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# Effect of International Electricity Trade on Price of Electricity in Thailand

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**Abstract**

This paper investigates the effect on electricity prices of electricity import, export and generation in relation to Thailand. Time series analysis of data for the 60 months from 2010 to 2014 is used in determining electricity prices, with linear least squares regression being employed in constructing the model of electricity price function. Following expectation, empirical results show that increase in domestic electricity generation appears to have a negative effect on electricity prices. While increase in electricity export shows no effect, increase in import, surprisingly, appears to have a positive effect on electricity prices, possibly in accordance with different energy regulations across countries impeding efficiency in electricity trade negotiations. The challenge facing policy makers is to extract the maximum benefit from electricity trade with a view to lowering electricity prices, while not losing sight of the country's core responsibility of ensuring energy security.

*Keywords:* electricity; international trade; price; Thailand

## 1. Introduction

Electricity is a vital commodity that people cannot live without in the modern day. It provides the power necessary to households, businesses, industries, and the devices that connect individuals to each other and the world at large. Presently, demand for electricity is increasing at a far greater rate than overall energy use and is expected to almost double from 2004 to 2030 [1]. As a result, many countries are facing a problem due to lack of electricity supply.

This major challenge of ensuring adequate supply in the face of rapid growth in electricity demand confronts electric utilities in a number of developing countries, foremost among these being Thailand [2]. Hill (2016) points out that, for developing countries, the electricity planning problem can be more complicated than for developed countries. This is due to the fact that electric power industries are some of the most capital-intensive in any economy, depleting scarce financial resources. Furthermore, where countries lack energy resources, the need to import oil and other fuels involves a significant impact on foreign exchange reserves [3].

Electricity Generating Authority of Thailand (EGAT) states that, in 2015, the electricity peak demand for the country was 27,346 MW – an increase of 1.5% from the previous year, while gross energy generation and purchase reached 183,288.53 million units – an increase of 3.2% from the previous year. Thailand's electricity system remained stable with total generation capacity of 38,774 MW comprising domestic power generation of 35,387 MW accounting for 91%, and import from neighboring countries of 3,387 MW accounting for 9% [4] which represents a high percentage.

Thailand's interconnection for electricity with neighbouring countries consists of subregions as identified by the Heads of ASEAN Power Utilities/Authorities (HAPUA). One subregion involves Viet Nam, the Lao People's Democratic Republic (LPDR), Myanmar and Thailand while the southern subregion involves Peninsular Malaysia and Sumatra (Indonesia) (see Figure 1) [5].


Figure 1: ASEAN Power Grid
Source: International Energy Agency, 2015 [5]

Without international electricity co-operation, Thailand could face electricity shortages. Figure 2 shows monthly data for the country's electricity demand, supply and generation from 2010 to 2014. We can see that total electricity supply (generation + import - export) is higher than electricity demand (consumption). However, overall domestic electricity generation is only slightly higher than electricity demand, and in some periods lower. In accordance with economics theories, without international trade, excess electricity demand can occur for this country, leading to the possibility of higher electricity prices.

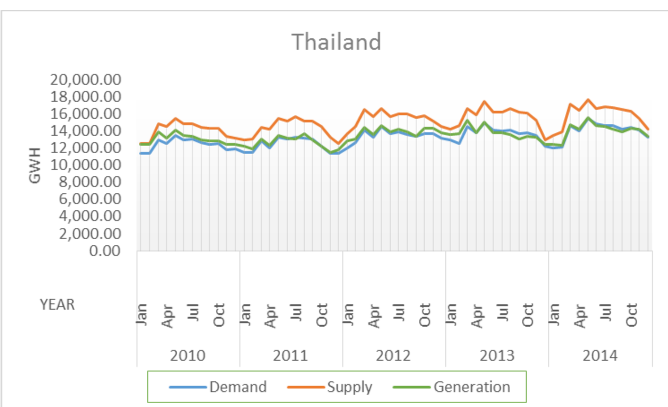


Figure 2: Electricity Demand, Supply and Generation in Thailand
Source: EGAT, 2016 [6]

As a result, it is prudent for electric utilities and energy planners to prepare for, not only electricity-capacity increases, but also the import of supply from neighbouring countries in order to meet anticipated growing demand. While such trade with neighbouring countries has implications for Thailand's energy security, it may well reduce the cost of power generation and electricity prices. The purpose of this study is to explore the effect of electricity import, export and generation on the price of electricity in Thailand.

## 2. Conceptual Framework

Figure 3 shows the Representation of Electricity Market Framework which is developed from the Representation of a Commodity Market model of Labys and Pollak (1984, p. 48) [7], the Major Factors Affecting Supply Adequacy model of the California Energy Commission (CEC) (Pryor et al., 2010) [8] and Boonyasana (2013) [9]. Electricity price equilibrium is determined by demand and supply. Electricity demand is dependent on the economy, demography, weather or season, demand response and interruptibles [8]. On the other hand, electricity supply is dependent on generation, import and export, together with the external influences of distribution loss, taxes, subsidies, sequestration and technologies [9].

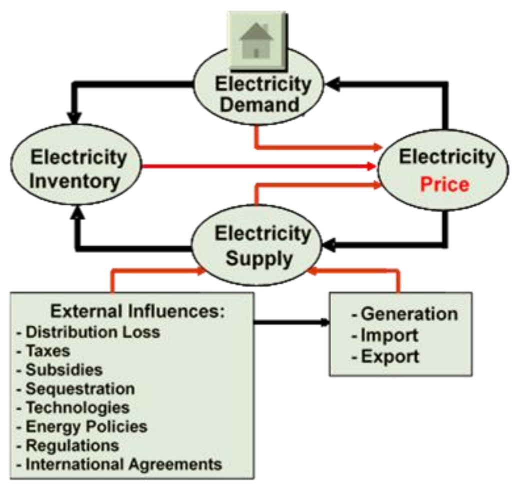


Figure 3: Electricity Market Framework
Source: Boonyasana, 2013 [9]

From Figure 3, we see that, when producers change their price in response to demand and supply, consumers will change their demand in response to price. To avoid this problem of endogeneity [10], this paper focuses solely on supply side which involves the effect of generation, import and export on electricity price. In addition, this study assumes external influences are constant. Because our dependent variable is wholesale electricity prices, with EGAT selling to other suppliers, external influence effects should be minimal.

## 3. Methodology

### 3.1 Data

In this empirical study, the data set for Thailand is provided by the 60 months from 2010 to 2014, and includes electricity prices, generation, import and export made available by EGAT [6]. The table below contains the descriptive statistics for all data.

Table 1: Descriptive Statistics

| | **Descriptive Statistics (60 Months from 2010 to 2014)** | | | |
|---|---|---|---|---|
| | Mean | S.D. | Min | Max |
| Price (*Baht/kWh*) | 2.81 | 0.23 | 2.43 | 3.16 |
| Generation (*kWh*) | 14,355.46 | 1,082.54 | 12,244.12 | 16,754.97 |
| Import (*kWh*) | 889.78 | 341.85 | 143.13 | 1,596.69 |
| Export (*kWh*) | 119.21 | 55.28 | 19.14 | 250.76 |

Source: EGAT, 2016 [6]

Note: S.D., Min and Max indicate standard deviation, minimum and maximum respectively.

A time series regression model is suitable for evaluating the effect of international trade on Thailand's electricity price, with care taken to properly account for trend and seasonality. However, Figure 4 indicates no seasonal effect for electricity price.

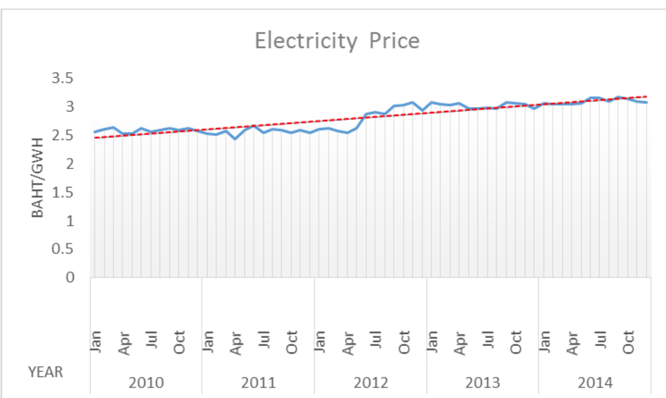


Figure 4: Electricity Prices in Thailand

Source: EGAT

To overcome the problem of different measurement scales for the dependent variable (Baht per kilowatt hour: Baht/kWh) and the independent variables (kilowatt hour: kWh), the natural logarithms (*ln*) of all variables are taken. Furthermore, Figure 4 shows that the data have exponential trending, so this series cannot be fit by a linear trend unless the natural logarithms are used.

3.2 Statistical Analysis

3.2.1 Unit Root Test

Before time series analysis is conducted, the Augmented Dickey-Fuller (ADF) unit root test is employed to check for stationarity [11]. From Table 2, the ADF unit root test results offer evidence of non-stationarity for electricity price which is the dependent variable. As a result, to avoid the non-stationary process, taking first differences (Δ) of all variables is recommended.

Table 2: Unit Root Test Results

| **Augmented Dickey-Fuller Test Statistic (ADF)** | | | |
|---|---|---|---|
| Variable | Constant Term | | |
| | Level | 1st diff | Conclusion |
| Price (*ln*P) | -1.147 | -9.558*** | I(1) |
| Generation (*ln*G) | -3.685*** | | I(0) |
| Import (*ln*M) | -5.804*** | | I(0) |
| Export (*ln*X) | -4.606*** | | I(0) |

Note: *** illustrates significance at 1% level.

3.2.2 Correlation Test

This paper employs the Pearson correlation test to check for multicollinearity, where high correlation exists between two or more independent variables [12]. The results show no high correlation among independent variables (see Table 3).

Table 3: Correlation Test Results of Independent Variables

| | **Correlation Test Results** | | |
|---|---|---|---|
| | *Δln* (G) | *Δln* (M) | *Δln* (X) |
| *Δln* (G) | 1 | | |
| *Δln* (M) | 0.535*** | 1 | |
| *Δln* (X) | 0.217* | -0.061 | 1 |

Note: *** and * illustrate significance at 1% and 10% levels respectively.

3.2.3 Testing for Serial Correlation

Consistency of results requires no serial correlation in the error terms, which is tested by means of the Durbin-Watson statistic [13; 14].

Price Equation 1:

$$\Delta \ln(P_t) = \alpha + \beta_1 \Delta \ln(G_t) + \beta_2 \Delta \ln(M_t) + \beta_3 \Delta \ln(X_t) + \varepsilon_t$$

(1)

After running the regression (Equation 1), the Durbin-Watson statistic result (2.44) indicates serial correlation may be present. This paper adopts the method of adding lagged values of the independent variables for dealing with the problem of serial correlation.

3.3 Empirical Models

This paper employs time series analysis to construct the model of electricity price. The explanatory variables are generation (G), import (M) and export (X). Such an approach shows the effects of Thailand's international electricity trade on price. Using Δ as a difference operator, the model is presented as below.

Price Equation 2:

$$\Delta\ln(P_t) = \alpha + \beta_1\Delta\ln(G_t) + \beta_2\Delta\ln(M_t) + \beta_3\Delta\ln(X_t) + \beta_4\Delta\ln(P_{t-1}) + \varepsilon_t \quad (2)$$

where $t$ denotes years, $\varepsilon_t$ is the error term and the lagged dependent variable ($P_{t-1}$) accounts for the autoregressive effects of the previous years.

3.4 ARCH, GARCH and TGARCH Effects

Engle (1982) [15] proposed a model called Autoregressive Conditional Heteroskedasticity (ARCH) with the variation of conditional variance. The ARCH model assumes that the variance of the present error term or innovation is a function of the actual dimensions of the previous time periods' error terms, with the variance often related to the squares of the previous innovations. Later, Bollerslev (1986) [16; 17] proposed the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model to overcome the higher order ARCH problem. The conditional variance is dependent on the previous squared errors and restricted variances of the GARCH model [18]. Following this, the threshold GARCH (TGARCH) model proposed by Zakoïan (1994) [19] extended the Taylor-Schwert GARCH (TS-GARCH) model allowing the conditional standard deviation to depend upon the sign of the lagged innovations.

The empirical analysis of this study compares regression coefficients of Ordinary Least Squares (OLS) [20; 21], as well as results of the ARCH, GARCH and TGARCH models to avoid Heteroskedasticity.

## 4. Results and Discussions

This study investigates whether increase in international electricity trade can reduce price of electricity, with a view to determining Thailand's future energy policies. Estimation for time series data determines the electricity price function, using 60 monthly data input from 2010 to 2014.

4.1 Time Series Analysis Results

Table 4 compares time series analysis results of Thailand's electricity price for four models. The OLS model is employed to show results of simple regression. Of the three ARCH family models, the GARCH model is selected to explain the findings because of giving the lowest values of Akaike Information Criterion (AIC) which is -4.383, and Schwarz Information Criterion (SIC) which is -4.134.

Table 4: Results of Time Series Analysis for Electricity Price

| | **Thailand's Electricity Price: Δ ln(P)** | | | |
|---|---|---|---|---|
| | OLS | ARCH | GARCH | TGARCH |
| $\Delta\ln(G_t)$ | 0.040<br>(0.071) | -0.003<br>(0.057) | -0.079*<br>(0.043) | -0.051<br>0.054 |
| $\Delta\ln(M_t)$ | -0.001<br>(0.011) | -0.004<br>(0.007) | 0.030***<br>(0.010) | 0.011<br>0.008 |
| $\Delta\ln(X_t)$ | -0.003<br>(0.008) | -0.005<br>(0.006) | -0.004<br>(0.005) | -0.005<br>0.007 |
| $\Delta\ln(P_{t-1})$ | -0.223*<br>(0.133) | -0.218<br>(0.143) | -0.334**<br>(0.144) | -0.360<br>0.159 |
| DW | 2.148 | 2.175 | 1.896 | 1.940 |
| AIC | -4.370 | -4.348 | -4.383 | -4.354 |
| SIC | -4.228 | -3.993 | -4.134 | -4.069 |
| Observation | 58 | 58 | 58 | 58 |

Notes: (1) Standard errors in ( ).
(2) ***, ** and * illustrate significance at 1%, 5% and 10% levels respectively.
(3) DW, AIC and SIC indicate Durbin-Watson Test, Akaike Information Criterion and Schwarz Information Criterion respectively.

The results of the GARCH model show that a rise of 1% in domestic generation decreases electricity price by about 0.08%. Surprisingly, a rise of 1% in electricity import is seen to increase price by about 0.01%, with the result being highly significant. For electricity export there appears no effect on price, holding everything else constant.

With the aim of avoiding biased results, the serial correlation test, the heteroskedasticity test (ARCH effect) and the test for normal distribution are employed in checking with regard to the GARCH model. The results show no serial correlation and no ARCH effect. In addition, residuals are found to be normally distributed (see Figure 5).

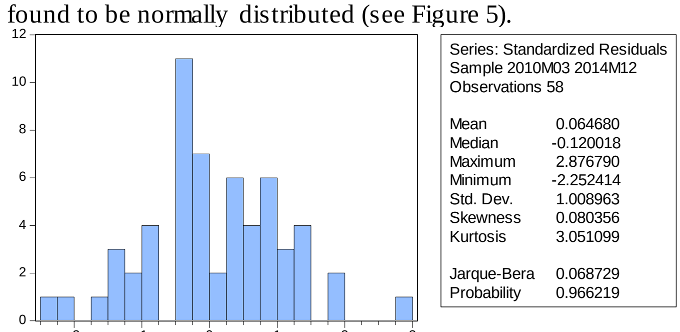

Figure 5: Normal Distribution of Residuals

4.1 Discussions

Even though domestic generation can decrease electricity price, as mentioned by Hill (2016), electricity planning in many developing countries, like Thailand, involves a number of complications. The capital-intensive nature of industry in any economy can be a drain on scarce finance, while lack of energy resources poses a constant threat. In addition, Thailand faces protests by Non-government Organizations (NGO) and local people against further construction of coal-powered electricity plants. The goal for policy makers is to raise community awareness with regard to the reality of current energy requirements, as well as devise strategies towards achieving the optimal balance between energy security and environmental protection.

Furthermore, consideration needs to be given as to why electricity import may not be economically favourable. Results of this study show that electricity import increases price with a high level of significance. This might be due to different energy regulations across countries resulting in obstructions to harmonious trade negotiations. Not every country can have every need fulfilled, leading to difficulties in maximizing energy efficiency [22]. The suggestion, therefore, is that Thailand should seek more electricity co-operation with neighbouring countries with a view to increasing the efficiency of international trade. When security of electricity supply goes up, and cost of production and price of electricity goes down, the outcome is a rise in the standard of living for the people of Thailand.

## 5. Conclusions

Electricity import can be an effective component of electricity supply measures. While such trade with neighbouring countries has implications for Thailand's energy security, it may well reduce the cost of power generation and electricity prices. This paper examines the impact of electricity import, export and generation on the price of electricity for Thailand. A period of 60 months from 2010 to 2014 provides data for time series analysis to determine electricity prices, while linear least squares regression is used to construct the model of electricity price function. As anticipated, it is found that increasing domestic electricity generation appears to reduce electricity prices. However, in an unexpected finding, increase in electricity import appears to raise electricity prices. One possible explanation for this is that different energy regulations across countries may pose a restriction on the efficiency of trade negotiations. The difficulty for policy makers lies in extracting maximum advantage from electricity trade with a view to reducing electricity prices, while at the same time safeguarding national energy security.

**Abbreviations**

EGAT, Electricity Generating Authority of Thailand; HAPUA, the Heads of ASEAN Power Utilities/Authorities; LPDR, the Lao People's Democratic Republic; kWh, kilowatt hour: Gigawatt Hour; P, acute wholesale electricity price; G, acute local electricity generation; M, electricity import; X, electricity export; eq., equation; ARCH, Autoregressive Conditional Heteroskedasticity; GARCH, Generalized Autoregressive Conditional Heteroskedasticity; TGARCH, Threshold GARCH; AIC, Akaike Information Criterion; SIC, Schwarz Information Criterion; NGO, Non-government Organizations.

## References

[1] World Nuclear Association. (2015) World Energy Needs and Nuclear Power. Available at: http://www.world-nuclear. org/information-library/current-and-future-generation/world-energy-needs-and-nuclear-power.aspx (accessed 30 January 2016).

[2] Nakawiro, T., Bhattacharyyaa, S.C., & Limmeechokchai, B. (2016) Expanding Electricity Capacity in Thailand to meet the twin Challenges of supply security and environmental protection. Available at: http://www.akiedu.org/pdf/Asean_ Electricity_new.pdf (accessed 1 March 2016).

[3] Hill, L. (2016) Power to The People: Integrated Resource Planning in Developing Countries. Available at: http://web. ornl.gov/info/ornlreview/rev28_2/text/irp.htm (accessed 3 March 2016).

[4] Electricity Generating Authority of Thailand (EGAT). (2016) EGAT Operation in 2015 and Direction in 2016. Available at: http://www.egat.co.th/en/index.php?option =com _content&view=article&id=qxc303&Itemid=146 (accessed 15 March 2016).

[5] International Energy Agency (IEA). (2015) Development Prospects of the ASEAN Power Sector, Towards an Integrated Electricity Market. Available at: https://www.iea.org/ publications/freepublications/publication/Partnercountry_De velopmentProspectsoftheASEANPowerSector.pdf (accessed 1 March 2016).

[6] Electricity Generating Authority of Thailand (EGAT). (2016) Energy Statistic of Thailand 2015. Available at: http://www.eppo.go.th/info/cd-2015/index.html (accessed 15 March 2016).

[7] Labys, W.C. & Pollak, P.K. (1984) Commodity Models for Forecasting and Policy Analysis. Croom Helm Ltd. Sydney.

[8] California Energy Commission (CEC). (2010) Summer 2010 Electricity Supply and Demand Outlook. Staff Report, California Energy Commission. March. Available at: http:// www.energy.ca.gov/2010publications/CEC-200-2010-003/

CEC-200-2010-003.PDF (accessed 15 March 2016).

[9] Boonyasana, K. (2013) World electricity co-operation. Unpublished PhD thesis. University of Leicester, available at: https://lra.le.ac.uk/handle/2381/27793 (accessed 12 May 2016)

[10] Antonakis, J., Bendahan, S., Jacquart, P., & Lalive, R. (2014) Causality and endogeneity: Problems and solutions. In D.V. Day (Ed.), The Oxford Handbook of Leadership and Organizations (pp. 93-117). New York: Oxford University Press.

[11] Dickey, D.A. & Fuller, W.A. (1979) Distribution of the Estimators for Autoregressive Time Series with A Unit Root. Journal of the American Statistical Association. 74, 427-431.

[12] Blalock, H.M. Jr. (1963) Correlated Independent Variables: The Problem of Multicollinearity. Oxford University Press. 42(2), 233-237.

[13] Durbin, J. & Watson, G.S. (1950) Testing for Serial Correlation in Least-squares Regression, I. Biometrika. 37, 409-428.

[14] Durbin, J. & Watson, G.S. (1951) Testing for Serial Correlation in Least-squares Regression, II. Biometrika. 38, 159-178.

[15] Engle, Robert F. (1982) Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. Econometrica. 50(4), 987–1007.

[16] Bollerslev, T. (1986) Generalized Autoregressive Conditional Heteroskedasticity. Journal of Econometrics. 31(3), 307–327.

[17] Bollerslev, T. (2009) Glossary to ARCH (GARCH). Duke University. Available at: http://public.econ.duke.edu/~boller/ Papers/glossary_arch.pdf (accessed 15 March 2016).

[18] Hossain, A., Kamruzzaman Md. & Ali Md.A. (2015) ARIMA with GARCH Family Modeling and Projection on Share Volume of DSE. Economics World. 3(7-8), 171-184.

[19] Zakoïan, J.-M. (1994) Threshold Heteroskedastic Models. Journal of Economic Dynamics and Control. 18, 931-955.

[20] Dougherty, C. (2011) Introduction to Econometrics. 4th ed. OUP Oxford.

[21] Green, W.H. (2008) Econometric Analysis. 6th ed. Upper Saddle River, N.J. Prentice Hall.

[22] Rungrodruttanagorn, S. & Boonyasana, K. (2016) Thailand's Electricity Co-operation with Neighbouring Countries. SIBR 2016 Conference on Interdisciplinary Business and Economics Research, 2nd-3rd June 2016, Bangkok.

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# Commonwealth Energy and Sustainable Development Network (CESD-Net)

CESD-Net is a major global initiative in energy and sustainable development. The objective of network is to promote energy and sustainable development in commonwealth countries.

Focussing on Multidisciplinary Research, Promoting Future Low Carbon Innovations, Transferring Knowledge and Stimulating Networking among Stakeholders to Ensure the UK Achieves World Leading Status in Energy and Sustainable Development. https://www.weentech.co.uk/cesd-net/

The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

**Editors:**

**Dr. Singh** is Senior Scientist at Indian Agricultural Research Institute, New Delhi, India. Her area of expertise are bio energy and bio fuels, environmental engineering, carbon accounting and renewable energy integration for rural development.

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