Convergence Patterns and Transition Paths of Alternative and Renewable Energy Consumption across Provincial Clusters in Thailand

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(Received: January 25, 2021; Revised: May 28, 2021; Accepted: June 22, 2021)

Abstract

This study examines the stochastic conditional convergence of alternative and renewable energy consumption and determines the structural breaks across 18 provincial clusters in Thailand over the period 2001 – 2018, to find out the convergence patterns and the transition paths of the long-term development. The result reveals that there is no convergence characteristic across the entire sample clusters owing to the existence of two breaks. However, alternative and renewable consumption of 18 provincial clusters can be partially merged into three unique sets of equilibrium with the different transition paths as follows: 1) the group with a high level and showing continued growth (power and cogeneration); 2) the group with a medium level and experiencing a sharp decline (heat), and 3) the group with a low level and maintaining a constant (biofuel). In response to renewable development, Thailand should set out identical alternative targets towards the unique distribution characteristics of renewable instead of a common alternative energy policy like AEDP 2015. To enhance the broader cooperation and reduce the dispersion across provincial clusters in the long run, it is necessary to expand the use of solar power and to convert biomass into the cogeneration of heat and power

Keywords: 1) Convergence 2) Alternative Energy 3) Renewable Energy 4) Structural Break 5) Provincial Clusters

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Introduction

Energy is an essential factor for the country's economic development. However, the continued expansion of consumption has affected energy security, the environment, people's health, and an obstacle to long-term economic growth. One solution to the problem of energy demand coupled with sustainable economic development is to use alternative energy. Past studies have found that if alternative energy use continues to increase over the long term, it will support economic growth (Bhattacharya, et al., 2016, pp. 733-741), promote environmental quality (Fotourechi, 2017, pp. 61-64), and improve the quality of life (Choesawan, 2019, pp. 1-28)

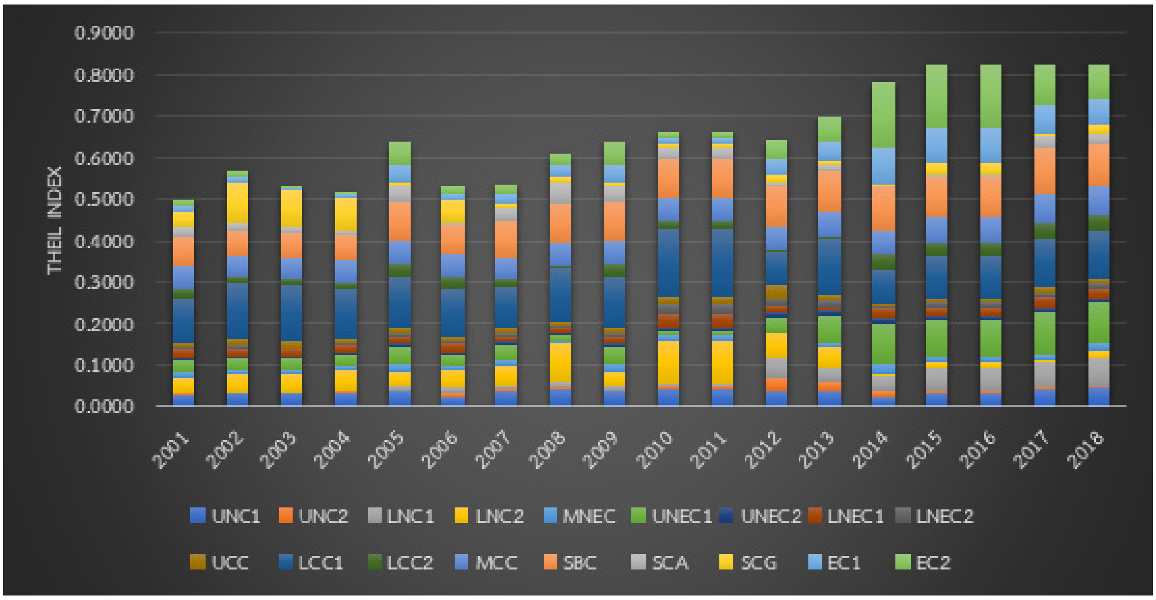
Thailand has increased its use of alternative energy. In 2001, the amount of alternative energy consumption increased to 4.3% of total commercial energy or approximately 8,447 tons. Compared to crude oil (ktoe), this was an average growth of 1.5 percent per year between 2001 and 2006. Then this increases to 8.6 percent of commercial energy use, or about 15,001 ktoe. In 2012, this was equivalent to average growth of 4.3% per year between 2007 and 2012 and increased to 14.1 percent of commercial energy consumption (18,209 kto) in 2018, or equivalent to average growth of 8.3 percent per year between the years 2013-2018.

However, such consumption is far from the goal that makes the country's energy secure and reduces the impact of greenhouse gases according to the Ministry of Energy's Renewable and Alternative Energy Development Plan 2015, which states that "The country must increase its share of alternative energy to total commercial energy by at least 30 percent by 2036, or approximately 53,450 ktoe" (Alternative Energy Development Plan, 2015, pp. 9-17). In this way, to achieve that goal, a country's long-term energy equilibrium is essential because it must forecast shared averages under close economic conditions (Mohammadi and Ram, 2012, pp. 1882-1887). The search for additional measures to support energy balance is inevitable.

Therefore, there is a proposal under the country reform framework on the energy of the Office of the National Economic and Social Development Council or the NESDC to allocate energy targets according to economic development by area. Implementation of such a proposal, economic groups in each area need to have a smaller energy consumption gap over the long term based on the concept of convergence over the period (Meng, et al., 2014, pp. 343-357). However, the country still lacks sufficient knowledge to explain the distribution pattern of energy consumption by area of how big or small is the energy consumption gap between different economies. In addition, there is no conclusion which economic groups have the energy consumption gap increasing or decreasing from the average, especially when the energy consumption characteristics and the development structure are necessary conditions for dispersion.

According to the preliminary information on IRENA (2017, pp. 21-23), it found the differences in alternative energy sources used over time, alternate between renewable energy (traditional renewable energy) and alternative energy (modern renewable energy). In 2001, 70 percent of the alternative energy used came from renewable energy for heating. Unlike in 2006, when the use of renewable energy for heating was reduced to 30 percent, replacing it with renewable energy to make fuel. It accounted for 54% of total alternative energy in 2012. Most of the alternative energy comes from renewable energy for heating. In 2018, more than 65% of Thailand's alternative energy source, was replaced by renewable energy for electric power. With such an energy situation, it is possible that a structural shift in alternative energy use may occur.

When considering the spatial development into 18 provincial clusters according to the 13th National Economic and Social Development, Strategy No. 10 on energy, the Theil Index was used to study energy consumption differences (Picture No. 1).



Picture No. 1 Theil Index of Alternative Energy Classified by Provincial Cluster, 2001-2018

The graph's height (aggregate index value) reflects energy consumption between different provincial clusters, while the box size (disaggregated index value) reflects the energy consumption within the provincial clusters by comparison between the periods. Initially, it was found that the consumption difference between the provincial clusters increased after 2011 (the height of the graph increased), while the energy consumption within the provincial clusters differed only in some provinces, for example, the Lower Northern Provincial Cluster 2 (LNC2), the Upper Northeastern Provincial Cluster 1 (UNEC1), the Eastern Provincial Cluster 1 (EC1), and the Eastern Provincial Cluster 2 (EC2). It is possible that the energy use and development structure will differ at the provincial clusters level. Therefore, it is an impetus to study the distribution pattern of energy consumption in terms of time dimensions and spatial development under the concept of convergence over a time period, to find a way to allocate the country's alternative energy use targets and search for ways to support energy consumption and reduce the gap in energy development between the provincial clusters.

Objectives

This study has three objectives. First, to investigate the Stochastic Conditional Convergence and find the Structural Break location of alternative energy use in 18 provincial clusters. Second, to examine the Club Convergence and the Club Merging character of alternative energy use in each provincial cluster in the long term. Finally, the third one is to analyze the transition paths for alternative energy development under structural differences and energy consumption characteristics for different provincial clusters in Thailand.

Literature Review

With concerns about future energy use and the impact of climate change, this makes the phenomenon of energy convergence essential. It is also a new issue that explains the link between energy use and economic development. The principle is that the convergence of energy consumption is an important condition. Because national energy policy implementation will support economic development and energy use in the long term, it must forecast shared goals under close economic conditions (Mohammadi and Ram, 2012, pp. 1882-1887). Past studies have attempted to examine the convergence of energy indicators, beginning with Maza and Villaverde (2008, pp. 4255-4261), who divided the validation into Beta and Sigma. The beta convergence explains that economies with low energy consumption grow faster than ones with high energy consumption. The first group can follow and move towards the same energy equilibrium average in the long run. The Sigma model describes convergence through changing the energy-growth gap between economic groups. However, both tests were under the same economic structure and mainly were studied through a Panel model, for example, Hao, et al. (2015, pp. 2617-2625) and Akarsu and Berke (2016, pp. 1-29). However, Meng, et al. (2013, pp. 536-545) noted that the test lacked a detailed reflection of how convergence occurred and could not conclude the cause of the divergence of energy use.

With its limitations, convergence over time is a popular tool for both short- and long-term results. The time-series technique was implemented through the Unit Root test, which can be verified in both Beta and Sigma. However, this technique is unsuitable for testing when energy variables change structurally rapidly, such as global energy consumption patterns and the country's economic policy adjustment. Lee, et al. (2012, pp. 81-107) found discrepancies in Unit Root test results. Lee and Tieslau (2019, pp. 1-10) attempted to control the tolerances and presented a Two-Step LM Unit Root method. Later, Payne, et al. (2017, pp. 715-728) reinforced the empirical study that without considering the structure and composition of energy, it will affect the study results and cause policy proposals to distort the actual energy situation.

Although there is currently support for alternative and renewable energy, this has caused many economies to try to set a common framework for alternative energy development both nationally and regionally. However, convergence studies for alternative energy indicators are still limited. Examples include Payne, et al. (2017, pp. 715-728), Lean, et al. (2016, pp. 3049-3061), Solarin, et al. (2018, pp. 17289-17299), Berk, et al. (2018, pp. 103922), and Kasman and Kasman (2020, pp. 5901-5911).

With differences in economic structure between groups, it caused an argument over convergence Kasman and Kasman (2020, pp. 5901-5911) found that alternative energy structures were shifted among 15 EU countries, causing group convergence rather than convergence. It is consistent with Phillips and Sul (2007, pp. 1771-1855), showing that similar economic characteristics and developmental structure patterns within the subgroups but different in large groups caused no convergence, and there is a possibility of convergence within specific groups. Few studies have focused on the link between alternative energy use and economic development along with convergence. Only Kasman and Kasman (2020, pp. 5901-5911) studied high-income economies. It may be said that this study is the preliminary study for investigating convergence patterns of alternative and renewable energy use in middle-income economies. However, the difficulty of the investigation was the group selection process. Phillips and Sul (2007, pp. 1771-1855) proposed the Log t technique. Later Schnurbus, et al. (2017, pp. 1039-1042) added the club merging classification test method. For this reason, it makes it possible to examine regional alternative energy and provincial clusters in Thailand classified according to energy use characteristics.

Methods

This study applied Two-Step LM Unit Root to investigate convergence over time and to detect the structural break positions of provincial alternative energy use. In addition, the Log t technique from the Time-Varying Nonlinear Factor model was used to examine the group's convergence pattern and analyze the transition path of alternative and renewable energy development both within and between the provinces. The details are shown as follows.

1.1 Two-Step LM Unit Root

With a structural change taking place; as a result, convergence detection over time using the Unit Root lacked consistency. Lee, et al. (2012, pp. 81-107) presented the Two-Step LM Unit Root in a test, and it was divided into two steps. The first step is to estimate the first difference of the internal variables ΔY_{it} with the first difference of the external variables (e.g., constants, trends, dummy variables) ΔZ_{it} which can be represented as $\Delta Y_{it} = \delta' \Delta Z_{it} + u_t$,where i denotes a group of provinces and t denotes the year to check for convergence over time of all 18 provincial clusters in the Panel. The LM statistics were used to test the hypothesis $\delta' = 1$ (Unit Root occurred).

However, the structural shift can occur at both Level Shift and Trend Breaks because

$Z_{it}=[1,t,D_{1it},D_{2it},DT^*_{1it},DT^*_{2it}]$, Lee and Tieslau (2019, pp. 1 -10) estimate Trend Breaks and expand the model as follows:

$$\Delta Y_{it} = \acute{\delta}\Delta Z_{it} + \emptyset_i \tilde{S}_{it-1} + \varepsilon_{it} \quad (1)$$

The LM statistic can be used to test the Unit Root for both structural change ($\tilde{\tau}^*_{LM}$) and non-structural change (LM), which is calculated $\tilde{\tau}^*_{LM} = (\sqrt{N}[\bar{t} - \tilde{E}(\bar{t})]/\sqrt{\tilde{V}(\bar{t})}$ where $\tilde{E}(\bar{t})$ is the mean of the mean $\bar{t}$ whereas $\tilde{V}(\bar{t})$) is the variance of the mean $\bar{t}$ which can be obtained from $\bar{t} = \frac{1}{N}\sum_{i=1,N} \tilde{\tau}^*_i$ whereas the value of $LM = (N[\bar{t} - \tilde{E}(\bar{t})]$ Nevertheless, Trend Breaks tend to cause Serial Correlation in the error term (Lee and Strazicich, 2003, pp. 1082-1089). Second, before checking for convergence over time for provincial clusters (i), a delay estimator $\Delta \tilde{S}_{t-j}$ should be added in the model and can be rewritten as $\Delta Y_{it} = \delta' \Delta Z_{it} + \emptyset_i \tilde{S}_{it-1} + \sum_{j=1} d_{ij} \Delta \tilde{S}_{it-j} + \varepsilon_{it}$.

With Trend Break positioning, interference parameters and Serial Correlation issues were resolved. However, test bias was found. Lee and Tieslau (2019, pp. 1-10), therefore, proposed the criteria to find the position of Trend Breaks3 ($\hat{T}_{B1}$ and $\hat{T}_{B2}$) to reduce bias and strengthen testing. The model can be presented as

$$\Delta Y_{it} = \acute{\delta}\Delta Z_{it} + \emptyset_i \tilde{S}^*_{it-1} + \sum_{j=1}^{k} d_{ij} \Delta \tilde{S}_{it-j} + \varepsilon_{it} \quad (2)$$

The Univariate LM ($\tilde{\tau}^*_{LM}$) statistic could be used to test the Unit Root under the main hypothesis $\emptyset_i = 0$ for provincial clusters i. The optimal delay value ($\hat{k}$) was calculated from the sum of the d_{ij} values. The Max F statistic was used to test Joint Significance and prove the positions $\hat{T}_{B1}$ and $\hat{T}_{B2}$ that cause structural changes. Notes that trend breaks location uses the following criteria: (1) $t \le \hat{T}_{B1}$, the result will be $\tilde{S}^*_{it} = (1/\lambda^*_{i1})\tilde{S}_{it}$ (2) if $T_{Bi1} < t \le T_{Bi2}$, the result will be $\tilde{S}^*_{it} = (1/\lambda^*_{i2})\tilde{S}_{it}$ and (3) if $T_{Bi2} < t \le T$, the result will be $\tilde{S}^*_{it} = (1/(1-\lambda^*_{i2}))\tilde{S}_{it}$, where $\lambda^*_{i1} = {T_{Bi1}}/{T}$ and $\lambda^*_{i2} = {(T_{Bi2}-T_{Bi1})}/{T}$

1.2 Log t Test

The Time-Varying Nonlinear Factor model was used to characterize alternative energy sources with different usage structures and different development gaps (between alternative and renewable energy). Where Y_{it} represents the amount of alternative energy use, i represents the provincial clusters, and t represents the year range. Whereas the differences can be classified as 1) time-specific traits (δ_{it}) and 2) shared characteristics in the system (u_t),the dynamic equation can be expressed as $Y_{it} = \left(\frac{g_{it}+a_{it}}{u_t}\right)u_t = \delta_{it}u_t$. The distance between Y_{it} and u_t describes the difference and transition of energy development (Transition Path), where $h_{it} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N}\delta_{it}}$ shows the weight of alternative energy use in each provincial group compared to the average alternative energy consumption of all 18 provincial clusters. The transition paths can be obtained from $\delta_{it} = \delta_i + \frac{\sigma_i \xi_{it}}{L(t)t^{\alpha}}$, where δ_i represents parameter values that do not change over time but differ by province group. α represents the Speed of Convergence, L(t) is the equation moves towards equilibrium (L(t)), causing $\xi_{it} \rightarrow iid(0,1)$ (Camerero, et al., 2013, pp. 1-20). The Transition Path hypothesis testing is obtained from the main hypothesis $H_0: \delta_i = \delta$ and $\alpha \ge 0$ and $\alpha \ge 0$ and the secondary hypothesis $H_1: \delta_i \ne \delta$ and $\alpha < 0$

With test bias which may be caused by the characteristic of the displacement equation model, Phillips and Sul (2007, pp. 1771-1855) proposed the Log t technique by adjusting the transition path weights in the logarithmic form (H_{it}) and measure the distance between Y_{it} and u_t from this equation

$$\log\left(\frac{H_1}{H_t}\right) - 2\log(t) = a + b\log(t) + \varepsilon_t \quad (3)$$

The equation moves towards equilibrium $L(t)$ is rewritten as $\log(t+1)$, and the length values $\log(t)$ is estimated from b, resulting in the velocity of motion (a) with a standard deviation of Heteroscedasticity and Autocorrelation Consistent (HAC). The t-statistic was used to test the hypothesis. In principle, if the statistic $t_{\hat{b}}$ is less than -1.65, the hypothesis $\hat{b} = 2\hat{a}$ can be rejected to confirm the convergence in the Panel. However, the rejection of the hypothesis does not confirm the occurrence of the convergence phenomenon. Phillips and Sul (2009, pp.1153-1185) proposed algorithm guidelines for testing Club Convergence and Club Clusters. Later, Schnurbus, et al. (2017, pp. 1039-1042) developed an algorithm for club merging. Although the Clustering Algorithm proposed by Phillips and Sul (2007, pp. 1771-1855) could identify identical development clusters, Phillips and Sul (2009, pp. 1153-1185)found a tendency to exaggerate the number of clusters due to problems Cross-Endogenous Bias. Schnurbus, et al. (2017, pp. 1039-1042) proposed a method for testing the Merging Clustering Algorithm to reduce the bias.

This study used STATA statistics program and applied the instruction set developed by Du (2017, pp. 882-900) to examine Club Convergence and Club Merging of alternative energy use at provincial level in Thailand.

Data

The data used in the study were the time- series data on alternative energy at the provincial level of Thailand since the year 2001-2018 which alternative energy source can be classified into renewable energy (traditional renewable) and alternative energy (modern renewable). According to the Department of Alternative Energy Development and Efficiency definition (AEDD, 2015, pp. 2-7), alternative energy is electric and thermal energy derived from solar, wind, biomass, biogas, and municipal waste. It also includes biofuels containing ethanol and biodiesel. Renewable energy is the energy obtained from agricultural, household, and industrial waste.

As for provincial clusters, 18 provinces were classified according to the framework of the National Economic and Social Development Plan No. 13, the NESDC's 10th Strategy on Energy. The use of renewable energy and alternative energy in 18 provincial clusters was calculated from the energy consumption of 76 provinces except for Bueng Kan and Bangkok, which is from the Thailand Energy Database of the Ministry of Energy. It is expressed in kilograms of crude oil equivalent (kgoe) to control the difference in economic size at the provincial level and reflect energy consumption levels. Conversion to per capita energy consumption is essential. The variables used in the study consisted of Alternative Energy Consumption per Capita (AEP) and Renewable Energy Consumption per Capita (REP) and are all in kgoe per capita. The provincial population data were obtained from the population survey database from the National Statistical Office.

Table No. 1 Descriptive Analysis of AEP and REP, between 2001 and 2018

Provincial Cluster	AEP (kgoe per capita)		REP (kgoe per capita)	
	Mean	Std. Dev	Mean	Std. Dev
Upper Northern Provincial Cluster 1 (UNC1)	1,547.32	361.93	872.33	212.56
Upper Northern Provincial Cluster 2 (UNC2)	663.14	155.11	885.17	295.12
Lower Northern Provincial Cluster 1 (LNC1)	2,216.27	1,203.02	1,004.56	176.75
Lower Northern Provincial Cluster 2 (LNC2)	2,958.43	800.09	1,016.13	268.44
Middle Northeastern Provincial Cluster (MNEC)	2,443.16	472.37	867.81	387.37
Upper Northeastern Provincial Cluster 1 (UNEC1)	2,697.02	802.67	969.25	358.40
Upper Northeastern Provincial Cluster 2 (UNEC2)	830.19	246.94	840.04	174.98
Lower Northeastern Provincial Cluster 1 (LNEC1)	4,180.10	636.18	752.89	244.40
Lower Northeastern Provincial Cluster 2 (LNEC2)	1,729.72	328.05	1,026.75	222.24
Upper Central Provincial Cluster (UCC)	1,555.70	317.60	737.64	329.27
Lower Central Provincial Cluster 1 (LCC1)	4,386.23	1,800.13	636.27	137.94
Lower Central Provincial Cluster 2 (LCC2)	4,709.11	1,357.76	807.71	182.00
Middle Central Provincial Cluster (MCC)	487.32	89.38	614.26	241.68
Southern Boarder Provincial Cluster (SBC)	1,336.69	206.94	1,050.05	168.72
Southern Cluster-Andaman Coast (SCA)	2,055.91	1,115.97	954.60	166.11
Southern Cluster-Gulf Coast (SCG)	726.42	216.08	1,046.80	195.07
Eastern Provincial Cluster 1 (EC1)	1,343.32	319.51	681.25	163.10
Eastern Provincial Cluster 2 (EC2)	4,692.06	1,885.50	661.72	115.24

Note: 1) UNC1 consists of Chiang Mai, Mae Hong Son, Lampang, and Lamphun; 2) UNC2 consists of Chiang Rai, Nan, Phayao, and Phrae; 3) LNC1 consists of Tak, Phitsanulok, Phetchabun, Sukhothai, and Uttaradit, 4) LNC2 consists of Kamphaeng-Phet, Nakhon Sawan, Phichit, and Uthaithani; 5) MNEC consists of Kalasin, Khon Kaen, Mahasarakham, and Roi Et; 6) UNEC1 consists of Loei, Nong Khai, Nong-Bua-Lamphu, and Udon Thani; 7) MCC consists of Nakhon Phanom, Mukdahan, and Sakon Nakhon; 8) LNEC1 consists of Chaiyaphum, Nakhon-Ratchasima, Burriram, and Surin; 9) LNEC2 consists of Yasothon, Sisaket, Amnat-Charoen, and Ubon-Ratchathani; 10) UCC consists of Chainat, Ayutthaya, Lopburi, Saraburi, Singburi, Ang-Thong; 11) LCC1 consists of Kanchanaburi, Ratchaburi, and Suphanburi; 12) LCC2 consists of Prachuap-Khiri Khan, Phetchaburi, Samut Songkhram, and Samut Sakhon; 13) MCC consists of Nonthaburi, Pathum Thani, Nakhon-Pathom, and Samut Prakan; 14) SBC consists of Narathiwat, Pattani, and Yala; 15) SCA consists of Krabi, Trang, Phang Nga, Phuket, Ranong, and Satun; 16) SCG consists of Chumphon, Nakhon Si Thammarat, Phatthalung, Surat Thani, and Songkhla; 17) EC1 consists of Chachoengsao, Chonburi, and Rayong; and 18) EC2 consists of Chanthaburi, Trat, Nakhon-Nayok, Prachin-Buri, and Sa Kaew.

Table No. 1 shows the mean and standard deviation of AEP variables and REP variables classified by provincial clusters during 2001-2018. It was found that in 18 provinces, per capita alternative energy (modern renewable) consumption was very different. In particular, the Lower Central Provincial Cluster 2 (LCC2) had the highest mean at 4,709.11 kgoe per capita, while the Middle Central Provincial Cluster (MCC) had the lowest mean at 487.32 kgoe per capita. However, when considering the standard deviation, it shows apparent differences in the use of alternative energy between the provinces over time. Especially in the Eastern Provincial Cluster 2 (EC2), the Lower Central Provincial Cluster 1 (LCC1), and the Lower Central Provincial Cluster 2 (LCC2), these provinces had standard deviations over time that is quite distant from other provinces. Initially, it was assumed that the standard deviation was not distributed around the mean. This may be due to the amount of alternative energy in the provinces occurring at various levels. There is a tendency to change the structure of energy consumption. Therefore, the investigation of convergence phenomena should also consider the structural variables of changing energy consumption.

However, little difference was found for the mean and standard deviation of per capita renewable energy consumption (REP) variables in 18 provinces over time. The mean was 614.26-1,050.05 kgoe per capita, and the standard deviation was between 163.10 -387.37 kgoe per capita.

Results

The study results were divided into three parts: (1) the results of the LM Unit Root Test to analyze convergence phenomena over time and to locate the year that caused the structural change in alternative energy use, (2) the results of the Log t test to analyze the phenomenon of convergence to groups and the merger of alternative energy between groups of provinces, and (3) the results of the analysis of development paths for alternative energy development at the provincial clusters level. The details are shown as follows.

1) LM Unit Root Test Results and The Search for Structural Breaks

With differences in each province's size and economic structure, the variables used to test convergence over time should be in the logarithmic form of comparative energy consumption (Payne, et al., 2017, pp. 715-728). Alternative energy consumption per capita by comparison (Relative AEP_{it}) is equal to $\ln\left(\frac{AEP_{it}}{AEP_t}\right)$,where AEP_{it} represents the per capita alternative energy of the provinces i, t represents period, and AEP_t represents the national average alternative energy per capita during the period t.

Estimating the coefficient δ' in Equation (1) of the Relative AEPit variable and testing the LM hypothesis found that the LM value |-2.935| is less than the critical value |-3.402| in an absolute value form (Table No. 2).

Table No. 2 Results of LM Unit Roots with ($\tilde{\tau}^*_{LM}$) / without (LM) Structural break

Variable	LM	$\tilde{\tau}^*_{LM}$	CADF
Relative AEP_{it}	-2.935	-3.806	-2.573
Relative REP_{it}	-4.584**	-4.725**	-3.253*

Notes: CADF denotes Cross-Sectionally Augmented ADF, where critical value obtained from Pesaran (2004, pp.435) is -2.942. LM denotes Panel LM without Breaks, where critical value obtained from Lee and Tieslau (2019, pp.1-10) is -3.402 and $\tilde{\tau}^*_{LM}$ denotes LM Panel with Level Shift and Trend Breaks, where critical value obtained from Lee and Tieslau (2019, pp.1-10) is -3.997 ii) ** and * represent a statistical significance at the 5% level and at 10% level, respectively

The primary assumption cannot be rejected. The Unit root emerged of alternative energy (modern renewable) consumption per capita by comparing all 18 provinces in the Panel. This reflected that the amount of alternative energy consumption of the provincial clusters did not adjust in the same direction. Therefore, the equilibrium of the average energy consumption of the whole country does not occur. The hypothesis test $\tilde{\tau}^*_{LM}$ considering the structural transformation shows a similar test result, that is, the Unit Root occurs because of the value $\tilde{\tau}^*_{LM}$ |-3.806| is less than the critical value |-3.997| in an absolute value form. It points out that when the energy structure changes abruptly (shocks), the amount of alternative energy between the 18 provinces will increase or decrease permanently over time. This creates a new equilibrium for the average energy across the country, and it could not return to the average energy equilibrium of the entire country. When considering the Power of Test, it was found that $\tilde{\tau}^*_{LM}$ gave better test results than LM. It was possible to use CADF to strengthen the tests to confirm the degree of Lagged Level and the First Difference of Relative AEP_{it} variable. This makes the Univariate LM Unit Root essential in convergence testing under the structural transition of alternative energy in each province.

On the contrary, for the LM and $\tilde{\tau}^*_{LM}$ ˜ hypothesis tests of the Relative REP_{it} variable, no unit root occurrence of renewable energy (traditional renewable) per capita in comparison was found. It is because the LM |-4.584| and the $\tilde{\tau}^*_{LM}$ |-4.725| values in an absolute value term are greater than the critical values (Table No. 2). The main hypothesis that stationarity property exists was therefore rejected. It is possible that all 18 provinces may have the same amount of renewable energy consumption in the same direction. The sudden changes in the energy structure did not cause the use of renewable energy among the 18 provincial clusters to deviate from the original average equilibrium. In the past, the use of renewable energy for all 18 provinces tends to follow the same goals. Therefore, the gap in the development of renewable energy at the provincial level in the long term is not a concern.

When estimating the coefficients $\emptyset_i$ in the equation (2) of the Relative AEPit variable and testing the hypothesis $\tilde{\tau}^*_{LM}$,for each provincial cluster, it was found that 9 out of 18 provinces with Unit Root occurred in the use of alternative energy (modern renewable) per capita. The nine provinces consist of Upper North Provincial Cluster 2 (UNC2), Upper Northeastern Provincial Cluster 2 (UNEC2), Middle Central Metropolitan Provincial Cluster (MCC), Southern Cluster-Andaman Coast (SCA), Southern Cluster-Gulf Coast (SCG), Lower Northeastern Provincial Cluster 1 (LNEC1), Lower Central Provincial Cluster 1 (LCC1), Lower Central Provincial Cluster (LCC2), and Eastern Provincial Cluster 2 (EC2).

When estimating d_{ij} in equation (2), calculated the appropriate delay ($\hat{k}$), then searched for structural transitions, it was found that there were two levels of occurrence, $\hat{T}_{B1}$, and $\hat{T}_{B2}$, as shown in Table No. 3.

Table No. 3 Results of Univariate LM Unit Roots ($\tilde{\tau}_{LM}$) and structural break positions ($\hat{T}_{B1}$ and $\hat{T}_{B2}$) by Provincial Cluster, 2001-2018

Provincial Cluster	Univariate LM Unit Root_AEP				Univariate LM Unit Root_REP			
	$\tilde{\tau}^*_{LM}$	$\hat{k}$	$\hat{T}_{B1}$	$\hat{T}_{B2}$	$\tilde{\tau}^*_{LM}$	$\hat{k}$	$\hat{T}_{B1}$	$\hat{T}_{B2}$
Upper Northern Provincial Cluster 1 (UNC1)	-4.102*	2	2005	2011	-4.105*	4	2004	2013
Upper Northern Provincial Cluster 2 (UNC2)	-3.652	4	2006	2012	-5.487***	2	2004	2012
Lower Northern Provincial Cluster 1 (LNC1)	-5.069***	3	2004	2014	-4.664**	3	2005	2012
Lower Northern Provincial Cluster 2 (LNC2)	-5.285***	2	2005	2014	-4.581**	3	2004	2012
Middle Northeastern Provincial Cluster (MNEC)	-6.162***	2	2004	2013	-4.685**	4	2005	2013
Upper Northeastern Provincial Cluster 1 (UNEC1)	-4.142*	4	2013	-	-6.554***	3	2004	2012
Upper Northeastern Provincial Cluster 2 (UNEC2)	-3.846	8	2006	2011	-5.798***	5	2005	2012
Lower Northeastern Provincial Cluster 1 (LNEC1)	-3.565	3	2013	2016	-3.645	6	2004	2013
Lower Northeastern Provincial Cluster 2 (LNEC2)	-6.214***	1	2004	2014	-4.235*	5	2005	2012

Provincial Cluster	Univariate LM Unit Root_AEP				Univariate LM Unit Root_REP			
	$\tilde{\tau}^*_{LM}$		$\hat{T}_{B1}$	$\hat{T}_{B2}$	$\tilde{\tau}^*_{LM}$	$\hat{k}$^	$\hat{T}_{B1}$	
Upper Central Provincial Cluster (UCC)	-4.836**	2	2005	2011	-4.423**	3	2006	2012
Lower Central Provincial Cluster 1 (LCC1)	-3.717	5	2013	2016	-3.795	6	2004	2013
Lower Central Provincial Cluster 2 (LCC2)	-3.617	6	2012	2016	-4.621**	4	2005	2012
Middle Central Provincial Cluster (MCC)	-3.832	2	2006	2012	-3.441	7	2005	2010
Southern Boarder Provincial Cluster (SBC)	-4.154*	3	2005	2011	-7.515***	1	2006	2012
Southern Cluster-Andaman Coast (SCA)	-3.745	8	2006	2011	-4.684**	4	2006	2013
Southern Cluster-Gulf Coast (SCG)	-3.568	7	2007	2012	-5.225***	2	2004	2012
Eastern Provincial Cluster 1 (EC1)	-4.856**	6	2004	2011	-3.589	6	2004	2012
Eastern Provincial Cluster 2 (EC2)	-3.687	2	2013	2016	-3.420	7	2005	2012

Notes: i) $\tilde{\tau}^*_{LM}$ denotes LM Unit Root, where critical value is -4.980 at 1% level, -4.379 at 5% level and -4.097 at 10% level, respectively. $\hat{k}$ represents optimal lag and $\hat{T}_{B1}$ and $\hat{T}_{B2}$ represent the position of Structural Breaks

ii) ***, **, and * represent a statistical significance at 1% level, 5% level, and 10% level, respectively

Joint Significance tests with Max F statistics show that the provinces of UNC2, UNEC2, MCC, SCA, and SCG had the first structural change between 2005 – 2006 and the second time during the year 2011 – 2012. The provinces of LNEC1, LCC1, LCC2, and EC2 also had two structural transitions. The first one occurred during 2012 – 2013 and the second time during 2015 – 2016.

From the inspection, the structural change in 2005 was caused by two main reasons. The first reason, the Department of Energy Conservation announced Phase 3 Energy Conservation Plan. The use of electricity and heat with combined heat generation technology (Cogeneration) from biomass and biogas is promoted. This makes the food processing industry that depends on alternative energy in the form of heat, paper, and textiles expand. The second reason is that the price of oil has risen sharply. Gasoline increased from 19.37 baht per liter to 25.46 baht per liter within six months, and diesel increased from 14.59 baht to 23.01 baht. Thus, the demand for biofuels has increased.

The second structural change in 2012 came from the country that has set goals for Solar power generation for the first time. It started from surveying the distribution of solar radiation and assigning commercial energy areas to private investments. In 2012 – 2013, the investment value in solar energy grew by more than 80%, especially in the northeastern and central regions of the country. In addition, during this period, the Department of Alternative Energy encourages the cultivation of fast-growing trees and energy crops to build local biomass power stations. Thus, causing a change in the energy use structure. Between 2015 and 2016, there was another restructuring after the alternative energy targets were revised in the Alternative Energy Development Plan 2015 by increasing the proportion of electricity from solar and wind on land. The system for purchasing electricity from alternative energy (Feed in Tariff) has been adjusted to attract significant private investments. Furthermore, the proportion of biogas from industrial waste was also adjusted in the development plan. At the same time, the proportion of biofuels from biodiesel was cut due to the shortage of palm oil in the northeastern and southern regions of the country. Therefore, it is possible that such structural changes may diversify alternative energy development at the provincial level, especially among the above nine provinces. Therefore, analysis of convergence patterns and understanding the transitional paths of alternative energy development by provincial clusters is an issue that should pay an important attention.

While testing the Univariate LM Unit Root of the Relative REP_{it} variable by provincial clusters, it was found that most of the provinces had stationarity property of using renewable energy (traditional renewable) per population. Only five provinces were found with Unit Root occurring, which consists of Lower Northeastern Provincial Cluster 1 (LNEC1), Lower Central Provincial Cluster 1 (LCC1), Middle Central Provincial Cluster (MCC), Eastern Provincial Cluster 1 (EC1), and Eastern Provincial Cluster 2 (EC2). When testing Joint Significance with

Max F, it was found that structural changes occurred at approximately the same time in most provincial clusters for the first time during the year. 2004-2005 and the second time during the year 2011-2012. It is the same period as the transition from renewable energy from household waste to alternative energy from agricultural and industrial materials. The Department of Renewable Energy's data shows that, the amount of renewable energy (modern renewable energy) of 9,523 ktoe was greater than the amount of alternative energy (traditional renewable energy) of 7,294 ktoe for the first time in 2012, indicating that the country's energy development has entered the renewable (modern renewable energy) energy era.

2) Log t Test Results: Club Convergence and Club Merging

The Log t value of the Relative AEPit variable is obtained from the coefficient b in the equation (3). When testing the hypothesis with the t statistic value (Table No. 4).

Table No. 4. Results of Log t within the Panel

Variable	Coefficient ($\hat{b}$)	t-Statistics
Renewable Energy per Capita by Comparison (Relative REP)	-0.485	-9.516
Renewable Energy per Capita by Comparison (Relative REP)	0.346**	-1.172

Notes: i) According to Phillip and Suls (2007, pp. 1771-1855), critical value at 5% level is -1.652

ii) ***, **, and * represent a statistical significance at 1% level, 5% level, and 10% level, respectively

It was found that the $t_{\hat{b}}$ (-9.516) value was less than the critical value (-1.652). Therefore, the main hypothesis can be rejected, and it can be confirmed that there is no convergence of alternative energy in 18 provinces due to different equilibrium speeds. However, there is a possibility of Club Convergence. Club Clustering checking is therefore necessary.

From the $t_{\hat{b}}$ test of the Relative REPit variable, it was found that the main hypothesis could not be rejected because the $t_{\hat{b}}$ (-1.172) value was greater than the critical value (-1.652), making the subgroup convergence test is insignificant.

When examining the subgroups of the Relative AEPit variable using an algorithm, it was found that the convergence of alternative energy consumption per population of the provinces in Thailand can be classified into five subgroups, as shown in Table No. 5.

Table No. 5 Results of Club Clustering for Relative AEP

Club	Coefficient $\hat{b}$	t-Statistic	Mean	Std. Dev	Member
Club 1 [4]	0.615***	2.563	4,491.87	1,419.89	Lower Northeastern Provincial Cluster 1 (LNEC1), Lower Central Provincial Cluster 1 (LCC1), Lower Central Provincial Cluster 2 (LCC2), Eastern Provincial Cluster 2 (EC2)
Club 2 [4]	-0.467**	-0.194	2,578.72	819.54	Lower Northern Provincial Cluster 1 (LNC1), Lower Northern Provincial Cluster 2 (LNC2), Middle Northeastern Provincial Cluster (MNEC), Upper Northeastern Provincial Cluster 1 (UNEC1)
Club 3 [2]	-0.396*	-0.932	1,892.82	722.01	Lower Northeastern Provincial Cluster 2 (LNEC2), Southern Cluster-Andaman Coast (SCA)
Club 4 [5]	0.164**	1.226	1,301.89	284.41	Upper Northern Provincial Cluster 1 (UNC1), Upper Central Provincial Cluster (UCC), Southern Boarder Provincial Cluster (SBC), Eastern Provincial Cluster 1 (EC1), Southern Cluster-Gulf Coast (SCG)
Diver-gence [3]	-0.115	-6.253	660.22	163.81	Upper Northern Provincial Cluster 2 (UNC2), Upper Northeastern Provincial Cluster 2 (UNEC2), Middle Central Provincial Cluster (MCC)

When examining Merging Clubs, it was found that only Club 2+3 which had a statistical value of t (-0.237) more than the critical value (-1.652). This resulted in the Merging Clubs of only three provinces, including one divergence group (Table No. 6).

Table No. 6 Results of Club Merging for Relative AEP

Cluster	Club Merging			Speed (%)	Member
Cluster 1 [4]	Club 1+2 [4] -0.126 (-3.256)	-	-	30.75	Lower Northeastern Provincial Cluster 1 (LNEC1), Lower Central Provincial Cluster 1 (LCC1), Lower Central Provincial Cluster 2 (LCC2), Eastern Provincial Cluster 2 (EC2)
Cluster 2 [4]	-	Club 2+3 [6] -0.286** (-0.237)	-	-23.35	Lower Northern Provincial Cluster 1 (LNC1 Lower Northern Provincial Cluster 2 (LNC2), Middle Northeastern Provincial Cluster (MNEC), Upper Northeastern Provincial Cluster 1 (UNEC1), Lower Northeastern Provincial Cluster 2 (LNEC2), Southern Cluster-Andaman Coast (SCA)
[2]	-	-	Club 3+4 [2] -0.147 (-1.885)	-19.81	
Cluster 3 [5]	-	-	-	8.22	Upper Northern Provincial Cluster 1 (UNC1), Upper Central Provincial Cluster (UCC), Southern Boarder Provincial Cluster (SBC), Eastern Provincial Cluster 1 (EC1), Southern Cluster-Gulf Coast (SCG)

Notes: i) [...] represents the order of the Club and Merging Cluster

ii) For Merging, corresponding coefficient is presented and and (...) represents t-Statistic

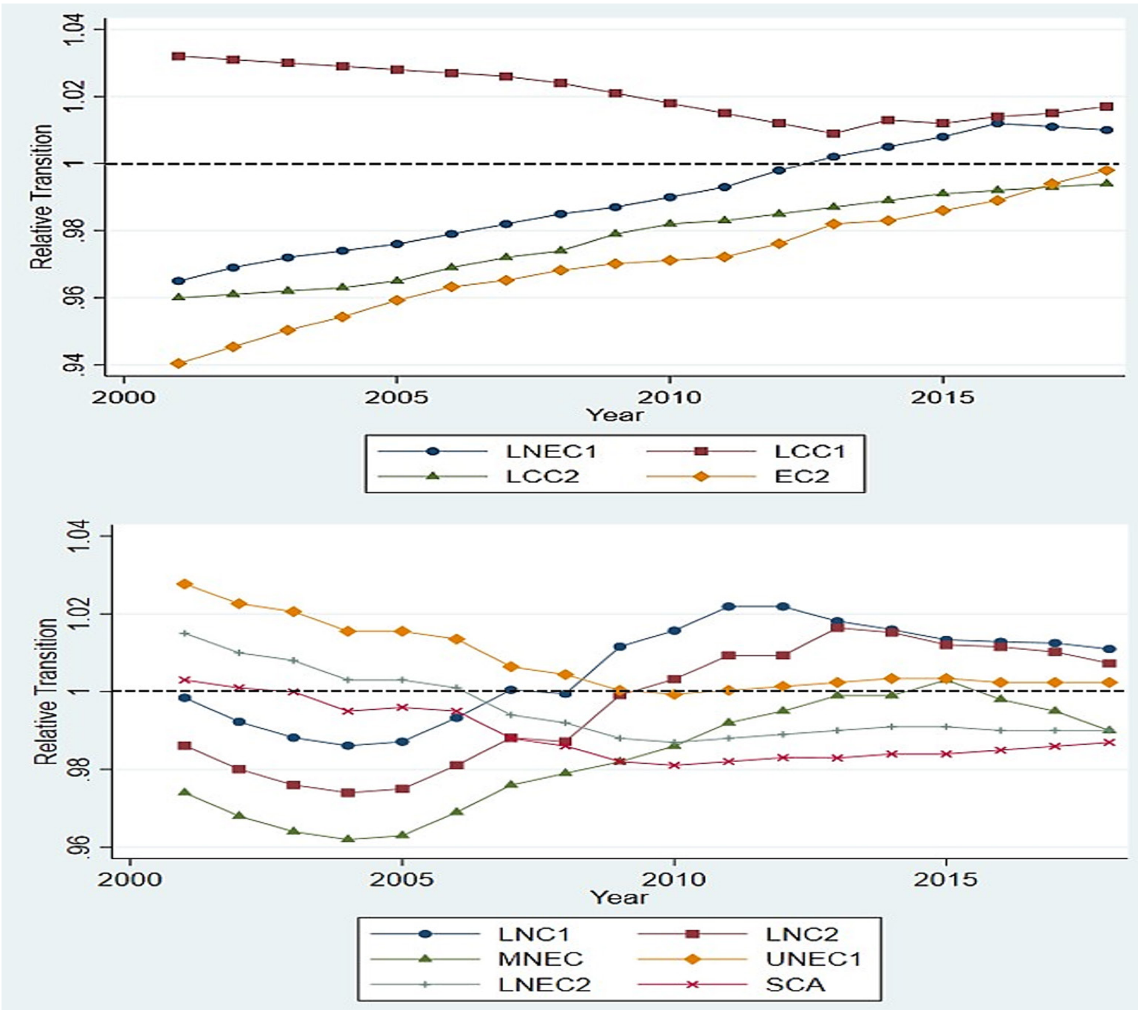
iii) ***, **, and * represent a statistical significance at 1% level, 5% level, and 10% level, respectively

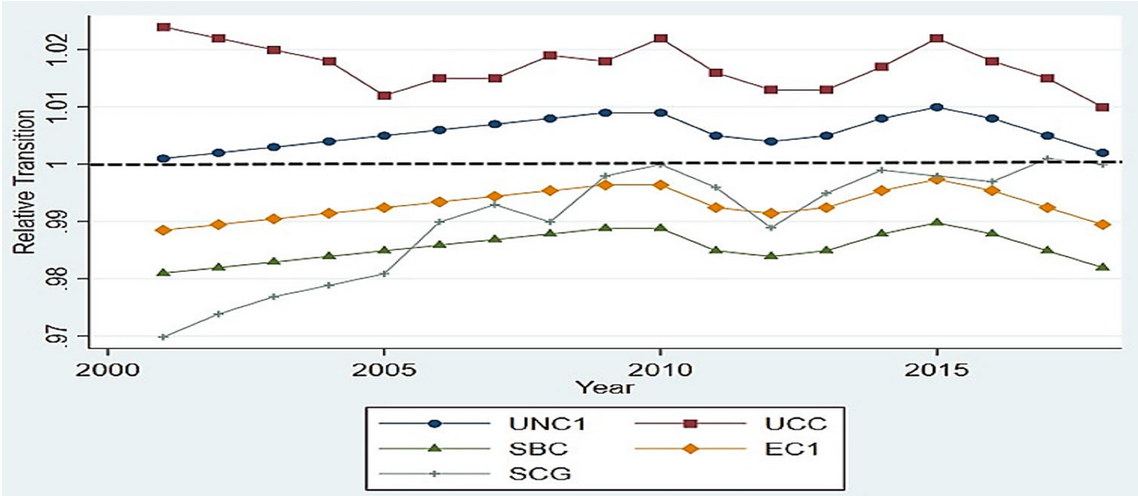
The first group was LNEC1, LCC1, LCC2, and EC2. The second group was obtained through Merging Clubs of Club 2 and Club 3. The members were LNC1, LNC2, MNEC, UNEC1, LNEC2, and SCA. The third group was obtained from Club 4. The members were UNC1 UCC, SBC EC1, and SCG. For the Divergence group, the member consists of UNC2, UNEC2, and MCC.

Considering the Speed of adjustment to the equilibrium obtained by estimating $\hat{a}$ in equation (3), it was found that the first group had the highest Speed of adjustment to the equilibrium at 30.75 (Table 6). It shows a sudden change. As a result, members of Group One (LNEC1, LCC1, LCC2, and EC2) have increased their alternative energy consumption in the same direction at an average speed of

30.75 percent and are likely to reach the same long-term energy equilibrium level. In the third group, although its members (UNC1, UCC, SBC, EC1, and SCG) had increased alternative energy use, their average speed was 8.22 percent. With its low speed of adaptation, it may hinder long-term to reaching equilibrium. While the second group with the combination of Club 2 and Club 3, obtained the speed to equilibrium at-23.35. The minus sign reflected that its members (LNC1, LNC2, MNEC, UNEC1, LNEC2, and SCA) had reduced energy consumption at an average speed of 23.35 percent. However, adjusting toward equilibrium is likely not to occur in the long term. When considering the average alternative energy consumption (Table No. 5), group one had the highest mean at 4,491.87 kgoe, followed by the second group at 2,235.77 kgoe (Club 2 mean was 2578.72 kgoe and Club 3 was 1,892.82 kgoe). In contrast, the average was relatively low in the third group at 1,301.89 kgoe.

By analyzing the Speed of adjustment to the equilibrium and the average energy consumption obtained from combining the three clusters, three characteristics of provincial-level alternative energy can be proposed in the long term as follows: 1) Provinces with high average energy consumption and continual increase, 2) The provincial clusters with moderate average use of energy but tends to decrease, and 3) provincial clusters with low average energy consumption and a stable trend. Details of energy consumption trends and long-term equilibrium adjustments for the three features are shown in Picture No. 2.





Picture No. 2 Transition Path of Relative AEP by Club Merging

3) The Analysis Results of Transition Paths of Alternative Energy Development

The parameter value δ_{it} shows the transition periods of alternative energy in the provinces by comparison (Relative Transition). Picture 2 above shows the transition path of the LNEC1, LCC2, and EC2 provinces that are likely to increase significantly by comparison. There was an average growth of the group at 11.53% per year during the year 2001 – 2018, and the usage patterns were classified into heat (48.30 percent), electricity (37.40%), and biofuel (14.30%). After 2012, solar power generation and cogeneration from palm oil were the main reasons for the rapid expansion of alternative energy in the LNEC1 LCC2 EC2 provinces. From Thailand's Alternative Energy Report in 2012 – 2018 by the Ministry of Energy shows that solar power generation in Nakhon Ratchasima and Chaiyaphum has grown by an average of 48.60% per year. Phetchaburi and Prachuap Khiri Khan grew 32.50 percent per year, while Sa Kaeo and Prachinburi grew 27.10 percent per year. Meanwhile, the use of palm oil as a substitute for cassava and sugarcane for cogeneration production grew on average across the three provincial groups from 5.2 percent in 2013 to 27.6 percent in 2018. Although LCC1 provinces had high average energy consumption from 2001 – 2018 (Table 5), relative energy consumption has slowed down. Part of this is probably the result of the rice-pledging project of Suphan Buri and Ratchaburi and the use of bagasse in the paper and plywood industries of Ratchaburi and Kanchanaburi. Consequently, the production of combined heat generation from biomass tends to decrease in comparison.

Picture No. 2 in the middle shows that the alternative energy development path of the provinces LNC1, LNC2, MNEC, UNEC1, LNEC2 and SCA has a downward trend in comparison with an average negative group growth of 4.17% per year during the year 2001 – 2018. The consumption patterns were classified into heat (77.40 percent), electricity (15.30 percent) and biofuels (7.30%). When analyzing trends in energy consumption, it was found that the consumption among provincial clusters decreased during 2001 – 2005, then increased slightly during the year 2012 – 2016. There was another slowdown after 2016, mainly due to heat production from agricultural crops of the provinces LNC1, LNC2 and MNEC, and a slowdown in combined heat production from agricultural waste from the provinces of UNEC1, LNEC2 and SCA. The report about the alternative energy situation in 2012-2018 by The Ministry of Energy shows an increase in the use of maize for heat production in Phetchabun, Uttaradit, Phitsanulok, and Nakhon Sawan. Meanwhile, cassava from Kamphaeng Phet, Khon Kaen, and Kalasin is also used to produce more heat in the textile industry. Furthermore, rice straw from Nakhon Sawan and Kamphaeng Phet and the tops of sugarcane leaves from Khon Kaen and Uttaradit are also used to produce heat in the food processing industry. With the price of agricultural products changing rapidly, after 2016, the production of thermal energy from cassava, rice straw, and sugarcane leaf tops decreased by comparison. This resulted in fluctuations in biomass heat production in the food processing and textile industries of the LNC1, LNC2 and MNEC provinces. Bagasse used to produce cogeneration power for Udon Thani Nong Bua Lamphu and Loei also tended to slow down in comparison. As a result, the use of alternative energy in the provinces UNEC1, LNEC2 and SCA decreased. It is possible that the use of alternative energy in almost all forms of heat causes the continuity of the energy consumption of these provinces. Only a small proportion of energy is generated in the form of cogeneration and electricity.

Picture No. 2 below shows the alternative energy development paths of the provinces UNC1, UCC, SBC, EC1, and SCG, which are comparatively stable. With an average growth of only 3.25% of the group during 2001-2018, most of the consumption patterns are biofuels (82.70 percent). The key driver is palm and coconut biofuels, accounting for 36.5% of the group's total alternative energy. Biomass heat from para rubber maize and sugarcane accounted for 43.3%. The report on the alternative energy situation in 2012-2018 of the Ministry of Energy shows that biofuels from palm oil are used a lot at Surat Thani, Chumphon, Nakhon Si Thammarat, followed by Phatthalung, Narathiwat, Chonburi. Biofuels from coconut oil are primarily used in Nakhon Si Thammarat, Chumphon, Surat Thani. Whereas biomass for thermal energy from para rubber is distributed in Yala, Chumphon, Nakhon Si Thammarat, Narathiwat, Pattani, and Rayong, maize is mainly used in Lampang and Lop Buri. As can be seen, the group's use of alternative energy is still happening by comparison. Nevertheless, the quantity used remains a challenge to the group's ability to develop alternative and renewable energy in the future.

Conclusion and Discussion

The cooperation of the provinces is an essential factor in developing the country's alternative energy consumption. Achieving such cooperation requires an understanding of the distribution patterns of energy consumption both in terms of time dimensions and spatial development. Therefore, it gave impetus to study the distribution model according to the concept of convergence overtime throughout the development of Thailand's alternative energy at the provincial level through the three study objectives. The first was to bring the Two-Step LM Unit Root to check for converge over time during the year 2001-2018. Second, the Log t technique was applied to find convergence patterns and club merging characteristics of long-term energy consumption. Third, the Transition Paths were applied to analyze the transitional paths of the provincial cluster's alternative energy development with structural differences.

Alternative energy sources are classified into two types: renewable energy (traditional renewable) and alternative energy (modern renewable). Furthermore, to reflect the spatial development, 18 provincial clusters were studied in accordance with the framework of the National Economic and Social Development Plan No. 13 on the energy of the NESDC. Therefore, the variables used are in the form of renewable energy per capita (REP) and alternative energy per capita (AEP) by comparison.

The study results indicated that the per capita use of renewable energy in all 18 provincial clusters developed in the same direction, and convergence over time occurred. When there is a structural change, it does not affect development, and it shows that the behavior of renewable energy in all 18 provinces tends to follow the same goals. However, no convergence phenomenon was found throughout the period for per capita alternative energy of all 18 provincial clusters. When they did not adjust in the same direction, the average energy consumption equilibrium across the country does not occur. Especially when there is a sudden structural change, it will make the use of alternative energy of all 18 provinces change permanently, and it cannot return to the average use level of the group. It is difficult for the alternative energy of the current 18 provincial clusters to support the common national goals under the Alternative Energy Development Plan (AEDP) 2015. This is because the targets are set on average growth forecasts under equilibrium assumptions. It is different from a study by Payne, et al. (2017, pp. 715-728), which found convergence in alternative energy per capita consumption in 42 US states and enabled the energy use of all 42 states to support the energy targets set by the federal government. As well as Kasman and Kasman (2020, pp. 5901-5911), convergence was observed in 15 EU member states. However, such a study does not characterize energy and does not consider the structural differences between renewable energy and alternative energy.

When conducting a provincial clusters study, it was found that 9 out of 18 provincial clusters had diverted energy from the group. The main cause is the change in economic structure and energy characteristics. There was a change in the structure during the year 2005 – 2006 and during the year 2011 – 2012 among Upper Northern Provincial Cluster 2 (UNC2), Upper Northeastern Provincial Cluster 2 (UNEC2), Middle Central Provincial Cluster (MCC), Southern Cluster-Andaman Coast (SCA), and Southern Cluster-Gulf Coast (SCG). As for the Lower Northeastern Provincial Cluster

1 (LNEC1), Lower Central Provincial Cluster 1 (LCC1), Lower Central Provincial Cluster 2 (LCC2), and Eastern Provincial Cluster 2 (EC2), there was a change in structure between the years 2012 - 2013 and between the years 2015-2016. In 2005-2006, there was a promotion for the use of electricity and combined heat energy. As a result, the use of biomass and biogas has grown exponentially, especially in the food processing industry, paper, and textile. While in 2011-2013, there was a strong promotion of the use of solar power, along with the promotion of energy crops to establish a biomass power station to produce heat. In 2015-2016, the power purchase system has been adjusted to motivate the private sector to invest in alternative energy and the proportion of biofuels has been reduced due to the shortage of palm oil. By such changing the various alternative energy structures, the convergence of the 18 provincial clusters is difficult to occur. This is supported by a study Solarin, et al. (2018, pp. 17289-17299) that found convergence of alternative energy use in 10 countries of the Organization for Economic Cooperation which is mainly due to the use of solar energy. In this regard, the search for niche alternative energy development approaches is interesting and examining convergence patterns and club merging characteristics is essential.

The Club Convergence and Club Merging examination results revealed three convergence groups and one divergence group. When considering the equilibrium speed and average energy consumption, by comparison, it was found that the distribution patterns and characteristics of the provincial-level alternative energy development can be classified into three characteristics as follows:

The first group 1 has high average energy consumption and steadily increasing. The first group's members include Lower Northeastern Provincial Cluster 1 (LNEC1), Lower Central Provincial Cluster 1 (LCC1), Lower Central Provincial Cluster 2 (LCC2), and Eastern Provincial Cluster 2 (EC2). The continued increase is due to the expansion of solar energy for electricity generation and the increase of palm oil biomass for cogeneration.

The second group has a moderate average energy consumption but tends to decrease. Group members include Lower Northern Provincial Cluster 1 (LNC1), Lower Northern Provincial Cluster 2 (LNC2), Middle Northeastern Provincial Cluster (MNEC), Upper Northeastern Provincial Cluster 1 (UNEC1), North Northeastern Province Group Lower 2 (LNEC2), and Southern Cluster- Andaman Coast (SCA). The reduction was due to the use of local agricultural plants to produce heat. When agricultural commodity prices change, it will affect the continuity of the group's use of alternative energy

The third group has low average energy consumption and a stable trend. The members of the group consist of Upper Northern Provincial Cluster 1 (UNC1), Upper Central Provincial Cluster (UCC), Southern Border Provincial Cluster (SBC), Eastern Provincial Cluster 1 (EC1), and Southern Cluster-Gulf Coast (SCG). Most of the group's energy forms are palm oil and coconut oil biofuels.

The results obtained from the distributions of alternative energy use under the concept of Convergence over time and Club Convergence to groups lead to the following policy recommendations:

First, although the implementation of the AEDP 2015 plan has increased the country's alternative energy supply, the provinces' energy consumption gap will hinder the achievement of the country's long-term alternative and renewable energy development goals. Therefore, the alternative energy target level should be set in line with the development characteristics of the provinces instead of setting a common target across the country. It should also support electricity from solar energy and combined cycle energy from biomass to promote the use and reduce the long-term energy development gap between the provinces.

Second, the NESDC's Energy Reform Framework proposes to allocate the target to six regions for energy security in the AEDP 2018 draft. However, with different energy consumption patterns, target allocation should be more open than just considering the geographic location and should be considered on the differences of 3 specific characteristics of the development among the provincial clusters.

Third, with the characteristics of renewable energy development, The Provincial Energy Office and the Office of Strategy Management for Provincial Cluster should support the following additional measures: 1) High Average Energy Group should be supervised and supported for technology in order to attract continued investment in solar and cogeneration 2) For the Medium-Average Energy Group, the consumption depends on the price of agricultural products. Cooperation should be implemented with the provincial agricultural office to use the yield data to forecast alternative energy production in advance. In addition, it should coordinate with the transfer of technology from heat energy to combined heat energy that can be used for both electricity and heat to reduce fluctuations in consumption. 3) For the Low Average Energy Sector, the usage characteristics should be expanded to include combined heat and solar energy. However, with similar energy sources, biomass power stations should be established to support heat and electricity by the community (Distributed Green Generation).

However, provincial clusters that have diverged from the country's alternative and renewable energy development should not be ignored. According to development characteristics, the study of factors causing convergence and divergence is an interesting research question and can be further developed into future studies. Especially, if driving alternative energy in a common goal is still the country's priority policy.

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