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Article

Allocation of Energy Saving Target for Provinces Based on Cluster Analysis in Vietnam

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Abstract: In order to meet the national energy saving goals set in the Vietnam National Energy Efficiency Program in the period of 2019 – 2030 (VNEEP), the Vietnamese government has adopted a series solutions and policies to improve energy efficiency. The Vietnam's 63 provinces will be as main actor for the national achievement in energy efficiency. Thus, understanding the province's potentiality of energy efficiency is useful for the harmonious and sustainable development between the economy and energy systems. In this study, provincial and national data from General Statistic Office are analyzed in terms of the energy efficiency levels. With the trends of economic development and energy consumption in both national and regional levels, the Lorenz curve between Vietnamese energy consumption and GDP is investigated. The Lorenz coefficient shows the energy allocation is nether reasonable nor balanced. By using clustering method, the 63 provinces of Vietnam clustered into 7 groups that the provinces in the cluster has the similar indexes of energy efficiency i.e. ability, responsibility, potential and difficulty. The energy consumption and GDP are predicted in the period of 2019 – 2025. Based on the difference of GDP development and energy consumption levels, the target of energy efficiency for each province through clustering is set. The results show that 33 provinces included in the cluster 1, 2, 3, 4 and 6 are heavy contribution. Among them, the provinces in the cluster 2 and 3 need to focus on the industry sector in their energy saving policy. The cluster 7 included the under-developed provinces can learn development's experiences of the provinces in the cluster 1, 2, 3 and 4 to find the best way of their future development.

Keywords: energy efficiency; clustering analysis; allocation target; Vietnam

1. Introduction

An overarching goal of Vietnam's National Energy Efficiency Program period of 2019-30 (VNEEP) is to address energy in tandem with economy development [1]. Specific goal includes: (i) Mobilizing all domestic and international resources to promote EE&C through synchronous implementation of state management tasks and measures, technical assistance, scientific and technology research and product development, market transformation, training and development of human resources, making use of experience and support of the international community in the EE&C sector; (ii) Forming the EE&C habit in every social activity; reducing energy intensity in various professions, economic sectors; energy efficiency becoming the frequent activity for designated energy users and key energy-intensive economic sectors; orienting towards the green growth and sustainable development. In line with these goals, the central government chose to set targets under the metric of 8.0 – 10% energy saving based on the prediction of total energy consumption requested for economic development in the period. The VNEEP divided into 2 stages, in which, the first stage is in period of 2019 – 2015 with 5.0% saving energy.

To achieve a national target, targets are allocated sub-nationally to provinces, cities, sectors, and enterprises. For the VNEEP, a province's target is set in the Province's Action plan on energy efficiency. In a strong effort to meet the target, provinces need to use a more scientific methodology

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to better estimate the varying potential for energy saving across the provinces, and to facilitate a change in development mode, as well as to achieve an equitable distribution of targets.

Overall national-level targets are allocated to sub-sets of the economy (e.g. provinces, economic sectors) through a variety of approaches. Target may be distributed relatively evenly among the chosen sub-set, based on equal percent reduction. Target allocation can use assessment of energy efficiency potential in each sub-set of the economy to provide guidance, or use more complex allocation methodologies that apply varying criteria for different economic sectors. For example, in China, China's national-level target to reduce energy use per unit of GDP by 20% during the 11th FYP was allocated to each province through a process in which the target was divided relatively evenly between provinces [2]. The central government requested that each province propose its own target. Most provinces proposed a 20% target in line with the national target, although some proposed higher and others proposed lower targets. After some negotiation, the State Council approved the provincial targets. In the UK, the process for setting the Climate Change Agreement targets began with information-gathering on the part of the government [3]. The government obtained information regarding energy efficiency potential in energy-intensive industries through the Energy Efficiency Best Practices Program which produced good practice guides and case studies, new practice case studies, and information on future practices as well as through a report on projections of industrial sector carbon dioxide emissions under a business-as-usual scenario as well as two scenarios that included all cost-effective and all technically-possible technologies [4]. Then, for the ten largest energy-consuming sectors, individual companies made estimates of what energy-efficiency improvements they were willing to commit to be based on an assessment of their potential and provided this information to their trade associations. More complex allocation method using multiple criteria applied to set targets is the "Triptych approach". This method used to establish the European Union's Kyoto Protocol negotiation target, divided the overall greenhouse gas (GHG) emissions target between the 15 countries that made up the EU at that time [5, 6]. The approach focused on three key energy-consuming sectors of the economy: industry, electricity, and domestic (buildings and transportation) sectors. The allowance for industry was determined by projecting physical activity at an average of 1.2% per year (2.1% per year in countries with GDP/capita less than 75% of EU average and 1.1% for other member countries), assuming that de-carbonization of fuels in industry increased 0.17% per year, and that energy efficiency improved 1.5% per year for all countries. The allowance for electricity took country-specific conditions, such as opposition to nuclear power, into account and assumed electricity growth would be limited to 1% per year for EU overall (1.9% for countries with GDP/capita is less than 75% of EU average and 0.9% for other countries). The allowance for the remaining more domestically oriented sectors (residential, transport, services) was based on projected population values and an assumption that there would be convergence to similar living conditions among countries by 2030. This meant that per capita emissions for all EU member states were assumed to be equal in 2030 at a level below current levels, in line with general assessments of emission reduction potentials in these sectors (at EU level). The base year (1990) per capita emissions were then extrapolated to 2030 and multiplied with 2010 population levels to determine the 2010 allowance. Domestic sector energy values were climate-corrected to account for different heating and cooling energy needs among countries. The sectoral allowances were then combined to set a total target for each country, such that the overall EU target could be met. Other allocation methods include distributing a target to sub-regions based on one main indicator, such as GDP per capita, or distributing the target based on equal cost or cost optimization. Other multi-criteria decision analysis methods can also be used, such as Analytic Hierarchy Process (AHP), or Cluster Analysis. Decision-makers identify the criteria and assign subjective ranking to them. Because some important criteria are hard to quantify, expert judgment supplements the quantitative analysis. Criteria such as "capability" or "innovation potential" or "leadership" can be assigned quantitative values and used along with reported data on energy consumption and economic structure. The combined effect of the criteria and their rankings are calculated and yield a preferred option. In China, the Central government in the 12th Five-Year Plan, allocated the reduction of energy intensity target to provinces by taking a two procedure: grouping the provinces into different clusters at first and then assigned reduction target to each cluster. In this allocation plan of the energy intensity

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target, the 31 Chinese provinces are divided into 5 clusters with reduction form of 5 levels ranging from 10% to 18%.

This paper adopts the cluster analysis in multivariate statistical analysis to group the 63 Vietnamese provinces into clusters based on provincial similarities in economic, emissions, and reduction potential. Then energy saving targets are assigned to each cluster according to the equity or efficiency principle, and allocation results and policy implications are also discussed. This allocation method emphasizes the major differences between regional clusters while it ignores the minor differences within each cluster.

2. Data and methodology

2.1. Indicator selection and cluster analysis method

Allocation principles in energy efficiency efforts are often based on economic ability, energy consumption levels and energy saving potential. Indicators should be selected to reflect the characteristics of different provinces, especially the characteristics of energy consumption and energy conservation. There are four categories of the indicators used in the study (Table 1). The first category includes indicators reflecting the responsibility of energy conservation. If the total economic volume and energy consumption of the region are large, the responsibility of energy conservation is heavy. The second category includes the indicators reflecting the energy conservation potential or difficulty, which can take into account the energy intensity, industrial structure, urbanization rate and other indicators. The third category includes the indicators reflecting the energy conservation ability. The indicators reflect regional economic development and regional financial strength.

Table 1. List of the indicator for provincial clustering

No.	Category	Indicator	Explanation
1.	Responsibility	The proportion of energy consumption (PEC)	Reflecting the contribution to the achievement of national targets
2.		Proportion of GDP to the country (PGDP)	Reflecting the contribution to the national GDP
3.		Per capita energy consumption (PCEC)	Reflecting the level of energy consumption
4.		The proportion of industrial added value to GDP (PI)	Reflecting the contribution to the provincial GDP
5.		Regional GDP growth rate (RGDPGR)	Reflecting the rate of development
6.	Potential	Energy consumption per unit GDP, kgOE/VND mil. (ECPGDP)	Reflecting the potential of energy conservation.
7.		Energy consumption per unit of Industrial Value Added (ECPIGDP)	Reflecting the potential of energy conservation in industry

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8.		The proportion of the third industry(or second industry) of GDP (3rdIPGDP)	Reflecting economic structure, the high proportion of industry, the potential of energy conservation is relatively large.
9.	Ability	GDP per capita (PCGDP)	Reflect the level of economic development
10.		Proportion of local financial expenditure to the country (PFE)	Reflecting the financial strength
11.		Investment in fixed assets (IFA)	Reflecting the financial strength
12.	Difficulty	Urbanization rate (UR)	Reflecting the change of residential energy consumption

Based on the 12 indicators above, the cluster analysis as a multi-variate statistical analysis is applied to group the similar provinces into clusters. Cluster analysis methods fall into two categories: hierarchical cluster methods and non-hierarchical cluster methods. Following suggestions from related researches [7, 8, 9], this study adopts a two-step procedure: the hierarchical cluster method is first employed to establish the proper number of clusters, then the cluster centroids from the first step are used as the initial condition of a non-hierarchical cluster method, which helps to fine-tune the results from the hierarchical cluster method.

For the first step of hierarchical cluster analysis, the method of Ward [10] is selected because it outperforms other hierarchical cluster methods when outliers are absent [7]. Some researches on regional cluster analysis also suggest that Ward's method gives the best interpretative solution [8; 9]. In Ward's method, the union of two clusters occurs when it results in minimum information loss, which is measured by an increase in error sum of squares (S). If there are n clusters, and Sk is the error sum of squares for the kth cluster, then:

$$S_k = \sum_{i=1}^{n_k} \left(x_i - \overline{x_k} \right)' \left(x_i - \overline{x_k} \right) \qquad \text{(Eq.1)}$$

where n_k is number of provinces in the kth cluster, x_i is a column vector comprising the 12 indicators of i_{th} province, $\overline{x_k}$ is the centroid of the k_{th} cluster (averages of provinces within this cluster). Total error sum of square is defined as:

$$S = \sum_{j=1}^{n} S_j$$

In each step, every possible fusion of two clusters is considered and the pair of clusters which lead to the least increase in S will be united. In the second step, the number and centroids of clusters generated from Ward's method are used as initial conditions for the K-means non-hierarchical method [11]. The procedure is as follows: (i) definition of k initial cluster centroids; (ii) an observation is assigned to the nearest cluster, followed by a recalculation of the new cluster centroid; (iii) repeating step 2 until the results remain unchanged.

2.2 Allocation method

Here, G_i is defined as the reduction target for the ith cluster of province, G_i is computed as follows:

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$$G_i = a \times W_i \quad \text{(Eq.2)}$$

where a is an adjustment coefficient (a>0); and Wi is the weight for the ith cluster (0<Wi<1); The relationship between provincial and nation energy efficiency target is calculated as follows:

$$EC_y = \sum_{i=1} \frac{Y_{i,y}}{Y_y} \times EC_{i,y} \quad \text{(Eq.3)}$$

where $EC_{i,y}$ and EC_y are the energy consumption of the ith cluster and of the whole nation in y year, respectively. $Y_{i,y}$ and Y_y are the GDP of the ith cluster and of the whole nation in y year, respectively. In Eq. (3) the energy consumption of the ith cluster and of the whole nation in y year can be computed from their respective values in the period of 2011 – 2018 using historical trend and the reduction targets (this study is based on the 5% national energy consumption reduction target):

$$EC_y \times (1-5\%) = \sum_{i=1} \frac{Y_{i,y}}{Y_y} \times EC_{i,y} \times (1 - a \times W_i) \quad \text{(Eq.4)}$$

This equation indicates that the GDP of the nation and each province should be forecasted first in order to determine the value of a. Then the reduction targets (Gi) of each cluster can be computed from Eq. (2). Finally, Wi determines the relative value of the reduction target of each cluster, and is calculated as follows:

$$W_i = \sum_{j}^{12} \alpha_j \times \frac{X_{i,j}}{X_{j,\max}} \quad \text{(Eq.5)}$$

where, $X_{j,max}$ (j=1,2,…,12) represents the maximum value of the jth indicator in all regions; $X_{i,j}$ (j=1,2,…,12) represents the mean value of the j_{th} indicator for the i_{th} cluster; αj is the weight for each indicator, which approves $\sum_{j}^{12} \alpha_j = 1$. The value of αj is based on different allocation principles.

2.3. Allocation principles

The allocation target based on each province's potential for energy saving, along with consideration of economic development level. It considers equity based on past performance and potential for improvement. The target allocation takes into account the historical variation in energy consumption trends among the provinces, and applies similar energy consumption trends for the years of the first stage of the VNEEP (2019 – 2025). Provincial energy trends are assumed to remain similar (e.g., fast-growing provinces still grow faster than slow-growing provinces). The rate of economic (GDP) growth was assigned to each province based on its growth rate trend in the past with an adjustment referring to the national growth rate.

Since this is a methodology for allocating a national target among the provinces, the analysis combines top-down national projections with bottom-up provincial in terms of energy and GDP to determine provincial intensity targets that will meet the national target. In other words, based on a chosen national intensity target level, iterative calculations are done on the provincial levels to determine provincial targets. Because the methodology is developed for the implementation of the VNEEP, it focuses on the years 2019 to 2025, with 2017 as the base year.

The methodology has three main steps:

Step 1. Project National-Level Values to 2025.

Step 2. Project Provincial-Level Energy and GDP Values to 2025.

Step 3. Calculate Provincial energy saving Target Allocations.

The adjustment of targets is a process of trial and error until a satisfactory allocation scheme is obtained. In addition, special circumstances should be taken into account in the adjustment of targets. It depends on the actual situation of the country and the regions. Allocation schemes can also be used as a basis to negotiate with regions.

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When adjusting the targets, it should be paid enough attention to the balance between the realization of regional goals and the realization of national goals. Usually for the target of energy consumption reduction rate, the trial calculation is carried out by adjusting one percent point upward or downward each time until the ideal result is obtained.

2.4. Data sources

The economic development and energy consumption in Vietnam's 63 provinces were taken based on statistics in period of 2011 – 2018 from the General Statistic Office, Ministry of Plan and Investment, Vietnam.

3. Results

3.1. Energy efficiency development analysis

The development trends of the economy and the energy consumption in recent years is considered as main factors affect the energy efficiency of national and provincial level. Figure 1 shows the total economic development and energy consumption in Vietnam form 2011-2018.

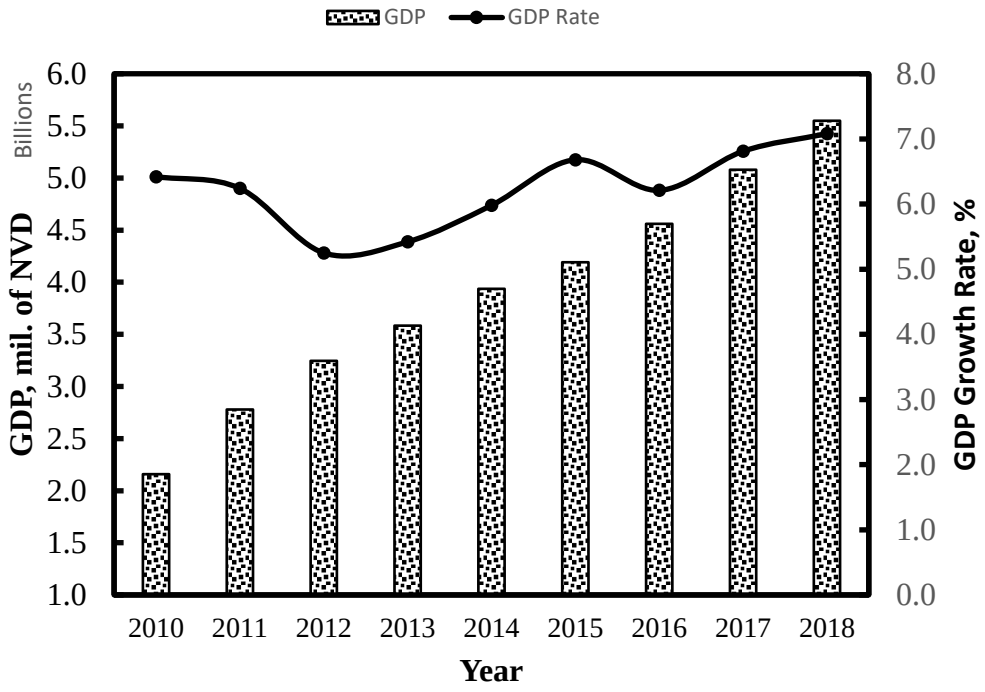

Figure 1. The total economy development and GDP's growth rate of Vietnam from 2010 – 2018

It can see that the tendency of economy development in Vietnam is considerably in the period of 2011 - 2018. The total GDP of Vietnam was just 2.1 million of VND billion in 2011 but in 2018, it reached 5.5 million of VND billion, about 2.6 times expanded. Vietnamese economic growth remained in stable at the range of 5.0 – 7.0% in the period. The rate is highest in 2018 with 7.08%, appositionally to the global economic growth rate. Influences of the changes in the Vietnamese government policy for restructure of economy may attribute to the stability of the GDP's growth rate.

With the high growth of the Vietnamese economy, the demand for energy is also increasing. The energy consumption in the period of 2011 – 2018 is shown in Figure 2 confirmed that the energy consumption increased consistent with economic development. In 2018, the total energy consumption reached 62.59 million of TOE increases 32% in comparison with the consumed energy amount in 2011. Under the guidance of energy conservation and energy efficiency policies, there was an improvement of energy efficiency. The energy intensity index decreased in the period, from 17.44

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kgOE/mil. of VND to 11.28 kgOE/mil. of VND. (see Figure 2). In the period, the reduction of the energy intensity is about 65%.

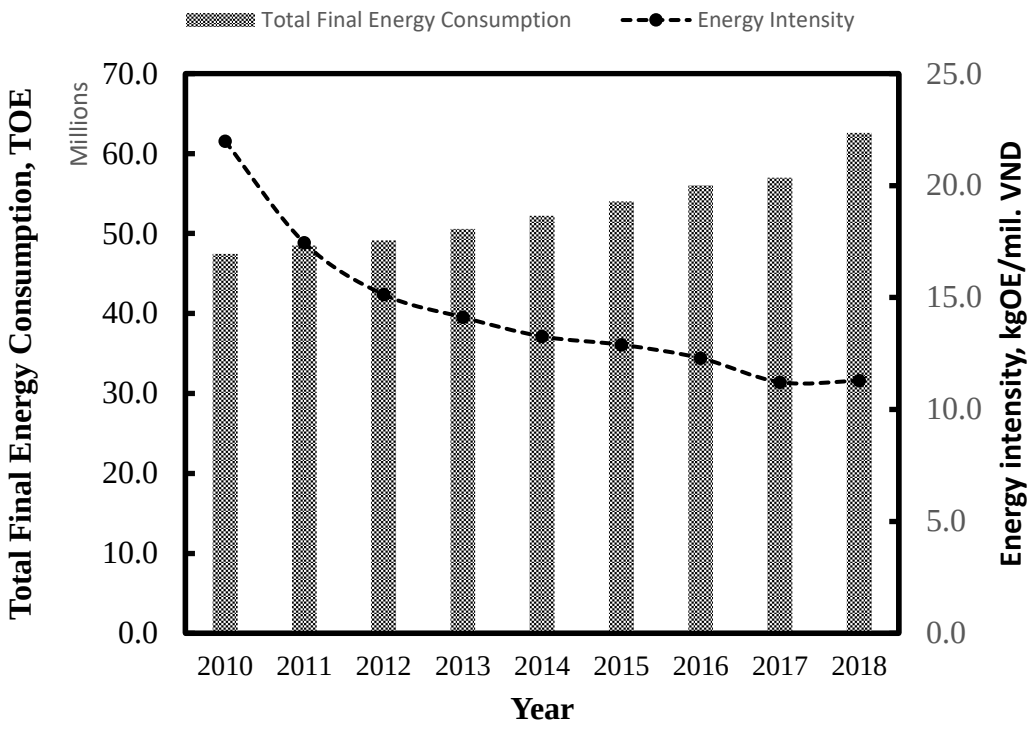

Figure 2. Vietnam's energy consumption and energy intensity from 2010 – 2018

In Vietnam, the energy resources and the energy demand are distributed reversely. The imbalanced distribution is also a cause for different energy efficiency levels in different provinces. Through the economic development and energy consumption analysis, the fitting method of the Lorenz curve is employed to explain the relationships between energy consumption and GDP development levels in recent years. With the application of the Lorenz theory, it can represent the energy allocation situation in different provinces and also show the national energy allocation situation in different years. The overall energy allocation situation in recent years will be explored and presents in Figure 3.

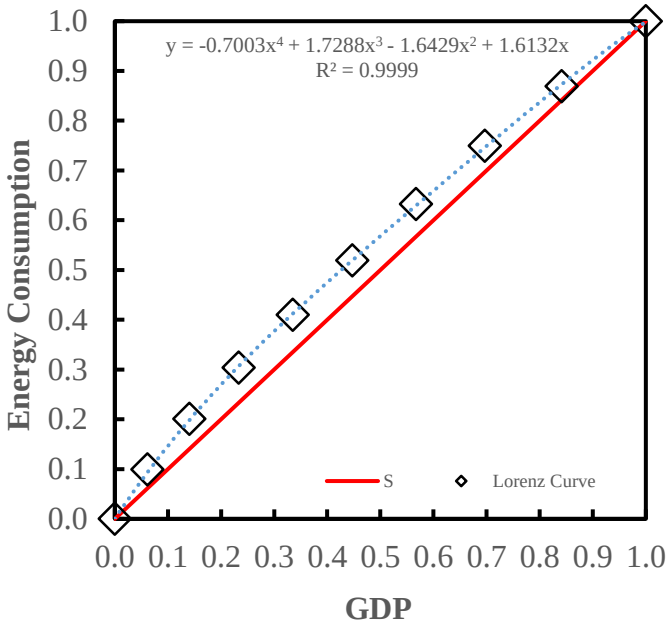

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Figure 3. The Lorenz curve of Vietnam's energy consumption and GDP from 2010 – 2018

The *S* line in Figure 3 stands for absolute equality which is an ideal energy allocation situation. The fitted curve shows a polynomial relationship between the accumulative values of GDP and final energy consumption in the period of 2010 – 2018. It can see that the Lorenz curve is a convex above the *S* line which resulted from the more consumed energy than the output of GDP meaning that the low energy efficiency level in the period. The area between the Lorenz curve and the absolute equality line is 0.0511 said as Lorenz coefficient represents the overall wastage caused by inefficiency allocation since the energy allocation in Vietnam was nether reasonable nor balanced. The extensive economic development and the imbalance between the energy supply and -demand can be considered as the main reasons for the low energy allocation efficiency. Based on this circumstance, it should improve the national energy intensity as the main way of energy saving allocation for the provinces.

3.2. Cluster analysis

In order to eliminate the effects of different scales, the cluster analysis is carried out with standardized variables. Table 3 shows the indicator values as input for clustering. It takes note that the original data collected in the series of Statistical Yearbook for national and provincial level in period of 2011-17 published by General Statistics Office of Vietnam.

Table 2. Indicator value for provincial cluster analysis

Province Name	Responsibility					Potential				Ability		Difficulty
	PEC	PGDP	PCEC	RGDPGR	PI	ECPGDP	ECPIGDP	3rdIPGDP	PFE	IFA	PCGDP	UR
Ha Noi	0.12	0.11	0.87	0.09	0.33	0.01	18.46	0.64	0.10	308,219,000	85.97	0.49
Vinh Phuc	0.01	0.01	0.67	0.08	0.60	0.01	10.32	0.32	0.02	28,229,259	79.05	0.23
Bac Ninh	0.02	0.03	1.16	0.19	0.74	0.01	8.90	0.23	0.01	119,257,000	133.33	0.26
Quang Ninh	0.03	0.02	1.18	0.10	0.57	0.01	10.61	0.36	0.03	60,597,259	103.04	0.64
Hai Duong	0.02	0.02	0.61	0.09	0.54	0.01	15.80	0.34	0.02	37,016,000	50.30	0.25
Hai Phong	0.05	0.03	1.38	0.14	0.42	0.02	16.56	0.53	0.02	71,874,346	82.98	0.47
Hung Yen	0.02	0.01	0.87	0.08	0.56	0.02	29.50	0.32	0.01	31,188,080	49.38	0.13
Thai Binh	0.02	0.01	0.69	0.10	0.33	0.02	41.30	0.36	0.01	51,308,565	37.25	0.11
Ha Nam	0.01	0.01	0.68	0.11	0.60	0.01	19.08	0.30	0.01	23,499,246	48.61	0.16
Nam Dinh	0.01	0.01	0.44	0.07	0.37	0.02	26.65	0.41	0.01	29,565,705	28.29	0.18
Ninh Binh	0.02	0.01	1.10	0.08	0.39	0.03	49.06	0.48	0.01	23,846,935	44.28	0.21
Ha Giang	0.00	0.00	0.07	0.07	0.22	0.00	9.41	0.47	0.01	7,094,614	22.35	0.15
Cao Bang	0.00	0.00	0.12	0.07	0.22	0.00	16.50	0.53	0.02	7,335,759	24.47	0.23
Bac Kan	0.00	0.00	0.31	0.05	0.15	0.01	67.09	0.52	0.01	4,289,017	27.82	0.19
Tuyen Quang	0.00	0.00	0.17	0.09	0.25	0.01	16.43	0.48	0.01	6,966,859	32.22	0.14
Lao Cai	0.01	0.01	0.56	0.10	0.39	0.01	12.35	0.46	0.01	19,307,282	52.24	0.23
Yen Bai	0.00	0.00	0.30	0.06	0.27	0.01	28.29	0.50	0.01	10,365,716	29.71	0.21
Thai Nguyen	0.01	0.02	0.38	0.13	0.56	0.01	7.81	0.32	0.01	50,008,720	68.09	0.35
Lang Son	0.00	0.00	0.28	0.06	0.19	0.01	23.89	0.56	0.01	10,569,443	35.59	0.20
Bac Giang	0.01	0.01	0.45	0.13	0.48	0.01	16.75	0.31	0.02	35,138,403	42.05	0.11
Phu Tho	0.01	0.01	0.46	0.08	0.39	0.01	30.01	0.39	0.02	23,656,951	35.06	0.19
Dien Bien	0.00	0.00	0.20	0.07	0.23	0.01	21.33	0.56	0.01	8,172,864	24.15	0.15

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Lai Chau	0.00	0.00	0.27	0.12	0.49	0.01	15.02	0.35	0.01	3,946,049	30.66	0.17
Son La	0.00	0.01	0.14	0.10	0.35	0.00	7.36	0.42	0.02	14,825,440	34.49	0.14
Hoa Binh	0.00	0.01	0.17	0.09	0.45	0.00	7.54	0.32	0.01	10,677,100	44.58	0.15
Thanh Hoa	0.06	0.02	0.99	0.09	0.44	0.03	57.14	0.41	0.04	105,175,585	37.64	0.17
Nghe An	0.01	0.02	0.24	0.08	0.30	0.01	14.90	0.47	0.03	55,381,000	34.14	0.15
Ha Tinh	0.01	0.01	0.26	0.11	0.38	0.01	13.46	0.43	0.02	30,343,995	39.63	0.18
Quang Binh	0.01	0.01	0.46	0.07	0.24	0.01	37.16	0.57	0.02	16,532,400	34.60	0.20
Quang Tri	0.00	0.00	0.29	0.07	0.26	0.01	25.96	0.52	0.01	12,067,441	39.25	0.30
Thua Thien-Hue	0.01	0.01	0.31	0.08	0.34	0.01	19.53	0.54	0.01	18,849,760	36.67	0.49
Da Nang	0.02	0.01	1.01	0.07	0.34	0.02	23.15	0.64	0.02	36,042,929	72.02	0.88
Quang Nam	0.01	0.01	0.30	0.05	0.44	0.01	12.16	0.42	0.03	24,055,527	55.86	0.24
Quang Ngai	0.01	0.01	0.23	0.01	0.50	0.00	5.29	0.31	0.02	21,600,359	50.84	0.15
Binh Dinh	0.01	0.01	0.37	0.07	0.33	0.01	15.13	0.40	0.01	31,481,000	41.27	0.31
Phu Yen	0.00	0.01	0.19	0.07	0.30	0.01	6.06	0.45	0.01	13,116,400	35.94	0.29
Khanh Hoa	0.01	0.01	0.44	0.08	0.33	0.01	11.97	0.55	0.01	36,748,000	57.07	0.45
Ninh Thuan	0.00	0.00	0.35	0.09	0.21	0.01	31.60	0.40	0.01	6,777,700	33.07	0.36
Binh Thuan	0.00	0.01	0.16	0.07	0.30	0.00	9.98	0.38	0.01	20,026,152	44.95	0.39
Kon Tum	0.00	0.00	0.23	0.08	0.27	0.01	20.29	0.42	0.01	10,210,013	34.24	0.36
Gia Lai	0.00	0.01	0.13	0.08	0.23	0.00	4.61	0.45	0.01	18,952,056	38.59	0.30
Dak Lak	0.00	0.01	0.15	0.07	0.14	0.00	14.46	0.45	0.02	22,777,564	34.64	0.24
Dak Nong	0.00	0.00	0.10	0.08	0.17	0.00	6.06	0.38	0.01	9,697,057	39.71	0.15
Lam Dong	0.00	0.01	0.18	0.08	0.17	0.00	4.88	0.35	0.01	23,500,000	54.86	0.39
Binh Phuoc	0.01	0.01	0.44	0.07	0.37	0.01	15.66	0.36	0.01	18,433,920	53.06	0.20
Tay Ninh	0.01	0.01	0.59	0.08	0.39	0.01	17.23	0.35	0.01	22,626,374	56.87	0.22
Binh Duong	0.06	0.04	1.55	0.09	0.70	0.01	16.80	0.26	0.02	81,284,638	119.75	0.76
Dong Nai	0.12	0.05	2.22	0.08	0.65	0.03	36.93	0.25	0.03	69,170,731	92.37	0.35
Ba Ria-Vung Tau	0.02	0.05	0.86	-0.04	0.80	0.00	2.55	0.15	0.01	39,627,000	249.49	0.52
Ho Chi Minh city	0.12	0.17	0.81	0.08	0.30	0.01	13.02	0.70	0.05	365,710,000	122.71	0.81
Long An	0.02	0.02	0.83	0.10	0.47	0.01	24.57	0.34	0.02	26,237,219	61.26	0.18
Tien Giang	0.01	0.01	0.46	0.08	0.30	0.01	29.33	0.30	0.01	29,138,940	43.65	0.16
Ben Tre	0.01	0.01	0.31	0.07	0.17	0.01	35.22	0.47	0.01	15,293,000	31.08	0.11
Tra Vinh	0.00	0.01	0.20	0.12	0.32	0.01	14.18	0.32	0.01	20,697,998	39.22	0.18
Vinh Long	0.00	0.01	0.15	0.06	0.18	0.00	16.94	0.47	0.01	12,604,154	41.28	0.17
Dong Thap	0.01	0.01	0.26	0.06	0.24	0.01	28.51	0.39	0.01	16,670,744	36.28	0.18
An Giang	0.01	0.01	0.18	0.05	0.15	0.01	23.35	0.55	0.02	12,372,899	33.98	0.31
Kien Giang	0.02	0.01	0.53	0.07	0.20	0.01	14.73	0.43	0.02	43,527,058	43.12	0.29

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Can Tho	0.01	0.01	0.40	0.07	0.34	0.01	16.63	0.56	0.01	54,888,604	61.51	0.67
Hau Giang	0.00	0.00	0.10	0.07	0.22	0.00	7.90	0.48	0.01	16,680,500	33.60	0.26
Soc Trang	0.00	0.01	0.11	0.04	0.17	0.00	12.26	0.42	0.01	9,774,546	33.62	0.31
Bac Lieu	0.00	0.01	0.17	0.07	0.15	0.00	19.85	0.42	0.00	14,203,860	37.50	0.29
Ca Mau	0.00	0.01	0.15	0.04	0.29	0.00	10.63	0.43	0.01	11,361,073	38.00	0.23

The dendrogram obtained by using the Ward's method for the lustering of the 63 provinces shows in Figure 4. It indicates that provinces can be grouped into 7 clusters. The detail provinces included in each cluster is shown in Table 3. The centroids of the 7 clusters will be used as initial condition for the K-means method, where the same result is still obtained (see Table 4), confirming that the result from Ward's method is reasonable.

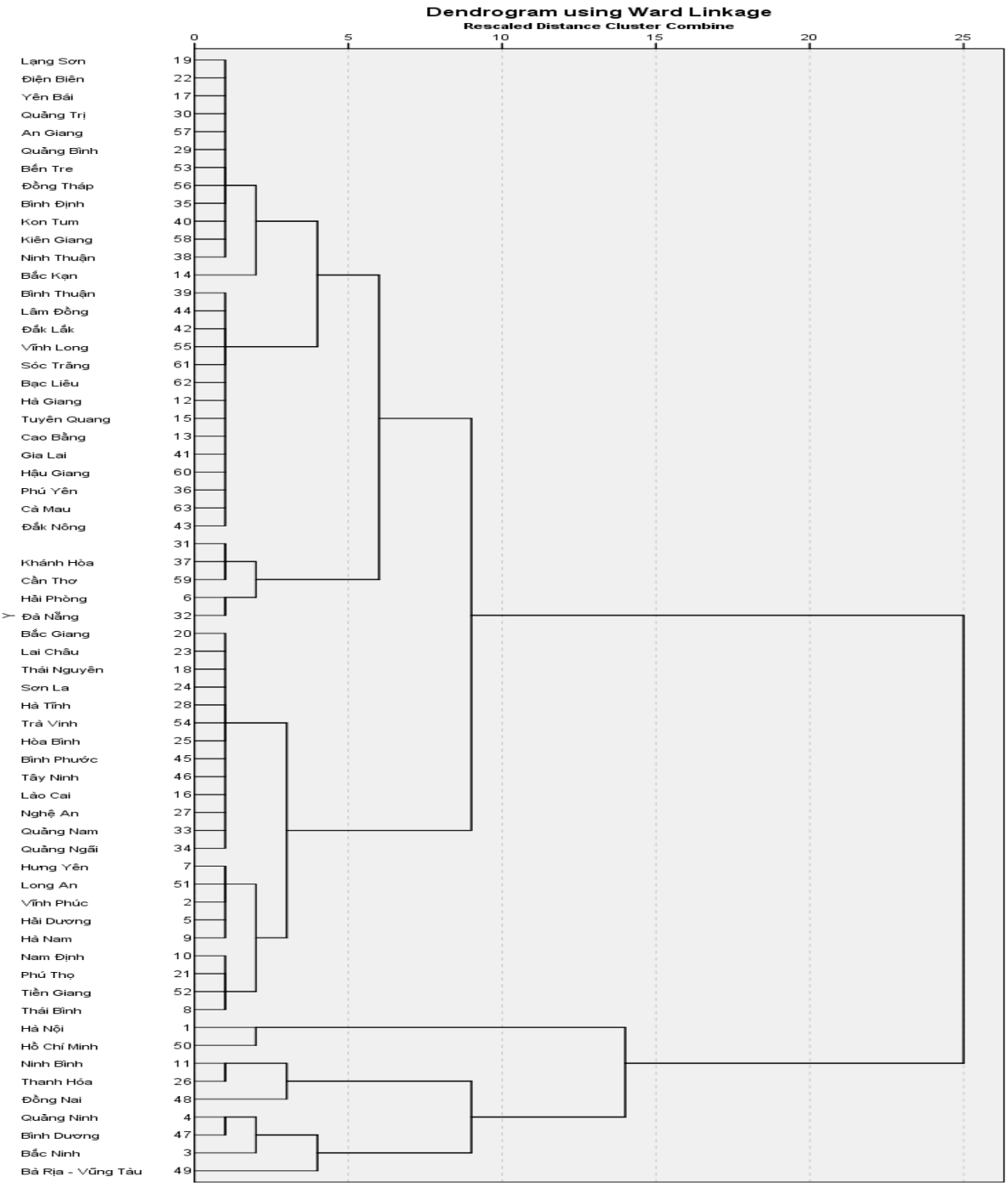

Figure 4. Dendrogram from the Ward's method

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Table 3. Results of the cluster analysis

Cluster	Number of provinces	Province included
1	2	Ha Noi, Ho Chi Minh city.
2	3	Ninh Binh, Thanh Hoa, Dong Nai.
3	4	Quang Ninh, Binh Duong, Bac Ninh, Ba Ria-Vung Tau.
4	9	Hung Yen, Long An, Vinh Phuc, Hai Duong, Ha Nam, Nam Dinh, Phu Tho, Tien Giang, Thai Binh.
5	13	Bac Giang, Lai Chau, Thai Nguyen, Son La, Ha Tinh, Tra Vinh, Hoa Binh, Binh Phuoc, Tay Ninh, Lao Cai, Nghe An, Quang Nam, Quang Ngai.
6	5	Binh Thuan, Khanh Hoa, Can Tho, Hai Phong, Da Nang.
7	27	Lang Son, Dien Bien, Yen Bai, Quang Tri, An Giang, Quang Binh, Ben Tre, Dong Thap, Kon Tum, Kien Giang, Ninh Thuan, Bac Kan, Binh Thuan, Lam Dong, Dak Lak, Vinh Long, Soc Trang, Bac Lieu, Ha Giang, Tuyen Quang, Cao Bang, Gia Lai, Hau Giang, Phu Yen, Ca Mau, Dak Nong, Bình Định.

Table 4. Mean values of indicator at the cluster centroids

Indicator	Cluster						
	1	**2**	**3**	**4**	**5**	**6**	**7**
The proportion of energy consumption	0.12	0.12	0.04	0.02	0.01	0.07	0.00
The proportion of GDP	0.11	0.17	0.03	0.02	0.01	0.04	0.01
Per capita energy consumption	0.87	0.81	1.07	0.61	0.48	1.72	0.22
Regional GDP growth rate	0.09	0.08	0.14	0.07	0.08	0.10	0.07
The proportion of industrial added value to GDP	0.33	0.30	0.59	0.45	0.39	0.59	0.25
Energy consumption per GDP (TOE/VND mil)	0.01	0.01	0.02	0.01	0.01	0.02	0.01
Energy consumption per unit of Industry Value added GDP (TOE/VND mil)	18.46	13.02	33.02	15.50	17.89	23.43	20.41
The third industry proportion of GDP	0.64	0.70	0.32	0.38	0.40	0.34	0.46
The proportion of financial expenditure in the whole country	0.10	0.05	0.03	0.02	0.01	0.02	0.01
Investment in fixed assets (VND bil.)	308,219,000	365,710,000	112,216,293	50,762,601	26,438,572	74,109,905	11,201,543
Per capita GDP (VND mil/capita)	85.97	122.71	85.48	85.23	48.19	98.37	34.45
Urbanization rate	0.49	0.81	0.22	0.39	0.27	0.53	0.22

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Clusters 1 is region with a developed economy but with low reduction potential. Cluster 1 includes two municipalities, i.e., Ha Noi and Ho Chi Minh city, and represents the most advanced level of economy, with its per capita GDP over VND 90 mil. and the highest sharing of the total energy consumption (24%) as well as of GDP (28%) those are much higher than the other 6 clusters. This high level of living standard also leads to high per capita energy consumption. However, its economic structure and energy efficiency are relatively optimal, indicating a low reduction potential. Cluster 2 includes 3 provinces, which are featured by large scale industry and high total energy consumption which shares 20% of the national energy consumption whistle contributed 8.0% share of GDP. The cluster 3 seems to be energy efficiency likely as the cluster 1 because of the GDP share contribution is higher than the energy consumption share. It also takes note that the number of provinces in this cluster is two times higher than in the cluster 1. Cluster 7 has numerous of provinces, taking almost 1/3 number of the Vietnam's provinces (27/63), however, it is less contribution in the GDP although energy consumption takes about 11% of the national level. It is noticeable for cluster 6, which included 5 provinces. A characteristic of these provinces is that the service sector takes high share in the economy. However, the cluster's energy consumption share is higher than its contribution on national GDP may attribute to problems in behavior's energy use. Table 5 shows the indicator values for all clusters.

Table 5. Indicator values for the clusters

Cluster	PEC	PGDP	PCEC	RGDPGR	PI	ECPGDP	ECPIGDP	3rdIPGDP	PFE
1	0.24	0.28	1.68	0.17	0.62	0.02	31.48	1.33	0.15
2	0.20	0.08	4.31	0.25	1.49	0.08	143.13	1.14	0.08
3	0.12	0.14	4.75	0.34	2.81	0.04	38.86	0.99	0.07
4	0.14	0.11	5.71	0.78	4.16	0.13	226.56	3.07	0.14
5	0.09	0.13	4.23	1.18	5.44	0.10	159.71	4.82	0.19
6	0.09	0.07	3.55	0.43	1.78	0.06	87.84	2.81	0.08
7	0.11	0.19	6.04	1.84	5.92	0.18	528.51	12.44	0.29

3.3. National-level projection of energy consumption and energy saving.

National-level projections of energy and intensity for the first stage of the VNEEP are based on three main assumptions: (1) a national energy saving improvement target of 7% over the period of 2019 - 20125; (2) annual GDP growth of 7.6%; and (3) a little shift in energy structure, from 41% industrial, 25% residential, 34% other energy (service, transportation, etc..); to 37%, 27% and 26%, respectively. Using these assumptions, energy and GDP are projected out to 2025. Figure 5 shows the results of the national-level projections of energy consumption, saving and energy intensity.

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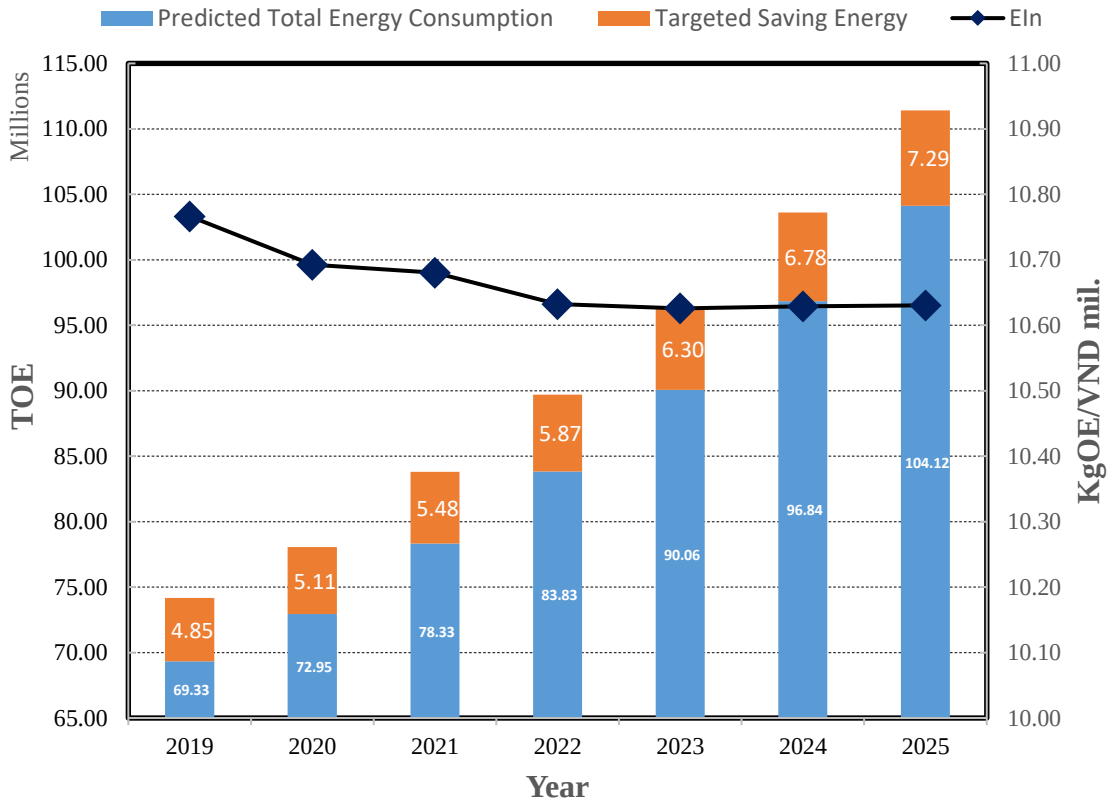

Figure 5. National-level Projection of energy consumption, saving and energy intensity

In national level, the energy consumption increases yearly and will reach about 104 mil. TOE. Assignment of 7% energy saving, the total energy saving in the period is about 41.67 mil. TOE. The energy intensity will decrease yearly from 2019 to 2023 and be level-off in the remaining year. In general, the improvement of the energy intensity will be not much due to small lifting the economy structure.

3.4. Allocation of energy efficiency target for the provinces

Under the national socio-economic development defined in the national-level projection in cooperation with historical trend of each province, the regional energy consumption and the socio-economic development is projection. Table 6 shows the predicted amount of the final energy consumption for each province. The predicted results confirm the consistency to the province clustering. Provinces included in the cluster 1, 2 and 3 are main players in the future energy consumption of Vietnam. As shown in Table 6, the energy consumption for each province increases yearly in the period. All provinces, the energy consumption in 2015 will be double in comparison in 2019. It means that the regional economic development still bases the intensive energy consumption.

Table 6. The predicted energy consumption for each province in the period of 2019 – 2025 (in TOE)

	2019	2020	2021	2022	2023	2024	2025
Ha Noi	9,017,766	10,042,358	11,183,365	12,454,012	13,869,028	15,444,819	17,199,649
Vinh Phuc	1,190,791	1,305,978	1,432,307	1,570,856	1,722,808	1,889,458	2,072,228
Bac Ninh	670,599	812,131	983,535	1,191,113	1,442,503	1,746,949	2,115,649

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Quang Ninh	12,209,577	14,004,249	16,062,718	18,423,760	21,131,848	24,237,996	27,800,713
Hai Duong	3,115,964	3,482,698	3,892,595	4,350,735	4,862,795	5,435,122	6,074,810
Hai Phong	5,617,010	6,544,701	7,625,607	8,885,032	10,352,461	12,062,247	14,054,417
Hung Yen	849,051	950,713	1,064,546	1,192,010	1,334,736	1,494,551	1,673,501
Thai Binh	502,116	566,303	638,694	720,340	812,423	916,277	1,033,407
Ha Nam	1,156,384	1,335,866	1,543,207	1,782,729	2,059,427	2,379,072	2,748,329
Nam Dinh	340,916	376,139	415,000	457,876	505,182	557,376	614,962
Ninh Binh	2,927,064	3,282,853	3,681,888	4,129,426	4,631,363	5,194,311	5,825,687
Ha Giang	47,165	53,468	60,614	68,714	77,896	88,306	100,107
Cao Bang	155,522	171,991	190,203	210,344	232,618	257,250	284,491
Bac Kan	63,552	71,144	79,644	89,159	99,811	111,736	125,085
Tuyen Quang	778,963	884,415	1,004,144	1,140,080	1,294,419	1,469,651	1,668,606
Lao Cai	302,364	353,322	412,869	482,451	563,760	658,772	769,797
Yen Bai	898,748	1,004,227	1,122,086	1,253,777	1,400,923	1,565,338	1,749,050
Thai Nguyen	1,891,718	2,276,209	2,738,847	3,295,516	3,965,328	4,771,279	5,741,039
Lang Son	619,681	693,217	775,479	867,504	970,448	1,085,609	1,214,436
Bac Giang	2,755,421	3,260,703	3,858,642	4,566,230	5,403,574	6,394,468	7,567,069
Phu Tho	902,888	1,013,270	1,137,148	1,276,171	1,432,190	1,607,283	1,803,781
Dien Bien	115,410	128,964	144,110	161,035	179,947	201,081	224,697
Lai Chau	49,809	60,190	72,735	87,895	106,215	128,352	155,104
Son La	190,824	226,716	269,359	320,022	380,215	451,729	536,695
Hoa Binh	205,644	235,150	268,889	307,469	351,584	402,029	459,712
Thanh Hoa	3,478,599	4,003,904	4,608,535	5,304,472	6,105,503	7,027,498	8,088,724
Nghe An	909,522	1,040,597	1,190,561	1,362,138	1,558,440	1,783,033	2,039,993
Ha Tinh	2,559,503	3,043,808	3,619,752	4,304,674	5,119,196	6,087,841	7,239,771
Quang Binh	687,728	773,173	869,233	977,228	1,098,640	1,235,137	1,388,593

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Quang Tri	94,908	108,411	123,835	141,454	161,579	184,567	210,826
Thua Thien-Hue	416,696	469,986	530,091	597,882	674,343	760,583	857,851
Da Nang	651,707	736,685	832,745	941,330	1,064,074	1,202,822	1,359,663
Quang Nam	660,156	770,883	900,181	1,051,167	1,227,478	1,433,360	1,673,775
Quang Ngai	3,315,835	3,727,322	4,189,874	4,709,827	5,294,305	5,951,315	6,689,859
Binh Dinh	559,803	626,898	702,034	786,175	880,401	985,921	1,104,087
Phu Yen	75,886	85,915	97,270	110,125	124,680	141,157	159,813
Khanh Hoa	332,571	375,871	424,810	480,119	542,630	613,281	693,129
Ninh Thuan	613,363	695,618	788,903	894,698	1,014,681	1,150,753	1,305,074
Binh Thuan	492,199	558,226	633,109	718,038	814,360	923,604	1,047,501
Kon Tum	71,206	81,557	93,413	106,992	122,545	140,359	160,762
Gia Lai	810,375	931,652	1,071,079	1,231,372	1,415,654	1,627,515	1,871,082
Dak Lak	416,740	466,538	522,287	584,697	654,565	732,781	820,344
Dak Nong	115,157	136,149	160,968	190,312	225,005	266,022	314,517
Lam Dong	583,821	671,884	773,231	889,866	1,024,093	1,178,567	1,356,342
Binh Phuoc	784,451	901,571	1,036,177	1,190,881	1,368,681	1,573,028	1,807,884
Tay Ninh	357,055	405,017	459,422	521,135	591,137	670,543	760,615
Binh Duong	2,004,434	2,282,318	2,598,725	2,958,998	3,369,216	3,836,305	4,368,148
Dong Nai	3,916,494	4,407,172	4,959,325	5,580,654	6,279,826	7,066,594	7,951,933
Ba Ria-Vung Tau	1,616,462	1,684,554	1,755,514	1,829,464	1,906,528	1,986,839	2,070,533
Ho Chi Minh city	6,144,729	6,923,308	7,800,538	8,788,919	9,902,534	11,157,252	12,570,951
Long An	383,633	444,156	514,227	595,354	689,279	798,022	923,920
Tien Giang	603,448	681,552	769,766	869,397	981,923	1,109,014	1,252,554

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Ben Tre	193,391	214,288	237,444	263,101	291,531	323,034	357,940
Tra Vinh	3,349,935	3,867,035	4,463,956	5,153,019	5,948,446	6,866,656	7,926,603
Vinh Long	88,270	97,823	108,411	120,145	133,150	147,561	163,533
Dong Thap	112,213	124,388	137,883	152,843	169,425	187,807	208,183
An Giang	145,961	160,145	175,707	192,781	211,514	232,068	254,619
Kien Giang	959,997	1,059,947	1,170,303	1,292,150	1,426,682	1,575,221	1,739,225
Can Tho	144,715	159,318	175,395	193,094	212,578	234,029	257,645
Hau Giang	24,956	27,699	30,743	34,122	37,873	42,035	46,655
Soc Trang	40,189	44,294	48,819	53,806	59,302	65,359	72,035
Bac Lieu	102,300	113,163	125,180	138,472	153,176	169,441	187,433
Ca Mau	93,017	102,088	112,044	122,971	134,964	148,126	162,572

The VNEEP has set the goal of the national level target is 7% saving of total energy consumption in the period of 2019 – 2025, the 63 provinces are main actors to implementation of the national target. Therefore, allocation of the national target to the provincial target ensures that sum of the province saving energy amount has to meet the national energy saving amount. The allocation mechanism has to be based on the provincial characteristic of energy efficiency such as responsibility, ability, potential, difficulty.

Using MATLAB genetic algorithm programming, the amount of saving energy of each province was iteratively calculated and re-examined to meet the national goal. Detail calculation results are shown in Table 7.

Table 7. Result of target allocation

Cluster	Number of provinces	Province included	Allocated target in %
1	2	Ha Noi, Ho Chi Minh city.	7.25
2	3	Ninh Binh, Thanh Hoa, Dong Nai.	7.90
3	4	Quang Ninh, Binh Duong, Bac Ninh, Ba Ria-Vung Tau.	7.65
4	9	Hung Yen, Long An, Vinh Phuc, Hai Duong, Ha Nam, Nam Dinh, Phu Tho, Tien Giang, Thai Binh.	7.25
5	13	Bac Giang, Lai Chau, Thai Nguyen, Son La, Ha Tinh, Tra Vinh, Hoa Binh, Binh Phuoc, Tay Ninh, Lao Cai, Nghe An, Quang Nam, Quang Ngai.	6.75
6	5	Binh Thuan, Khanh Hoa, Can Tho, Hai Phong, Da Nang.	7.0
7	27	Lang Son, Dien Bien, Yen Bai, Quang Tri, An Giang, Quang Binh, Ben Tre, Dong Thap, Kon Tum, Kien Giang, Ninh Thuan, Bac Kan, Binh Thuan, Lam Dong, Dak Lak, Vinh Long, Soc	4.75

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	Trang, Bac Lieu, Ha Giang, Tuyen Quang, Cao Bang, Gia Lai, Hau Giang, Phu Yen, Ca Mau, Dak Nong, Bình Định.

As seen in Table 7, each cluster assigns different energy saving target. There are 28 provinces included in the cluster 1, 2, and 3 assigned higher rate of saving energy than the national rate. These provinces had high economic development level and high energy consumption. Among those cluster, the cluster 1 included Ha Noi and Ho Chi Minh city contributes highest share for national GDP assigned lower energy saving rate than the cluster 2 and 3. It is reasonable assignment because of their high percentage of energy consumption in service sector (logistic, transportation, commercial etc.). The cluster 2 and 3 assigned 7.90 % and 7.65 %, respectively. The provinces include in these clusters had economic development based secondary industry. The provinces in the cluster 4 has restructured economy based on industrialization recently and will play important role in the future of Vietnam energy consumption. The cluster 5 included Hai Phong, Can Tho, Da Nang, and Binh Thuan province is allocated 7.0% equal to the national goal level because these provinces had economic development strongly focused on services. The cluster 4 and 7 are set 6.75% and 4.50% saving target, respectively. Specially, the cluster 7 included 27 provinces assigns only 4.75% energy saving rate. These provinces are lowest level of economy development with economy feature is only based on the primary industry. Table 8 shows the amount of saving energy for provinces consistency with the 7.00% national energy saving target in the period of 2019 – 2025.

Table 8. Amount of saving energy for each province in the period of 2019 – 2025 (in TOE)

	2019	2020	2021	2022	2023	2024	2025
Ha Noi	608,163	636,747	682,593	723,548	775,644	831,490	907,987
Vinh Phuc	62,893	65,891	70,679	74,967	80,190	85,616	90,981
Bac Ninh	141,838	155,518	174,406	193,494	216,413	241,614	268,541
Quang Ninh	139,901	148,614	161,585	173,749	188,392	203,893	219,650
Hai Duong	96,709	101,802	109,709	116,913	125,642	134,772	143,892
Hai Phong	251,900	274,709	306,450	338,181	376,241	417,833	461,933
Hung Yen	89,274	93,398	100,048	105,970	113,196	120,689	128,074
Thai Binh	110,907	117,611	127,661	137,038	148,337	160,271	172,363
Ha Nam	51,249	55,728	61,990	68,213	75,674	83,800	92,380
Nam Dinh	68,584	70,712	74,675	77,963	82,097	86,287	90,259
Ninh Binh	107,631	116,716	129,486	142,099	157,220	173,635	190,896
Ha Giang	3,389	3,493	3,687	3,848	4,050	4,255	4,449
Cao Bang	3,386	3,443	3,587	3,694	3,838	3,979	4,106
Bac Kan	5,548	5,708	6,015	6,267	6,586	6,907	7,210
Tuyen Quang	7,418	7,736	8,261	8,722	9,287	9,871	10,442
Lao Cai	32,587	34,792	38,016	41,083	44,766	48,691	52,716
Yen Bai	13,558	13,932	14,664	15,258	16,014	16,776	17,489

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Thai Nguyen	47,914	56,188	67,296	79,791	95,325	113,692	135,030
Lang Son	12,032	12,353	12,990	13,505	14,162	14,823	15,440
Bac Giang	64,844	69,849	76,987	83,930	92,255	101,221	110,552
Phu Tho	55,592	58,139	62,257	65,918	70,389	75,022	79,584
Dien Bien	6,373	6,699	7,209	7,672	8,233	8,819	9,403
Lai Chau	11,666	13,288	15,468	17,820	20,689	23,980	27,673
Son La	13,813	14,378	15,326	16,152	17,168	18,214	19,232
Hoa Binh	11,714	12,229	13,072	13,817	14,729	15,671	16,595
Thanh Hoa	336,574	354,550	382,350	407,742	438,490	470,679	502,878
Nghe An	60,592	62,923	66,916	70,360	74,615	78,977	83,200
Ha Tinh	24,664	24,769	25,494	25,935	26,616	27,262	27,787
Quang Binh	22,252	22,885	24,107	25,106	26,372	27,650	28,851
Quang Tri	10,174	10,509	11,117	11,627	12,266	12,915	13,533
Thua Thien-Hue	27,595	28,662	30,488	32,063	34,009	36,005	37,938
Da Nang	84,201	88,109	94,401	100,010	106,852	113,949	120,947
Quang Nam	43,899	50,562	59,499	69,302	81,344	95,316	111,211
Quang Ngai	22,979	23,579	24,784	25,753	26,991	28,235	29,395
Binh Dinh	353	362	381	396	415	434	453
Phu Yen	112	118	127	136	146	157	169
Khanh Hoa	39,538	40,225	41,929	43,202	44,903	46,581	48,089
Ninh Thuan	11,889	12,277	12,985	13,578	14,321	15,075	15,794
Binh Thuan	15,392	16,002	17,037	17,934	19,040	20,176	21,279
Kon Tum	6,889	7,201	7,707	8,156	8,704	9,273	9,831
Gia Lai	10,175	10,515	11,129	11,646	12,291	12,948	13,575
Dak Lak	15,478	15,928	16,788	17,494	18,387	19,289	20,139
Dak Nong	3,960	4,256	4,681	5,092	5,585	6,114	6,664
Lam Dong	13,304	13,885	14,838	15,679	16,708	17,772	18,815
Binh Phuoc	33,658	34,668	36,575	38,147	40,131	42,138	44,034
Tay Ninh	54,019	56,821	61,189	65,158	69,971	75,000	80,015
Binh Duong	298,120	313,554	337,625	359,494	386,014	413,719	441,343

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Dong Nai	634,731	662,537	708,124	748,351	797,598	848,491	898,388
Ba Ria-Vung Tau	68,905	63,636	60,361	56,530	53,451	50,433	47,333
Ho Chi Minh city	605,601	632,994	677,452	716,902	765,101	815,012	864,102
Long An	110,793	117,284	127,087	136,184	147,159	158,723	170,403
Tien Giang	70,045	73,267	78,469	83,099	88,749	94,607	100,378
Ben Tre	21,553	22,206	23,434	24,450	25,729	27,023	28,248
Tra Vinh	17,312	18,426	20,072	21,625	23,493	25,474	27,496
Vinh Long	8,732	9,005	9,511	9,932	10,461	10,997	11,505
Dong Thap	24,458	25,096	26,379	27,411	28,730	30,055	31,291
An Giang	21,382	21,632	22,426	22,980	23,755	24,508	25,162
Kien Giang	53,808	56,128	59,951	63,315	67,437	71,693	75,860
Can Tho	40,651	42,891	46,328	49,483	53,299	57,303	61,321
Hau Giang	4,121	4,244	4,478	4,670	4,913	5,158	5,390
Soc Trang	7,673	7,719	7,957	8,108	8,334	8,550	8,729
Bac Lieu	8,545	8,738	9,154	9,480	9,903	10,325	10,713
Ca Mau	10,097	10,232	10,625	10,905	11,291	11,668	12,000
Grand	*4,863,109*	*5,118,069*	*5,518,073*	*5,887,049*	*6,340,115*	*6,821,503*	*7,331,133*
National Target	**4,852,954**	**5,106,651**	**5,483,135**	**5,868,063**	**6,304,246**	**6,779,126**	**7,288,525**

4. Discussion

The economic development and energy consumption are two core variables effect on Vietnamese energy efficiency. Based on the actual energy efficiency situation, the Vietnam government has improved the energy efficiency for 15 years, started from 2006 with the Vietnam National Energy Efficiency Program. The new era of the Vietnam energy efficiency strategy started in early of 2019 and will implement continuously until 2030. Three main aspects, i.e., policy, technology and industry are main coordinators for improvement of the feature of the Vietnam energy efficiency. It also confirms that provinces play an important actor for achievement of the national energy efficiency target, therefore, the allocation of the national target to provinces is need.

The allocation mechanism proposed mainly considers the regional local economic development level, energy consumption historical trend and tendency of economic development combined with the required energy consumption. Based on the calculated energy consumption requirement and analysis of regional economic structure, this work suggest a mixture of economic-oriented and energy-oriented method to build up The 5-year socio-economic development Plan in terms of sustainable development and energy consumption reform for each province from 2021 to 2025. The provincial government can distinguish, anticipate and obligate indicators to restrict energy consumption as well as evaluate the province's energy efficiency within the possibility. It also reduces the pressure on energy saving for low developed provinces in the short term and finally archive the long-term goal of Vietnam's energy secure strategy.

5. Conclusion

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Understanding the potentiality of energy efficiency is useful for the harmonious and sustainable development between the economy and energy systems. In this study, provincial and national data are collected to analyze the energy efficiency levels in Vietnam. The trends of national and regional economic development and energy consumption are used to predict the energy consumption requirement need for economic development in the period of 2019 – 2025. It also reveals that the energy saving allocation in Vietnam is uneven. Combined with the different GDP development and energy consumption levels, the target regions of energy efficiency analysis are newly divided via a cluster analysis method. The provinces are classified into 7 clusters. Based on this, a quantitative calculation method is employed to estimate the amount of saving energy of each province. The results show that 33 provinces included in the cluster 1, 2, 3, 4 and 6 are heavy contribution. Among them, the provinces in the cluster 2 and 3 need to focus on the industry sector in their energy saving policy. The cluster 7 included the under-developed provinces can learn development's experiences of the provinces in the cluster 1, 2, 3 and 4 to find the best way of their future development.

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