Integrated Consumption and Benefit Evaluation Model of Clean Energy Based on CGE Model

Haotian Wu[*]

Shanghai Investigation, Design & Research Institute Co., Ltd, Shanghai 200335, China

50201603@ncepu.edu.cn

[*]*corresponding author*

Abstract: At present, the development of advanced technologies such as ultra-high voltage has achieved far-reaching, large-scale and accumulated power transmission, and the global energy Internet is gradually taking shape. The original high-energy consumption and low-efficiency power generation methods can no longer meet the requirements of the contemporary economy and society. Clean energy has become the main direction of electric power development: wind power is the main clean energy source, and its production technology is relatively mature, but there are difficulties in consumption. The main purpose of this paper is to study the integrated consumption and benefit evaluation model of clean energy based on the CGE model. Combining the fuzzy grey relational cluster analysis theory, this paper proposes a new method for evaluating the characteristics of new energy consumption strategy implementation indicators based on demand response, and evaluates the new energy consumption strategy. Experiments have shown that in terms of the impact on traditional electricity prices, due to the increase in solar electricity price subsidies, its prices also show a downward trend. Similar to the change trend of fossil energy.

1. Introduction

In the era of rapid economic development, there are more and more requirements for energy and more and more constraints on energy. Optimizing the development structure of energy has become an urgent need for energy development, and the importance of developing renewable energy has become increasingly prominent. The state also proposes to speed up the reform of energy production and consumption, and accelerate the transformation of the direction of energy development. It is clearly stated that increasing the supply of clean and green energy and increasing the proportion of clean energy production and consumption are the basis of the energy revolution

[1-2].

In a related study, Cauwer et al. proposed an ensemble model for energy consumption and range estimation [3], which enables energy-efficient routing. The ensemble model predicts the energy consumption of all road segments in the road network and applies the shortest path algorithm to calculate energy-efficient routes. Danyali et al. introduced a new dual-input non-isolated zero-voltage switching (ZVS) dc-dc boost converter [4]. The proposed converter has a simple and compact structure, minimal number of power switches and magnetic components, and high efficiency.

Based on the CGE model, this paper studies the integrated consumption and benefit evaluation model of clean energy. Aiming at the benefits brought about by the implementation of the new energy consumption strategy, a comprehensive evaluation index system is constructed, combined weighting based on the AHP and entropy weight method, and combined with the fuzzy grey theory, a new energy consumption based on demand response is proposed. Strategy evaluation method, and applied to the comprehensive evaluation of new energy consumption. The application results show that the comprehensive evaluation method used can objectively and accurately evaluate the benefits brought by industrial users' participation in new energy consumption, and can provide strong support for power grid companies and relevant investors in new energy consumption. good application prospects.

2. Design and Research

2.1. Theoretical Basis of the CGE Model

General equilibrium theory is one of the well-known theories in economics, and it is a commonly used auxiliary tool in the process of economic and policy research and analysis. The CGE model is based on the general equilibrium model, and most of the data come from the input-output table, which also continues many practices of the input-output model [5-6].

(1) Basic principles of the model

In practical application, the idea of general equilibrium theory is the same as the idea of solving equations. When some variables or coefficients change, the equation solutions after transformation of each department (that is, the equilibrium consumption and equilibrium consumption of the CGE model) are obtained through the equations price). The equation of the model consists of two parts, exogenous variables and endogenous variables. The main function of the exogenous variables is to analyze the numerical changes of the relevant indicators after the model is impacted; the endogenous variables are the research objects of the CGE model and represent the system. Internal commodities, labor, capital, taxation, consumption, income and other elements are affected when exogenous variables change.

(2) Content of the model

As mentioned earlier, the CGE model assumes that the market involved in the model has a perfectly competitive structure. That is to say, there will be no excess supply and demand for products, manufacturers and residents are both price takers, and there is no arbitrage phenomenon for producers. The typical standard structure of the CGE model mainly has six modules [7-8]. A typical CGE model is mainly composed of three parts:

1) Database. The basis of the CGE model for policy research is the database, that is, the SAM table mentioned above. Although the data sources are not limited, most of them currently come from input-output tables and related statistical data.

2) The CGE model itself. Because the general structure of the CGE model is general, when

researchers use this model for analysis, the specific structure of the model is determined according to actual needs, whether the data is desirable, whether the research object has research significance, and other factors.

3) Departmental knot principle. Since each research object and research purpose are different, for different research objects, the key modules of the research in the structure of the CGE model are also different. Some departments can be subdivided according to actual needs, and the Relative data structures are split and merged.

The data base is the SAM table established according to the actual research object. In short, the operating steps of the model are to break the equilibrium state of the SAM table by changing some coefficients related to the researched policies, and then the model goes through operations to regain equilibrium [9-10].

(3) Introduction to the concept of SAM

The Social Accounting Matrix (SAM) is a matrix double-entry accounting table that can be used to describe the social and economic operation. The structure and data of the SAM table are the basis of the CGE model. Combined with social and economic data and other relevant information and data, the structure is expanded and some account units are added, such as production factors, resident users, enterprises, etc., which can intuitively express the quantitative changes of each account within a certain period of time [11-12] .

SAM principle: Simply put, SAM is the balance of the total value of the rows and columns, and the corresponding number of rows and columns is equal. Moreover, each data in the table has a double meaning, which is determined according to the row and column where it is located. Compared with ordinary bookkeeping accounts, the SAM table simplifies the relatively complex bookkeeping procedures, and can make some research key objects more prominent according to the requirements.

SAM structure: A standard macro SAM in which the data is presented in the form of a total amount without deep refinement.

Balance of the SAM table: Due to the diverse data sources and the statistical errors in the data of different statistical units, the initial SAM table needs to be balanced. There are many methods of balance. The most commonly used methods are the cross entropy method, the least square method, and manual Balance method, this paper chooses the cross-entropy method according to the actual situation.

2.2. Principles of Index System Construction

Demand response benefit analysis indicators cover three aspects: power generation companies, power grid companies and end users [13-14]. For power generation companies, demand response can facilitate the integration of clean energy generation into the grid by flattening the electricity load curve and reduce the need for system reserve capacity. For grid companies, demand response has transformed grid companies' power purchase mix by facilitating the integration of clean energy generation into the grid. For end users, demand response provides a way for users to participate in power generation side dispatch to obtain economic benefits. After determining the demand response benefit evaluation index, it is necessary to quantitatively analyze different demand response modes of action, and to improve the problems existing in the demand response mode of action. Specifically, the compilation of the demand response benefit evaluation index system needs to follow the following principles: scientific, reasonable, systematic, dynamic and static, and operable.

2.3. The Equation System of the CGE Model

After the parameters of each module are explained, the next step is the equation system of the renewable energy CGE model study. Combined with the structure of CGE mentioned above and the research purpose of this paper, the structure of the model is divided into seven modules, including energy, production, trade, price, income and consumption, macro variables and macro closure [15-16].

(1) Energy module

The energy module of the renewable energy CGE model is divided into two levels of nested production functions. The specific structure is shown in the figure below. The energy module describes the input-output relationship of energy production.
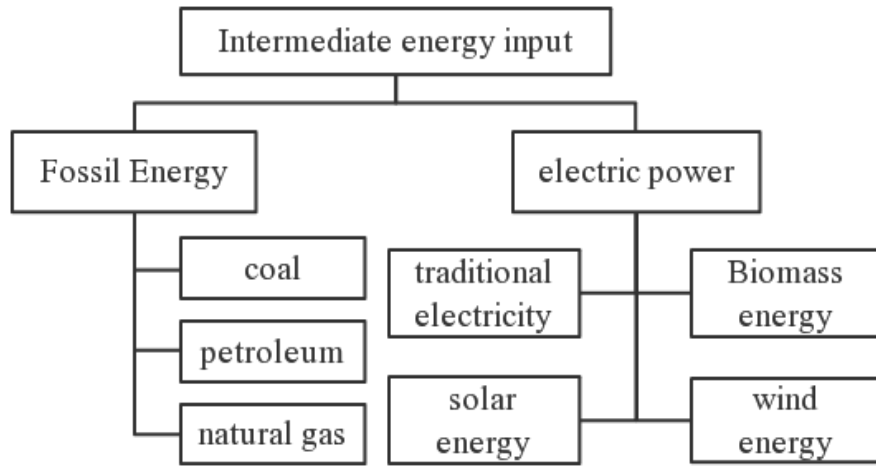

Figure 1. Nested structure of energy modules

This module contains two layers of two-layer nested CES production functions. The first layer of structure includes electricity and fossil energy, and describes the substitution relationship between electricity and fossil energy through CES.

The second-layer structure of the energy module is to describe the demand for electricity and fossil energy respectively, and the specific classification is shown in Figure 3 (for the convenience of formulating, the traditional energy is defined as thermal power).

Include an equation for CO2 emissions in this module, which will be used later in the study of the environmental effects of renewable energy policies. First, it is necessary to clarify the source of carbon emissions. This time, it is set to two parts. One part comes from intermediate inputs (only consumption in the province); the other part comes from residents and government consumer goods (final consumer goods) [17-18]. The specific calculation formula is:

$$TCO_2 = \sum_i \sum_j QINT_{i,j} \cdot PQA_j \cdot CO2_j + \sum_i (QH_i + LOGD_i) \cdot PQ_i \cdot CO2_i \qquad (1)$$

TCO2 is the total carbon emission, QINTi,j is the value of each intermediate input, PQAj is the corresponding price, CO2j is the carbon emission corresponding to each part of the intermediate input, and the sum is the carbon emission of the intermediate input; QHi and LOGDi are the residents, respectively And government consumption, PQi is also the corresponding price, CO2i is the carbon emission of each part, and the sum is the carbon emission of intermediate consumer goods.

3. Experimental Research

3.1. New Energy Consumption Problem

Development problems faced by new energy consumption: the phenomenon of new energy curtailment has eased year by year, but the problem of limited consumption is still serious, and it is still at a relatively high level in the national grid system. The main problems are as follows: First, there is a serious shortage of new energy consumption space. The scale of the power supply and the scale of the load do not match, the total installed capacity of the power supply is about three times the maximum load, and the new energy consumption market is limited. Second, the scope of new energy consumption is not large. Self-provided power generation enterprises and self-operated power grids have closed business models. Except for some self-provided power generation companies that participate in new energy consumption in the form of new energy substitution transactions, other self-operated power grids basically do not participate in new energy consumption. Third, the problem of grid peak regulation has existed for a long time.

3.2. Evaluation Indicators

(1) Construction of evaluation index system
Demand response can participate in different integrated utilization methods of distributed energy (microgrids, virtual power plants, and combined cooling, heating and power systems, etc.). Evaluate. From the perspectives of economy, environment and social benefit, this paper adheres to the principles of combining scientificity and systematicness, representativeness and comparability, independence and practicability, quantitative and qualitative, and establishes a comprehensive evaluation index system of clean energy efficiency.
(2) Preprocessing of evaluation indicators
After the initial establishment of the demand response implementation benefit evaluation index system, the evaluation index system needs to be correlated and standardized. The correlation test is mainly used to analyze the overlap and inspection between indicators to establish an indicator system with independent characteristics. Standardized processing is used for consistent and dimensionless processing, and preparatory work is done for the evaluation of demand response benefits.

3.3. Improved Grey Relational Comprehensive Evaluation Model

According to the basic situation of the analytic hierarchy process and the entropy weight method and the theoretical basis of the fuzzy grey relational cluster analysis comprehensive evaluation method, an improved grey relational comprehensive evaluation model based on the combination weighting method is constructed to evaluate the research projects.
(1) Weight calculation
Through the combination of AHP and entropy weight method, the more complex objects in new energy consumption are quantified and correlated with fuzzy grey theory, and a new evaluation method suitable for new energy consumption strategy is proposed.

$$U_i = Y_i \left/ \sum_{j=1}^{n} Y_j \right. \tag{2}$$

After the consistency check, the result meets the requirements.
The weight results obtained by the entropy weight method are as follows

$$V_j = \frac{1 - S_j}{\sum_{j=1}^{n}(1 - S_j)} \tag{3}$$

Combining the above two weighting results by exponentiation, the result of the final combined weighting can be obtained, that is, the final weighting result, specifically:

$$w_i = U_i V_i \Big/ \sum_{j=1}^{n} U_j V_j \tag{4}$$

(2) Calculation of correlation degree
Using the obtained combined weighting result wij of the jth evaluation index of the ith scheme and the optimal weight value wj* of the index to calculate the correlation coefficient εij, we can get:

$$\varepsilon^i{}_j = \frac{\min\limits_{i} \min\limits_{j}\left|w_j^* - w_{ij}\right| + \rho \max\limits_{i} \max\limits_{j}\left|w_j^* - w_{ij}\right|}{\left|w_j^* - w_{ij}\right| + \rho \max\limits_{i} \max\limits_{j}\left|w_j^* - w_{ij}\right|} \tag{5}$$

where ρ is taken as 0.5.
Using the calculated correlation coefficient, the parameter correlation degree Pi can be further calculated as:

$$P_i = \sum_{j=1}^{m} \omega_j \varepsilon^i{}_j \tag{6}$$

Then, the calculated values of Pi are sorted by size, and then the pros and cons of the compared schemes can be obtained.

4. Experimental Analysis

4.1. Determination of Parameters of CGE Model

In the previous introduction to the system of equations and variables, it can be seen that there are many parameters involved in the construction of the model, which are mainly divided into three types: the first is the elasticity coefficient (mainly substitution elasticity). σen as in the energy

module, j is the demand substitution elasticity parameter of the energy composite element. The second category is share parameters, such as δfen,j and δele,j in the energy module, which respectively express the share coefficients of fossil energy elements and power elements; the third category is tax parameters, such as income tax, tariff, indirect tax, etc.

The details are shown in Table 1.

Table 1. Relevant elastic coefficient table

	Armington	CET	Fossil Energy	Electricity	Energy
Agriculture	3	5	1.25	5	0.6
Industry	3	5	1.25	5	0.6
Construction industry	3	4	1.25	5	0.2
Service industry	3	4	1.25	5	0.25
Coal	3	4	1.25	5	0.5
Fuel	3	4	1.25	5	0.5
Natural gas	3	4	1.25	5	0.5
Electricity	1.1	0.5	1.25	5	0.1
Wind energy	1.1	0.5	1.25	5	0.1
Biomass	1.1	0.5	1.25	5	0.1
Solar energy	1.1	0.5	1.25	5	0.1

4.2. Energy Effect Analysis of Solar Electricity Price Subsidy

The model is run according to the programming, and according to the different subsidy levels set, the price changes of each energy source are compared with the simulation results of the base year. The data is divided into two parts: the impact of solar electricity price subsidies on other energy prices and the impact on other energy consumption. The specific impact trends are as follows.

(1) Impact on other energy prices

Table 2. The impact of solar electricity tariff subsidies on energy prices Unit: %

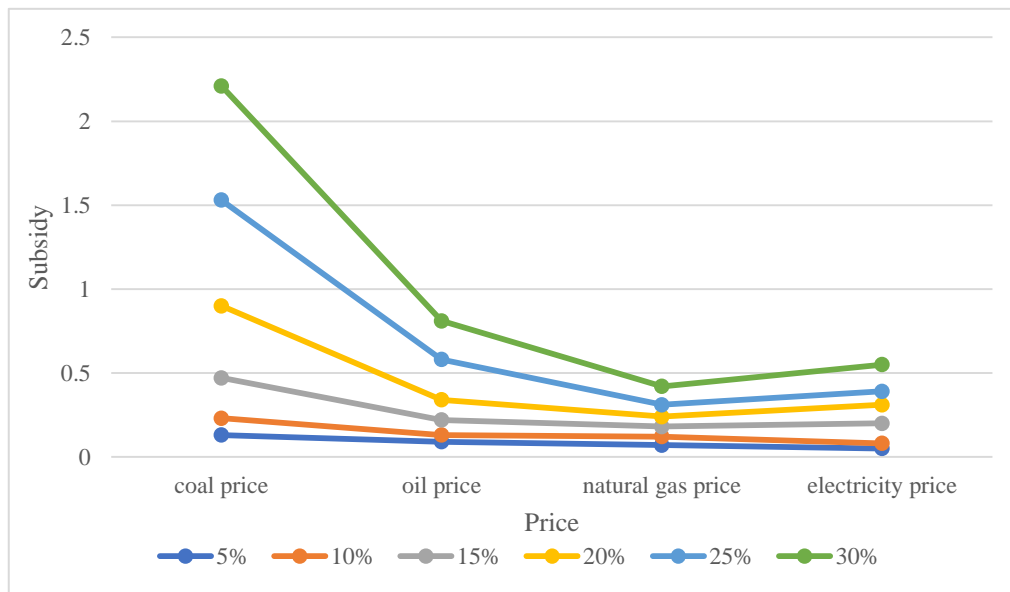| Subsidy		5%	10%	15%	20%	25%	30%
Changes in each indicator	Coal price	0.13	0.23	0.47	0.90	1.53	2.21
	Oil price	0.09	0.13	0.22	0.34	0.58	0.81
	Natural gas price	0.07	0.12	0.18	0.24	0.31	0.42
	Electricity price	0.05	0.08	0.20	0.31	0.39	0.55

Figure 2. Analysis of the impact of solar electricity tariff subsidies on energy prices

As can be seen from Figure 2, with the increase of solar electricity price subsidy, the price of traditional energy shows an increasing trend, which can be divided into two situations. When the solar electricity price subsidy is below 20%, the increase of traditional energy price is not very obvious. , the growth rate is relatively low, in the process of changing solar electricity price subsidies from 20% to 30%, a total of 10%, the price of oil increased by 0.47%, and the price of natural gas increased by 0.18%. In particular, coal energy, with the increase of subsidies, was the most affected, and its price increased most obviously, with a total change of 2.08%. It can also be seen that the development of solar energy resources can increase the price of traditional energy, thereby restraining the corresponding consumption, reducing the use of traditional energy, and increasing the proportion of clean energy consumption, so as to achieve the purpose of energy reform.

(2) Impact on consumption of other energy sources

According to the different subsidy levels set, the simulation results of the changes in the consumption of each energy source compared with the base year are shown in Table 3.

Table 3. The impact of solar electricity tariff subsidies on energy consumption Unit: %

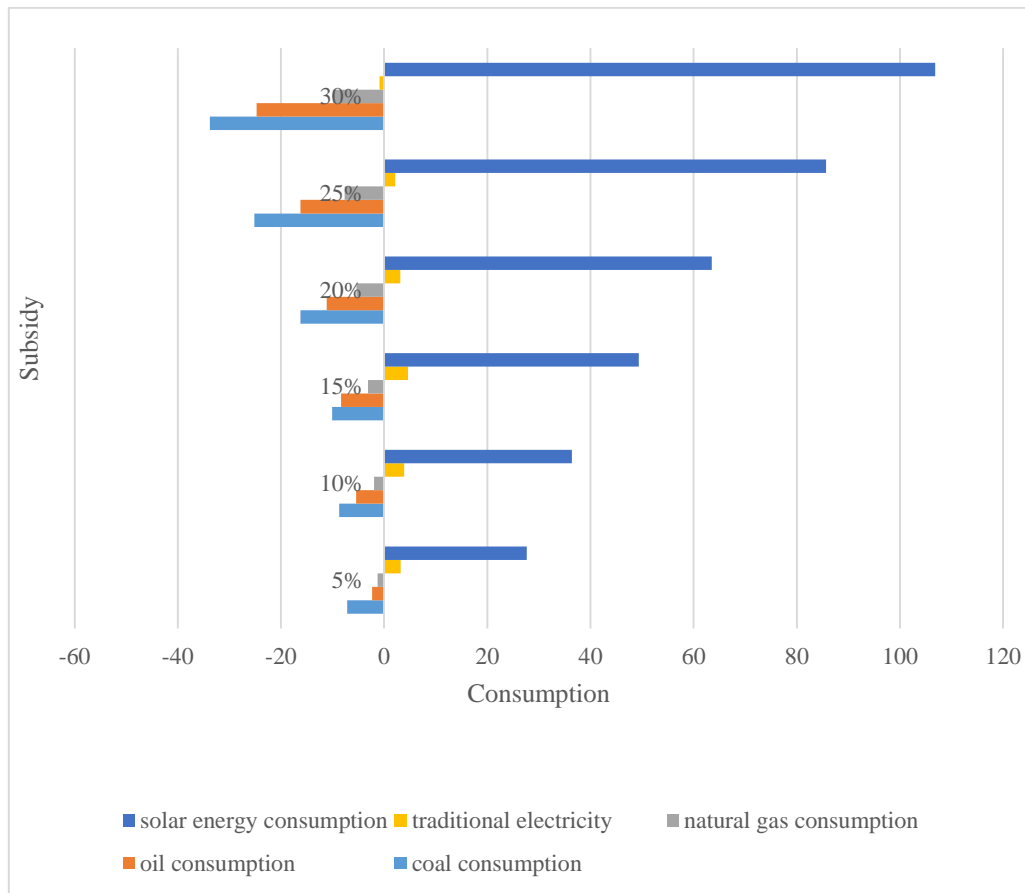| Subsidy		5%	10%	15%	20%	25%	30%
Changes in each indicator	Coal consumption	-7.16	-8.73	-10.11	-16.254	-25.13	-33.76
	Oil consumption	-2.33	-5.41	-8.34	-11.13	-16.21	-24.72
	Natural gas consumption	-1.27	-1.98	-3.12	-5.34	-7.65	-9.97
	Traditional electricity	3.21	3.87	4.65	3.13	2.12	-0.87
	Solar energy consumption	27.65	36.41	49.34	63.54	85.65	106.8

Figure 3. The impact of solar electricity tariff subsidies on energy consumption

It can be seen intuitively from the figure that various types of energy consumption are specifically affected by the increase in solar electricity tariff subsidies. The most obvious one is the consumption of solar energy. When the consumption of solar energy increases, the consumption of other traditional energy sources will also be affected. In addition, for the impact of oil and natural gas prices, before 20%, the degree of impact is not very obvious, the specific reduction degrees are 2.33%~11.13%, 1.27%~5.34%, but between 20%~30%, the degree of influence increases . In terms of the impact on the price of traditional electricity, due to the increase in solar electricity price subsidies, the price of solar energy also shows a downward trend. The trend of change is similar.

5. Conclusion

At present, clean energy power generation has remarkable characteristics, namely cleanliness, convenience and economy, and is the main energy for future development. However, at this stage, the traditional energy consumption structure is limited by many situations, which directly limits the sustainable development and coordinated utilization of energy. Combining with the development of new energy in my country, the existing research on the evaluation of the implementation effect of the new energy consumption strategy has considered the implementation basis, comprehensive benefits and later operation of the new energy consumption strategy to varying degrees, and constructed a comprehensive comprehensive evaluation index. The system provides a reference basis for the benefit evaluation of new energy utilization in my country.

Funding

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Gupta V , Sajnani M . Risk and benefit perceptions related to wine consumption and how it influences consumers' attitude and behavioural intentions in India. British Food Journal, 2020, 122(8):2569-2585. https://doi.org/10.1108/BFJ-06-2019-0464

[2] Hu C , Testa C J , Born S C , et al. E-factor analysis of a pilot plant for end-to-end integrated continuous manufacturing (ICM) of pharmaceuticals. Green Chem. 2020, 22(13):4350-4356. https://doi.org/10.1039/D0GC01397H

[3] Cauwer C D , Verbeke W , Mierlo J V , et al. A Model for Range Estimation and Energy-Efficient Routing of Electric Vehicles in Real-World Conditions. IEEE Transactions on Intelligent Transportation Systems, 2020, 21(7):2787-2800. https://doi.org/10.1109/TITS.2019.2918019

[4] Danyali S , Moradkhani A , Aazami R , et al. New Dual-Input Zero-Voltage Switching DC-DC Boost Converter for Low Power Clean Energy Applications. IEEE Transactions on Power Electronics, 2021, PP(99):1-1. https://doi.org/10.1109/TPEL.2021.3072291

[5] Lee D H . Efficiency and economic benefit of dark-fermentative biohydrogen production in Asian circular economies: Evaluation using soft-link methodology with data envelopment analysis (DEA) and computable general equilibrium model (CGE). International Journal of Hydrogen Energy, 2020, 45(6):3688-3698.

[6] Batley R J , Mani J S , Broszczak D A , et al. Finding alternative uses for Australian rosella (. Animal Production Science Anim. Prod. Sci. 2022, 62(6):581-589. https://doi.org/10.1071/AN21475

[7] Medeiros D L , Kiperstok A C , Nascimento F , et al. Human urine management in resource-based sanitation: water-energy-nutrient nexus, energy demand and economic performance. Sustainable Production and Consumption, 2021, 26(-):988-998.

[8] Vakulchuk R , Overland I . Central Asia is a missing link in analyses of critical materials for the global clean energy transition. One Earth, 2021, 4(12):1678-1692.

[9] Boffardi R , Ioppolo G , Arbolino R . A two-step approach to evaluate drivers and barriers to clean energy policies: Italian regional evidence. Environmental Science & Policy, 2021, 120(6514):173-186.

[10] Islam A , Hossain M B , Mondal M , et al. Energy challenges for a clean environment: Bangladesh's experience. Energy Reports, 2021, 7(1):3373-3389. https://doi.org/10.1016/j.egyr.2021.05.066

[11] Ranjbar B , Nguyen T , Ejlali A , et al. Power-Aware Run-Time Scheduler for

Mixed-Criticality Systems on Multi-Core Platform. IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, 2020, PP(99):1-1.

[12] Wu H M . The impact of non-clean energy consumption on economic growth: Evidence from symmetric and asymmetric analyses in the US. Energy & Environment, 2020, 31(2):291-307. https://doi.org/10.1177/0958305X19865102

[13] Kaldellis J K , Zafirakis D . Prospects and challenges for clean energy in European Islands.The TILOS paradigm. Renewable energy, 2020, 145(Jan.):2489-2502.

[14] Park J , Hong H G , Kwon T Y , et al. Flexible Hybrid Approach for a 3D Integrated Physics Package of Chip-Scale Atomic Clocks. IEEE Sensors Journal, 2020, PP(99):1-1.

[15] El-Taweel N A , Zidan A , Farag H . Novel Electric Bus Energy Consumption Model Based on Probabilistic Synthetic Speed Profile Integrated With HVAC. IEEE Transactions on Intelligent Transportation Systems, 2020, PP(99):1-15.

[16] Thamlikitkul V , Rattanaumpawan P , Sirijatuphat R , et al. Integrated one-day surveillance of antimicrobial use, antimicrobial consumption, antimicrobial resistance, healthcare-associated infection, and antimicrobial resistance burden among hospitalized patients in Thailand - ScienceDirect. Journal of Infection, 2020, 81(1):98-106. https://doi.org/10.1016/j.jinf.2020.04.040

[17] Akhtar I , Kirmani S , Suhail M , et al. Advanced Fuzzy-Based Smart Energy Auditing Scheme for Smart Building Environment With Solar Integrated Systems. IEEE Access, 2021, PP(99):1-1. https://doi.org/10.1109/ACCESS.2021.3095413

[18] Tey T O , Chen S , Zhi X C , et al. Synthesis of a sustainable integrated biorefinery to produce value-added chemicals from palm-based biomass via mathematical optimisation. Sustainable Production and Consumption, 2021, 26(1):288-315. https://doi.org/10.1016/j.spc.2020.10.012