Comprehensive benefits assessment of different new energy generation technologies for global energy Internet development

Bo Yang [1], Liangzhong Yao [1], Shengchi Yan [1], Nana Li [2], Yuanzhi Cao [1], Hongfen Cui[1], Xianjun Ge[3, a, *]

[1] China Electric Power Research Institute, Beijing, China
[2] State Grid Energy Research Institute CO., LTD., Beijing 102209, China
[3] Tsinghua University, Beijing, China

[*, a] Corresponding author e-mail: 243635691@qq.com

Abstract. The development of economy and society consumes a large-scale traditional fossil energy, which results the surface subsidence, water pollution, climate change, acid rain, fog, haze environmental problems and so on. The emergence of the global energy internet has played a crucial role in solving these problems. To meet the sustainable development needs of global energy, clean energy is fundamental. We should promote the development of clean alternative and electric energy alternative, and expand the scale of clean energy development and utilization. The innovation and economic improvement of clean energy generation technology provide a good prospect for the development of clean energy. In this paper, we put forward a comprehensive benefits assessment of different new energy generation technologies for global energy Internet development. The research results show that wind power, photovoltaic power generation and biomass power generation have the very good comprehensive benefits for the global energy internet.

1. Introduction

The development of economy and society consumes a lot of energy. A large-scale traditional fossil energy were developed and used, which results the surface subsidence, water pollution, climate change, acid rain, fog, haze environmental problems and so on. Fossil energy resources are limited and non-renewable. Considering the impact on human survival and sustainable development, how to do energy transformation, to ensure energy supply clean, efficient and safe, become the focus of common concern around the world. The emergence of the global energy internet has played a crucial role in solving these problems[1,2].

The world is rich in clean energy resources such as water energy, wind energy and solar energy. According to the World Energy Council, the global developable clean energy resources are more than 150 quadrillion kwh [3,4].

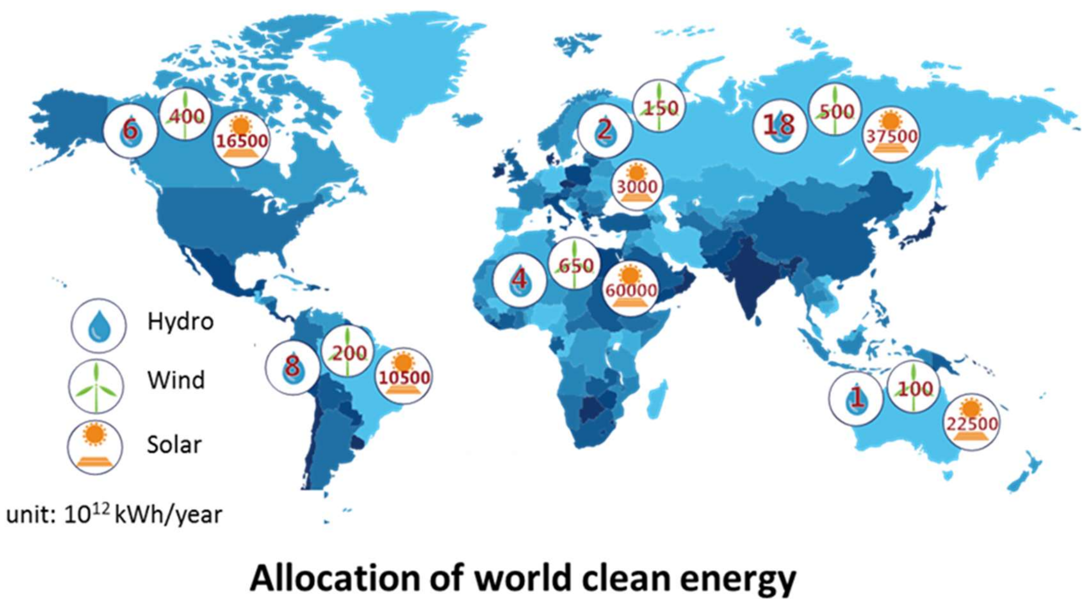

Figure 1. Global clean energy resources distribution

The distribution of clean energy resources is very uneven. Water energy resources are mainly distributed in major river basins in northeast Asia, South America, North America and central Africa. Wind energy resources are mainly distributed in the Arctic, Asia, Europe and North America and Africa, South America, North America and Oceania offshore area. Solar energy resources are mainly distributed in middle and low latitudes near the equator such as East Africa, North Africa, the Middle East, Australia and Chile. In addition, in the earth's other desert, gobi desert and other dry climate areas also have high-quality solar resources. Most of these clean energy rich areas are vast and sparsely populated, hundreds to thousands of kilometers away from the production and living centers of human beings, which requires to be widely distributed, developed and utilized [5,6].

Table 1. Distribution of water energy, wind energy, solar energy and other resources in the world

Region	water energy,		wind energy		solar energy	
	Theoretical reserves (trillions of kwh/year)	proportion (%)	Theoretical reserves (trillions of kwh/year)	proportion (%)	Theoretical reserves (trillions of kwh/year)	proportion (%)
North America	6	15	400	20	16500	11
South America	8	21	200	10	10500	7
Europe	2	5	150	8	3000	2
Asia	18	46	500	25	37500	25
Africa	4	10	650	32	60000	40
Oceania	1	3	100	5	22500	15
Total	39	100	2000	100	150000	100

Source: World Energy Council; The intergovernmental panel on Climate Change (IPCC), the IPCC Special Report: Renewable Energy Resources and Climate Change Mitigation (SRREN), May 2011.

Only a small amount of resources can be developed to meet the needs of human society for a long time. Therefore, in the aspect of energy development and utilization, the use of clean energy to replace fossil energy will become the way and trend of global energy development in the future. Electricity is convenient, clean and efficient. All clean and fossil energy can be converted into electricity. At the same time, electric energy can be converted into heat and mechanical energy efficiently and quickly, and is controlled precisely. As a result, electric energy has become a hub for the transformation of different energy sources. In addition, power can be transmitted over long distances, produced on a large scale, and transmitted instantly to users. In this way, it is inevitable to adjust the energy consumption pattern and implement electric energy substitution [7].

To meet the sustainable development needs of global energy, clean energy is fundamental. We should promote the development of clean alternative and electric energy alternative, and expand the scale of clean energy development and utilization. In terms of terminal energy demand, the proportion of electricity will increase further, which will promote the global connectivity within the scope of the power grid and realize the interconnection of globalization clean energy configuration. The power grid configuration energy resources benefit is more obvious [8].

Global energy is a major innovation in the field of energy in the 21st century, it is a collection of energy transmission, the allocation of resources, market, information interaction, intelligent service. Global energy is a sharing, connectivity, open compatible "giant system", which can create huge economic, social and environmental benefit value of peaceful development platform. It will profoundly change the world energy development, economic growth, social life and the ecological environment.

2. The comprehensive benefit evaluation index system for new energy generation technology promoting global energy internet development

2.1. The basis of the global energy Internet

Innovation breakthroughs in uhv, smart grid and clean energy and domestic and foreign practices have laid the foundation for building a global energy Internet.

(1) UHV. Uhv refers to the transmission technology of ac voltage grade 1000kv and above, dc voltage grade + / - 800kv and above. All the major clean energy bases and load centers around the world are within the uhv configuration range. The distance of uhv dc transmission can reach 5000 km and the capacity can reach 15 million kW. Solar power in the Middle East, Africa and other desert regions can be delivered to load centers in various regions, depending on ultra-high voltage transmission, wind power in the Arctic, and photovoltaic power in the Middle East and Africa. The ultra-high voltage backbone network connecting countries and continents will realize the clean energy development.

(2) Smart grid.

With the continuous development of grid technology and a wide range of fusion and intelligent technology, grid function by a single power transmission carrier becomes an intelligent infrastructure which have powerful energy resources optimization allocation function.

(3) Clean energy technology.

The innovation and economic improvement of clean energy generation technology provide a good prospect for the development of clean energy. In the perspective of technical innovation, the maximum capacity of wind power has reached 8 MW, low speed fan can be adapted to the lowest annual average wind speed 5.2 m/s, the latest wind power prediction system is suitable for a variety of terrain and climate. The efficiency of solar power generation is greatly improved, the efficiency of crystalline silicon cell is increased by 0.3 to 0.5 percentage points every year, and the efficiency of thin film cell is increased by 1.0 to 1.5 percentage points every year. In terms of economy, the development cost of global clean energy power generation projects has dropped significantly in recent years, and the market competitiveness has been continuously improved. The global land wind power and photovoltaic power leveling costs have been reduced to 0.06~0.09 usd/(k W·h) and 0.08~0.20 usd/(k W·h) respectively. In the next five to 10 years, the cost of generating electricity from clean energy will be comparable to or lower than that of fossil fuels.

2.2. The comprehensive benefit evaluation index system for new energy generation technology promoting global energy internet development

Build global energy Internet will promote the development of the world's energy into electricity as the center, to a new stage of clean energy as the leading factor, to achieve the global optimal allocation of resources, energy security will be safer, more efficient and more friendly, produce a great environmental, economic and social benefits.

The innovation and economic improvement of clean energy generation technology provide a good prospect for the development of clean energy. In order to evaluate the comprehensive benefit for new energy generation technology promoting global energy internet development, an evaluation index is established, which contains of technology, economy, society, environmental perspectives.

Table 2. The comprehensive benefit evaluation index system for new energy generation technology promoting global energy internet development

The principal aspect	Specific indicators
Technology	Technical maturity
	Supporting the construction of the global energy Internet
	Power generation efficiency
Economy	Adaptability to the development of power grid
	The cost trend
	Market maturity
Society	Related industries development promoting
	Policy support
Environment	Resource reserve and distribution
	The ecological environment influence of new energy generation development

3. Quantitative analysis methods for comprehensive benefits assessment of different new energy generation technologies for global energy Internet development

Matter-element extension model takes matter-element theory and extension set theory as a framework. The level of one thing can be determined through established classical field, controlled field, evaluation level, and correlation function of each level. The basic steps of the improved matter-element evaluation method are as follows: firstly, the object is divided into j levels and the range of each level is determined by database or experts; secondly, determine the index weight by subjective and objective method which based on AHP-Entropy method; Finally, substitute index value into level collection, calculate the improved correlation degree and determine the level of matter-element. The level which the correlation degree is max is the level of matter-element.

Matter element is the logic unit of matter-element extension model; it uses an ordered triple $R = (P,,)$ to describe things. P, C, V represent the name, the characters, and the value of one thing, respectively. The basic steps of improved matter-element extension model are as follows.

(1) Determine the classical domain, controlled field and matter-element of the object to be evaluated.

Suppose the classical domain matter-element as follows:

$$\boldsymbol{R}_j = (\boldsymbol{P}_j, \mathrm{c}_i, \mathrm{v}_{ij}) = \begin{bmatrix} P_j & c_1 & v_{1j} \\ & c_2 & v_{2j} \\ & \vdots & \vdots \\ & c_n & v_{nj} \end{bmatrix} = \begin{bmatrix} P_j & c_1 & \langle a_{1j}, b_{1j} \rangle \\ & c_2 & \langle a_{2j}, b_{2j} \rangle \\ & \vdots & \vdots \\ & c_n & \langle a_{nj}, b_{nj} \rangle \end{bmatrix} \tag{1}$$

Where P_j represents the j th grade, c_1, $c_2,\cdots,c_n$ are n different characteristics of P_j and v_{1j}, $v_{2j},\cdots,v_{nj}$ are the value ranges of P_j about c_1, $c_2,\cdots,c_n$ respectively, namely the classical field.

Suppose the controlled field matter-element as:

$$\boldsymbol{R}_p=(\boldsymbol{P},\boldsymbol{C}_i,\boldsymbol{V}_{pi})=\begin{bmatrix} P & c_1 & v_{p1} \\ & c_2 & v_{p2} \\ & \cdots & \cdots \\ & c_n & v_{pn} \end{bmatrix}=\begin{bmatrix} P & c_1 & \langle a_{p1},b_{p1}\rangle \\ & c_2 & \langle a_{p2},b_{p2}\rangle \\ & \cdots & \cdots \\ & c_n & \langle a_{pn},b_{pn}\rangle \end{bmatrix} \tag{2}$$

Where p represents all grades of the object to be evaluated, and $v_{p1},v_{p2},\cdots,v_{pn}$ are the value ranges of p about c_1, $c_2,\cdots,c_n$, namely the controlled field of p.

Suppose the matter-element to be evaluated as:

$$\boldsymbol{R}_0=(\boldsymbol{P}_0,\boldsymbol{C}_i,\boldsymbol{V}_i)=\begin{bmatrix} P_0 & c_1 & v_1 \\ & c_2 & v_2 \\ & \cdots & \cdots \\ & c_n & v_n \end{bmatrix} \tag{3}$$

Where $\boldsymbol{P}_0$ represents all grades of the object to be evaluated, and $v_1,v_2,\cdots,v_n$ are actual data of P about $c_1,c_2,\cdots,c_n$.

(2) Normalization

When an actual value of index exceeds the controlled field, the correlation function cannot be calculated, namely the denominator is zero. In this case, matter-element and extension model cannot be used to evaluate the performance of energy saving and emission reduction. Therefore the classical domain and matter-element evaluation should be normalized.

Normalize the classical domain $\boldsymbol{R}_j'$ as follows:

$$\boldsymbol{R}_j'=(\boldsymbol{P}_j,\boldsymbol{C}_i,\boldsymbol{V}_{ij}')=\begin{bmatrix} P_j & c_1 & \left\langle \frac{a_{1j}}{b_{p1}},\frac{b_{1j}}{b_{p1}}\right\rangle \\ & c_2 & \left\langle \frac{a_{2j}}{b_{p2}},\frac{b_{2j}}{b_{p2}}\right\rangle \\ & \cdots & \cdots \\ & c_n & \left\langle \frac{a_{nj}}{b_{pn}},\frac{b_{nj}}{b_{pn}}\right\rangle \end{bmatrix} \tag{4}$$

Normalize the matter-element evaluation $\boldsymbol{R_0'}$ as follows:

$$\boldsymbol{R}_0'=\begin{bmatrix} P_0 & c_1 & v_1/b_{p1} \\ & c_2 & v_2/b_{p2} \\ & \cdots & \cdots \\ & c_n & v_n/b_{pn} \end{bmatrix} \tag{5}$$

(3) Weight determination

The index weight is determined by subjective and objective method which based on AHP method.

(4) Establish and calculate the correlation function

The correlation of each index about each level is represented by D_{ij} which represents the distance of $\boldsymbol{R_0'}$ to the normalized classical field.

$$D_j(v_i') = \left| v_i' - \frac{a_{ij}' + b_{ij}'}{2} \right| - \frac{1}{2}(b_{ij}' - a_{ij}') \tag{6}$$

The comprehensive correlation function of traditional element extension model is $N' = 1 - \sum_{i=1}^{n} Dw_i$. And suppose $N'_{j'}(p_0) = \max\{N_j(p_0)\}$, the matter-element to be evaluated p0 belongs to the j'th level.

As we can see the level of one thing is obtained by calculating correlation function in traditional model. From the perspective of algorithm, correlation degree can be regarded as an extension of membership degree in fuzzy mathematics, so the correlation degree principle is equivalent to the maximum membership principle. In some case, however, the maximum membership principle cannot reflect the ambiguity of object's boundary. It will loss information and lead to the deviation of results. So in this paper both the closeness degree criteria and the maximum degree of membership criteria are considered to determine:

$$N' = 1 - \frac{1}{n}\sum_{i=1}^{n} Dw_i \tag{7}$$

And then, the improved correlation function is as follows:

$$N = \frac{1}{2} * [(1 - \frac{1}{n}\sum_{i=1}^{n} Dw_i) + (1 - \sum_{i=1}^{n} Dw_i)] \tag{8}$$

Where n represents the value of closeness function; D represents the distance; wi is the weight.

(5) Rating

Suppose $N_{j'}(p_0) = \max\{N_j(p_0)\}$, the matter-element to be evaluated p0 belongs to the j'th level.

Suppose:

$$\bar{N}_j(p_0) = \frac{N_j(p_0) - \min_j N_j(p_0)}{\max_j N_j(p_0) - \min_j N_j(p_0)} \tag{9}$$

And

$$j^* = \frac{\sum_{j=1}^{m} j\bar{N}_j(p_0)}{\sum_{j=1}^{m} \bar{N}_j(p_0)} \tag{10}$$

Where j* represents the level variable eigenvalue of p0. The attributive degree of the matter-element to be evaluated tends to adjacent levels from j* can be judged from it.

4. Conclusion

To meet the sustainable development needs of global energy, clean energy is fundamental. We should promote the development of clean alternative and electric energy alternative, and expand the scale of clean energy development and utilization. In recent years, the innovation and economic improvement of clean energy generation technology provide a good prospect for the development of clean energy. The cost of global clean energy power generation projects has dropped significantly in recent years, and the market competitiveness has been continuously improved.

According to the result of evaluation, wind power, photovoltaic power generation and biomass power generation have the very good comprehensive benefits for the global energy internet. Hydrogen technology, carbon capture and sequestration technologies have good application prospect, but these techniques are heavily influenced by internet resource conditions, policy support, cost trend change under certain constraints.

Acknowledgments

This work was financially supported by SGCC’s Science and Technology Project: Research on Key Technology of Large-scale Energy Storage Application Adapting to Global Energy Internet.

References

[1] Jing P, Guizhi X U, Zhao B, et al. Large-scale Energy Storage Technology for Global Energy Internet[J]. Smart Grid, 2015.
[2] Lin W, Yong Y U, Liang Y, et al. Research on Information and Communication Technology Supporting Global Energy Internet[J]. Smart Grid, 2015.
[3] LIU Zhenya. Global Energy Internet[M]. Beijing: China Electric Power Press, 2015: 2-5.
[4] Xue B, Tang Z. Progress and Prospect of Key Technologies for the Global Energy Internet[J]. Electrical Automation, 2017.
[5] Wu J. Information and Communication Technology Supporting Global Energy Internet[J]. China Computer & Communication, 2017.
[6] Hu L, Liu K Y, Sheng W, et al. Research on maximum allowable capacity of distributed generation in distributed network under global energy internet considering static voltage stability[J]. Journal of Engineering, 2017, 1(1).
[7] Huang C, Chen S, Yan Z. Electricity trading in global energy internet[C]// IEEE Conference on Energy Internet and Energy System Integration. IEEE, 2017:1-5.
[8] Sun W, Tian K, Tan Y, et al. Key Technologies and Research Prospects of Global Energy Internet[J]. Process Automation Instrumentation, 2017.