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Study the Development of Paddy Residue Power Generation Based on LCA: A Review

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Abstract: Now a days, the world needs a systematic monitoring system on the environmental impacts due to the increasing awareness of sustainable energy development. LCAs have become the essential tool for this application. Since, biomass has created the greatest potential in energy industries, the environmental impact towards its consumption has become the main concern. This study reviews the LCA studies of biomass power generation. Then, it focuses on the LCA of paddy residue-based power generation specifically in Malaysia. As a consequence, the reviewer can understand and be familiar with the current situation of LCA studies in biomass power generation, especially paddy residue electricity generation. The scenario of paddy residue-based power generation in Malaysia could be a case study in this review study. Hopefully, this study can encourage the application of LCA tools among researchers in evaluating the environmental impacts of developing a sustainable nation.

Key words: Paddy residue, power generation, Life Cycle Assessment (LCA), biomass, Malaysia

INTRODUCTION

The entire world is facing a similar phenomenon in energy production concerning global environmental issues. Dependency on fossil fuel in generating electricity is the main cause contributed to GHG emissions (Shekarchian *et al*., 2011). Regarding this issue, a systematic monitoring system on the environmental impacts is needed to control and secure the sustainable living factors. One approach to measure these anxieties is Life Cycle Assessment (LCA). LCA is a practice that assesses the environmental effect for the whole cycle of its lifetime (Kasmaprapruet *et al*., 2009). Due to established and precise results acquired in the LCA application, presently this analysis has become widespread in environmental analysis. For example, LCA can become an instrument throughout the verdict constructing progression to decide which the most suitable technology is for the assembly of biofuels in terms of an environmentally friendly point of view (Muench, 2015). So far, only inadequate investigation has been through deviations in LCAs of electricity production from biomass resources (Muench, 2015). The main constraint in the application of LCAs studies is due to inadequate data inventory available in some countries. However, in LCA application, the transparency of obtaining information is necessary to be reported.

MATERIALS AND METHODS

A review of LCA application in biomass electricity generation: In early 2000, only five researchers studied the life cycle assessment of biomass system from 1999-2005 which analysed the emissions of carbon dioxide (Turconi *et al*., 2013). However, in 2013, the number of LCA studies has greatly increased, wherein about 167 LCA trainings concerning the entire life cycle of electricityproduction have been critically reviewed in published articles (Turconi *et al*., 2013). Astrup *et al*. (2015) has carried out a critical review involving 250 individual case studies that evaluate the environmental aspect using the LCA approach. Related to this, the LCA tools turn into established environmental assessment throughout the world.

Now a days, the world is shifting to consume renewable sources. Biomass has created a great potential due to its convenience and availability factors. However, the effect on the environment raises serious concerns (Deborah *et al*., 2015). Due to these, most efforts are taken among researchers to study the environmental impact towards biomass consumption in energy industries. For biomass resources classifications, the category, feature and basis of feedstock, also the volume and sort of co-products are significant components that must be pondered upon (Turconi *et al*., 2013). In 2013,

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Table 1: LCA based on biomass resources (rice straw)

Years	Country	Focus	Reference
2013	Thailand	Consumption of rice straw for fuels and fertilisers	Deborah *et al.* (2015)
2014	Malaysia	Environmental evaluation of rice straw-based electricity generation	Silalertruksa and Gheewala (2013)
2014	Taiwan	Gasification technology using LCA for bioenergy from rice straw	Shie *et al.* (2014)
2016	India	Rice straw for bioethanol production focusing on environmental sustainability	Singh *et al.* (2016)

Silalertruksa and Gheewala (2013) studied the life cycle assessment of rice straw consumption in Thailand, specifically for fuel and fertiliser productions. Then, research (Shafie *et al.*, 2015) applied the LCA tools with a thought to analyse the environmental sides of rice straw as fuel in boilers for electricity generation in Malaysia. Table 1 lists the recent researches in LCA based on biomass resources (rice straw). All these studys focus on environmental and technological specifications.

Almost all studys applied the lifecycle to analyse the dissimilar indicators concerning rice straw-based power generation. Overall, the researchers in (Wiloso *et al.*, 2012) summarised that a systematic regulation in terms of preeminent training for LCA of biomass power production on plants is necessary and to concentrate on operational features (functional unit, allocation, system boundaries and impacts assessment) in addition to data features (technology and feedstock description).

LCA methodology standard: The application of the LCA method is supportive in examining (and helpful in decreasing) environmental effects. The LCA methodology determines the environmental effects of the use of biomass as a fuel in boilers. Numerous researchers have decided that this method is the greatest tool for estimating GHG emissions and helpful for environmental development. Although, some studys have already covered the application of LCA in biomass-based power generation, the outcomes vary according to the approaches applied, such as the Functional Unit (FU) and system boundaries setting. The key constraint of LCA is that the assumptions and selection of the allocation method during the training can affect the outcomes too.

An organised outline of the consequences of operational selections and technology performance is necessary to deliver apparent and stable ground work for the LCA modelling prospect of electricity technologies (Turconi *et al.*, 2013). The greatest precarious methodological features in relation to LCA trainings are recognised as: the meaning of the functional unit, the LCA methodology (e.g., IOA, PCA and hybrid), the emission allocation standard and/or system boundary development (Turconi *et al.*, 2013). It is very rare for the circulated trainings to be completely delivered and there are opaque explanations of all these features, in various circumstances avoiding an assessment of the authority of

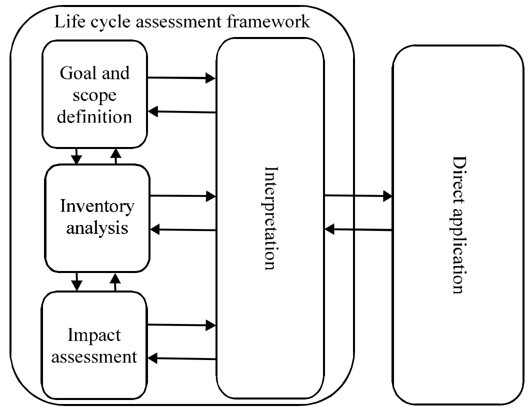


Fig. 1: Life cycle assessment framework (Bhat and Prakash, 2009; Shafie *et al.*, 2012)

outcomes and restrictive applicability of data and results in further perspectives (Astrup *et al.*, 2015). The systematic insertion of parameter uncertainty and variability in persuading parameters of the LCAs of bioenergy systems is an significant mission to be executed in order to examine more precise results that support policy makers to provide more sustained responses to bioenergy sustainability benchmark achievement (Sastre *et al.*, 2015).

The complexity of the particulars and period setting of an LCA study may differ to an outsized scope, provisional on the description of aim and scope (Bhat and Parakash, 2009). Figure 1 shows the life cycle assessment framework (Bhat and Parakash, 2009; Shafie *et al.*, 2012). The LCA framework standard must consist of goal/scope, inventory analysis, impact assessment and interpretation.

RESULTS AND DISCUSSION

Goal and scope definition: In LCA studies, it is essential for the researcher to decide the aim or goal of the study before starting the LCA procedure. Then, the Functional Unit (FU) applied in the training is decided. Functional unit refers to a measured recital of an item scheme on behalf of a practice as a reference unit in a life cycle assessment training. In electricity generation, the functional unit can be in the amount of electricity generated, whether kWh or MWh. As an example, this author applies 1.5 MWh of electricity generated from rice husk burning (Shafie *et al.*, 2012). The amount of FU set

Table 2: Impact method developed in different countries

Impact methods	Country
EcoPoints	Switzerland
CML 1992 and 2000	The Netherlands
EPS 2000	Sweden
Eco-indicator 95 and 99	The Netherlands
Impact 2002	Switzerland
EDIP 2003	Denmark
LIME	Japan
Traci 2005	USA

will be applied all over the study and will stimulate all the processes comprised in the LCA framework. Setting the goal and scope can help to decide the system boundaries of the study. System boundary consists of an entire cycle of the energy storage systems that are considered as a suitable backup and balancing tool in a large-scale energy grid (Bhat and Parakash, 2009) as an example here in Malaysia, a complete sequence energy investigation of rice husk in generating electricity in Malaysia begins with paddy production till electricity production (Shafie *et al*., 2012). The decision of setting system boundaries cannot be too broad or too narrow. The LCA studies only consider the processes included in the system boundaries only.

Life Cycle Inventory (LCI): Inventory analysis comprises data assortment and calculation techniques to compute appropriate inputs and outputs of a product structure (Liu *et al*., 2010). In general, LCI investigation is to compile a list of cradle-to-grave inventory data by counting the balance of flows involving inputs and outputs, such as materials and energies, during the entire cycle of a product or structure (Abdelhady *et al*., 2014). According to Gao *et al*. (2014) inventory analysis is a practice for guessing the use of resources and the amounts of leftover movements and emissions produced by or else attributable to a product's cycle. However, appropriate life cycle inventory datasets reflecting the local conditions and the temporal scope of the study must be applied, founded on the scope of an individual research (Deborah *et al*., 2015). For example, in the LCA of rice straw utilisation for fuel, the Ecoinvent 2.0 database that complemented with the Thai LCI data were used as the data source (Silalertruksa and Gheewala, 2013).

Impact assessment: Life cycle impact assessment is constructed on the inventory analysis data created for the component procedures. The impact assessment part may contain components, for example, conveying inventory data to impact classification, modelling the inventory data within impact classification (characterisation) and perhaps accumulating the results obtained in very precise circumstances and only when meaningful (weighting). There is partiality in the life cycle impact assessment part, for instance, the selection, modelling and evaluation of impact classifications. Consequently, transparent is vital to impact assessment to confirm that assumptions are noticeably defined and stated.

Interpretation: In the circumstance of life cycle inventory studies, the outcomes are reliable with the clear goal and scope appropriate to make the decisions and suggestions. This part comprises result, assumption and limitation related with the interpretation of the result and finally the data quality assessment. Table 2 shows some examples of impact methods developed in different countries. Table 3 shows the lists of current LCA studies in paddy residue-based power generation. The setting of functional unit and system boundary vary among the researchers. The criteria such as local condition, transportation and technology are the most influential criteria to the output. Thailand provides a lot of RNDs in the field of LCA studies in paddy residue-based power generation compared to other countries

Lca of paddy residue based power generation: case of malaysia: Recently, several investigations on paddy residue for power in terms of ethanol and electricity generation have been carried out. The assessment of environmental aspects towards rice straw consumption for electricity generation is significant to be examined due to the important attention for technology investment. Evidence on the environmental phase should be scattered to completely recognise the track of Malaysia's prospective energy (Ali *et al*., 2012). Even though LCA studies on paddy residue-based electricity generation have already been conducted in Malaysia, the local conditions such as power plant locality, crop extra evaluation to decrease the environmental impacts. Table 4 shows the LCA of paddy residue-based power generation in Malaysia. Rice straw as fuel in power plants contributes more 628 $CO_{2\text{-eq}}$ to the environment. This is due to more processes included in the analysis which are the rice straw collection centre and rice straw collection process. However, rice husk is directly transported to the power plant without any storage process applied in the analysis. The utilisation of rice straw in electricity generation creates a huge potential due to the abundant availability of rice straw in the fields. Since transportation plays an important role in GHG emissions, an optimum route analysis should be made to solve the problem. Paddy residues still emit lower GHG emissions compared to conventional fossil fuels in Malaysia (Shafie *et al*., 2012).

Table 3: Current LCA studies in paddy residue based power generation

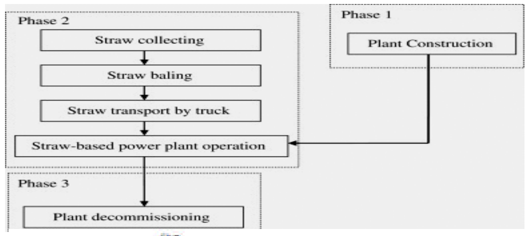
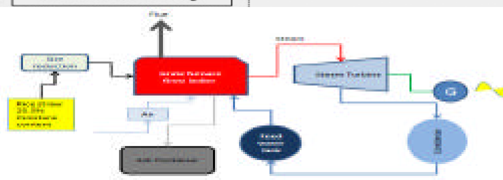
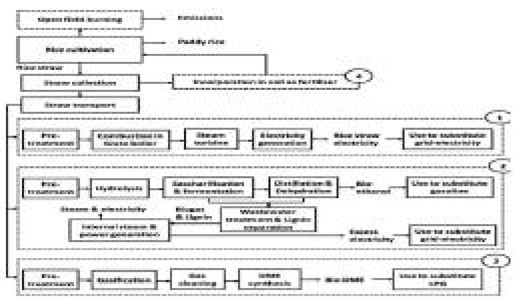
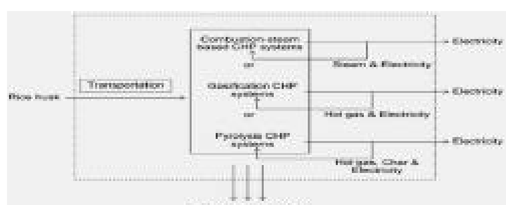
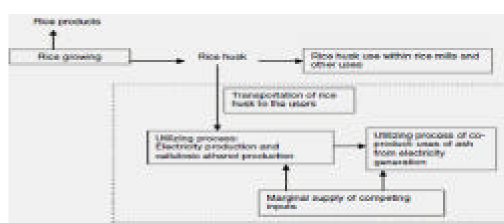
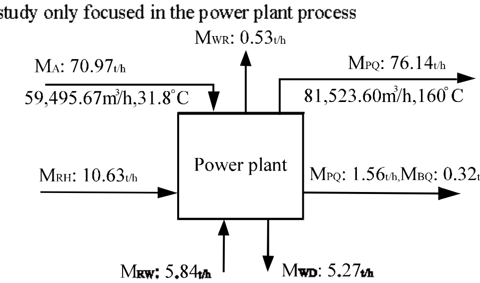
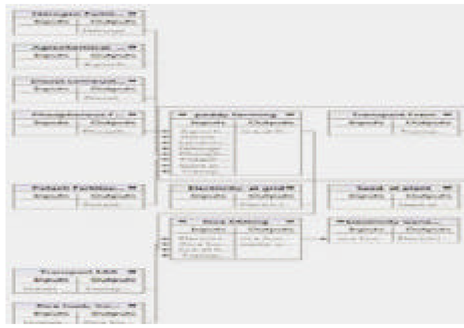
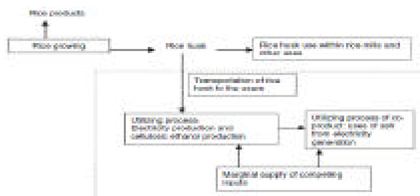
Researches	Goal scope	FU	System boundary	Results
Liu *et al*. (2010)	Electricity generation in China using rice straw	Nil		7.27 g CO_2/kWh-this study did not consider the plantation and harvesting processes
Abdelhady *et al*. (2014)	Electricity generation in Egypt using rice straw	Only considered the power plant process		10.9 g CO_2/kWh- Neglected the cultivation and harvesting processes harvesting processes
Gao *et al*. (2014)	Rice straw-based electricity generation in China	A bale (700 kg) in electricity generation	Harvesting ->Bale->Transport->CHP	1253.60 g CO_2-eq/kWh
Silalertruksa and Gheewala (2013)	Rice straw-based electricity generation in Thailand	Nil		614 g CO_2-eq/kWh
Rachman *et al*. (2015)	Rice husk-based electricity generation in Indonesia	Nil	The study only focuses in the power plant process	229.45 g CO_2-eq/kWh
Prasara *et al*. (2012)	Rice husk for power generation in Thailand (1st CASE)	To process 200,000 tonnes/ year of rice husk		1563.66 g CO_2 -eq/kWh
Prasara and Grant (2011)	Rice husk for power generation in Thailand (2nd CASE)	To process 1000 tonnes of rice husk		1036.99 g CO_2-eq/kWh
Chungsangunsit *et al*. (2014)	Power generation from rice husk in Thailand	Generated 1 MWh of electricity at power plant	The study only focused in the power plant process 	17.27 g CO_2-eq/kWh

Table 4: LCA of paddy residue based power generation in Malaysia

Paddy residue	References	FU	System boundary	Result g CO_2-eq/kWh	Conclusion
Rice husk	Shafie *et al.* (2012)	1.5 Mwh electricity generated		217	Most significant processes are from transportation and milling processes
Rice straw	Shafie *et al.* (2015)	1 kWh of electricity		845	Contribute 96.65% of CO_2 gas to GHG emissions

CONCLUSION

Now a days, there is an awareness to study the environmental impact towards the power generation in countries worldwide. LCA has become the best practical tool to evaluate the environmental assessment. The adoption of LCAs in this area can help researchers, the government and stakeholders to obtain an accurate result. Malaysia still lacks the LCA data result. However the result can optimize the efficiency of the process in terms of environmental impact. With that, the forecasting data can be tabulated to generate a sustainable energy development for the nation.

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