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Global renewable energy development: Influencing factors, trend predictions and countermeasures

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ABSTRACT

Promoting the development and utilisation of renewable energy is the current trend of energy policy in various regions. First, we divide the world into seven regions based on the Engineering News-Record (ENR) regional classification—Asia-Pacific, Middle East, Canada, the United States, Latin America, Europe and Africa—and analyse the status of renewable energy from political, technical, economic and social perspectives. Second, an integration forecasting model is proposed, which includes differential autoregressive integrated moving average model (ARIMA), neural network model (NNM), support vector machine model (SVM), and predicts the development prospects of renewable resources by one-way regression in various regions. Finally, corresponding countermeasures are proposed for these seven regions.

1. Introduction

Renewable energy is an important component of energy supply that can effectively optimise energy structures, balance supply and demand contradictions and protect the ecological environment. The International Renewable Energy Agency stated that renewable energy must account for two-thirds of the total energy supply in the world by 2050 (Global energy transformation: a roadmap to 2050, 2018 International Renewable Energy Agency). The development of renewable energy has received widespread attention in recent years (Shi et al., 2016; Shi et al., 2018). Promoting the development and utilisation of renewable energy has been become a common consensus and concerted effort of all countries in the world.

By the status and trends of renewable energy, the related researches have important guiding significance for the development of renewable energy in various regions. In this respect, a scientific indicator framework is needed to drive the assessment of renewable energy. Subsequently, a scientific forecasting model is also needed to ensure the accuracy of predicted results. Research on renewable energy development has been a hot topic of the energy economy, and many scholars have adopted different evaluation indicators for renewable energy. Table .1 summarizes the relevant studies focusing on renewable energy development.

The indicators for measuring sustainable energy development are summarized including economic, technical, political and social factors, which can reflect the development of renewable energy comprehensively. Economic factors pay attention to the level of regional economic development, urbanization development and consumption of residents. Technical factors take the research and development of renewable energy technologies into account, energy security and power supply requirements. Political factors involve the completeness of the renewable energy policy system, the supervision of relevant government legislation, and the stability of policy implementation. Social factors focus on residents' awareness of renewable energy, the environment, and social resources. At the same time, these are also in line with the sustainability indicator system developed in Agenda 21.

Currently, the most common determined trend prediction model is time series prediction, which includes traditional quantity models, artificial intelligence models and hybrid models and so on (Shaikh et al., 2017; Ji et al., 2018; Ma et al., 2019). Among them, the differential autoregressive moving average model (ARIMA) is mature for long-term and short-term prediction due to its effective time series approximation (Shi et al., 2011). The neural network model (NNM) is a kind of artificial intelligence model that identifies the data and correlation among various factors to predict the future development trend. Due to its learning ability and fault tolerance, it is widely used in the prediction of big data (Park et al., 2017; Mason et al., 2018); As for support vector machine model (SVM), the application of SVM focuses on the prediction

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Table 1
Summary of studies on renewable energy development.

Scholars	Research subject	Influencing factor
Zhang et al. (2010)	Long-term predictions regards the role of renewable energy in China's energy system transformation.	Financial risks, Technical risks and Policy risks
Wang et al. (2018)	The relationship between renewable energy and its driving force	Supply structure, Energy security and Carbon emissions
Diao et al. (2013)	The operation and evolution of renewable energy	Energy, Environmental, Economic, Social and Technological factors
Aslani et al. (2012)	The main factors affecting renewable energy generation,	Policy, Economic market and Technical factors
Guo et al. (2017)	Trends in the field of renewable energy power generation	GDP, Population, Industry, Structure, Electricity price, Technological progress and Urbanisation
Haar et al. (2017)	Factors that contribute to the development of renewable energy	Resource, Economic, social and Political factors
Yun et al. (2015)	Advancing societal readiness toward renewable energy system	Technologies and Social factors
Patlitzianas et al. (2016)	Driving forces for renewable development in GCC countries	Economic, Legislative & Regulative, market and Technology
Zhao et al. (2019)	Indicators that affect the development of renewable energy power generation projects in China	Technology R&D, Economy and urbanization development, R&D personnel and ability, Incentive policy system, Industry standards and market access, Market demand for power supply and Government policy implementation.
Krajnc et al. (2005)	A model for integrated assessment of sustainable development	Environment, Economy Society and Sustainability:
Ji and Zhang (2019)	Understanding the role of financial development on renewable energy development	Financial indicators, energy consumption structure
Zhang et al., 2019bZhou et al., 2019	Uncertain investment decisions in low-carbon transition toward renewable energy.	The market price of electricity, Fossil fuel cost, carbon dioxide price, investment cost and Feed-in tariff policy

of short-term small-scale data and nonlinear data (Yang et al., 2014; Guo et al., 2017). Another method uses the causal relationship of things to speculate about the causal relationship prediction of the development trend. It mainly analyses the degree of interaction between various factors and predicts the target (Lin et al., 2013; Zhang et al., 2019a). But a single predictive model cannot improve prediction accuracy. In this study, multiple prediction models were used to develop the comprehensive prediction, including differential ARIMA, NN and SVM. Comprehensive use of the advantages of three models, including ARIMA model linear time series approximation ability, NN data recognition simulation function and SVM model adequately solve limited samples, to effectively overcome the shortcomings of a single algorithm deficiency and improve the robustness and accuracy of the prediction model.

With the accelerated development of renewable energy in the world, Sustainable energy is used in various fields, such as the power sector (Sakaguchi et al., 2015; Ruth Dominguez et al., 2015; Farooq et al., 2013), fever refrigeration (Connor et al., 2013), automotive traffic (Richardson et al., 2013; Xu et al., 2019), communications (Sheng et al., 2016), logistics (Xu et al., 2015; Yu et al., 2018) and the construction sector (Zhou, 2018). Renewable energy generation is the most widely used and representative development direction of renewable energy in each region. Therefore, this study uses the forecasting results in the field of renewable energy power generation as a trend, which can reflect the development of renewable energy in each region representatively.

In view of the benefits of renewable energy development, the integrated renewable energy development indicator system and forecasting the development trend of renewable energy will help each region to plan accordingly for the development of the region. Therefore, this paper will classify global regions by the ENR classification standard, combine the influence factor system of each region, use renewable energy power generation as the evaluation field, analyse the status quo of renewable energy in each region and make trend predictions to produce relevant recommendations for renewable energy development and promote the development of renewable energy power generation. This study will help managers grasp the status and trends of renewable energy development in the region and understand the indicator system that affects the development of renewable energy to formulate corresponding solutions.

The rest of the paper is organised as follows: Section 2 establishes an architecture of development factors and analyses the current status of global renewable energy development; Section 3 combines renewable energy power consumption change data to forecast development trends; the data analysis and results are discussed in Section 4; and some concluding remarks are given in Section 5.

2. Influencing factors and data source

Based on the regional division of the ENR report, the Asia Pacific, Middle East, Canada, the United States, Latin America, Europe and Africa were selected to build an architecture in combination with sustainable energy development factors, including economic, technological, political and social factors. At the same time, according to the factor substitution method (Wang et al., 2017), the substitution indicators related to the influencing factors are analysed to predict the development trend of renewable energy in each region.

2.1. Economic factors

The development of renewable energy is inseparable from the economic development of a country and is the direct driving force for the development of renewable energy. Since there is a two-way causal relationship between renewable energy and economic growth (GDP per capita), the development and consumption of renewable energy depends to a certain extent on per capita economic income, and the promotion of economic development is conducive to the development of renewable energy (Soheila et al., 2017). At the same time, the development of renewable energy is inseparable from financial support. Economic growth is conducive to financing investment, resisting the financial risks brought about by the development and utilisation of renewable energy (Zeng et al., 2014), stimulating investors' willingness to invest in renewable resources and is beneficial to exploring the development potential of renewable energy and ensuring sustainable development in the field of renewable energy generation (Masini et al., 2012).

Therefore, we shall scientifically analyse the impact of economic growth factors on the development of renewable energy. The factors that measure regional economic development are various and include domestic economic development and the living standards of residents.

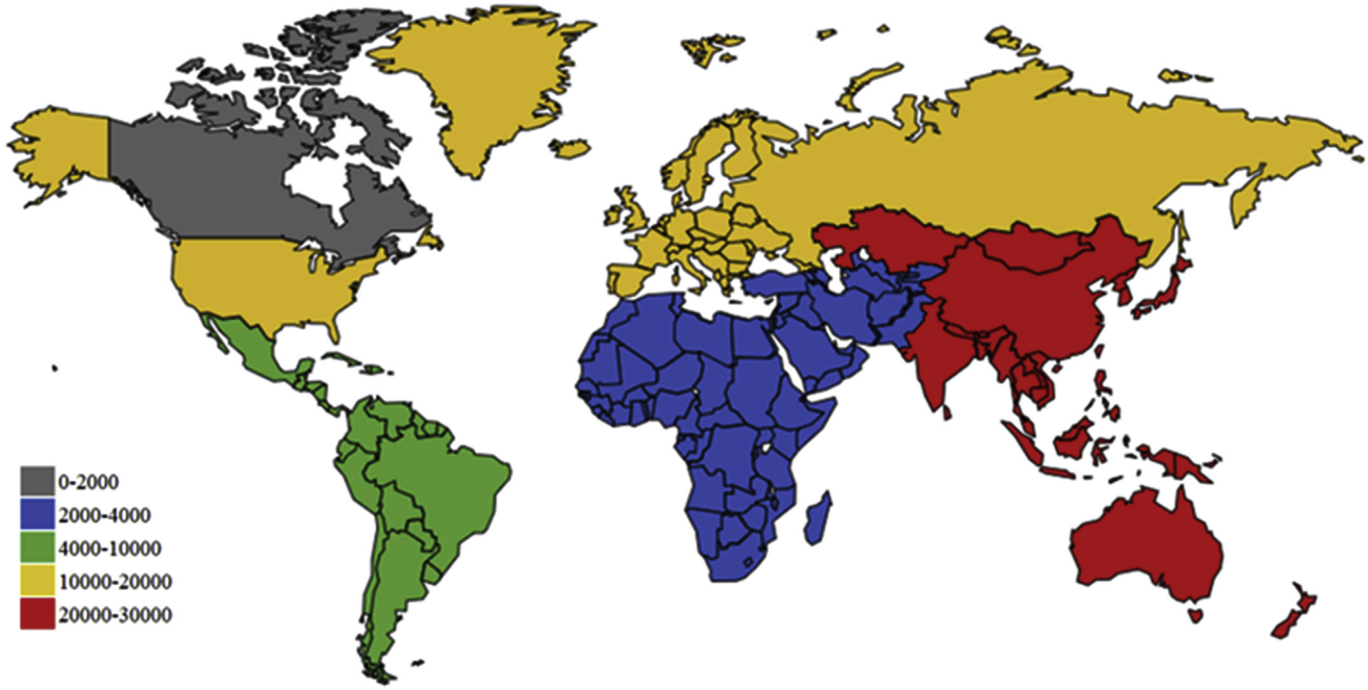

Fig. 1. GDP in each region in 2018 Unit: billions of US dollars (Sources: The World Bank).

Domestic economic development refers to the overall economic development level of a country, with GDP as a surrogate indicator. Economic growth will help increase investment in renewable energy development in the region and promote the development of renewable energy. Fig. 1 below shows a summary of the GDP of each region in 2018. We can see that the overall GDP of the Asia-Pacific region is the highest. In Europe and the United States, although the number of countries is small, the developed countries are intensive and the level of economic development is relatively high. Latin America and Africa are generally developing countries, and the overall economic development level is in the middle and lower reaches.

The living standard of residents refers to the consumption level of living products and labour services used by residents in a certain stage of social production and development. Electricity consumption is the most accurate indicator of the living standards of residents. When the living standards of residents are high and the demand for electricity increases, the demand for renewable energy generation will be stimulated to some extent. Fig. 2 below shows the electricity consumption of residents in various regions in 2016. Among them, the Asia-Pacific region, the United States and Europe are the three regions with the highest level of economic development, and the overall living standards of the residents are in the forefront. In Canada, due to the small population, residents use less electricity, but the unit level is higher. In the Middle East, Latin America and Africa, although the population base is large, the unit level is low, and the whole is still in the middle and lower reaches.

2.2. Technical factors

Renewable energy technologies are key to ensuring a competitive, cost-safe and sustainable energy supply (Rexhäuser et al., 2015). Promoting the development of renewable energy technologies will reduce development and maintenance costs and improve reliability, applicability and energy conversion efficiency to promote the development of renewable energy power generation (Dincer et al., 2001).

Factors that affect technological development include new energy utilisation capabilities, power generation capabilities and research and development capabilities.

New energy utilisation refers to forms of energy other than traditional energy sources. Renewable energy generation in each region is used as a surrogate indicator, indicating the development level of renewable energy power generation in various regions. Fig. 3 below shows the amount of renewable energy generated in each region in 2016. Among them, the European region is the region with the largest amount of renewable energy. Secondly, hydropower generation in Latin America accounts for more than 50% of the total power generation. Therefore, renewable energy generation in Latin America is relatively large. In the United States and the Asia-Pacific region, although the proportion of renewable energy is only about 18%, the total amount of power generation is large, so the renewable energy base is large. The Canada is one of the regions with more developed renewable energy sources, with renewable energy generating accounting for 64% of total electricity generation. The Middle East and Africa are still dominated by thermal power, and renewable energy generation accounts for a relatively low proportion.

The power generation capacity reflects the change in power demand and is an integral part of the effective supply capacity of renewable energy power. The total power generation is used as a surrogate indicator to reflect the development trend of power generation capacity in various regions. Under the global trend of promoting renewable energy generation, the total power generation demand will promote the progress of renewable energy power generation. Fig. 4 below shows the distribution of power generation by region in 2016. Among them, Asia Pacific, the United States and Europe are the three regions with the most power generation. This is followed by the Middle East and Latin America, while Africa and Canada generate the least amount of electricity.

R&D capability is a key factor affecting renewable energy generation. Hydroelectric power generation and solar photovoltaic power generation are the two most widely used types in the field of renewable energy power generation. Therefore, this study uses the development cost of both as a surrogate indicator. A weak R&D capability will result in low utilisation of renewable energy and high development costs, hindering the applications of renewable energy generation. Fig. 5 and Fig. 6 below shows the minimum, the weighted average and the maximum profile of the levelling costs in hydroelectric power generation

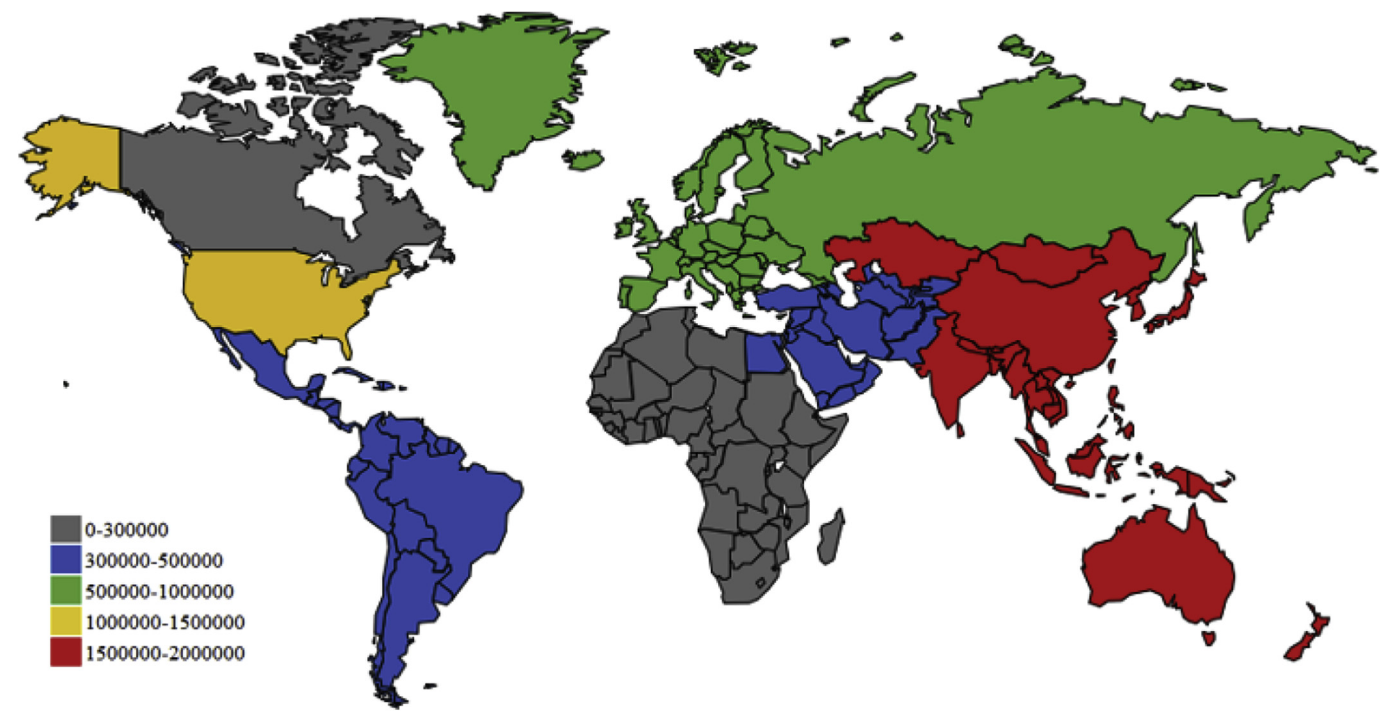

Fig. 2. Electricity consumption of residents in various regions in 2016 Unit: Gigawatt Hour (Gwh)(Sources: International Energy Agency).

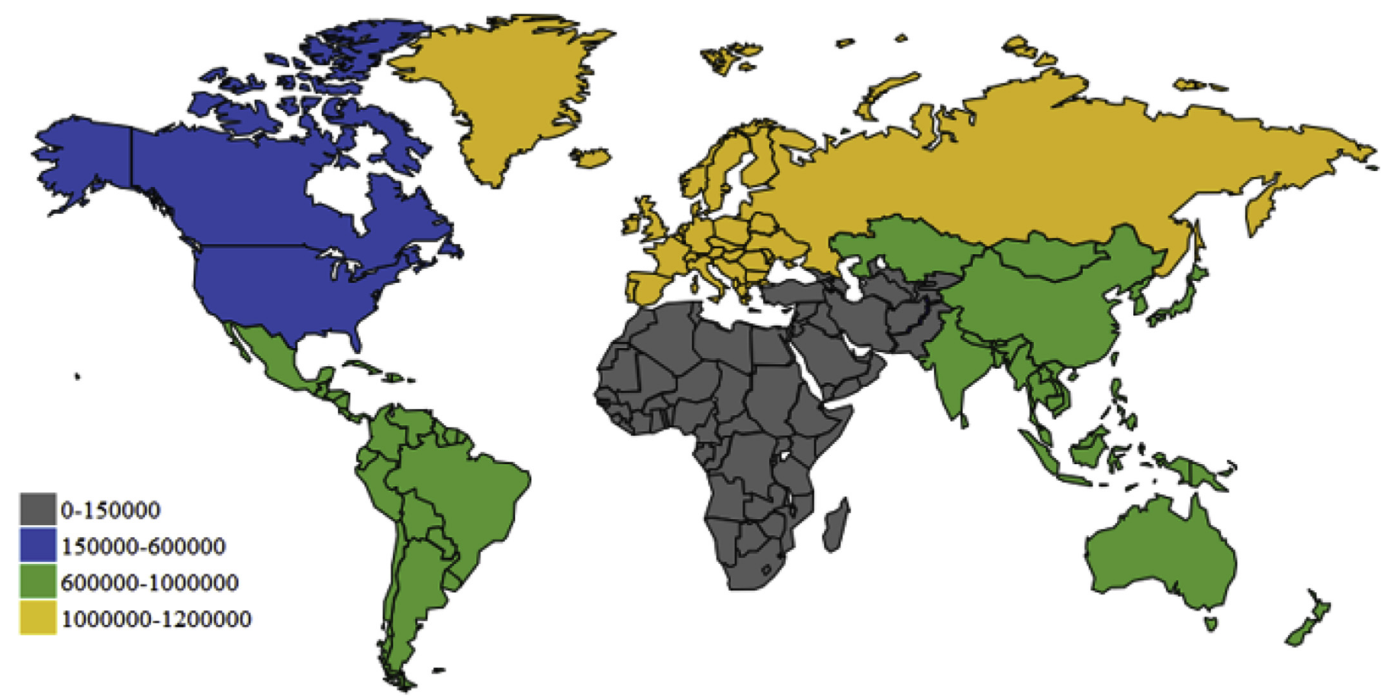

Fig. 3. Renewable energy generation by region in 2016 Unit: Gwh (Sources: International Energy Agency, the World Bank).

and solar photovoltaic power generation for each region. All in all, the cost of renewable energy generation in the United States, Canada, and Latin America is relatively low. The Asia-Pacific region and Europe have developed rapidly in recent years, and the cost of power generation has declined significantly. The cost of generating electricity in the Middle East and Africa is relatively high.

2.3. Social factors

Social factors mainly concern society's awareness of renewable energy. The degree of social cognition affects the choices of public and financing institutions. Raising public awareness of the benefits of renewable energy facilitates the implementation of renewable energy projects (Mirza et al., 2009). Improving the awareness of financing institutions and power grid companies facilitates fundraising for raw energy utilisation and allows more resources to be invested in renewable energy power generation (Flacke et al., 2017).

In recent years, due to energy and environmental issues, the international community has emphasised the importance and accelerated the development and utilisation of renewable energy. Social recognition

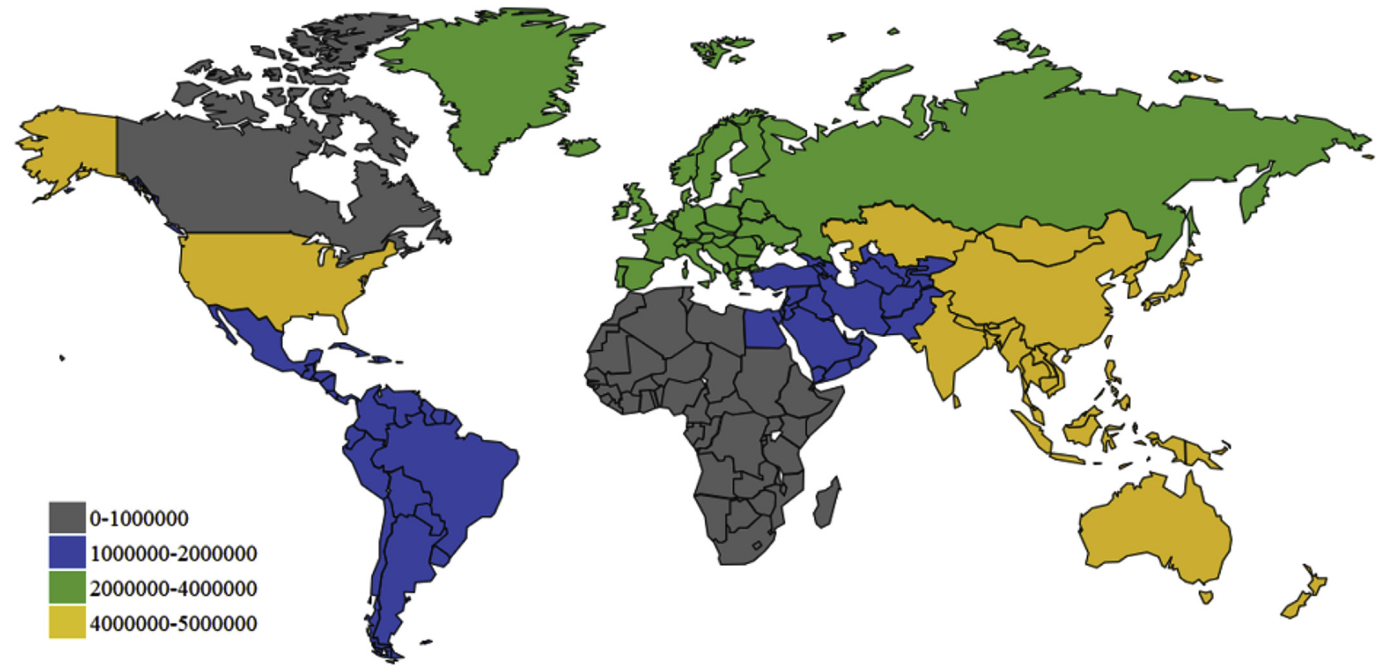

Fig. 4. Total power generation by region in 2016 Unit: Gwh (Sources: International Energy Agency).

of renewable energy in all regions is generally high. Therefore, the social factors in this paper are only used as common factors and will not be analysed in detail.

2.4. Policy factors

Policy factors mainly refer to the policies and regulations of renewable energy development, and power generation application in a country or region. They have a very important impact on the future development trend of a country's renewable energy and are the strongest driving force for this development (Haar et al., 2006). The government should actively implement more policies to support renewable energy health, continuously improve the renewable energy policy system and make important contributions to the establishment of a sustainable energy system so the long-term health of renewable energy can be realised (Zeng et al., 2013). On the one hand, governments should improve welfare through renewable energy incentives, including subsidies and on-grid tariffs, clarify investment income, attract investors to invest in renewable energy and stimulate the development of renewable energy (Yang et al., 2018; De Arce et al., 2016); on the other hand, governments develops renewable energy development plans to guide the healthy development of renewable energy, realizes a diversified and large-scale renewable energy portfolio, and achieves a safe and clean renewable energy generation.(Schuman et al., 2012).

To accelerate the development and utilisation of renewable energy, most countries in the world have adopted a positive and preferential policy system. The specific indicators include macroeconomic policies, government credibility and renewable energy development plans.

The renewable energy development plan is an overall strategic plan for the development goals and safeguard measures of renewable energy based on the development status of renewable energy resources and technologies. It plays a vital role in the development and utilisation of renewable energy in the future. Fig. 7 below shows the planning of national renewable energy policies and renewable energy targets. Among them, the United States, Europe, and Canada generally have relatively complete renewable energy development policies and targets.

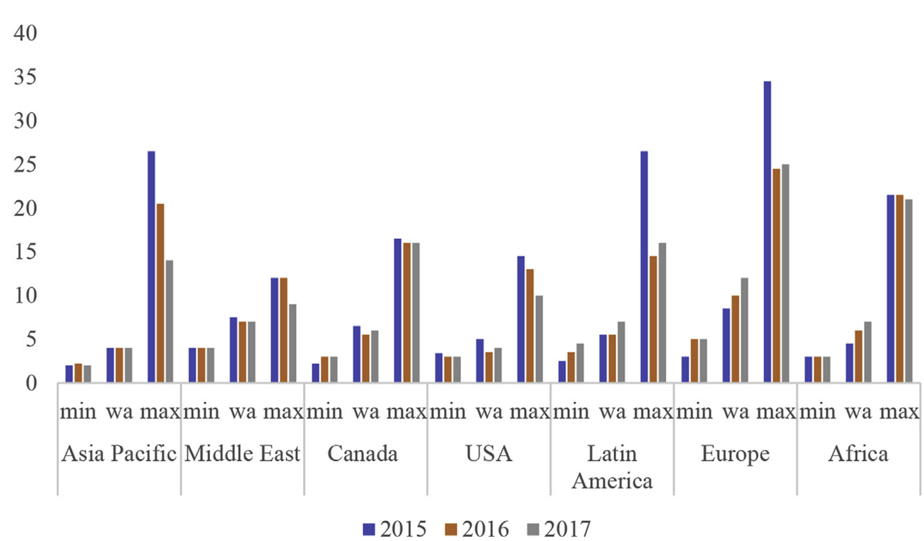

Fig. 5. Water levelling costs by region Unit: cents/kilowatt hour (Kwh)(Sources: renewable global status report).

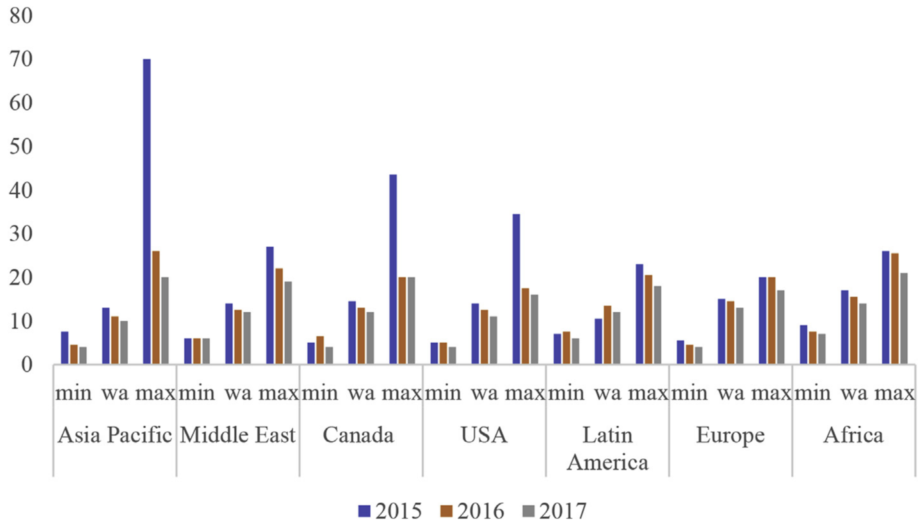

Fig. 6. Solar photovoltaic levelling costs by region Unit: cents/kwh (Sources: renewable global status report).

Some countries in the Asia Pacific and Latin America regions lack clear development policies or targets. The overall renewable energy system in Africa and the Middle East is relatively inadequate.

Government credibility is the belief that the government relies on the recognition of universal behavioural norms and networks by members of society, reflecting the degree of trust of the government. Higher government credit rating index facilitates the implementation of renewable energy policies to promote renewable energy development. Fig. 8 below shows the weighted average of the government credibility indices for each region in 2017. Among them, the United States, Canada, Europe and the Middle East have higher government credibility indicators, while the Asia-Pacific and African regions have relatively low credibility indicators.

Macroeconomic policies refer to the guiding principles and measures formulated by a state or government to solve economic problems consciously and systematically using certain policy tools to improve the overall social and economic welfare, improve the operation of the national economy and achieve certain policy objectives. Different macroeconomic policies will guide and plan the country's economic development and industrial structure. In the long run, they greatly influence people's demand for renewable energy.

2.5. Indicator system framework

Based on economic factors, technical factors, political factors and social factors, this paper constructs a renewable energy indicator framework. Through the substitution of relevant indicators, paper qualitatively analyses or quantifies each factor to predict the trend of renewable energy. Table .2 establishes the indicator system predicted in this paper.

3. Forecasting methods

3.1. Autoregressive integrated moving average model

The ARIMA model transforms a non-stationary time series into a stationary time series and converts the dependent variable only to its hysteresis value, the present and lag values of the random error term.

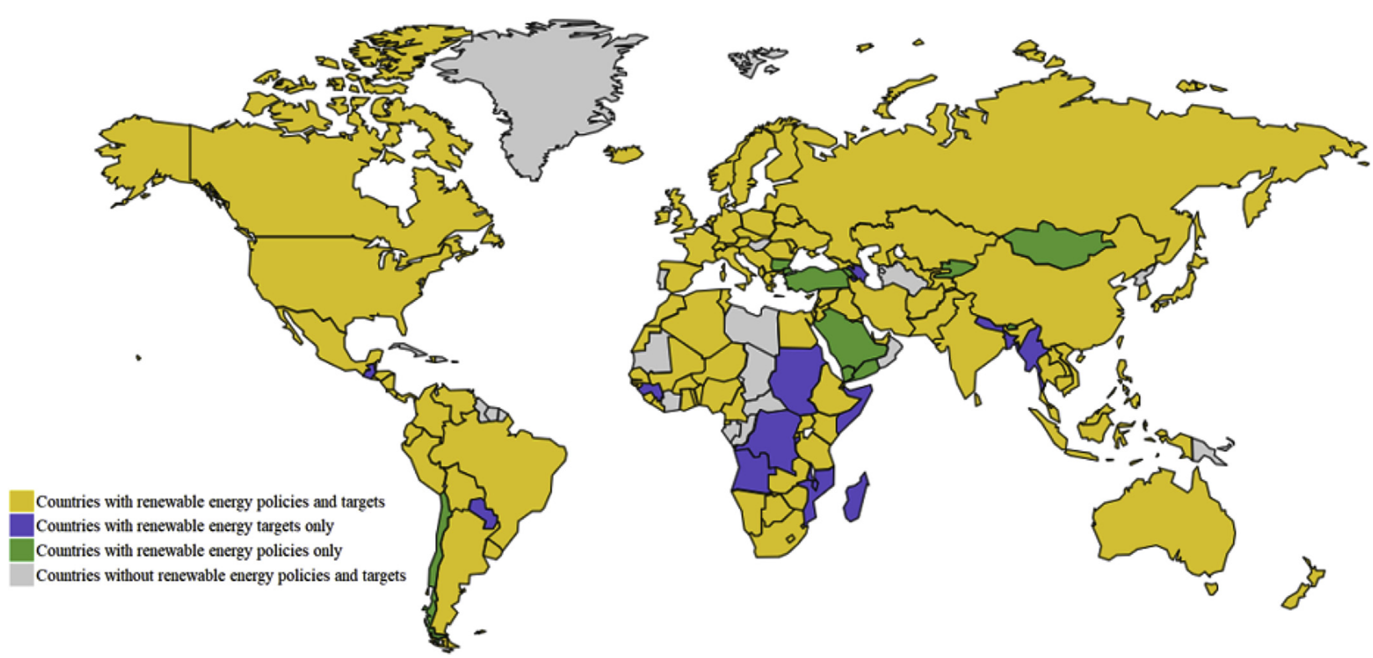

Fig. 7. Distribution of renewable energy policies by region.

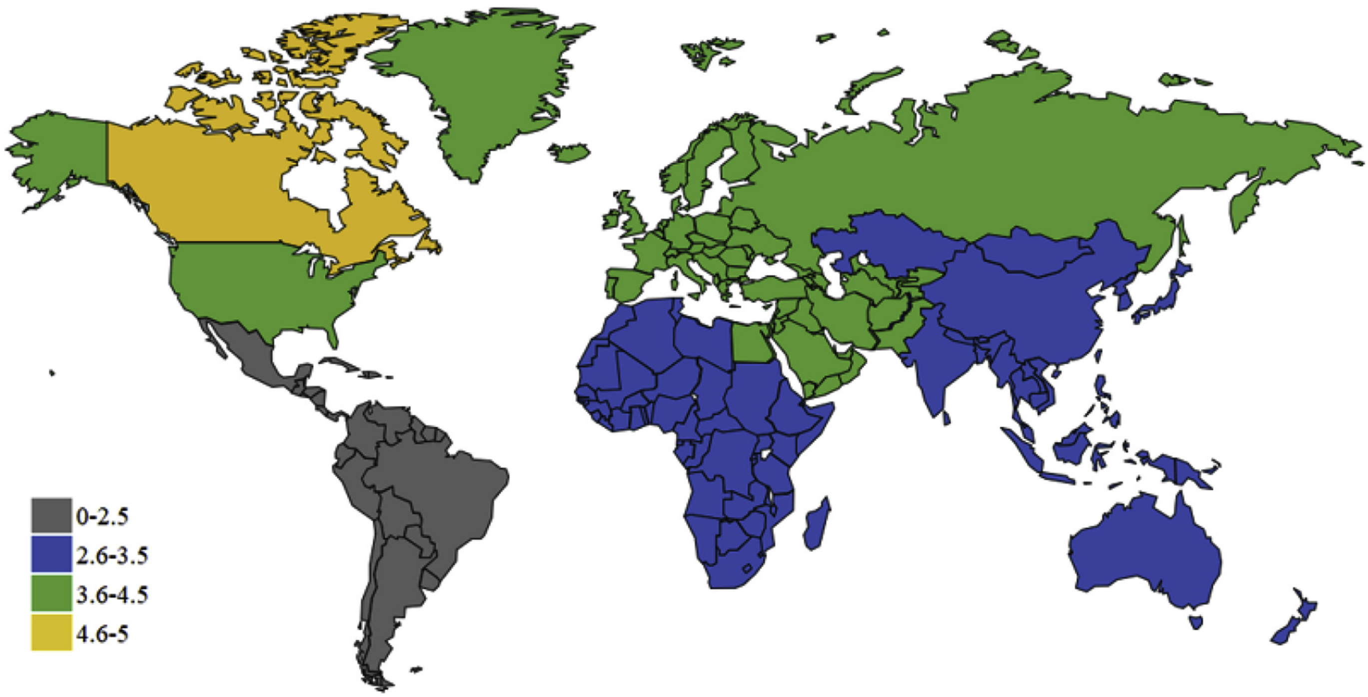

Fig. 8. Government credit rating index by region in 2017 (Sources: Global Competitive Report).

The model is widely used in short-term prediction. The ARIMA (p, d, q) is as follows:

$$\phi(\mathrm{B})(1-\mathrm{B})^{d}y_t = \theta(B)\varepsilon_y \tag{1}$$

$$(\mathrm{B}) = 1 - \phi_1 B - \phi_2 B - \ldots\phi_q B^p \tag{2}$$

$$\theta(\mathrm{B}) = 1 - \theta_1 B - \theta_2 B - \ldots\phi\theta_q B^q \tag{3}$$

In the above formula, $(1-B)^d$indicates that the sequence is d-differentiated, $\phi(B)$is an autoregressive coefficient polynomial, $\phi(B)$ represents a moving average coefficient polynomial and p and q represent the autoregressive and moving average orders, respectively. By making $\omega_t = (1-B)^d y_t$, the ARIMA (p, d, q) model can be expressed as

$$\omega_t = \phi_1\omega_{t-1} + \phi_2\omega_{t-2} + \ldots+\phi_p\omega_{t-p} + \varepsilon_t - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} - \ldots-\theta_q\varepsilon_{t-q} \tag{4}$$

Based on the obtained data, the values of each factor are predicted according to the procedure in Fig. 9. On the one hand, the ARIMA model system has strong linear prediction ability and the future is projected from a given data centre with small error. On the other hand, using the ARIMA model predictions as a baseline value can automatically derive better results without relying on the skills of people in statistical prediction and practice sequence prediction (Martin et al., 2014).

3.2. Neural network model

The neural network (NN) is a relatively new information processing discipline that is essentially an adaptive nonlinear system for massively parallel processing. Jürgen Schmidhuber gave an overview of its history and application development (Schmidhuber et al., 2015). It has strong robustness and fault tolerance and is expert in association, generalisation, analogy and promotion.

The NN determines the relationship between the input and output variables by mimicking the network functions of neurons in the biological neural network and the edges connecting these neurons. The learning process of the NN algorithm is actually an iterative process of adjusting the thresholds and transfer functions of each neuron, connecting the weights of the neurons and the network structure to minimise the fitting error (Jammazi et al., 2012; Hinton et al., 2015; Pao, 2009). The mathematical expression of the neuron model is:

$$y_i = f(S_i) \tag{5}$$

$$S_i = \sum_{i=1}^{n} w_{ij}x_j - \theta_i = W_i X - \theta_i \tag{6}$$

The column vector X is the input vector, the row vector is i's connection weight vector and s_j represents the input of a neuron. If the threshold θ_i is also considered the 0th input of the neuron and its value X_0 = -1, $W_{i0} = \theta_i$, then the equation can also be expressed as:

Table 2
Indicator system framework.

Primary aspects	Influencing factor	Substitute indicator
Economic factors	Domestic economic development	GDP
	The living standard of residents	Residents' electricity consumption
Technical factors	New energy utilization	Renewable energy generation
	The power generation capacity	The total power generation
	R&D capability	The development cost
Social factors	society's awareness of renewable energy	Qualitative analysis
Policy factors	The renewable energy development plan	Qualitative analysis
	Government credibility	Government credibility Qualitative analysis
	Macroeconomic policies	Qualitative analysis

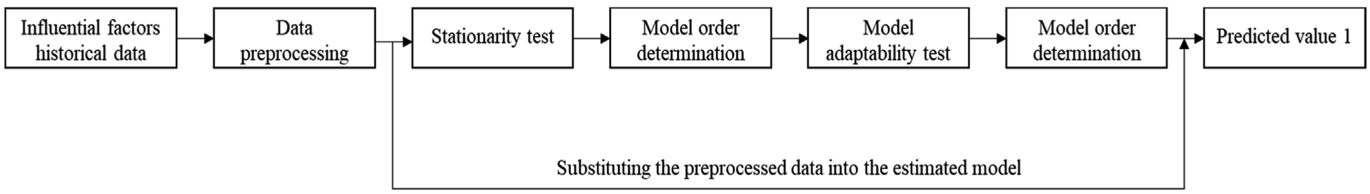

Fig. 9. ARIMA modelling prediction flow chart.

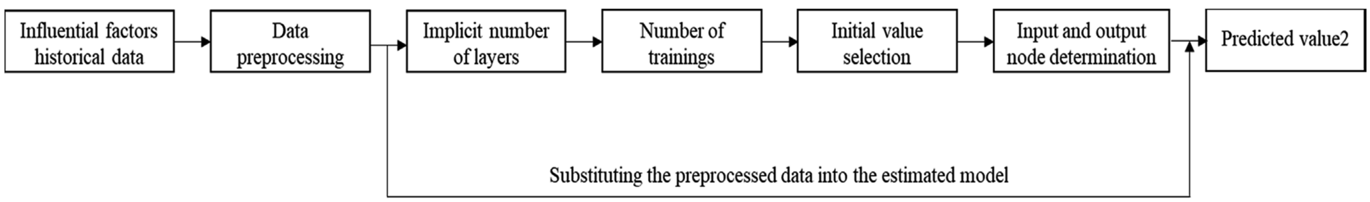

Fig. 10. Neural network modelling prediction flow chart.

$$S_i = \sum_{i=1}^{n} w_{ij}x_j \tag{7}$$

The NN can automatically learn previous experiences from data samples without repeated query and representation processes. It can automatically approximate the functions that best characterise the rules of the sample data. It is the most commonly used method for nonlinear prediction, as it compensates for the low accuracy of nonlinear prediction of the ARIMA model. Therefore, according to Fig. 10, the known data are brought into the prediction flow chart of the NN to obtain the predicted value 2, and the original reference value is corrected to improve the prediction accuracy.

3.3. Support vector machine model

SVM theory is based on the principle of structural risk minimisation. By finding a balance between the complexity of the model and the training error, an optimal network structure can be obtained.

The standard algorithm for SVM is $\varepsilon - SVR$,given the training set $T = \{x_t, y_t\} \in R^n \times R$, $(t = 1,2, ..., T)$ in which $x \in R^n$is the input value of t periods and y_t is the observations. The basic idea of SVR is to transform the original data x_t from the low-dimensional feature space to the high-dimensional feature space through the mapping function $\phi(\bullet)$ and then perform a linear regression on the data in the high-dimensional feature space. Its specific form can be described as:

$$\phi(\bullet) f(x) = w^T\phi(x) + b \tag{8}$$

in which $\phi(\bullet)$ is a nonlinear mapping function, x is an input vector and $f(\bullet)$ is the predicted result. Based on the principle of structural risk minimisation, the SVM translates model parameter w^T and the estimation process of b into a planning problem that minimises the maximum error limit:

$$\min_{w \in R^n, b \in R, \xi, \xi^*, b,} \frac{1}{2}\langle w, w\rangle + C \sum_{i=1}^{T} (\xi_i + \xi_i^*) \tag{9}$$

$$s.\ t. \begin{cases} (\langle w, \phi(x_t)\rangle + b - y_t \leq \varepsilon + \xi_t^* \\ y_t - (\langle w, \phi(x_t)\rangle + b) \leq \varepsilon + \xi_t^* \\ \xi_t \xi_t^* \geq 0 \quad t = 1,2, ..., T \end{cases} \tag{10}$$

where b is the offset, ξ and ξ^* are the slack variables and ε is the maximum error allowed by regression; constant $C > 0$ is the penalty factor, and the control pair exceeds the allowable error ε. Controlling the degree of error penalties beyond the allowable error is a compromise between confidence range and empirical risk.

Thus, we obtain the final forecast:

$$f(x) = \sum_{i=1}^{T} (\overline{\alpha}_i^* - \overline{\alpha}_i) K(x_i, x_j) + \overline{b} \tag{11}$$

where the corresponding coefficient $\alpha_i - \alpha_i^{(*)} \neq 0$ is a support vector.

An important feature of the Vapnik Chervonenkis (VC) dimension learning machine is its ability to generalise unknown data. Its training of data is equivalent to a linear constrained quadratic programming problem, so it can obtain a unique global optimal solution, unlike NNs which easily fall into local minima (Yan et al., 2003). The known data are taken into the prediction flow chart of Fig. 11 below, and the obtained prediction value is more accurate in smaller sample data.

3.4. One-way regression prediction

A unary regression refers to the correlation form in which a dependent variable change with an independent variable and it can be used to establish the relationship between the influencing factor and the target. It focuses on the quantitative adjoint relationship between variables and describes the relationship with a mathematical expression to determine the effect of one or more variables (independent variables) on the degree of influence of another variable (dependent variable). A linear regression model involving only one independent variable can be expressed as

$$y = \beta_0 + \beta_1 x + \varepsilon \tag{12}$$

where β_0, β_1 are constants, and ε obeys the normal distribution $N(0, \sigma^2)$'s random variable.

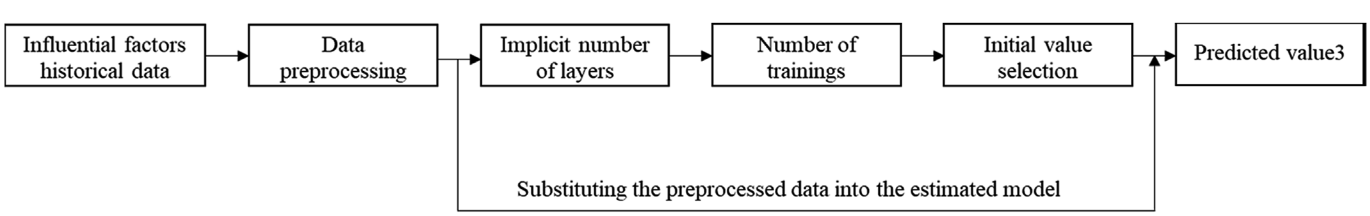

Fig. 11. SVM modelling principle and prediction flow chart.

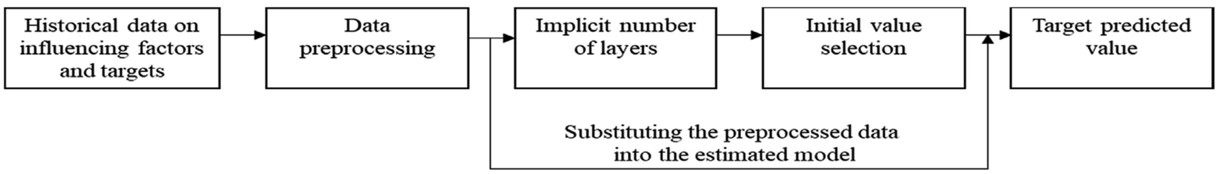

Fig. 12. One-way regression model prediction flow chart.

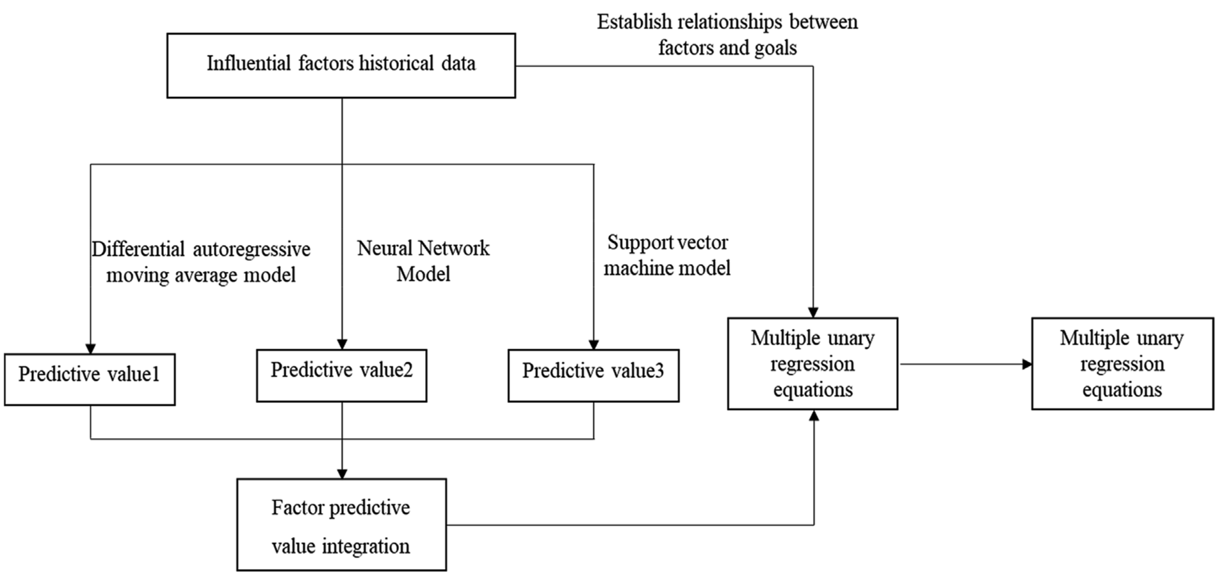

Fig. 13. Forecasting flow chart.

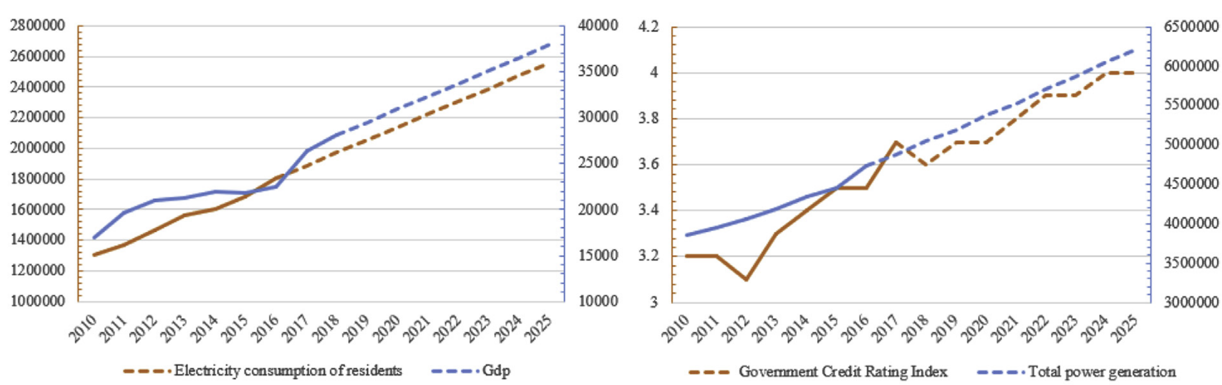

Fig. 14. Forecast values of influencing factors in the Asia-Pacific region.

Fig. 12 shows the principle and modelling steps of the one-way regression model and the prediction flow chart. The purpose of the one-way regression model is to establish the relationship between each influencing factor and the goal, and based on this mutual relationship to obtain the predicted value of the target.

3.5. Forecasting process

As shown in Fig. 13, this study combines the strengths of the three predictive models using a hybrid model to obtain predictions superior to a single model. Then, the one-way regression equation is used to establish the relationship between each factor and the target and integrate the prediction results of the three models into multiple one-way regression equations. Finally, the target values obtained by the unary regression equation are averaged to obtain the final predicted value of the target.

During the forecasting process, through the ARIMA model, based on the data from various impact indicator over the years, the development trend of renewable energy and various impact indicators are predicted. However, when the data is nonlinear, the predicted value will deviate.

Then, by preprocessing and training the initial data, NN model and SVM model are used to correct the prediction data to improve the prediction accuracy. The NN model has a certain degree of fault tolerance and generalization ability, and can connect the predicted objective with the respective impact indicators. However, it requires a large amount of data, and the output is difficult to interpret and the credibility cannot be judged. The advantage of SVM model is that it processes the small sample data and the nonlinear data, which can complement the ARIMA model and ANN model.

By using the integrated model, the advantages and disadvantages of these three models are complemented, which is beneficial to reduce the error of predicted value, improve the robustness and accuracy of the predicted data.

4. Results and discussion

4.1. Asia Pacific

We can see from Fig. 14 that each indicator curve rises linearly, reflects the rapid development trend of Asia-Pacific region. In the future, Asia-Pacific is one of the regions with the potential for renewable energy development.

On economic development, although the development of countries in the Asia-Pacific region is uneven at present, but the overall economy in the Asia-Pacific region maintains rapid growth. It is predicted that the total GDP of the Asia-Pacific region will reach 37,125 billion dollars in 2025 from $28,125 billion dollars in 2018, which increases by 35% in 2016. At the same time, the electricity consumption of residents is also growing at a rapid rate of 4% per year. Economic growth will greatly promote the demand for renewable energy.

In terms of technological development, it is predicted that total power generation in 2025 will reach 1,001,940.1Gwh. At the same time, the weighted average cost of levelling renewable energy in the Asia-Pacific region has remained stable. The renewable energy development costs of various countries are declining each year.

Considered social policy, most all countries in Asia-Pacific region have renewable energy development policies and targets. A few countries have only renewable energy development goals or plans. For example, China has promulgated the 13th Five-Year Plan for Renewable Energy Development plan the future development of renewable energy. In addition, the Asia-Pacific region has demonstrated the fastest growth of government credibility, and most countries in the region are relatively stable in social politics; the renewable energy policy is detailed, which is convenient for the governments to promote the development of renewable energy.

4.2. Middle East

The economic development in the Middle East is relatively fast in Fig. 15, the living standards of residents are increasing rapidly, and the demand for power generation is increasing year by year. However, due to the unstable political environment and social unrest in the Middle East, the government's credibility has declined year by year, which has seriously obstructed the development of renewable energy.

On economic development, nearly half of the countries in the Middle East belong to higher income levels, but a quarter of them are low- and middle-income countries. In recent years, social unrest and lower oil prices have delayed the economic development of some countries. Therefore, the GDP in the Middle East is predicted to have low trend growth, which will increase by 15% in 2025, compared to 2016. As for residential electricity consumption, the Middle East maintained a steady growth rate of 2–3%. In the absence of external factors, the demand for renewable energy in the Middle East has maintained stable growth.

In terms of technological development, it is predicted that the total power generation in the Middle East will grow at a rate of 3.5% per year, which is the fastest of all regions. Although the renewable energy development costs in the Middle East are only in the midstream level in various regions, the huge electricity demand will promote the development of renewable energy in the Middle East and increase the demand for renewable energy.

Considered social policy, due to the serious problem of simplification of the energy structure in the Middle East, countries plan to increase investment in renewable energy power generation projects in the future and encourage investment in renewable energy. Compared to other regions, the renewable energy policies and targets in the Middle East have yet to be improved. At the same time, the credibility of most governments in the Middle East tends to decline in the future. The political and social environments in some regions are facing greater pressure, which is not conducive to the promotion of renewable energy policies. Therefore, the development of renewable energy in the Middle East requires further planning.

4.3. Canada

We can see the development trend of various impact indicators in Canada from Fig. 16. In recent years, Canada's economy has gradually recovered and maintained its vulgar growth. As a result, the total power generation and residential electricity consumption also show the same curve trend. On the other hand, the Canadian government's credibility has been steadily improved, renewable energy development policies have been improved. Canada's renewable energy demand will remain stable.

On economic development, Canada's economic growth has weakened in recent years. Since reaching its lowest point in 2016, the Canadian economy has begun to recover gradually, and its growth rate has been relatively slow, experiencing economic fatigue. It is predicted that the GDP will be 1901 billion dollars by 2025, and the economic growth will be slower compared to other areas, which will affect the field of renewable energy. At the same time, the power generation of Canadian residents has fluctuated steadily between 16,000Gwh–17,000Gwh in recent years; it is predicted that there will be only a small increase. The Canadian economy will not have much incentive for the development of renewable energy.

In terms of technological development, the demand for electricity in Canada has remained stable, total power generation has grown slowly and renewable energy generation has grown at a relatively high rate. It is expected that more than 70% of power generation will be provided by renewable energy by 2025. At the same time, due to the early development of renewable energy in Canada, renewable energy power generation technology is already developed, and the costs are low.

Considered social policy, Canada has relatively complete development planning and development goals, and to promote renewable development, the Canadian government has developed several detailed

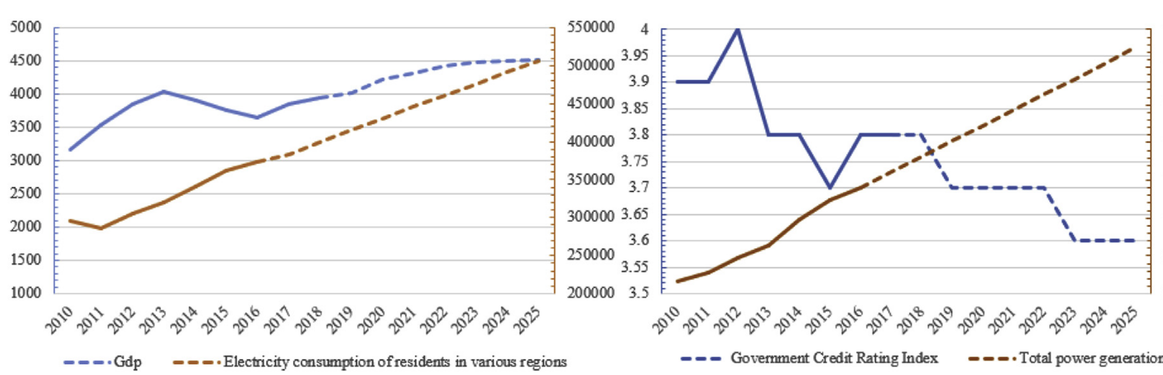

Fig. 15. Forecast values of influencing factors in the Middle East.

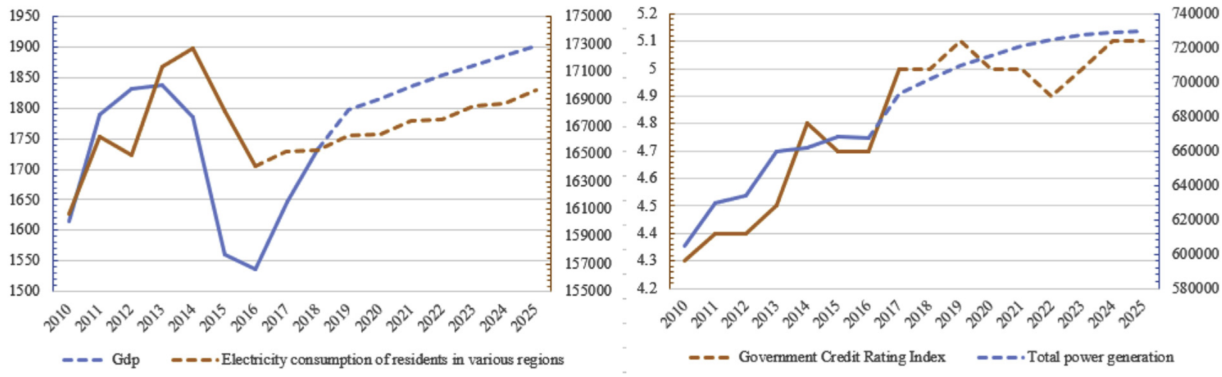

Fig. 16. Forecast values of influencing factors in Canada.

policy indicators, including tax policies, project support policies, incentive policies, etc. Canada was one of the first countries to promote renewable energy power generation. In 2015, the renewable energy supply has reached 2/3 of total electricity consumption, which is the highest in the world.

4.4. The United States

We can see that the United States will maintain steady economic growth in Fig. 17. At the same time, it is predicted that the demand for power generation in the United States will remain basically unchanged or slightly decline in the future. Under the circumstance of the increasing credibility of the US government and the improvement of the renewable energy power generation system, the US renewable energy is developing rapidly in the future.

On economic development, GDP keeps growing at a relatively high rate in US. It is estimated that by 2025, the GDP will reach 25,368 billion dollars, an increase of 24% compared to 20,513 billion dollars in 2018. Besides, US residents' electricity consumption will remain almost unchanged in the future, fluctuating at 1,400,000Gwh. In the future, the US economy will maintain a moderate growth rate as a whole, which will help ensure the stable growth of the US economy and drive the development of renewable energy.

In terms of technological development, the total demand or power generation in the US has remained unchanged at around 410,000Gwh in recent years, while renewable energy generation has continued to increase. In addition, the cost of renewable energy generation in the US has dropped significantly, which will facilitate the further development of renewable energy generation. It is expected that the share of renewable energy generation will increase from 15% to 18% between 2016 and 2025.

Considered social policy, coal-fired and gas-fired power generation accounts for the largest share of the US power supply structure at present. And the Clean Power Plan, promulgated in August 2015, proposes that the 2030 US power plant carbon emission target will be reduced by 32% from 2005, which means that renewable energy and other power generation projects will receive support, and a series of renewable energy development plans and preferential policies will be formulated. At the same time, the US government's credibility grows steadily and the political situation is relatively stable, facilitating the implementation of relevant renewable energy development policies.

4.5. Latin America

The economic downturn in Latin America has been severe in recent years in Fig. 18. It is predicted that although the economy will gradually recover, it is still one of the regions with the slowest economic development. At the same time, it is predicted that the credibility of Latin American governments will continue to decline. Although the total generation demand and resident power generation will increase steadily, the energy structure will not change much and renewable energy development will be slow.

On economic development, Latin American countries have low economic levels and the economy is developing slowly which will grow by 0.5% annually. Although the resident power generation will increase year by year,it is difficult for these countries to invest heavily in the field of renewable energy to promote the development of renewable energy.

In terms of technological development, Electricity consumption in various countries in Latin America is uneven, but the overall total power generation is growing rapidly, placing its current power market in a state of oversupply. In addition, Latin America is a region dominated by hydropower, with hydropower accounting for more than 50% of total electricity generation. However, in recent years, the proportion of renewable energy generation has been gradually decreasing. It is predicted that the power generation mode dominated by traditional energy sources in Latin American countries will not change in the short term, and the development of renewable energy power generation is slow.

Considered social policy, the overall social development in Latin

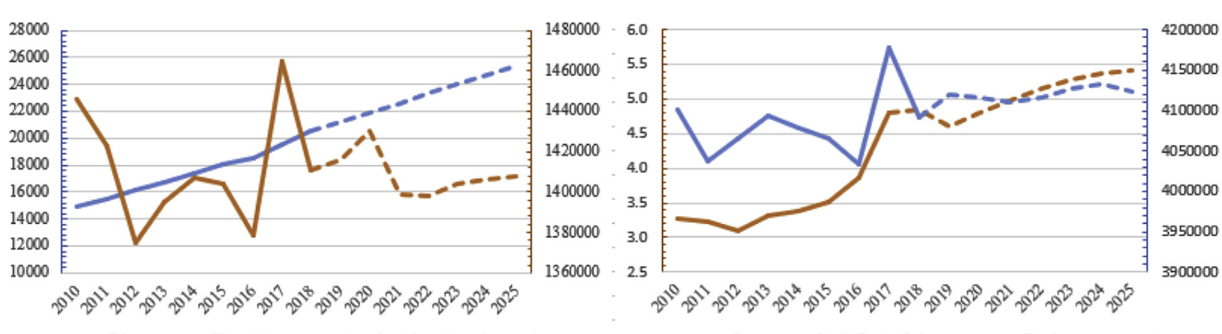

Fig. 17. Forecast values of influencing factors in the US.

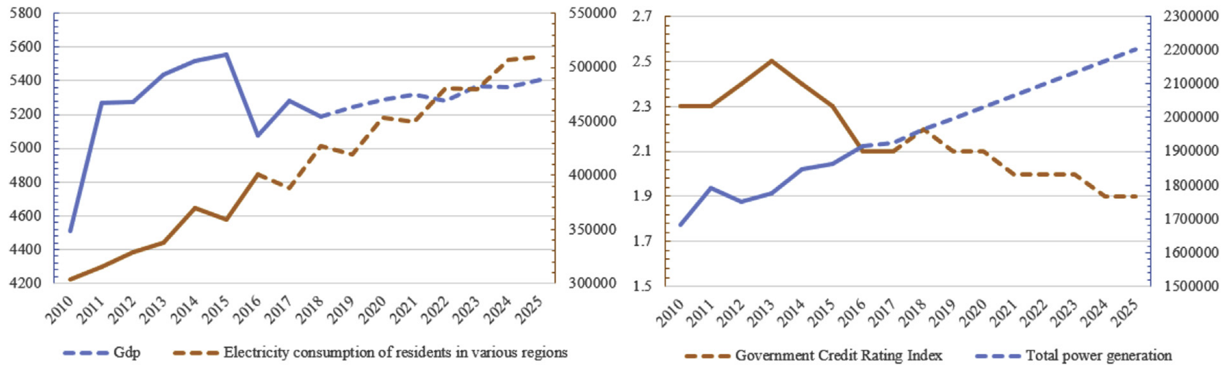

Fig. 18. Forecast values of influencing factors in Latin America.

America is relatively low. Although almost all countries have developed relevant renewable energy development policies and targets in Latin America, lack detailed implementation plans and preferential policies. Besides, the credibility of the local governments is the lowest of all regions. All of the above are the difficulties faced by Latin American energy structure changes.

4.6. Europe

It is predicted that the future GDP will grow slowly and total power generation in Europe will decrease linearly from Fig. 19. However, with the political stability and government credibility of the European region rising year by year, European governments are actively pursuing the status of renewable energy leaders and increasing the energy structure. European renewable energy is developing rapidly.

On economic development, in Europe, the overall economy is developed and developed countries are relatively more. However, in recent years, the economic growth rate is slightly weak and the overall GDP has fluctuated. By 2025, European GDP is expected to reach 23,084.3 billion dollars, compared to other regions, this is a slow. At the same time, the trend of household electricity consumption in European is declining. The demand for renewable energy generation is low, which is not conducive to the development of renewable energy.

In terms of technological development, in recent years, demand for electricity in Europe has continued to decline, and the total power generation has followed suit. It is estimated that by 2025, the total power generation will reach 3,578,751Gwh, a decrease of 1.4% compared to 3,630,637Gwh in 2016. However, the amount and proportion of renewable energy generation is rising at a relatively rapid rate. At the same time, European wind power, photovoltaic power generation and other new energy technologies are advanced, and development costs are low, which is one of the areas where renewable energy development is relatively fast.

Considered social policy, most countries in Europe are politically developed, the legal system is mature and government credibility is generally high. However, the risk of uncertainty and instability in European politics has increased in recent years, which has put great pressure on the stability and public security of European society and hindered the implementation of renewable energy development policies to a certain extent. However, all European countries have sound renewable energy development policies and target plans, and the European Union has stated that it will continue to seek global climate protection and new power energy leadership and plans to stop investing in coal-fired power plants after 2020. The policy drive guarantees its enthusiasm and initiative in the field of renewable energy and environmental protection.

4.7. Africa

In recent years, Africa's indicators, including economic development level, power generation, and government credibility, have maintained relatively rapid growth in Fig. 20. However, due to the weak foundations in all aspects of Africa, it is predicted that renewable energy will develop slowly in the future.

On economic development, Africa is the most concentrated region of developing countries and the region with the lowest level of economic development. From 2010 to 2017, the African economy demonstrated an unstable upward trend, and most countries have positive annual GDP growth. Therefore, the African economy still has a high probability of rapid development. By 2025, Africa's GDP will reach 2721 billion US dollars. At the same time, with the further development of the African economy, the level of electricity consumption of African residents has increased, and so has the demand for renewable energy.

In terms of technological development, to keep up with the rapid pace of economic development, investment in power generation is also increasing. Therefore, the total power generation demand has also maintained a relatively high speed, which is expected to increase 18% in 2025 compared to 2016, but in terms of renewable energy utilisation,

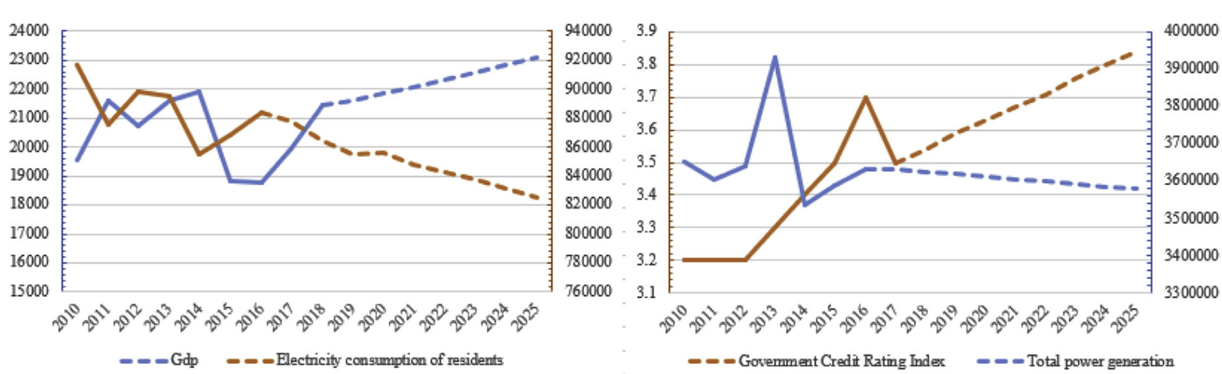

Fig. 19. Forecast values of influencing factors in Europe.

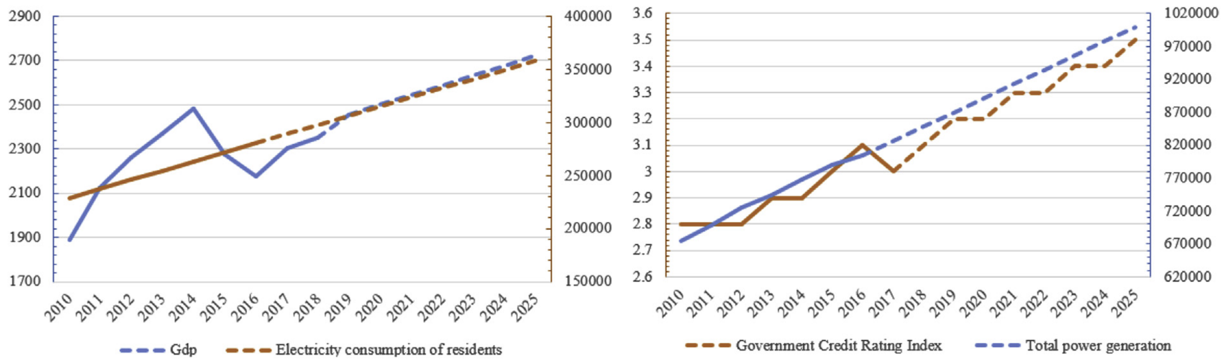

Fig. 20. Forecast values of influencing factors in Africa.

the growth rate of renewable energy generation is much lower than the growth rate of total power generation, and because of the low level of economic development in Africa, the cost of renewable energy generation is higher than in other regions and will affect the development of renewable energy power generation in Africa.

Considered social policy, compared to other areas, African area is the most imperfect area of renewable energy development systems, with only one-half of countries possessing clear renewable energy development plans and targets. Although government credit rating index is growing, most countries are still at a low level, and Africa has the most severe political instability in the world today, which is not conducive to the implementation of renewable energy development policies. At present, Africa is also increasing the development and utilisation of clean energy, but only a few relatively developed countries will significantly increase their investment in renewable energy power generation projects such as wind power, hydropower and solar energy.

5. Conclusion

In this paper, we selected four factors to measure the development of renewable energy, economic factors, political factors, social factors and technical factors, to predict the future development of renewable energy in various regions. Combining the data analysis, we find that the predicted value of the ARIMA model is relatively optimistic, usually the upper bound of the predicted value. The trend of the predicted value of the NN model is relatively flat, usually the lower bound of the predicted value. The predicted data of the SVM model fluctuates significantly. The integrated model combines the characteristics of the three models and obtains more accurate predictions. Then according to the prediction situation of Fig. 21 and Fig. 22, the analysis shows that:

(1) The Asia-Pacific region has the most rapid economic development and the highest demand for electricity in recent years. With the increasing maturity of renewable energy technologies and the consummate policy system for renewable energy, renewable energy development will gradually accelerate and the development of renewable energy in the Asia-Pacific region has great potential.
(2) The Middle Eastern economy has boosted its demand for renewable energy. However, the backwardness of renewable energy utilisation technologies and the imperfect development plans for renewable energy are not conducive to the sustainable development of renewable energy in the Middle East. Therefore, in the next few years, it is predicted that renewable energy in the Middle East will not develop much and renewable energy demand remains basically unchanged.
(3) Canada can develop renewable energy earlier with a higher degree of utilisation and improved relevant policy systems. Although economic development has been slow in recent years, it has ensured steady growth of renewable energy. In the future, it is predicted that the development of renewable energy in Canada will grow on a small scale based on the development of existing renewable energy and the development trend is relatively slow.
(4) The US economy is growing steadily, and renewable energy technologies are developing rapidly. The implementation of sound policies is conducive to rapid growth. Thus, the US energy structure will gradually change, and the use of renewable energy will increase substantially.
(5) Latin America's economic growth is slow, and the low demand for renewable energy, low levels of government credibility and imperfect renewable energy development plans will lead to policy implementation difficulties. Although the amount and proportion of renewable energy generation in Latin America is relatively high at

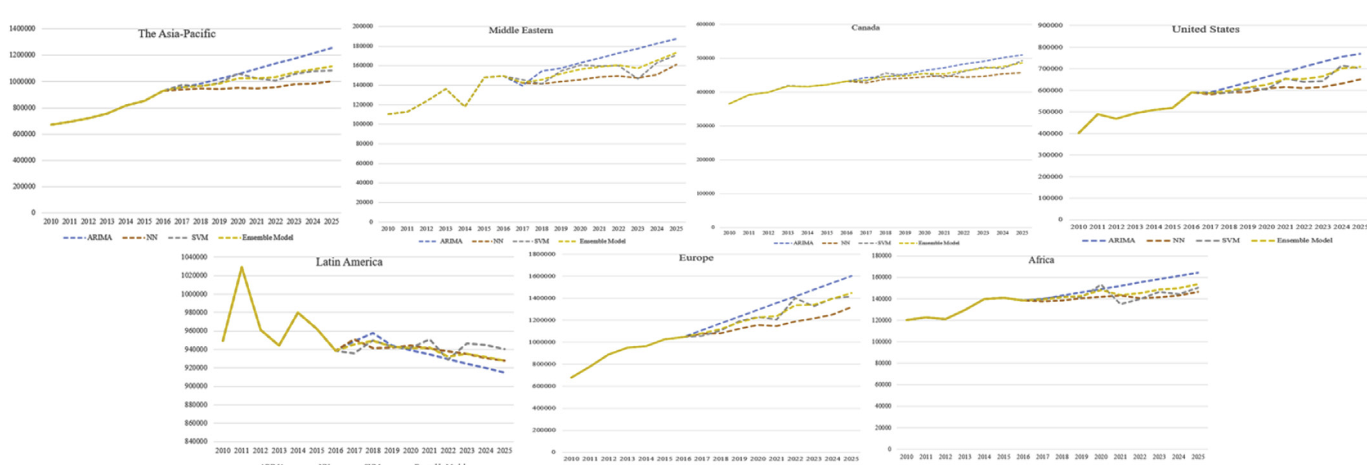

Fig. 21. Renewable energy trends predicted by each model.

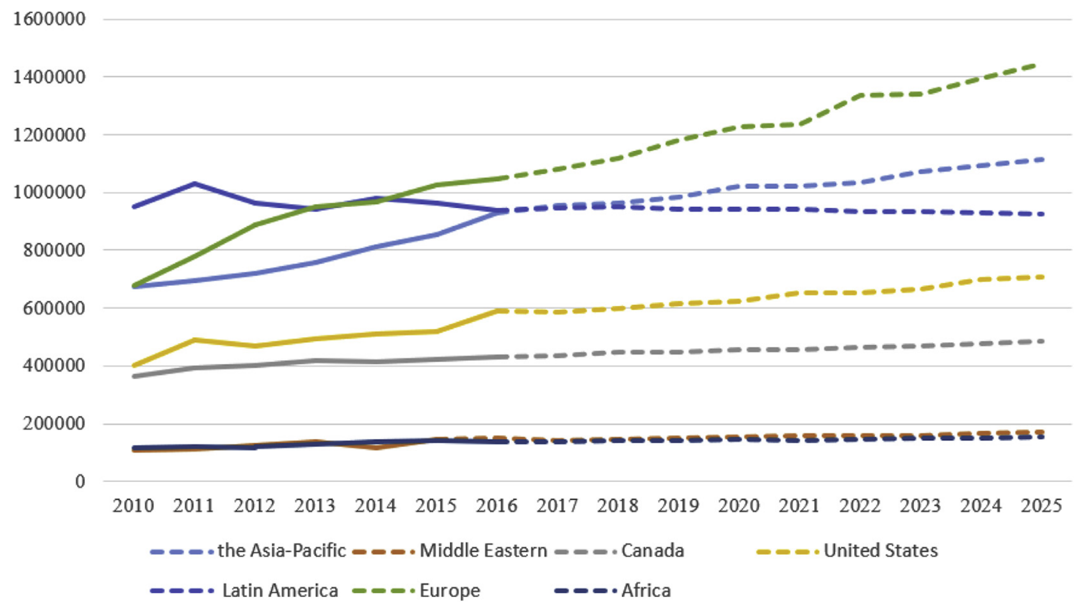

Fig. 22. Forecast of renewable energy development trends by region.

this stage, the development of renewable energy has begun to decline year by year.

(6) Europe has experienced slow economic development in recent years, but it actively advocates the use of renewable energy and environmental protection and strongly supports renewable energy development policies. Developed technology and political drive have promoted the rapid development of renewable energy in Europe. In the future, Europe will be one of the regions with the fastest growth in renewable energy use and the highest proportion of renewable energy.

(7) Africa's economy and demand have developed rapidly in recent years due to the weak economic foundation, underdeveloped technology and imperfect policy system, but only a few countries have the ability to support the rapid development of renewable energy. Based on the current stage, Africa's renewable energy development process tends to be at a standstill.

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