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POTENTIALS FOR ELECTRIC ENERGY GENERATION FROM RICE HUSK RESIDUE IN SURINAME

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Abstract. *This article presents the potential of rice husk to generate electrical energy in Suriname and the environmental problems of rice husk dumping The study is done by first making a quick scan of the rice sector where the following is looked at: yearly rice production, rice husk disposal, dumping regulations. Further a literature study is conducted regarding rice husk composition, energy potential, environmental impact of rice husk dumping and energy conversion technologies. The study has pointed out that there are already cases of ecological disruption and health problems in the nearby area of dumping sites. The most obvious solution of the rice husk-dumping problem is to produce process heat or generate electricity with the rice husk. Looking from a strict financial point of view it may not be interesting to invest in power generation with rice husk due to higher kWh price. But the justification to invest in this project must be seen as a solution of the huge environmental problem the rice husk constitutes. In Nickerie N.V. EBS is the only power producer. For the power generation with rice husk four business models are proposed: Power generation by the Utility EBS, 2) A major rice generates power sells it to EBS, 3) a consortium of rice producers generates power and sell surplus to EBS 4) Rice producers generate electricity for their own use and sell surplus to EBS.*

Keywords: *rice husk, power generation, environment, paddy parboiling, cost of electricity*

1. INTRODUCTION

Since decades rice is being cultivated in Suriname and is the most important staple food that constitutes to the basic component in the diets of the Surinamese people. This rice growing culture was brought to Suriname by the Indian and Asian immigrants in the nineteenth century, who had rice as the basis of their food. Now this commodity is an important export crop and foreign exchange earner. Rice production is an activity of medium and large-scale farmers using modern and market oriented production techniques.

Suriname consists of 10 districts and rice is cultivated mainly in the districts Nickerie, Saramacca and Coronie. In Nickerie, the most western district of Suriname, the rice industry is the most developed and has the largest rice plantation and rice mills.

The rice plantation sites are located in different regions in Nickerie: the Oostelijke-polders, the Westelijke polders, Groot Henar and Wageningen. In figure 1 a map is depicted of Nickerie with the different regions where rice is cultivated on a large scale, inside the map of Suriname with the annual production in 2010 of rice for the districts of Nickerie, Coronie and Saramacca.

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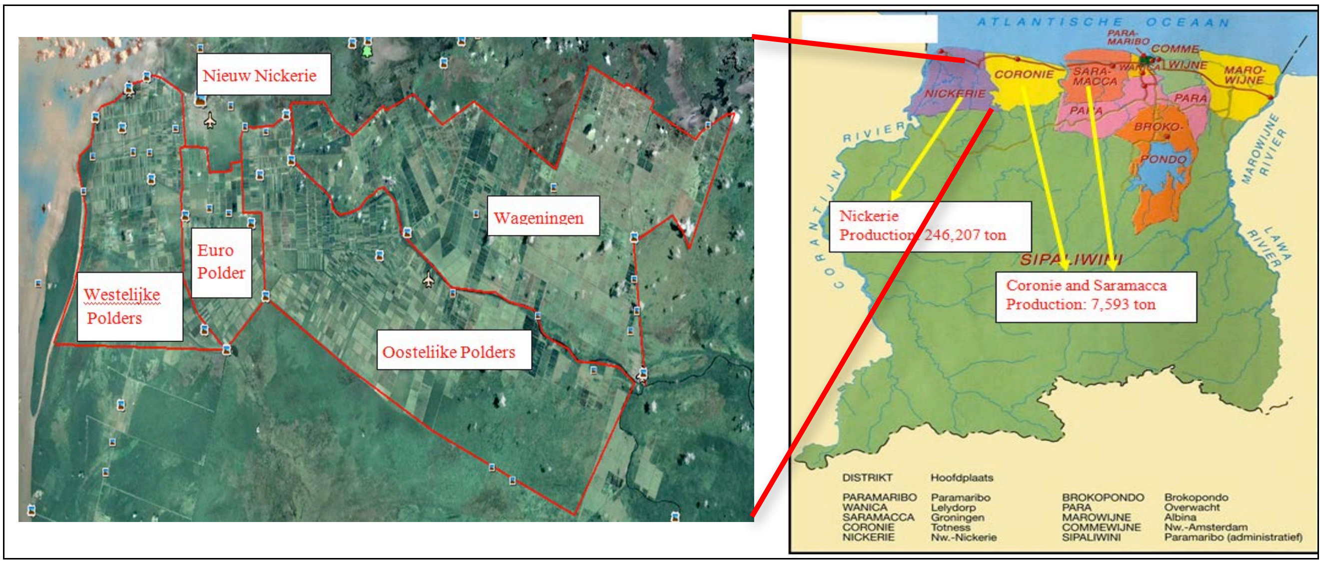

Figure 1. Map of Nickerie and Suriname indicating the rice cultivating areas

The total planted area in Suriname, in the year 2010, was 51,475 ha and the rice production 253,800 ton. This production represented a value of 27,000,000 USD and its share in the GDP is 1.9%. From this production 89,439 ton was exported and the rest was for local consumption (ADRON, 2011). In Suriname large scale rice production is being harvested two times per year. This is made possible through an irrigation project with a large scale government owned station pumping in the southwestern part of the district Nickerie with a pumping capacity of 30m^3/s that distributes water through channels for the rice plantations.

The average production rate in Suriname in 2010 was 4.93 ton/ha (ADRON, 2011). In the north of Brazil the avarege production rate in the harvest 2012/13 was 3.13 ton/ha, while in the Brazilian avarege production rate was 4.98 ton/ha in the same harvest (Santos, 2013).

Rice is being cultivated by small and big farmers. Small farmers are those who cultivate rice on an area of 0.1 – 12 ha, while big farmers are those who cultivate on areas larger than 12 ha. In Nickerie the small farmers are a very important player in the rice sector because they produce 56% of the total rice production per year (LVV, 2008). In large scale cultivation, the rice is being planted by air planes or mechanical and on the smaller scale by hand.

After harvesting the rice it is sold to the rice mill owners who process the rice. Part of the processed rice is sold locally and part is exported. The price of rice is fully liberalized and is determined on basis of supply and demand. The ministry of agriculture (LVV) carries out the government policy and has a facilitating role.

There are different organizations that represent the interest of the rice farmers. The most active one is the “Surinaamse Padie Boeren Organisatie” (SPBA). The rice mill owners are also organized in the “Vereniging van Rijst Exporteurs” (VRE). In Nickerie there is one research institute called “Anne Van Dijk Rijst Onderzoek Centrum” (ADRON) that is part of the “Stichting Nationaal Rijst Instituut” (SNRI) founded by the government of Suriname in 1986. The task of this institute is to promote research with respect to cultivation, processing, harvesting and marketing of the rice and further to guarantee seed supply availability.

In Nickerie there are 21 active rice mills (Van Veen A, 2010) and most of the rice mills are situated in the northern part of the district. In that part also is situated the urban area of Nickerie with the city of Nieuw Nickerie with a population of 40,219 inhabitants (ABS, 2010). This means that the rice mills are situated in urban or semi urban areas.

After processing the paddy in the rice mill the rice husk is disposed near the rice mills. Most of these rice mills burn the rice husk in open air. Another part just dumps the rice husk on their terrain and there are cases where the rice husk is being dumped in open water.

At this moment the rice millers do not have permit to burn the rice husk and there are also no regulations regarding dumping of rice husk. In 2005 the population living near the rice mills started complaining that they were experiencing health problems due to the burning of rice husk. Complaints such like burning eyes and irritation of the respiratory organs are the most common ones. Other complaints were that they were forced to stay most of the time in their house due to the smoke caused by the burning rice husk. These protests got the attention of the government and non-government organizations and discussion started about the impacts of rice husk dumping and potential solutions for this problem. In mid 2006 the ministry of agriculture installed a commission to study the problem regarding dumping of risk husk and solutions for this problem (Van Veen, 2010). Up till now this environmental burden is not solved yet. This environmental burden has to be solved by input of all stake holders, first of all it is important that the government make regulations concerning rice husk dumping. After wards a government institute e.g. NIMOS (health and environmental

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institute) can take the lead in solving this problem together with other stakeholders like the rice millers, rice growers, the parliament and the locals.

Burning rice husk can produce carbon-dioxide (CO2), carbon monoxide (CO), silicium bounds (Si-X) and ash particles in different sizes (Nimos, 2006). Dumping of rice husk the way it is done at this moment has the following impact the environment and community:

- Emission of greenhouse gasses;
- Influence on the health of the population living nearby the rice mills;
- Ecological disturbance; e.g. dumping rice husk in open water;
- Impact on the human well being e.g. the populations living near the rice mills have to stay most of the time in their houses due to the smoke of the burning rice husk.

The disposal of rice husk residues created an environmental problem in Nickerie. It is known that rice husk can be converted into an energy source to meet energy demands of parboiling, drying and milling systems. Rice husk can also be used in power generation as fuel. This paper presents a study on the potentials of generation of electricity from rice husk residue.

2. RICE HUSK POTENTIALS

The outermost layer of the paddy grain is the rice husk, also called rice hull. It is separated from the brown rice in rice milling and accounts for 20-25% of its weight. There are various uses for rice husk. It is highly resistant to moisture penetration and fungal decomposition. It therefore makes a good insulation material (EBS-BCE, 2007).

Handling of rice husk is difficult because it is bulky and dusty. It has angle of repose is about 40-45° which means that it's flow ability, e.g. in feed hoppers is very poor. Rice husk has low bulk density of only 70-110 kg/m³, 145 kg/m³ when vibrated or 180kg/m³ in form of brickets or pellets. It thus requires large volumes for storage and transport, which makes transport over long distances un-economical (Rice knowledge bank, 2013). Table 1 shows the properties of rice husk.

Table 1. Typical Proximate and Ultimate Analysis of rice husk (Kapur *et al.*, 1995)

Proximate Analysis (wt.%)	Moisture	8.9
	Volatile matter	60.6
	Fixed Carbon	8.60
	Ash	10.95
	Calorific Value (MJ/kg)	17.4
Ultimate Analysis (wt.%)	C	44.04
	H	6.55
	O	43.94
	N	0.24

Rice husk has a high calorific value of 13 to 15 MJ/kg (Jain, 2006) and therefore can be used as a renewable fuel, but it is difficult to ignite and it does not burn easily with open flame, unless air is blown through the husk. Rice husk is not an easy fuel. One concern in rice husk firing is the behavior of the ash, i.e., its slagging and fouling tendency caused by a low melting point of the rice husk ash.

When burned the ash content is 17-26%, a lot higher than other fuels (wood 0.2-2%, coal 12.2%). This means when used for energy generation large amounts of ash need to be handled (Jain, 2006). The ashes also have a high silica (SiO2) content and that makes it very abrasive and wears conveying elements very quickly.

Rice husk ash can be used as supplementary cementitious in concrete, however the ash has to meet certain quality and standard fineness. Study has shown that combustion period, chilling duration of the ash and grinding process and duration are important aspects in obtaining rice husk ash of standard fineness and quality (Zain, 2011). There are also some studies to use rice husk ash to make red brick for the building sector. A feasible study has been done in Suriname to use red mud, a residual of the bauxite industry and rice husk ash (Mahadew, 2007).

The use of rice husk can be in energy generation or non-energy applications. Table 2 shows detailed information regarding the utilization of rice husk

Table 2. Rice husk utilization

Non energy applications	**Energy generation**		
	Combustion	*Gasification*	*Pyrolysis*
1. Incorporation in soil	Heat generation		

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2. Bio-fertilizer additive 3. Animal husbandry - low quality feed - litter material - bed material for poultry 4. Sorbent material in environmental remediation 5. Building material with good thermal insulation Pest control agent	- cook stoves - furnaces for heating the air in rice dryers - brick kilns Steam generation for - parboiling - electricity generation from steam turbines - kinetic energy from steam engines	Gas for cook stoves Syngas for electricity generation	In research phase few commercial applications

Adapted form Rice knowledge bank (2013).

The production of rice in Suriname in 2010 was over 250.000 ton and this generated of over 50.000 ton of rice husk residue. The problem of residues disposal of rice husk is not unique for Suriname. The neighboring countries Guyana and Venezuela produces 646,000 tons and 567,000 tons of rice annually. The biggest neighbor producer is Brazil with an annual production of 12,000,000 tons in 2012. In Guyana most of the rice husk produced is burnt in open air, but in some cases the rice husk is used by the rice millers to generate process heat and electricity (Bhawan, 2006).

In Brazil rice husk is used for several purposes. It is used process heat generation for parboiled rice industry and also as bed material in the poultry industry and soil stabilizer for the rice planting area (Amato, 2012). It is also used for electricity generation. There are 8 thermoelectric power plants in Brazil that use rice husk with a total generation capacity of 32.6 MW. Table 3 gives an overview these power plants with their installed capacities based on data from the National Agency for Electric Energy (Aneel, 2013).

Table 3. Overview of rice husk based power plants in Brazil.

Overview of power plants in Brazil based on rice husk			
Powerplant	**Capacity (kW)**	**Owner**	**County**
Urbano Sinop	1200	Urbano Agroindustrial Ltda.	Sinop - MT
Kiarroz	1200	Indústria e Comércio de Arroz Fumacense Ltda.	Morro da Fumaça - SC
Urbano São Gabriel	2220	Urbano Agroindustrial Ltda.	São Gabriel - RS
Rical	2288	Sociedade Assistencial Bandeirantes	Vilhena - RO
Camil Alimentos -	4000	Camil Alimentos S.A.	Itaqui - RS
Itaqui	4200	Camil Alimentos S/A	Itaqui – RS
GEEA Alegrete	5000	Geradora de Energia Elétrica Alegrete Ltda.	Alegrete - RS
São Borja	12500	São Borja Bioenergética S/A	São Borja - RS

The potentials for the use of rice husk in Suriname can be for process heat and electricity generation.

2.1 Utilizing rice husk to generate process heat

As mentioned the rice husk can also be used to used generate process heat for the industry. The rice husk can be burnt in a steam boiler to generate steam. This steam can be used directly in the process or can be used indirectly from which heat is extracted for e.g. drying purposes. Because of uniformity of the rice husk a moving bed combustion chamber can be used in the boiler.

One of the main uses of process heat in the rice sector is to produce parboiled. The process of parboiled rice production is described as follow (Amato, 2012):

1. *Soaking with warm water;* To prevent the darker color change of parboiled rice, the temperature should be less than 70 °C and the moisture content is between 30 – 32%. The soaking time is about 4 – 5 hrs and a pH of 5 is suitable.
2. *Steaming;* The rice tanks are filled with the steam after the soaking process; the pressure in the tanks is about 100 psi. Required time of parboiling is about 15-20 minutes for each tank. The temperature is between 100 – 105°C. The purpose of this process is to improve the rice quality, increase the rice yield, increase the time of rice preservation and obtain higher nutrition values for the parboiled rice.
3. *Parboiled drying;* the purpose of drying parboiled paddy is to reduce the moisture content in order for proper milling and storage. The drying process of parboiled paddy is different and more special than raw rice milling

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due to high moisture content and texture changing of the starch. There are three steps of drying the parboiled paddy:

- 1st dry: at a temperature of 160 °C for 10 minutes. This is a continuous process.
- 2nd dry: at a temperature of 130 °C for 2 hours. This is a continuous process.
- 3rd dry: at a temperature of 120 °C for 4 hours. This step takes place in a batch.

4. *The parboiled rice milling;* the de-husking of parboiled paddy and polishing the brown rice.

The process flow diagram of the parboiled rice production process is shown in figure 2. From this figure it is clear that warm water and steam are needed for the production of parboiled rice and air is needed for the drying of the product.

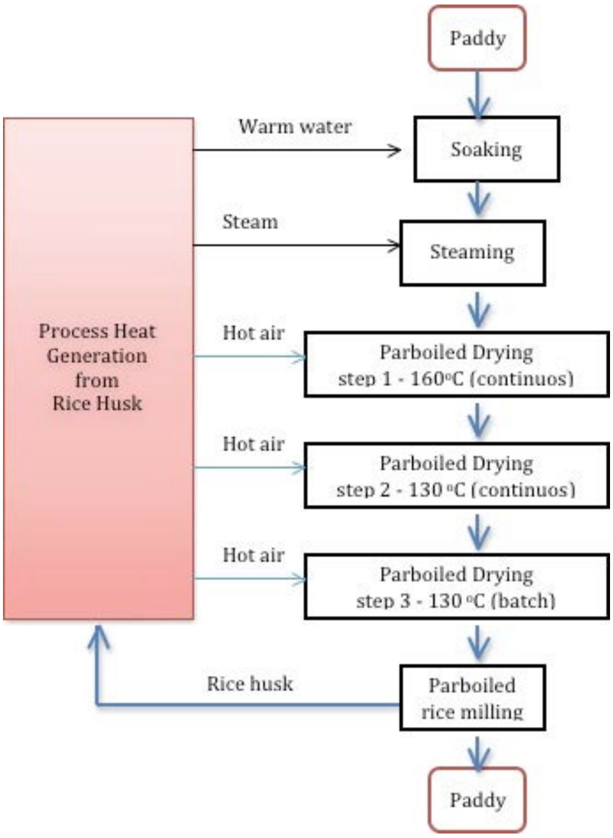

Figure 2. Production of parboiled rice and process heat from rice husk

To produce 1 ton of parboiled rice, 118 kg of rice husk is needed. This amount of rice husk will produce 0.7 ton steam at a temperature of 160 ^{o}C (Kapur *et al.*, 1995).(Amato, 2012)

Another option for the use of rice husk is electricity generation. The next sector will present the technological options for this alternative.

2.2 Rice husk for electricity generation

The main options for the generation of electricity from rice husk are combustion and gasification. In combustion systems the biomass is burnt in a furnace and the heat that comes free from the burning process is used to generate steam through heat exchangers. The steam then goes through a steam turbine where the thermal and kinetic energy is transferred to electricity. The system consist of a boiler (furnace and water compartment) where chemical bounded energy of the biomass is transferred to steam, the installation further consist of a steam turbine or steam engine and generator where energy of the steam is converted to electricity. After the turbine a condenser is installed to cool the steam afterwards the water is pumped to the boiler. The steam needed for this process has a higher temperature and of different quality then the steam used in the parboiled production process.

The steam engine or motor is normally used in small thermoelectric units with generation capacity from 40-250 kVA of electric power and permit intermittent of supply and flexibility of load (Rendeiro et al, 2008). This can be a suitable option for power generation for rice mills or other co-generation options.

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For bigger steam thermoelectric power plants the technological option is steam turbines with capacities rating from 0,250 to 150MVA (Rendeiro et al, 2008). Most of the thermo electric power plants operating on rice husk in Brazil are within the range of 1-5MVA.

Singh cited by Islam and Ahiduzzaman (2013) reported that for a steam turbine power plant the consumption of rice husk is 1,3 kg/kWh.

Another process to produce electricity is through the gasification of rice husk and its use internal combustion engines. Gasification is a process where biomass is burnt in a poor oxygen environment and during this process synthetic gas is produced. This synthetic gas which has high heating value can be used in an internal combustion engine or a gas turbine to transform the chemical bounded energy in the gas to electricity. For small scale electricity unit the use of an internal combustion engine is feasible due to low initial cost.

The internal combustion engine system consists of a gasifier where the rice husk is being gasified. After the gasification the synthetic gas leaves the gasifier and goes through a cleaning/cooling process. This cleaning process consists of removing particle from the gas in a cyclone and a dry filter and cooling the gas to a temperature suitable for injecting in the engine. Further depending on the type of internal combustion engine the installation also consist of a mixing block. For diesel engine the syngas is injected into the engine together with diesel oil as pilot fuel. For spark ignited engine only the syngas is injected into the engine. The typical capacities for spark ignited engines rate from 1-25 kVA, while diesel motors range form 25-500 kVA (Rendeiro et al, 2008). Therefore the spark ignited or diesel engines can be used for local co-generation in rice mills.

Islam cited by Islam and Ahiduzzaman (2013) reported that for a gasification power plant the consumption of rice husk is 1,86 kg/ kWh.

Rice husk combustion can be used for process heat generation and electricity generation in steam engines and turbines. Gasification of rice husk can be used in internal combustion motors to generate electricity. Both options (combustion and gasifying) have their typical capacity rates and uses.

In the next section the alternatives for Suriname will be described. The option to produce process heat for parboiled rice is also a very attractive option for the Surinamese rice sector, as there is no active parboiled rice plant in Nickerie. In this paper we will focus only on the potentials for electricity generation in Nickerie.

3. POWER GENERATION FROM RICE HUSK IN NICKERIE

The production of rice in Suriname in 2010 was over 250.000 ton and this generated of over 50.000 ton of rice husk residue. There are several methods to calculate the electricity generation potential of this residue that takes into account the technology and scale.

For small-scale electricity generation from rice husk in Brazil the energy production is 1,79 ton/MWh assuming an overall efficiency of 15% in the transformation process (Santos, 1999) (Oliveira et al, 2012). This value is also close to the one presented of 1,86 ton/MWh for gasifying units in India and Bangladesh (Islam and Ahiduzzaman 2013).

So there is a potential to generate 27.932 MWh with several small-distributed units with generation capacities under the 1MW that can be placed near the rice-mills mainly for local consumption. This is quite significant as the annual consumption of electricity in Nickerie is 47.470 MWh (Verlaan et al, 2008).

For large-scale generation there are other parameters. Some authors presents a rate of 1,3 ton/MWh for steam turbines without detailing its method (Islam and Ahiduzzaman 2013). Panday et al (2010) presents a rate of 1 ton/MWh considering a 2 to 10MW plant, a 90% combustion efficiency and converting 30% of the heat into electricity. This rate was also used in the pre-feasibility study of a 4MWe steam turbine power plant in Nickerie (EBS-BCE, 2007). This means that in thesis there is a potential to generate annually 50.000 MWh of electricity, or substitute all the carbon fuel nowadays used to supply Nickerie.

3.1 Power generation in Nickerie and electricity generation cost

The Suriname power sector consists of a number of independent power systems that the capital Paramaribo and the other mayor cities. In Nickerie the national utility company N.V Energie Bedrijven Suriname (N.V EBS) has a thermal power plant with an installed capacity of 16 MW. The power plant is owned and operated by the N.V. EBS and consists of four 2.1 MW diesel motors running on heavy fuel oil (HFO), three 2 MW diesel motors running on LVGO together with another 1.5 MW diesel motor. There are a total of approximately 10,000 electrical connections. The current peak power demand is 12 MW. The generation cost per kWh is approximately US$ 0.25/kWh. With the inclusion of transmission and distribution cost, the kWh price will be approximately US$ 0.27. At this moment the government subsidizes the electrical consumers. In the table 4 an overview is shown of the current electricity tariffs.

A pre-feasibility study of a 4 MWe rice husk power plant with an investment of US$ 11,4 million shows that the generation cost will be US$ 0,1562/kWh without taking into account the cost for rice husk (no cost for transportation, rice millers fee). Considering a scenario with a fuel cost of 15 US$/ton of rice husk the cost price will be US$ 0,1780/kWh (EBS-BCE, 2007).

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Table 4: Extract of the existing tariff structure in Nickerie

	Monthly in (USD)	US$/kWh
Households tariff consumption of 0 - 800 kWh a month	23	0,0400
Households tariff consumption above 801 kWh a month	30	0,0550
Not-Households tariff 1 -3 phase	42	0,0550
Commercial and industrial consumers HT	42	0,1354
Commercial and industrial consumers LT	42	0,1268

Another important issue in the implementation of a central power plant is the logistics of its supply. To generate 4MWe yearlong 37000 ton rice husk is needed and this will need a transport of 50 truck loads of 20m^3 per day to keep the plant running (EBS-BCE, 2007). In the next item the spatial distribution of the rice mills and the problems of logistics of transport will be discussed.

3.2 Spatial Distribution of rice mills and the problem of its logistics of transport

There are several studies that treated the problem spatial distribution. Hoffmann (1999) presents a method to evaluate regionalized energy generation with small scale power plants for rice husk residue, based technological and economic viability, geo-referenced inventory of residual biomass availability and a multi criteria decision approach.

In Nickerie there are 21 active rice mills with an installed milling capacity ranging from 2-7 ton/hr. These rice mills are located in de northern part of Nickerie and table 5 shows them with their milling capacities.

Table 5. Rice Milling Companies in Nickerie with production capacity

Rice Milling Company	**Milling capacity/ production (ton/hr)**
Rijstpak, Ramadhin	7
Sun Rice, NV REM (Benie), Nanni	6
Jaggernath, Narvin, Oemrawsingh	5
Kassisingh, Rijsthalm (Kalpoe), Laloe, Raj Rice, Sahara, Ini Dia, Karaya	4
Cherin Rice, Jawalapersad, Rigpal	3
Jokoe, Hira, NV Alesie	2

One of the important costs in the operation of a rice husk power plant is the transportation cost of the rice husk from the mills to the power plant. This due to the fact that rice husk has a low bulk density. Beside man hour rate also the distance and the type of road has influence on the transportation cost. That's why it is very important to have a very good logistic system for the transportation of this rice husk.

A 4 MW rice husk power plant was proposed in the centre of Nickerie in the year 2007 (EBS-BCE,2007). The largest distance between the site and the rice mills was 15 km, as shown in figure 3.

The average distance of the rice mills to the proposed power plant is 10 km. The transportation feasibility will be based on the following assumptions;

- Average truck capacity of 15 m^3
- Average distance of 10 km
- Roads are in good condition
- Average density of rice husk is 122 kg/m^3
- Power plant capacity of 4 MWe with base load operations
- Plant operation based on 24 hrs and 365 days a year.
- No cost for the rice husk

Based on the above-mentioned assumptions the transportation cost price is US$ 0,021 per kWh, taking into account a energy generation ratio of 1 ton/MWh for rice husk, a density of 122 kg/m^3 and transport with a 15 m^3 truck with an average cost of US$ 38,= per truckload. In the scenario with a rice husk cost of US$ 15/ton the total fuel cost (including transport) will be (US$ 727,607+US$ 15*35,040)/35,040,000 = US$ 0,0357 / kWh. In the scenario where pelletized rice husk is used with a bulk density of 608 kg/m^3(Van Tuyen, 2012) and the transportation is done with a truck of 15m^3, the average cost per truckload will be then US$ 55,=. In the scenario where there is no cost for the rice husk the transportation price will be US$ 0.006/kWh. In the case where the rice husk costs US$ 15/ton the total cost for transportation will be (US$ 211,316+US$ 15*35,040)/35,040,000 = US$ 0,021 / kWh. The reduction in the transportation cost will be 41%.

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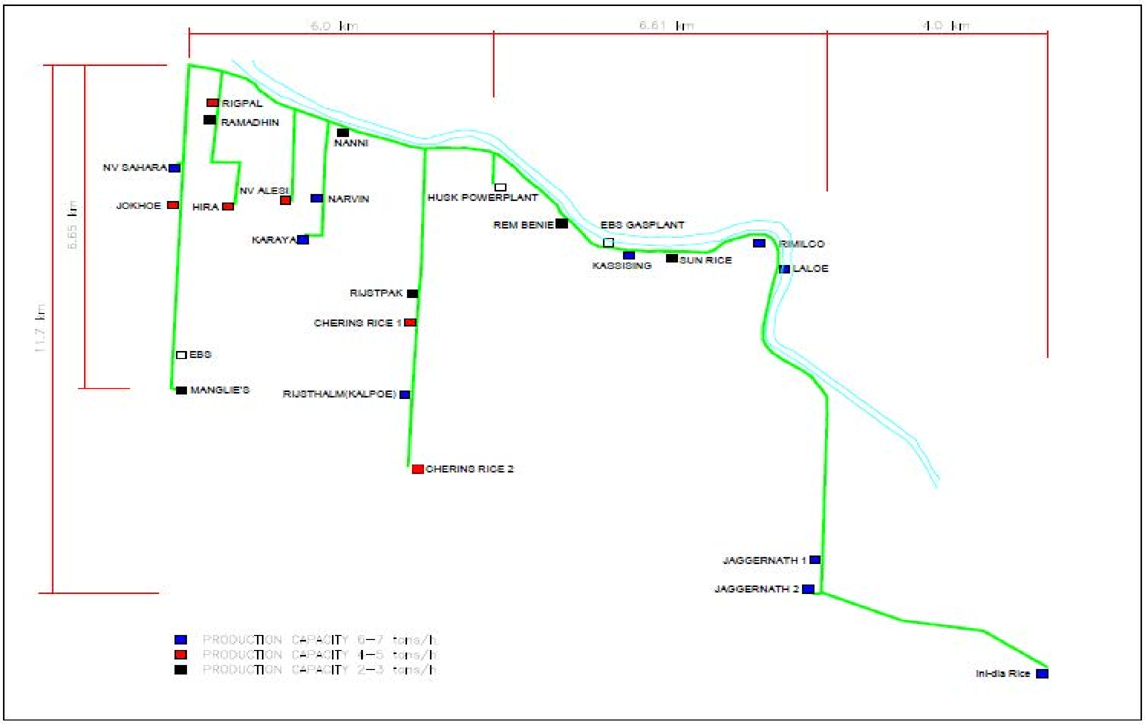

Figure 4. Routes to several rice mills with the distance shown. EBS proposed rice husk power plant is also shown.

The configuration depicts a centralized generation scheme where the utility N.V. EBS is the power producer and distributor. This option can also be implemented by another power generator company, major rice mill or parboiled rice producer. The generated electricity can be sold to the N.V. EBS through a Power Purchase Agreement (PPA).

As shown, one of the main additional costs is the transport of rice husk and its price.

3.3 Distributed generation

The above configuration depicts a centralized generation scheme where the utility N.V. EBS is the distributor. Another option is for the rice mills generate their own power, individually or in consortium, and sell the surplus to the N.V. EBS. This option will reduce consumption of electricity or diminish the peak demand on the generating capacity of the local utility. It will also reduce the volume of rice residue in almost 20% and produce ashes and silica as by-product of rice. It also has the advantage that the rice husk does not need to be transported to a central point and stocked.

The problem in Suriname is that the production capacity of the individual rice mills is not sufficient to feasible a state of the technology (art) commercial steam turbine turnkey system. Although cogeneration of electricity and process heat using rice husk is probably the best option for rice processing industries, its economic feasibility is sure for large-scale production with rice mills with a production capacity of 120 ton/hour, including selling surplus to grid (Kapur et. all, 1995).

Oliveira et al (2012) presents the main technical and economic issues related to the study of a rice husk small-scale thermal 1,2 MW steam turbine power generation from a Southern Brazilian Rice Processing Cooperative Agriculture with a processing capacity of 10 ton/hour.

But for smaller mills one of the technological options is the use of steam engines. Sookkumnerd et al (2005) shows that it is cost-effective to install steam engines in rice mills in Thailand with daily capacities of between 45 and 120 tons. This study also reports that the average electricity consumption to produce white rice is 44,8 kWh/ton.

These steam engine systems normally will have capacities from 40kVA up to 250kVA and are suited for the rice mills in Suriname.

Another option is the use of rice husk gasifier-based power generation. These option with diesel motor burning on synthetic gas from rice husk range from 25-500 kVA and are cost effective especially if the mill already has a diesel motor for power generation or as a backup system. There are several configurations for this alternative. At the University of Brasilia a downdraft gasifier technological with a 20kVA diesel motor was developed that showed the reduction of 73% of the specific consumption of diesel fuel and insignificant tar production for various types of biomass (Veras et al, 2007). This system can be adapted to work on pelletized rice husk.

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Kapur (1995) shows that the electrical energy demand of a modern mill in India with a average capacity of 2 ton/hour and 2400 annual operating hours is 105.6 MWh year. This mill will need to contract an average 44kW of electrical power from local utility or generate this on own account with a gasifier-based power generation set.

A survey within the 21 rice mills in Suriname showed that 15 of the mills dumped their rice husk and burned it in open air. Only 9 of the mills used part of the husk as energy source for drying (Sewradj, 2006). Another survey conducted with rice mills cost and milling yields. This survey showed the cost structure (distribution) to process a bag of wet paddy. For a medium size mill the both the cost of drying and electricity are 8,7% of the total costs and corresponds to 3,503 US$/ton (considering a exchange rate 2,71 SRD per US$ in 2008). The drying cost of this mill is relatively low as it uses rice husk as fuel for the dryer (Gijpstra, 2008).

Thus for a medium size rice mill with a production capacity of 4ton/h that operates for 2400 hours a year and 3,503 US$/ton for electricity, the total cost with electricity will be US$ 33.628.

The rice millers are in the category of industrial consumers with low and high tariff. The average use for the largest millers is approximately 400 MWh/year (EBS monthly bill for rice millers, 2012). The average cost for these users per kWh is 0.1268 kWh. On yearly basis the costs are US$ 50,720.

Considering a electricity price of 0.1268 US$/kWh (industrial LT) and a 44,8 kWh/ton (Kapur, 1995) we obtain for 9600 ton = US$ 54.534

By using 1 ton rice husk for 1 MWh electrical energy generation, 400 tonnes of rice husk will be needed for an average rice milling factory, since the electrical energy usage is 400 MWh per year. The large rice milling factories have an output capacity of 6-7 tons per hour. At this output capacity, 1.5 tons of rice husk is produced per hour. With a total of 2400 operating hours per year, the production of rice husk is about 3600 tonnes for the above-mentioned rice milling factories. Since 400 tons of rice husk is required for electricity production the rice milling factories

Since 400 tons of rice husk is required by the average rice milling factories for their own electricity generation, the remainder rise husk may be used to generate and sell electricity to the N.V. EBS.

4. ENVIRONMENTAL ASPECTS

In Suriname there are no regulations regarding rice husk disposal, this is one of the important aspects that have to be looked into when searching for a solution for this environmental burden.

Establishment of the rice husk processing factory with the aim of generating energy is an activity that falls under category A of the National Institute for Environment and Development in Suriname (NIMOS). Category A states that an Environmental Impact Assesment (MEA) should be performed. Category A comprises projects which have a negative impact on the environment and can delvelop irreversible effects on sensitive species or non-renewable sources.

Other aspect is the use of Clean Development mechanism (CDM) to co-finance electricity generation from rice husk. Electricity production by means of rice husk will reduce the CO2 emission due to substitution of fossil fuel. The reduction of CO2 by projects regarding green energy such as electricity generation by utilizing rice husk can be sold to rich industrialized nations. The income can be used for co-financing these green energy projects.

5. CONCLUSION

It has been shown that generation of electricity from rice husk can be an option to solve the disposal problem of this residue in the city of Nickerie in Suriname.

There is a potential to generate annually 50.000 MWh of electricity, or substitute all the carbon fuel nowadays used to supply Nickerie.

The spatial distribution of rice mills is discussed and a transport cost estimation is presented for a centralized generation scheme where the utility N.V. EBS is the power producer and distributor. This centralized generation can also be implemented by another power generator company, major rice mill or parboiled rice producer. The generated electricity can be sold to the N.V. EBS through a Power Purchase Agreement (PPA).

Another option discussed is the distributed generation by the rice mills to attend their own energy demands and sell the surplus to the utility company, and it s shown that it is also a viable option. There are four business models possible: Centralized Power generation by the Utility EBS, 2) A major rice mill generates power and sells it to EBS, 3) a consortium of rice producers generates power and sell surplus to EBS 4) Rice producers generate electricity for their own use and sell surplus to EBS.

Looking from a strict financial point of view it may not be interesting to invest in power generation with rice husk due to higher kWh price. But the justification to invest in this project must be seen as a solution of the huge environmental problem the rice husk constitutes.

6. ACKNOWLEDGEMENTS

This optional section must be placed before the list of references.

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8. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.