require that rice operator's brake from the current industry pathway dependencies and try something new. At the organizational level, we need to wonder if upper level managers possess

the entrepreneurial spirit to take on such an endeavour. Finding "willing" owners in an industry that has been static for many decades may be difficult.

Discussion

Looking at figure 22- the *Basic Design School Model-* we can see that the external and internal appraisal form the initial steps in strategy creation. This provides a solid starting point in determining the key success factors and distinctive competences needed for rice millers, or private investors, to form a viable business strategy. In reviewing the SWOT analysis, we can infer that the external conditions appear more favourable than internal ones for establishing rice husk co-gen projects. As an industry, rice millers can gain market advantages by using newer technologies, and gain additional profit by selling electricity; but internally, obtaining financing and pathway dependencies can be major obstacles.

It is important to note that the above SWOT analysis is only preliminary; meaning that important questions will necessitate further research. For example, will current Government policies hinder the financial viability of co-gen projects? Will obtaining credit to finance projects be a major roadblock? Also, can rice operators be persuaded to take on radical changes in their operations? While these questions are beyond the scope of this study, they will be important considerations for the actual project. Designing a realistic scenario for rice husk co-gen requires a reliable business strategy, which stems from a thorough SWOT analysis.

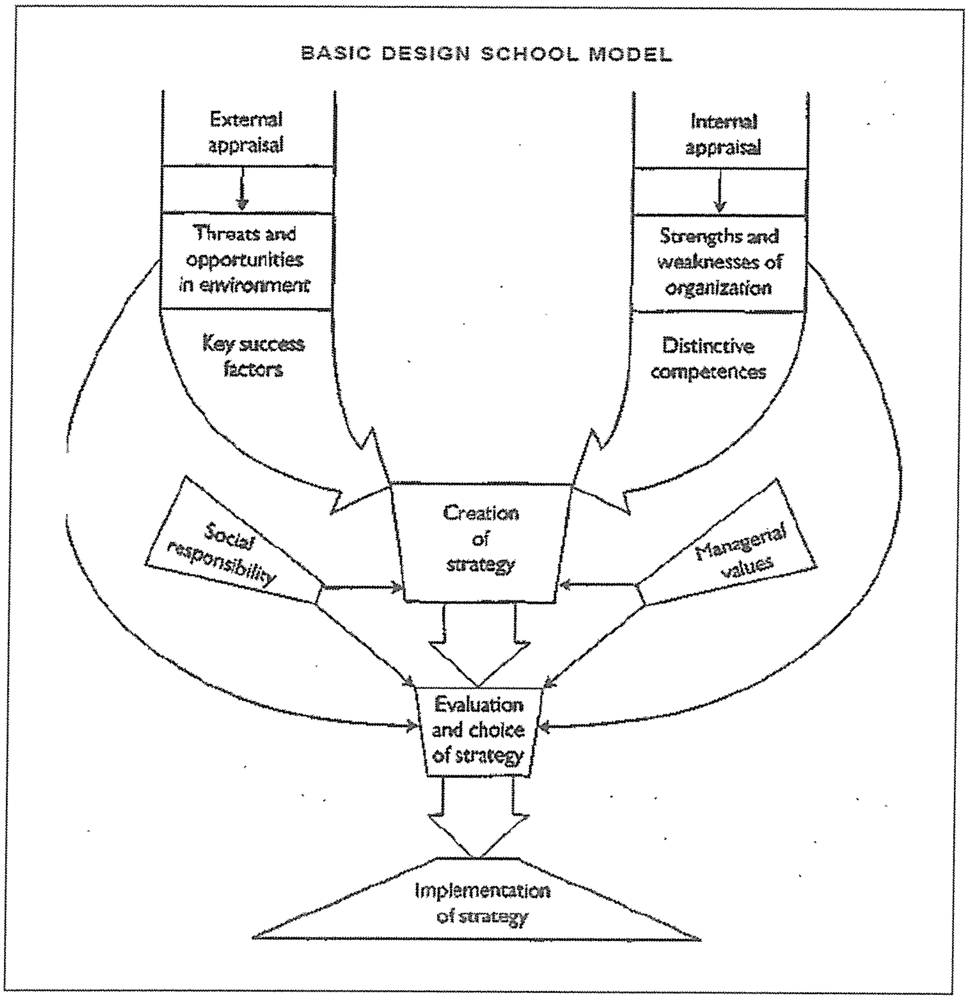


Figure 19- Strategy Formation Model (Mintzberg, Ahlstrand, & Lampel, 2005)

CHAPTER 8-
SOCIOECONOMIC & TECHNOLOGICAL BENEFITS

Ecuador's economy is predominantly petroleum based: in 2007, crude and refined oil products accounted for roughly 58% of total export revenues (TDS, 2009). This heavy reliance on oil, however, has caused financial hardship in recent years. The current global recession has weakened oil prices and, consequently, Ecuador's commercial activities (randstad, 2009). According to recent economic indicators, roughly 38% of the country currently lives below the poverty line (Index Mundi, 2010); and unemployment has increased to 9.1% (randstad, 2009).

To make matters worse, Ecuador has developed an unfavourable reputation at the international level. In 2008, President Correa halted all payments to foreign creditors, bondholders, and multilateral lenders; and proclaimed that the country is in default (Kueffner, 2008). Ecuador has now accumulated a debt of about ten billion dollars, which it is unable to repay (Kueffner, 2008). Moreover, in 2007, President Correa also made a unilateral decision to change existing contracts with oil companies, whereby the government would suddenly collect windfall oil profits of 99%- a drastic increase from the original agreed amount of 50% (Monahan, 2007). This erratic behaviour by the government is pushing away the foreign investments needed to fund commercial projects- like rice husk cogeneration.

While a single cogeneration plant is not going to drastically improve the socioeconomic conditions of the country, a combination of such projects can stimulate local economies and develop new industries. The next section outlines the expected social and technological benefits from bioenergy projects like rice husk.

Socioeconomic and Technological Benefits

- Job Creation: In the Philippines, a 1MW rice husk project led to the creation of 43 jobs: 25 jobs during the construction phase; and 18 permanent jobs to run the cogeneration plant (UNFCCC, 2006). Given that the plant proposed in this report is 4MW, we can expect the total number of jobs to increase. Moreover, as in the La Suerte project (from the Philippines), some of the permanent jobs require highly specialized professionals, like engineers (UNFCCC, 2006). Hiring such workers leads to a transfer-of-knowledge which can help to modernize the stagnant rice industry.

- Local Opportunities: The development of a cogeneration plant will also create indirect employment opportunities- known as the *trickle-down-effect*. Local businesses can supply construction materials; rental, purchase and/or fabrication of equipment and tools; transportation for biomass etc (UNFCCC, 2006). For example, at the ATB rice husk project in Thailand, local economic activity increased due to the transporting, housing, and catering needs of the CDM rice husk project (UNFCCC - A.T. Biopower Rice Husk Power Project).

- Cogeneration plants also monetize the energy potential of the rice husk that is otherwise lost to landfill disposal or livestock flooring. This brings "additional income to various players in the biomass supply chain (farmers, traders, agro processing industries such rice mills etc)" (UNEP and Energy Efficiency). Furthermore, as the demand for rice husk increases, so will its monetary value; consequently, the price of rice paddy will also increase, which benefits local farmers (UNFCCC - A.T. Biopower Rice Husk Power Project).

- Local Environment: When rice husk is used as a fuel, it reduces the environmental issues (i.e. air, water, and soil quality) associated with poor disposal practices. As previously discussed, rice husk is typically dumped in open fields where it can blow away into streets, water streams; or it can be left to decay naturally –which causes harmful methane emissions. The proposed cogeneration avoids these issues by collecting the rice husk from participating mills, and transforming it into energy. This, in turn, promotes sustainable practices in the agricultural industry (UNFCCC, 2006).

- As discussed in chapter one, when Ecuador faces energy shortages it must import deficits from neighbouring countries at higher costs. By developing decentralized energy projects in various regions around the country- like rice husk and bagasse cogeneration- it not only increases Ecuador's energy independence, but also helps to avoid paying a premium for electricity. Furthermore, the imported oil used to cover electricity shortages is very expensive and heavily subsidized; which means the financial burden is passed on to the public. A far more efficient use of this money would be to invest in renewable energy projects.

- Technology Transfer: Seeing as cogeneration equipment needs be imported from abroad (i.e. Europe or Japan), it leads to a transfer-of-technology to the Ecuadorian rice industry. This represents an opportunity for aging rice mills to update their facilities, and increase operational efficiency. Also, if the proposed rice husk project proves successful, it may be an impetus for technology development in other agro and woody based industries across the country (UNEP and Energy Efficiency).

- Farming technology: Implementing bioenergy projects also positively impacts farming. According to the United Nations Environment Program, when biomass is sold as fuel to mills, it introduces modern farm level machinery to facilitate, and improve, collection and baling processes (UNEP and Energy Efficiency).

CHAPTER 9-
CONCLUSION & DISCUSSION

Concluding Thoughts

Ecuador's national energy strategy to double the installed capacity of hydroelectric power appears to be a positive step in reducing its dependence on fossil fuels. Fossil fuels, more specifically oil derivatives, are a heavy financial burden for the country: in 2010 alone, subsidies will surpass the 3 billion USD mark. Making matters worse is the fact that Ecuador lacks the refining capacity to meet energy demands, and as a result, must import oil from neighbouring countries at a steep premium. This is uneconomical for a country with international debts it cannot repay. Consequently, the government has decided to invest in major hydro projects like the 1,500 MW Coca-Codo-Sinclair plant. While hydro power is a cleaner form of energy, with a cheaper overall price tag than oil, it is certainly not without its problems. In 2009, a severe dry spell crippled production from the country's major hydro plants, causing energy shortages nationwide; along with energy rationing in both the commercial and residential sectors. This clearly illustrates the need for a more balance energy portfolio.

For the foregoing reasons, this study examined the potential of decentralized energy in Ecuador. Bioenergy was selected because it is consistent with the country's mandate to expand the use of renewable technology; and also because agriculture is still a major component of the overall economy, meaning that there is a considerable amount of biomass readily available. Biomass, which is the input fuel in the bioenergy process, is certainly not a new technology. For example, in Sweden, biomass generates 32% of all energy, and has now surpassed oil to become the country's primary fuel source (Renewable Energy World, 2010). Because of the widespread use of biomass, its bioconversion technology is considered both reliable and economical.

Because rice is the second largest of any crop-type in Ecuador, its residue rice husk is plentiful and perennial; and with a calorific value of 13,607 J/kg, it is also a good input fuel. While many technologies exist to convert biomass to bioenergy, direct combustion FBC boilers is the best fit for the country's rice industry for the following reasons: (1) biomass flexibility; (2) pollution control; (3) ease of operation and maintenance; and (4) high efficiency. Firstly, having a system that accepts various types of biomass provides insurance when rice production decreases. Secondly, because FBC boilers produce lower levels of harmful pollutants, it assures a cleaner environment. Thirdly, Ecuador's rice industry is characterized by medium-sized mills that have undergone little change in many years; therefore the easy start-up and shut-down of FBC boilers make it a good choice. Lastly, the high combustion efficiency of the system yields greater electricity output, and thus greater long term profits for project operators.

This analysis also concluded that the county of Daule is the best location for setting up a cogeneration facility. Daule, which is located in the province of Guayas, has consistently yielded the highest rice production rates over the past decade. However, because the county is composed mainly of small to medium-sized mills, the biomass fuel (rice husk) from individual mills is insufficient and uneconomical to run FBC boilers.

As a result, a community approach is best suited for Daule, whereby the rice husk is collected from various mills and transported to a central processing facility. A rice husk plant in Uruguay - which faced the same challenges - successfully set-up a plant using a similar design, and now generates 10MW of electricity (UNFCCC - Galofer).

Past examples show that project success greatly improves when both primary and secondary stakeholders are engaged early on in the implementation process (Stanford University, 1995). For example, primary stakeholders like rice mills and trucking companies, are essential in obtaining and transporting biomass to the central facility; and without their participation, the project cannot move forward. In sum, to avoid major obstacles, project developers should gain the support of all relevant stakeholders identified in this report.

Using conservative estimates, the available rice husk in Daule was calculated at 40,284.42 tons/year; which equates to a total calorific value of 550.688 TJ/year. Also, after estimating the efficiency of the FBC boiler, and accounting for the energy needs of the system equipment, the net electricity output sent to national grid will be 28,605.098 MWh, or 3.842 MWe. The general costs of the FBC system (i.e. FBC equipment; procurement and transportation of biomass; and maintenance costs) amount to $2.4 million USD; however, it should be noted that labour and land costs were not included. Moreover, the estimated revenue from electricity sales totalled $2.8 million USDUSD/year. If project developers can sell carbon credits resulting from offsetting Green House Gases under the Kyoto Protocol; revenue increases to $4.9 million USD.

Aside from electricity generation, developing bioenergy projects has other positive impacts, namely social, technological and environmental. The proposed 4MWe plant is expected to directly create over 43 jobs; and as shown in similar projects, stimulate the local economy through the trickle-down-effect. Moreover, the implementation of an FBC boiler leads to a transfer-of-knowledge and transfer-of-technology, which will help to modernize the Ecuadorian rice industry. Also, using rice husk as fuel increases the value of the agro-waste; and, in turn, creates additional income for rice farmers and others in the biomass supply chain. Lastly, using rice husk as biofuel manages the current environmental issues associated with disposal: the harmful GHG emissions resulting from husk decay; and errant rice husk due to poor disposal practices by mills and farmers.

The objective of this study was to explore the potential of rice husk cogeneration in Ecuador. While the proposed model may be theoretical in nature, it does provide prospective developers with a comprehensive overview of the major challenges and potential benefits in developing a bioenergy project using rice husk.

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APPENDIX A:
Rice Mills in Ecuador

MINISTERIO DE AGRICULTURA, GANADERIA, ACUACULTURA Y PESCA
DIRECCION PROVINCIAL AGROPECUARIA DEL GUAYAS
DIAGNOSTICO DE LAS PILADORAS DE ARROZ UBICADAS EN EL CANTON **DAULE**

N°	NOMBRE PILADORA	PROPIETARIO	CANTON
1	AGRO. IND. ARROCERA EL JIGUAL	AGRONIND. ARROCERA EL JIGUAL	DAULE
2	SAN VICENTE	VICENTE SESME CANALES	DAULE
3	LIBERTAD	HDROS DE ALEJANDRO VERA QUINTO	DAULE
4	ALVARADO	IVAN ALVARADO ALVARADO	DAULE
5	ROSA MARIA	MARLON RUIZ FUENTES	DAULE
6	EL EDEN	EDEN AROCA RONQUILLO	DAULE
7	DON HUMBERTO	HUMBERO CAMBA BARZOLA	DAULE
8	FABRICIO	JUSTO ELIAS RONQUILLO RODRIGUEZ	DAULE
9	ANA ELVIRA	S.AL DE S.A (HERLEN RONQUILLO)	DAULE
10	LAS MARAVILLAS	JHONNY BRIONES RIVAS	DAULE
11	AMERICA	ESTEBAN BAJAÑA FUENTES	DAULE
12	LA PREFERENCIA	HUGO FAJARDO ALVARADO	DAULE
13	NARCISA	BLANCA ESPINOZA SAN LUCAS	DAULE
14	DIVINO NIÑO	JOSE FRANCO BARZOLA	DAULE
15	SAN ENRIQUE	ENRIQUE MIRANDA MARTINEZ	DAULE
16	LA PROMESA	DELIA BRIONES RUIZ	DAULE
17	CONSUELO	DOUGLAS F. BARZOLA PEÑA	DAULE
18	DOÑA LETICIA	ALFREDO PAREDES CATUTE	DAULE
19	JOSEFINA	LUIS ROBERTO CAMBA	DAULE
20	JESUS DEL GRAN PODER	DELFIN MARURI MORAN	DAULE
21	SAN ANTONIO	ANTONIO PACHAY MENDEZ	DAULE
22	ROSITA	RUFINO LEON MARTILLO	DAULE
23	SAN IGNACIO	PERFECTO LEON ARREAGA	DAULE
24	SAN CARLOS	CARLOS GENCON PALACIOS	DAULE
25	YOLANDITA	ROBERTO RONQUILLO RAMIREZ	DAULE
26	PROSEJUMA S.A	PROSEJUMA S-A- (LUIS PIANA)	DAULE
27	ROBERTO CARLOS	CARLOS PADILLA	DAULE
28	ROSITA	ROSITA RONQUILLO SANCHEZ	DAULE
29	NUEVO MILENIO	JULIO CAMPOVERDE JUMBO	DAULE
30	MARIA BELEN	SEGUNDO LOZANO LEON	DAULE
31	CAPRICHO	VICENTE RONQUILLO MENDOZA	DAULE
32	SANDRITA	EUCLIDES RIVAS VERA	DAULE
33	SAN VICENTE	HEREDEROS DE EDUARDO NAVARRETE	DAULE
34	LOS ANGELES	ANGEL FRANCISCO PILOSO MORAN	DAULE
35	SANTA RITA	AMERICA LEON LEON	DAULE
36	RICHARD	HECTOR ROMERO VILLAMAR	DAULE
37	SAN JACINTO	ROSENDO ROMERO VILLAMAR	DAULE
38	SANTA ROSA	HECTOR LARA RONQUILLO	DAULE
39	MI JESUS	PABLO VILLAMAR SILVA	DAULE

40	NARCISA	BLANCA ESPINOZA SAN LUCAS	DAULE
41	SAN PEDRO	DOLORES CONTRERAS DE ALMEIDA	DAULE
42	MARTHA VERONICA	ENRIQUE MORAN NARANJO	DAULE
43	JHONY GONZALO	TOMAS GONZALO SEGURA ALVARADO	DAULE
44	AGRICOLA BATAN S.A.	AGRICOLA BATAN S.A.	DAULE
45	VIRGEN NARCISA DE JESUS	ESPERANZA ELIZABETH MANTUANO MAN	DAULE
46	LUZ AMERICA	HERMANOS NAVARRETE BONILLA	DAULE
47	AGRICOLA RONQUILLO-HUAYAMAVE	TEODORO RONQUILLO	DAULE
48	CARMITA	CIRILO RONQUILLO	DAULE
49	CUATRO HERMANOS	OCTAVIO FITA MACIAS	DAULE
50	LINA MERCEDES	JACINTO AREVALO NARANJO	DAULE
51	LUIS ENRIQUE	ABAD VICENTE VARGAS ALVARADO	DAULE
52	ARROCERA EL REY	CARLOS VARGAS GUEVARA Y HNOS	DAULE
53	CATHERINE THALIA	ALFREDO SESME QUINTO	DAULE
54	VOLUNTAD DE DIOS	ALFREDO ANIBAL PAREDES CATUTE	DAULE
55	NAYID GRACIELA	FELIX AZAEL ALMEIDA QUINTO	DAULE
56	LORENA PATRICIA	LEON JOSE TORRES SOLORZANO	DAULE
57	CHINA	WILLIAM CHONG CHANG	DAULE
58	SAN VICENTE	VICTOR MENA PADILLA	DAULE
59	SAN VICENTE	WASHINGTON AREVALO	DAULE
60	HERMANOS CORTEZ	ANTONIO CORTEZ SALAZAR	DAULE
61	PATRICIA ALEXANDRA	GONZALO GONZALEZ TORRES	DAULE
62	ANGELITA	COLON JURADO ESPINOZA	DAULE
63	TRES HERMANOS	TOMAS NAVARRETE HERNANDEZ	DAULE
64	MARGARITA CECILIA	HONORATO Y LUIS BAJAÑA	DAULE
65	SARA PATRICIA	HILARIO MARIANO SANCHEZ VERA	DAULE
66	DIOSELINA	MEDARDO VERA QUINTO	DAULE
67	MERENGUE	EMERCIANO AVILA MEDINA-VILMA CASTR	DAULE
68	MONTE SINAI	ELIECER NARANJO	DAULE
69	TIO ADAN	WASHINGTON ERASMO GUAVILANEZ GU	DAULE
70	KATTY DEL CARMEN	GERMAN HUMBERTO MORENO MOTA	DAULE
71	TRES HERMANOS	TEOFILO ISMAEL REYES CAICEDO	DAULE
72	VOLUNTAD DE DIOS	FELICIANO MACLOVIO RONQUILLO GARC	DAULE
73	MARIA DE LOURDES	MODESTA GRACIELA GUERRERO ALVAR	DAULE
74	KATHERINE MERCEDES	MILTON AUGUSTO ESPINOZA PIN	DAULE
75	FUENTES	NELSON FUENTES ALVARADO	DAULE
76	SANTA LUCIA	BIENVENIDO ENRIQUE RONQUILLO BONI	DAULE
77	SAN VICENTE	GABRIEL BAJAÑA MENDOZA	DAULE
78	SANTA CLARA	MARIBEL GERMANIA GARCIA BARZOLA	DAULE
79	EMMY DANNY	WASHINGTON EMILIANO AREVALO ALVA	DAULE
80	SAN JOSE	AZUCENA FRANCISCA BAJAÑA BARZOLA	DAULE
81	FAVIOLA	BEATRIZ SENOVIA BERMEO ALCIVAR	DAULE
82	SAN JOSE	JOSE EULALIO MORA CARLO	DAULE
83	SAN VICENTE	EDUARDO NAVARRETE ALVARADO	DAULE

APPENDIX B:
Prices for Selling Electricity to the National Grid

REGULACIÓN No. CONELEC – 009/06

PRECIOS DE LA ENERGÍA PRODUCIDA CON RECURSOS ENERGÉTICOS RENOVABLES NO CONVENCIONALES

EL DIRECTORIO DEL CONSEJO NACIONAL DE ELECTRICIDAD
CONELEC

Considerando:

Que, el Art. 63. de la Ley de Régimen del Sector Eléctrico, establece que el Estado fomentará el desarrollo y uso de los recursos energéticos no convencionales a través de los organismos públicos, la banca de desarrollo, las universidades y las instituciones privadas;

Que, la seguridad energética para el abastecimiento de la electricidad debe considerar la diversificación y participación de las energías renovables no convencionales, a efectos de disminuir la vulnerabilidad y dependencia de generación eléctrica a base de combustibles fósiles;

Que, es de fundamental importancia la aplicación de mecanismos que promuevan y garanticen el desarrollo sustentable de las tecnologías renovables no convencionales, considerando que los mayores costos iniciales de inversión, se compensan con los bajos costos variables de producción, lo cual a mediano plazo, incidirá en una reducción de los costos de generación y el consiguiente beneficio a los usuarios finales;

Que, como parte de la equidad social, se requiere impulsar el suministro de la energía eléctrica hacia zonas rurales y sistemas aislados, en donde no se dispone de este servicio, con la instalación de centrales renovables no convencionales, distribuyendo los mayores costos que inicialmente estos sistemas demandan entre todos los usuarios del sector;

Que, para disminuir en el corto plazo la dependencia y vulnerabilidad energética del país, es conveniente mejorar la confiabilidad en el suministro, para lo cual se requiere acelerar el proceso de diversificación de la matriz energética, prioritariamente con fuentes de energía renovable no convencionales –ERNC-, con lo cual se contribuye a la diversificación y multiplicación de los actores involucrados, generando nuevas fuentes de trabajo y el desarrollo de una tecnología propia;

Que, la apertura a la competencia del Mercado Eléctrico Mayorista se justifica sobre la base de una generación que a la vez que garantice el suministro, respete el medio ambiente, incorporando tecnologías que la resguarden y preserven la utilización de los recursos no renovables, especialmente en zonas altamente sensibles como la Provincia Insular de Galápagos;

Que, como parte fundamental de su política energética, la mayoría de países a nivel mundial, vienen aplicando diferentes mecanismos de promoción a las tecnologías

8. PREVISIÓN DE ENERGÍA A ENTREGARSE

Los generadores que están sujetos al despacho centralizado, deben comunicar al CENACE, la previsión de producción de energía horaria de cada día, dentro de los plazos establecidos en los Procedimientos de Despacho y Operación, a efectos de que el CENACE realice la programación diaria.

Los generadores que no están sujetos al despacho centralizado, deberán cumplir con lo establecido en el Art.29 del Reglamento de Despacho y Operación.

9. PRECIO DE LA ENERGIA.

Los precios a reconocerse por la energía medida en el punto de entrega, expresados en centavos de dólar de los Estados Unidos por kWh, son aquellos indicados en el cuadro que se presenta mas adelante.

No se reconocerá pago por potencia a la producción de las centrales no convencionales.

CENTRALES	**PRECIO (cUSD/kWh)** Territorio Continental	**PRECIO (cUSD/kWh)** Territorio Insular de Galápagos
EOLICAS	9.39	12.21
FOTOVOLTAICAS	52.04	57.24
BIOMASA Y BIOGAS	9.67	10.64
GEOTERMICAS	9.28	10.21
PEQUEÑAS CENTRALES HIDROELECTRICAS HASTA 5 MW	5.80	6.38
PEQUEÑAS CENTRALES HIDROELECTRICAS MAYORES A 5 MW HASTA 10 MW	5.00	5.50

9.1. Consideración especial para la Provincia de Galápagos

Para la Provincia de Galápagos se aplicarán los precios, resultado de la multiplicación de los valores establecidos para proyectos ubicados en el territorio continental por un factor de mayoración. El factor de mayoración que se ha considerado para centrales no convencionales que se instalen en Galápagos son: 1.3 para centrales eólicas y 1.1 para las demás tecnologías.