Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 75 (2015) 2757 – 2763

Energy Procedia

The 7th International Conference on Applied Energy – ICAE2015

The Technical Efficiency of Rice Husk Power Generation in Thailand: Comparing Data Envelopment Analysis and Stochastic Frontier Analysis

Nattanin Ueasin[a], Shu-Yi Liao[b], and Anupong Wongchai[c,]*

[a]*Indo-China Country International Trade and Economic Research Sector, Faculty of Integrated Social Science, KhonKaen University, NongKhai Campus, NongKhai, Thailand.*
[b]*Department of Applied Economics, National Chung Hsing University, Taichung, Taiwan.*
[c]*Department of Agricultural Economics and Extension, Faculty of Agriculture, Chiang Mai University, Chiang Mai, Thailand.*

Abstract

Since the efficiency of rice husk biomass power plants in Thailand has never been reliably assessed, this study undertook the task of measuring the technical efficiency of Very Small Power Productions (VSPPs). The secondary data recorded in 2012 were collected from the power policy bureau in Thailand. Two concepts of Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) were adopted to analyze a group of 57 biomass power plants. The results indicated that a SFA model exhibited the highest score of 0.877, followed by a Constant Return to Scale-DEA (CRS-DEA) and Variable Return to Scale-DEA (VRS-DEA) at 0.841 and 0.722, respectively. Input surpluses of capacity and rice husks were highlighted to improve unit efficiency. Moreover, we found that the efficiency scores derived from the VRS-DEA and SFA models were more consistent than those computed by the CRS-DEA and SFA models. Accomplishing the Thai government's goal of sustainable, renewable energy will encourage more utility plants to use rice husk for electricity generation.

Peer-review under responsibility of Applied Energy Innovation Institute

Keywords: data envelopment analysis, rice husk, stochastic frontiers analysis, technical efficiency, very small power productions

1. Introduction

There has been an increasing trend in using rice husk biomass for electricity generation year by year as a result of government promotion programs and increased environmental awareness. Rice husk has a high

* Corresponding author. Tel.: +668-53-944-066 ext. 23; fax: +668-53-892-654
*E-mail address:*add.a@hotmail.com

Peer-review under responsibility of Applied Energy Innovation Institute
doi:10.1016/j.egypro.2015.07.518

biomass potential in Thailand because a rice processing system has been developed to collect about 90% of all rice husks at small additional cost. The estimated potential energy from rice husks is equivalent annually to about 23,000 kilotons of oil [1]. In 2001, the Thai government initiated the program of Very Small Power Productions (VSPPs) that generates electricity primarily from renewable energy materials. Up until that point, the capacity of the average VSPP plant was less than or equal to 10 megawatts (MW).

Since the rice husk VSPP generated has played an increasingly important role in the Thai energy industry each year, it has become necessary to measure the technical efficiency of rice husk power generation. Therefore, this study aims to measure the technical efficiency of rice husk power generation throughout Thailand using the concepts of Data Envelopment Analysis (DEA) and Stochastic Frontiers Analysis (SFA). In addition, this study attempts to determine which analysis technique is best suited as a research tool to compare the efficiency scores derived from the two methods.

2. Literature Review

Since rice husk biomass is one of the most significant biomasses in Southeast Asia, it offers many benefits for a variety of applications. One application is to use this material for energy generation. There has been a significant number of studies performed concerning the application of rice husk biomass that have employed a variety of research tools. For example, Zeng, Liu and Yu [2] studied the structure and properties of natural rubber filled with epoxidized natural rubber modified rice husk ash. Maamur and Jais [3] conducted a study on rice husk derived silica aerogel for use as a chromatographic packing material for color separation of purple orchid flowers.

Rausch and Mowers [4] measured the efficiency and distribution impacts of clean and renewable electrical energy standards in America. The empirical results demonstrated that electricity standards are 2 to 4 times more costly than a market-based carbon pricing policy. The current trends are more regressive and produce uneven regional impacts. In addition, revenues are too low to adjust for unintended distributional consequence.

Nattanin and Wongchai [5] assessed the operating efficiency scores of energy companies registered in the Taiwan Stock Exchange between 2003 and 2012. The empirical results showed that seven firms performed efficiently, ranking from 7.29 to 1.02. The company with the best operating performance was Taiwan Cogeneration Corporation, while the Great Taipei Gas Corporation exhibited the worst efficiency score. Furthermore, a Tobit regression model claimed that a higher number of local employees and a lower the number of shareholders in a company led to higher efficiency scores

At present, there appears to be no published reports concerning the studies of the efficiency measurements of rice husk biomass power plants in VSPPs. For the benefit of Thailand and the region, it is essential to assess the technical efficiency of VSPPs located throughout Thailand. In addition, this research focuses solely on power plants that utilize rice husk for electricity generation.

3. Materials and Methods

The secondary data for 2012 were collected from the power policy bureau, the energy policy and planning office, at the Ministry of Energy, Thailand. These data were cross-sectional of 57 VSPPs located throughout the country. Practically, the capacity of VSPPS is considered as being less than or equal to 10 MW. All of these VSPPs employed gas engine generators and also employed steam turbine generators. Notably, all the VSPP statistics are from the Metropolitan Electricity Authority and the Provincial Electricity Authority of Thailand.

Generally, there are two sides in the production function of electricity generation. The left side represents the inputs used to generate electricity, whereas the right side depicts the power generation output produced. The study utilizes the volume of electricity as one output [6] and considers two inputs, including the different sizes of capacity [7] and the quantity of rice husk [8].

Theoretically, efficiency is defined as the operation level that produces the greatest amount of output with the lowest amounts of input. Efficiency relates to the use of all inputs, for example money, time, natural resources, labor, etc. in producing any given output. It is the main factor to determine productivity. Efficiency measurement can range from 0.00 to 1.00. The maximum score (1.00) represents the highest efficiency while the scores of 0.00-0.99 show a firm's inefficiency, indicating the relative displacement from the frontier [9].

This study adopted the Constant Return to Scale (CRS-DEA), Variable Return to Scale-DEA (VRS-DEA), and SFA models to assess the technical efficiency of the VSPPs in Thailand in 2012. DEA is defined as a non-parametric method that is exclusively applied to measure the firm's efficiency scores [10]. In contrast, SFA is a parametric method that requires a specific function to compute the efficiency scores. It was first proposed by Aigner, Lovel, & Schmidt [11], and then developed by Meeusen & Van den Broeck [12].

The concept of the DEA model consists of two aspects, CRS-DEA and VRS-DEA. CRS-DEA implies a constant return to scale model, which is usually used in a competitive market. In contrast, the VRS-DEA means a variable return to scale model. It is best suited to an uncompetitive market. This study has adopted both aspects of DEA in order to compare the efficiency scores because there is no information about price competitiveness for VSPPs.

4. Results and Discussion

The findings show that the average scores for all 57 VSPPs are very high because the rice husk biomass power plants have high technical efficiency. The SFA model shows the highest average score at 0.877, followed by VRS-DEA at 0.841 and CRS-DEA at 0.722 as shown in Table 1.

Table 1. Descriptive statistics of efficiency scores, categorized by model

Efficiency Score	CRS-DEA	VRS-DEA	SFA
1.00	1	4	-
0.90-0.99	-	5	28
0.80-0.89	8	42	24
0.70-0.79	25	3	3
0.60-0.69	20	1	1
0.50-0.59	2	1	-
< 0.50	1	1	1
Number of VSPPs	57	57	57
Average efficiency score	0.722	0.841	0.877
Maximum efficiency score	1.000	1.000	0.974
Minimum efficiency score	0.336	0.354	0.413

Under the conditions of the CRS-DEA model, there was only one firm that performed efficiently. The largest group (25 firms) was found to be in the range of 0.70-0.79. The maximum score for the CRS-DEA

model is 1.000, while the lowest actual score was 0.336, which is the lowest number among the three approaches.

The VRS-DEA model found that only one firm performed efficiently. The remaining 56 firms operated relatively inefficiently. The majority of firms (42) were in a range of 0.80-0.89. With this distinctive method, the highest efficiency boundary was 1.00, while the lowest efficiency boundary was very low at 0.354.

The analysis of the SFA model showed that no firm performed efficiently at a score of 1.000. All 57 firms showed technical inefficiency with a range of different scores. Remarkably, the majority of firms (28) were in the range of 0.90-0.99. The highest and lowest efficiency scores derived from this method were 0.974 and 0.413, respectively.

Since the average efficiency scores of the CRS-DEA, VRS-DEA and SFA models were computed as 72.20%, 84.10%, and 87.70%, respectively, the VSPPs should increase their technical efficiency scores by around 12.3-27.8% in order to reach the highest efficiency score of 1.00. The different technical efficiency scores derived from the CRS-DEA, VRS-DEA, and SFA models resulted from the assumptions and limitations of the DEA and SFA concepts relating to relative competitiveness in the VSPP market.

To achieving their sustainable energy goals, the Thai government focuses on renewable energy use which will improve the economy and the country providing for energy security through the efficient use of sustainable resources. A practical way should be found to establish beneficial policies for rice husk biomass power plants. The Thai Government should encourage more biomass production from rice husk and focus on small scale farmer-cooperative rice mills, especially in rural areas. This approach would not only could reduce the cost of producing electricity for their own use, but could also be environmentally beneficial and increase farmers' incomes.

It would appear that biomass technology and supply chain development are useful policies that the government should emphasize in order to reduce production costs and increase the generation capacity in the near future. Since the initial capital investment for generation of rice husk biomass is high, research and development (R&D) is a useful strategy to improve technical efficiency, as well as to sustain renewable electricity for VSPPs. An intensive R&D project could find alternative ways to improve the technical efficiency of rice husk biomass power generation. This R&D should involve cooperation with other energy-related organizations at both national and international levels.

According to the DEA model, the input surplus demonstrates the ability to decrease the quantity of inputs used for VSPP electricity generation for a given quantity of output. Table 2 presents the descriptive statistics of the input surplus for capacity and rice husk. Overall, the study found that the lack of capacity and rice husk to be 2.37% and 1.30%, respectively. This technical inefficiency was caused by the insufficient quantities of capacity at 2.37%, together with rice husk at 1.30%. If the VSPP producers increase the quantities of these two inputs, the average technical efficiency score will increase.

Table 2. Descriptive statistics of the input surplus

Input	Average input surplus (1)	Average input used (2)	Ratio of input surplus [(1)/(2)]*100
Capacity (KW)	0.18	7.58	2.37
Rice husk (Ton/Year)	894.50	68,994.50	1.30

The consistency between the three aspects of the studied models was tested by Pearson correlation. Table 3 shows the correlation between the CRS-DEA model and the SFA model, which was very high at 0.872 at the statistical significance level of 1%. On the other hand, the correlation between the VRS-DEA

model and the SFA model was even higher (0.977) at the statistical significance level of 1%. The high correlation was the result of close average efficiency scores.

Table 3. Descriptive statistics of Pearson correlation categorized by model

Model	TE (CRS-DEA)	TE (VRS-DEA)	TE (SFA)
TE (CRS-DEA)	1.000		
TE (VRS-DEA)	0.910***	1.000	
TE (SFA)	0.872***	0.977***	1.000

Note: 1. TE is an abbreviation of Technical Efficiency
2. ** depicts a statistical significance level of 1%

The descriptive statistics of the correspondence analysis are shown in Table 4. The study ranged the efficiency scores from the highest to the lowest, and then separated them into two big groups, the best and worst practice groups. These two practice groups are included in the study to analyze the correspondence test in order to find the appropriate paired model to measure technical efficiency. The best practice group showed that the VRS-DEA and the SFA models performed with a higher correspondence, at 98.20%, than the CRS-DEA and the SFA models at a statistical significance level of 1.00%. The result shows that the VRS-DEA and the SFA models were more consistent than the other combinations.

Table 4. Correspondence analysis between the best and the worst practice groups

Model	CRS-DEA	VRS-DEA	SFA
Best practice group			
CRS-DEA	1.000		
VRS-DEA	0.829***	1.000	
SFA	0.813***	0.982***	1.000
Worst practice group			
CRS-DEA	1.000		
VRS-DEA	0.935***	1.000	
SFA	0.941***	0.998***	1.000

Note: *** depicts a statistical significance level of 1%

The worst practice group had the same results as the best practice group. The pair of VRS-DEA and SFA models had a higher correspondence (99.80%) than the pair of CRS-DEA and SFA models (94.10%) with a statistical significance level at 1%. In summary, the VRS-DEA and SFA models produced higher consistent results than the other pairings of models.

5. Conclusions

This study assesses the technical efficiency of VSPPs in Thailand using the CRS-DEA, VRS-DEA and SFA models. These power plants have utilized rice husk as the main raw material in the process of electricity generation. The findings show that the average technical efficiency scores were in the range of 72-88% which are below the maximum efficiency score. However, the overall assessment indicates that the three aspects showed very high efficiency scores. The inefficiency scores were in the range of 12-28% and were caused by input surpluses.

It is necessary to adjust the input surpluses in order to achieve the maximum scores for technical efficiency. The production function of VSPPs is required to increase the capacity by 2.37% on average, as well as increase the rice husk by 1.30%. New adjustments for production factors can provide better technical efficiency scores, employing the same input-orientated approach.

Comparing the descriptive statistics derived from CRS-DEA, VRS-DEA and SFA models, the SFA provided the best results because it could determine the relationship between the dependent and independent variables in this study. In addition, Pearson analysis showed that the pair of VRS-DEA and SFA models was more consistent from an overall perspective than the pair of CRS-DEA and SFA models, based on the various technical efficiency scores.

Increasing the VSPPs' efficiency scores not only means adjusting the production inputs, but also sustainable development needs to be promoted at all power production plants throughout the country. A firm's owner should learn how to manage effectively by making more effort to minimize production cost, to get rid of surplus inputs to increase output and to maximize net profit.

Acknowledgements

The authors would like to express our special gratitude to the Division of Research Administration, Khon Kaen University, Thailand, that gave us the Bomphor fund to conduct a wonderful research project (80% of research funding). In addition, we feel very grateful to Indo-China Country International Trade and Economic Research Sector members for their funding and their patient proof reading in the completion of this study (20% of research funding). The authors have now learned many new things about rice husk power production.

References

[1] Chungsangunsit T, Gheewala SH, Patumsawad S. Environmental assessment of electricity production from rice husk: A case study in Thailand. Electricity Supply Industry in Transition: Issues and Prospect for Asia 2014;**20**:51-62.

[2] Zeng ZQ, Liu HC, Yu HP. Structure and properties of natural rubber filled with epoxidised natural rubber modified rice husk. *Mater Res Innov* 2013;**17**:251-54.

[3] Maamur KN, Jais US. Rice husk derived silica aerogel as chromatographic packing material for colour separation of purple orchid (Cattleya bowringiana) folwer. *Mater Res Innov* 2009;**13**:334-36.

[4] Rausch S, Mowers M. Distributional and efficiency impacts of clean and renewable energy standards for electricity. Resour *Energy Econ* 2014;**36**:556-85.

[5] Nattanin U, Wongchai A. Operating efficiency analysis of energy industries in Taiwan. *Adv Mat Res* 2014;**870**:612-20.

[6] Bartelj L, Paravan D, Gubina AF, Golob R. Valuating risk from sales contract offer maturity in electricity market. *Int J Elec Power* 2010;**32**:147-55.

[7] Parpas P, Webster M. A stochastic multiscale model for electricity generation capacity expansion. *Eur J Open Res* 2014;**232**:359-374.

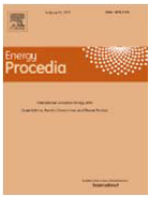
[8] Karim MR, Zain MFM, Jamil M, Lai FC, Islam MN. Use of wastes in construction industries as an energy saving approach. *Energy Procedia* 2011;**12**:915-19.

[9] Wongchai A, Tai CF, Peng KC. An application of super-efficiency and tobit method for financial efficiency analysis of food industrial companies in Taiwan. Proceedings of 2011 2nd IEEE International Conference on Emergency Management and Management Sciences 2011, 823-26.

[10] Charnes A, Cooper WW, Rhodes E. Evaluating program and managerial efficiency: An application of data envelopment analysis to program follow through. *Manage Sci* 1981;**27**:668-697.

[11] Aigner DJ, Lovell CAK, Schmidt P. Formulation and estimation of stochastic frontier production function models. *J. Econometrics* 1997;**6**:21-37.

[12] Meeusen W, Van den Broeck J. Efficiency estimation from Cobb-Douglas production functions with composed error. *Int Econ Rev* 1997;**18**,435-444.



Biography

Mr. Anupong Wongchai (Ph.D.) earned a Ph.D. degree in Agricultural Economics and Management, National Pingtung University of Sciences and Technology, Taiwan. He is an expert in efficiency measurement, adopting two concepts of DEA, and SFA. He is now working as a lecturer at Department of Agricultural Economics and Extension, Faculty of Agriculture, Chiang Mai University, Thailand.