VOL. 10, NO. 15, AUGUST 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

PADDY RESIDUE BASED POWER GENERATION IN MALAYSIA: ENVIRONMENTAL ASSESSMENT USING LCA APPROACH

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ABSTRACT

Malaysia is pleasant by plenty of biomass resources that can possibly be consumed as a supply of electricity production. One of them is paddy residues. Annually about 3.66 million tonne of paddy residue is left in the fields. Towards year 2020 this value is forecasted to increase to 7 million tonne per year due to emerging technology development in agriculture industries. Paddy residue can potentially be used as feedstock fuel for electricity generation in Malaysia. Paddy residue based power generation not simply might resolve the difficult of eliminating rice straw from paddy fields without open burning, but furthermore might decrease GHG emission that donate to climate change, acidification, and eutrophication, and amongst another ecological harms. Rice husk power generation would emit a total of 0.217 kg CO2/kWh, whereas rice straw results in some 0.43 kg CO2/kWh .These emission is smaller than conventional power generation in Malaysia.

Keywords: paddy residue, power generation, Malaysia, environmental, LCA.

INTRODUCTION

Paddy residue consists of paddy straw and rice husk. Both of these residues are still not fully utilized in Malaysia. Malaysia is distinctive of the prominent producers of paddy. It has gained 0.48 Million tonne of rice husk (UNDP, 2002) with 3, 176, 593.2 tonnes production of rice straw in a year (Malaysia Economics Statistics, 2011) due to the emerging technological development in agro-industry. Malaysia's agriculture department is targeting to expand the output of the paddy sector as of the recent harvest from 3 to 5 tonnes per hectare to about 8 tonnes per hectare in 2012 and 9 to 10 tonnes per hectare in 2020 (NCER, 2007). If the target is achieved with 10 tonnes per hectare, the output of paddy will be increased to 6, 575, 474.8 tonnes per year. According to national news agency (BERNAMA, 2013), 200,000 ha idle land in Malaysia will be used for paddy plantation. This will increase to about 30% of paddy production. The capacity of energy production from paddy residue is 5652.4 GWh that is 5.4% from whole electrical energy need in Malaysia. Inappropriately, growth of paddy residue based power generation keeps on small in Malaysia. Rice husk as fuel for power generation merely amounted to 1.38MW in 2009 (Energy Commission, 2009), whereas, rice straw utilization as feeding in biomass boiler even not accessible in Malaysia even in Southeast Asia(Carlos and Khang, 2008). The potential increase of paddy residue production in Malaysia, will cause the abundant of availability of this resources then create the problem of waste management if this residue cannot be manage in good solutions. The burning of paddy residue in the field will cause the pollution (Singh, 2015). By used the paddy residue in electricity generation can be one solution for waste management and also the pollution problem. Therefore, effort to identify the pathways to mitigation the environment emission is required (Mohammadi *et al*., 2014) in using paddy residue for electricity generation.

The evaluation of environmental performance of paddy residue based power generation are more important due to agriculture activities is responsible for remarkable environmental impacts (Fusi *et al*., 2014). Referred on environmental management in every crop growing accomplishments to electrical energy production possibly will identify the uppermost GHG release for entire scheme boundaries. Appliance of LCA (life cycle assessment) in this research for the reason that this is commonly recognized method of defining ecological significance of a specific item overs it whole creation sequence (Pant *et al*., 2011). This paper evaluates the environmental impact of paddy residue as fuel for electrical energy production in Malaysia by using the LCA approach.

OVERALL APPROACH

Life cycle assessment (LCA) is applied in this paper to estimate the environment impact of life cycle in electricity generation from paddy residue in Malaysia. LCA is the collection of data for the input and output indicated in the system boundary. Figure-1 show the scehme boundaries applied for paddy residue (rice husk and rice straw) used for electrical energy production in Malaysia.

Collected data

Mainly facts from paddy production areas are placed in the Northern region, which include the states of Kedah, Penang, Perlis and North of Perak. Paddy residue preparation contains of paddy farming, rice milling and transportation for rice husk system boundaries. The rice straw preparation consist of paddy farming, the collection

ARPN Journal of Engineering and Applied Sciences

of rice straw, transportation of rice straw to collection center and to power plant, lastly power generation.

The contain data assembly for inputs and outputs of the process indicated in Table-1. Some data were selected from literature reviews, and it was presumed that these data are the identical as the data used in Malaysia for the tools preferred in the research.

A research by (Morrow, Griffin, and Matthews, 2008), indicates that there is an ability that not wholly data necessary for an LCA study are prepared from one specific production, however frequently presumptions must be created to support evaluate the environment effects. Though, particular data are refer to some international databank such as United State Inventory Database, Australian Database and SimaPro software programme. The summary of the processes in the lifetime of paddy residue applied as fuel in electrical energy production and their data sources are presented in Table-1.

Table-1. Three processes of the life cycle of paddy residue combustion and their data sources.

<table>
<tr><th>Paddy residue</th><th>Practice</th><th>Subsystem</th><th>Sources of data</th></tr>
<tr><td rowspan="9">Rice husk</td><td rowspan="4">Paddy production</td><td>Fertilizer</td><td>Malaysia rice bowl farm, Literature (FOASTAT, 2007)</td></tr>
<tr><td>Pesticides</td><td>(MADA, 2012), Literature data (FAO, 2007)</td></tr>
<tr><td>Mechanical field operations</td><td>Questionnaire to selected farmer, Literature (Bockari-Gevoa, Wan Ishak, Azmi, and Chan, 2005)</td></tr>
<tr><td>Irrigation</td><td>Interview session (Senior Engineer,MADA)</td></tr>
<tr><td rowspan="3">Rice mill</td><td>Electricity consumption</td><td>Questionnaire to selected rice mill, Literature (Kasmaprapruet, Paengjuntuek, Saikhwan, & Phungrassami, 2009)</td></tr>
<tr><td>Combustion of rice husk</td><td>BERNAS rice mill, Literature (Kasmaprapruet et al., 2009)</td></tr>
<tr><td>Transportation</td><td>Data from questionnaire to selected paddy lorry driver</td></tr>
<tr><td rowspan="2">Rice husk boiler</td><td>Rice grain and rice husk</td><td>(Department of Statistics, 2009), Literature(Yossapol, 2008)</td></tr>
<tr><td>Water utilization and electrical energy production</td><td>Conversationmeeting (Boiler engineer, selected rice mill) and Literature (Jittima-Prasra, 2009)</td></tr>
<tr><td rowspan="4">Rice straw</td><td>Collection</td><td>Machine-driventools</td><td>Fouroccurrencetasks of rice straw in MADA area</td></tr>
<tr><td>Transportation</td><td>Transportmethod</td><td>Four occurrence tasks of rice straw in MADA area</td></tr>
<tr><td rowspan="2">Boiler</td><td>Rice straw bale combustion</td><td>Wood waste combustion</td></tr>
<tr><td>Electrical energy production</td><td></td></tr>
</table>

VOL. 10, NO. 15, AUGUST 2015 ISSN 1819-6608
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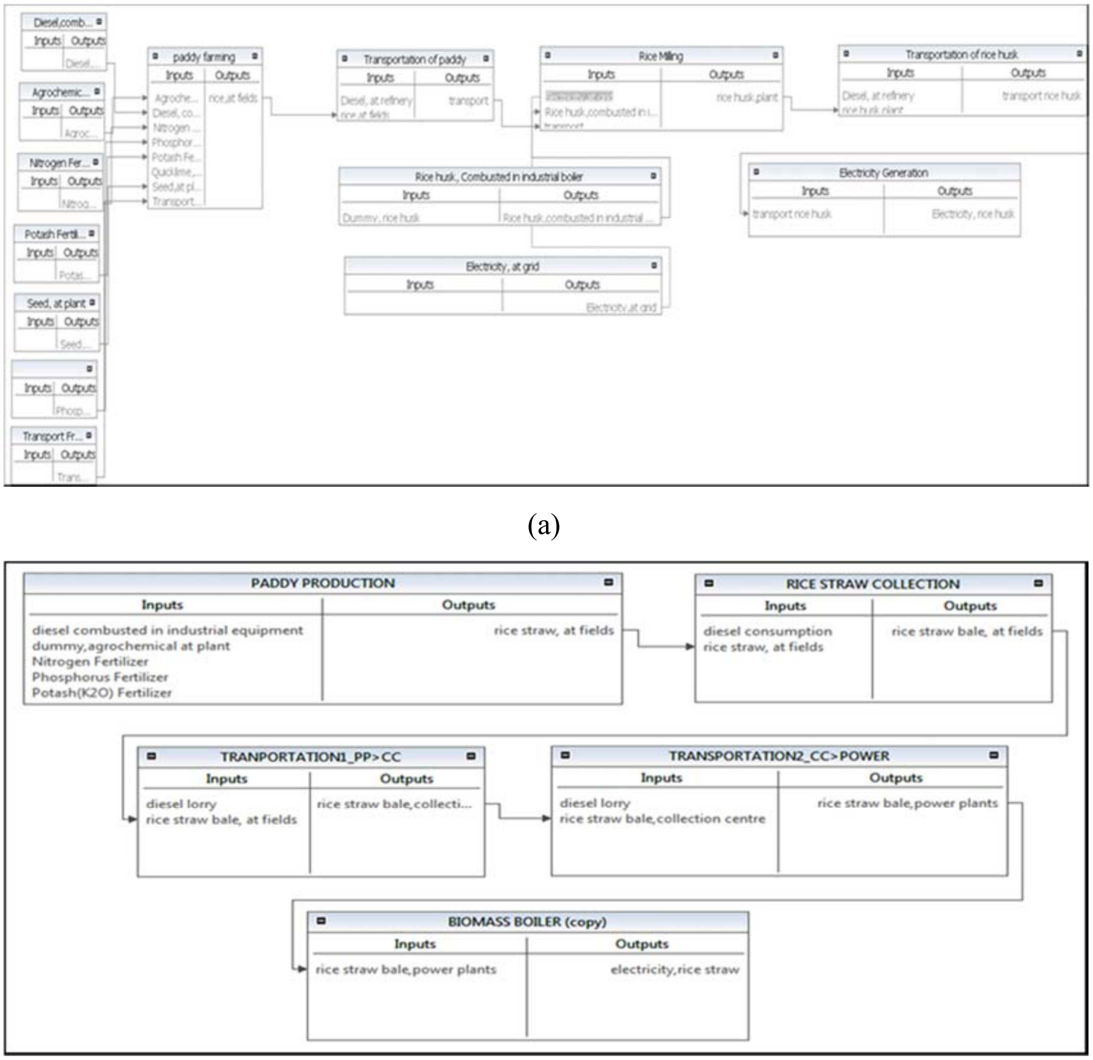

(a)

(b)

Figure-1. Show the scheme boundaries applied for paddy residue (a) rice husk and (b) rice straw used for electrical energy production in Malaysia.

Analysis of paddy residue lifecycle

Rice husk lifecycle involves three main processes, which are paddy production, rice milling, transportation and electricity generation as presented in Figure-1(a). The transportation of rice husk becomes the sub process of rice milling. A 1 tonne lorry is used to transport the paddy to mill, and a large truck is used to move the rice husk to the power plant. About 20-30% of paddy weight becomes rice husk after milling. In this analysis 20% conversion rate is used to estimate rice husk production from paddy, which is based on the experience from local mills (Zamil, 2010; Zulkifli, 2010). Equation 1 is used to calculate the rice husk availability in Malaysia.

$$Q_{RH}=P_P\times 0.2 \quad (1)$$

The LCI material input/output for paddy production is presented in Table-1. To run a 1.5 MWh electricity capacity power plant on full load, a steady supply of 10032 kg of rice husk is needed each day. The functional unit is 1.5 MWh electricity. The functional unit is chosen by referring to the output capacity from the only rice husk boiler installed in the Northern region. The rice husk needed for 1.5 MWh electricity is calculated based on equation 2.

$$W_{RH}=1500\times NPHR_{RH}/HHV_{RH} \quad (2)$$

Where W_{RH} = weight of rice husk, $NPHR_{RH}$ = Net plant heat rate of rice husk, HHV_{RH} = High heating value of rice husk.

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The release GHG records for conventional fuel such as coal and natural gas applied the databank commencing from NREL (NREL, 2012) and Malaysia Department of Environment (DOE, 2012).

Rice straw arrangement comprises paddy production procedure, collecting rice straw and transporting them to the power plant. The volume of rice straw creation (Q_{RS}) is obtained by equation 3 (Gadde, Menke, and Wassmann, 2009) proportional to paddy production (PP) in northern region. The value of SGR (straw to grain ratio) is 0.75 (Gadde *et al*., 2009).

$$Q_{RS}=PP\times SGR \quad (3)$$

The baling technique was applied as rice straw assembly in Malaysia since the technique is easy and comprises less charge. The regular bulk of a rice straw bale is 450 kg. Information were occupied from MADA B11, Kedah that has stated that 7L diesel was consumed per hectare of paddy fields, comprising completely equipment desired in rice-straw assembly by baling system. Transportation comprises the route of moving rice straw from paddy field to collection centre ($T1_{PP>CC}$) and collection centre to power plant ($T2_{CC>POWER}$). The common of lorries operated to carriage matter as of Malaysian paddy fields have a capability of amongst 1 to 3 tonnes per capacity(Abdullah, 2006). Here this investigation the $T1_{PP>CC}$ link uses a truck of less 1.5 tonne capability with 2 fixed bales of rice straw per truck. Rice straw moving energy is considered as of energy unit of diesel (43.1 MJ L^{-1}), oil intake (5.5 km L^{-1}), regular distance (100 km) and the quantity of rice straw (4853.1 kg ha^{-1}). The moving of rice straw bale as of the collection centre to the power plant, $T2_{CC>POWER}$ uses truck by 40'8" which takes 4km L^{-1} (Martensson, 2003) oil intake and is capable on the road to transport 20 bales per truck.

The CO_2, CH_4 and N_2O discharges as of moving rice straw are considered constructed by equation 4 and 5 (EPA, 2008).

$$E_{T,CO2} = \Sigma F_{VT}\times H_{CT}\times C_T\times FO_T\times (MW_{CO2}/MW_C) \quad (4)$$

$$E_P=A_S\times EF_{P,S} \quad (5)$$

Where $E_{T,CO2}$= Transportation emission of CO2, F_{VT}= Volume of oil combusted for transport, H_{CT}= Heat content of oil for transport, C_T= Carbon content of oil for transport, FO_T= Fraction oxidized of oil for transport, MW_{CO2}= Molecular weight of CO_2, MW_C= Molecular weight of carbon, EP= Emission pollutant (CH_4 or N_2O), $EF_{P,S}$ =Emission factor (CH_4 or N_2O).

Electrical energy production from rice straw, EO_{RS} is calculated created by equation 6 (Delivand, Barz, and Gheewala, 2011). HHV_{RS} and LHV_{RS} are 16.28 MJ/kg and 15.34 MJ/kg created by composed after crop activities(Domalski, Jobe, and Milne, 1986).

$$EO_{RS}= (Q_{RS}\times \eta\times LHV_{RS})/3.6\times T \quad (6)$$

Where EO_{RS}= Electrical energy production by rice straw (MW), Q_{RS}= Quantity of rice straw (k tonne/ha), ŋ=overall efficiency of plant, LHV_{RS}= Rice straw lower heating value (MJ/kg), T=Plant operating hours.

The release of CO_2 emission is 0.32 kg per kWh, estimated by equation 7 (EPA, 2008). Subsequently Malaysia yet does not possess rice straw as fuel in the boiler the release emission factor for rice straw fire was presumed as dry wood burning in the container, which was occupied as of USEPA External Combustion Report (EPA, 2003).

$$ERS_{POWER,CO2}=P_{C,RS}\times BF_C\times MW_{CO2}/MW_C/HHV_{RS} \quad (7)$$

Where $ERS_{POWER,CO2}$= GHG release from rice straw as fuel in boiler, $P_{C,RS}$= Carbon content in rice straw, BF_C= Burning fraction of rice straw, HHV_{RS}= Heating value of rice straw.

RESULTS AND DISCUSSIONS

Table-2 indicates the characterized results for 1.5 MWh capacity power plants using the CML 2001 impact assessment method. Roughly 97% of climate change impact is contributed by dinitrogen monoxide gases from a paddy plantation process. The acidification impact mostly caused by transportation and paddy plantation process. The paddy plantation process contributes more than 90% to the each environment impact assessment result. All the impact can be shortened by using the organic paddy plantation management where there is no chemical involve in paddy farming.

Table-2. Characterized outcomes for 1.5 MWh of electricity as consume rice husk in the container.

Impact factor	Component	Value
Climate change	kg CO_{2-Eq} toair	2565.36
Ozone depletion	kg CFC_{-11-Eq}	0.01
Eutrophication	kg PO_{4-Eq} to water	14.88
Acidification	kg SO_{2-Eq} to air	69.78

The GHG release in this paper are analyzed from paddy farming to rice straw -based electricity as shown in Figure-1. Table-3 indicates the release of GHG of entire cycle rice straw fired gases for 1kWh of electricity generation. The gained CO_{2-Eq} emission is 0.845 kg CO_2/kWh which is smaller than wheat straw fired, 1.076kg CO_{2-Eq}/kWh and *brassica carinata*fired with 1.086 kg CO_{2-Eq}/kWh (Sebastián, Royo, and Gómez, 2011). CO_2 emission consequences were gained following a research completed within 1999. Approximately 42.6% GHGs release were donated from CO_2 gas. Rice straw as fuel in the boiler had nil carbon radiations due to $CO_{2;BIOGENIC}$ spent is 1.67 kg/kWh.

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Table-3. Characterized results for LCA of 1 kWh of electricity (CML 2001).

Impact parameter	Value	Unit
Acidification	6.78×10^{-3}	kg $SO_{2\text{-}Eq}$
Climate change	4.30×10^{-1}	kg $CO_{2\text{-}Eq}$
Eutrophication	1.46×10^{-3}	kg $PO_{4\text{-}Eq}$
Toxicity	1.41×10^{-3}	kg 1,4-$DCB_{\text{-}Eq}$
Summer smog	5.22×10^{-3}	kg formed ozone

Table-3 indicates the characterized outcomes for 1 kWh of rice straw as fuel in boiler for electricity generation. The CO_2 gases effect climate change that donates the maximum effect to the atmosphere as matching to life cycle assessment on wood as fuel for electricity generation analysis in Japan (Tabata and Okuda, 2012). Mainly all the procedure released the greatest CO_2 gases, except the paddy farming which produced the CH_4 and N_2O gases. SO_2, NO_X and NH_4 all contribute to acidification (Kasmaprapruet *et al*., 2009). The maximum influence to mutually effects originates by rice straw transportation with 42.42% for acidification and 77.66% for climate change. These amounts are thought lesser than the amount as of conventional fuel power generation (0.3134 kg $SO_{2\text{-}Eq}$/kWh). Totally the effect resulted after paddy residue in power generation are much better compared to conventional type power generation (Chungsangunsit, Gheewala, and Patumsawad, 2004; Hartman and Kaltschmitt, 1999; Prasana-A and Grant, 2011; Ramjeawon, 2008). Figure-2 indicate the environment impact percentage of paddy residue as fuel power production in Malaysia. Rice straw contribute a greater effect with 38% growth on climate change associate to rice husk as fuel for electrical energy production due toward bulk logistic concern and similarly dissimilar set of scheme boundary. This outcome equalin conjunction with research in Thailand electricity generation where rice straw contribute a greater effect on climate change relate to rice husk electricity generation.

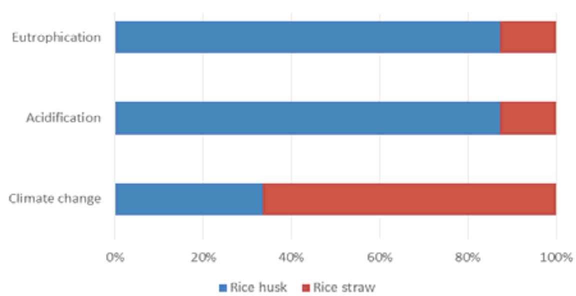

Figure-2. Environment impact percentage for paddy residue based power generation.

CONCLUSIONS

The total paddy residues available in the Malaysia are 3, 234 Million tonnes, which consists of 99.75% rice straw and 97.1% rice husk. The whole involvement of rice straw arrangement to GHG releases is 224.48 g $CO_{2\text{-}Eq}$/kg rice straw. Meanwhile, rice husk provides zero GHG emissions if the radius of rice mill is below 12 km. Rice husk power generation would emit a total of 0.217 kg CO_2/kWh, whereas rice straw results in some 0.43 kg CO_2/kWh. This emission is smaller than conventional power generation.

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