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ARTICLE

ENERGY INDICATORS FOR SUSTAINABLE DEVELOPMENT AND ITS APPLICATION EXAMPLES

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ABSTRACT

The Energy Indicator System for Sustainable Development (EISD) is a set of tool systems developed by the International Atomic Energy Agency (IAEA) to analyze energy-related development issues and decision-making. With the establishment of a range of indicators representing three dimensions of sustainable development social economic and environmental, the EISD indicators system serve as a useful tool for evaluating the current situation and predicting future development of energy issues. The background basic structure and applications of the EISD indicators system were introduced.

KEYWORDS

Energy Indicator System for Sustainable Development (EISD), Society, Economy, Environment

1. BACKGROUND OF THE EISD INDICATOR SYSTEM

The concept of sustainable development has been put forward for nearly 20 years. Quantitative measurement and monitoring of the degree of sustainable development has also become the research goal of various countries and relevant institutions.

The 1995 United Nations Work Plan for Sustainable Development (WPISD) was the first to research a sustainable development index system. This plan developed a set of index systems including environmental, social, economic, and institutional factors, which can carry out an overview evaluation of various aspects of sustainable development. Other important sustainable development indicator systems include the OECD and Eurostat's environmental indicator systems and the indicator systems developed by the International Energy Agency.

The above indicator systems and the sustainable development indicator systems developed by some countries are mostly focused on environmental sustainability. Even if some energy indicators are included, they are relatively scattered. In 1999, the International Atomic Energy Agency launched the "Energy Indicators for Sustainable Development (EISD)" project to promote research specifically on energy sustainable development indicators. The EISD indicator system is designed to provide research and decision makers with analytical and decision-making tools for sustainable development of energy issues, systematically provide energy, economic, environmental, and social data, and express the internal connections of these data for comparison, Trend analysis, and, where necessary, policy evaluation. The project integrates the work results of various UN member states and international organizations in terms of energy indicators and builds a widely recognized and universally applicable energy indicator system for sustainable development. Experts from the International Atomic Energy Agency (IAEA), the United Nations Department of Economic and Social Affairs (UNDESA), the International Energy Agency (IEA), the European Statistics Office (Eurostat), and the European Environment Agency (EEA) have all participated in the construction of the energy indicator system.

With the efforts of these institutions and project experts, the establishment of the sustainable development energy index system was finally completed in 2005. The International Atomic Energy Agency subsequently published a related report "Guidelines and Methodologies for the Sustainable Development Energy Indicator System" The report has a detailed introduction to the content structure and usage methods of the indicator system.

2. STRUCTURE AND FUNCTION OF THE EISD INDICATOR SYSTEM

2.1 Structure of EISD

The Energy Indicator System for Sustainable Development (EISD) organized by the International Atomic Energy Agency involves three major fields of society, economy, and environment (see Tables 1 to 3), and includes 30 core indicators [1]. Its structure from top to bottom each field contains three levels of subject-sub-theme-indicator. For example, the social domain includes two major themes, "equity" and "health", four sub-themes and four indicators; the economic domain includes two major themes, "energy utilization and production methods" and "energy security", eight sub-themes and 16 indicators; the environment field includes three major themes of "atmosphere", "water" and "soil", 6 sub-themes and 10 indicators. In addition, some indicators can be decomposed into multiple sub-indicators, such as the "air pollutant concentration" indicator (ENV2), which is decomposed

Table 1: Social domains of EISD sustainable development energy indicators

Topic	Subtopic		Energy indicator	Related parameters
Fair	Energy availability	SOC1	Proportion of households (population) without access to electricity or commercial energy or heavily dependent on non-commercial energy	Number of households (population) without access to electricity or commercial energy or heavily dependent on non-commercial energy Total number of households (population)
	Ability to pay energy bills	SOC2	Proportion of household income spent on fuel and electricity	Household income spent on fuel and electricity Household income (total income of all households and income of the poorest 20% of households)
Health	Polarization of energy consumption	SOC3	Household energy use and fuel composition by income group	Energy consumption per household by income group Average household income of various income groups Fuel composition by income group
	Safety	SOC4	Accident-year fatalities/energy production by fuel chain	Annual deaths by fuel chain

into the concentration data of several major air pollutants.

2.2 Role of the EISD Indicator system

Today's energy production and consumption in human society are mainly based on limited fossil energy, which is unsustainable. Moreover, whether it is the extraction, supply, and consumption of the entire energy chain or any one energy technology, pollutants will inevitably be emitted into the environment. For example, the burning of fossil fuels leads to urban air pollution, regional acid rain, and even global climate change; in some developing countries, the use of non-commercial biomass energy may even lead to desertification and reduction of biodiversity.

Since the existing energy production and consumption patterns cannot be completely changed in the short term, the impact of energy utilization on human health, society, atmosphere, soil, and water should be fully considered when choosing fuels, energy conversion technologies, transmission, and energy consumption methods. Environmental impact assessing the sustainability of current energy use developing balanced energy policies and incentives guiding energy investment and consumption changing the status quo building a harmonious relationship between energy and the economy, society and the environment. Based on the key role of energy in social, economic, and environmental issues, the Energy Indicator System for Sustainable Development (EISD) provides a suitable analytical tool for evaluating energy-related sustainable development.

EISD can reflect the overall level of sustainable energy development in a country or region. It is not just a collection of data, but more importantly, they are an extension and expansion of basic statistical data. Each indicator is often a combination of many aspects of energy production and consumption. The combination of all energy indicators can comprehensively describe the entire energy The state of the system and its interrelationship with socioeconomic and environmental factors are often not reflected in basic statistics.

The EISD can reflect progress toward achieving Sustainable Development Goals. For example, to meet a certain emission requirement, the energy sector can set relevant indicators, monitor the changes in indicators, understand the gap between the actual situation and the target, and determine corresponding action plans and countermeasures. Government departments can guide decision-making and analyze the effect of policy implementation through a set of comprehensive and simple data.

EISD can also reflect the impact of structural adjustment, technological progress, and policy measures. The changing trend of indicators not only describes the historical development process but also predicts prospects.

The establishment of a sustainable development energy indicator system helps to integrate energy development into social and economic planning, promotes the standardization of energy statistics, and improves information transparency.

Achieving sustainable development goals requires the joint efforts of all aspects of society, and promotes the rational development and utilization of energy resources and energy technologies through the implementation of scientific strategic planning and effective incentive policies. Therefore, EISD is a very useful analytical tool for the government, energy researchers, and statistical departments, it can provide the basis for the government's scientific planning and decision-making, and it guides the implementation of sustainable development actions.

3. APPLICATION EXAMPLES OF EISD INDEX SYSTEM

The EISD indicator of the International Atomic Energy Agency has been demonstrated and applied in countries such as Brazil, Cuba, Lithuania, Mexico, Russia, Slovakia, and Thailand. These countries selected several indicators from the EISD indicators according to their energy characteristics, analyzed the current and future energy systems and policies of each country, and completed the demonstration projects in 2005.

The application of the EISD index system in Brazil is currently recognized as the best example. Its research content and results are included in the research report Brazil: a country profile on sustainable development [2]. The following is a brief introduction.

In the Brazilian study, the researchers first used the EISD indicator to analyze and summarize the social, economic, and environmental data related to energy supply and consumption in Brazil, combined with the current state of energy policy, and the data spanned 20 to 25 years. Reflecting the historical development trend of various indicators, it depicts the overall picture of the basic situation of Brazil's energy [3].

First, the demonstration research of EISD starts from the historical data of the indicators and the characteristics of Brazil's energy status and development, including the status of energy supply and consumption, the status of local energy resources, and existing energy policies. Research results show that Brazil is rich in conventional and renewable and uranium resources but currently relies on oil, biomass, and hydropower as the main energy sources. The main domestic energy consumption is concentrated in the industrial and transportation sectors. In terms of energy technology, Brazil leads the world in ethanol vehicle fuel and biomass fuel. The past energy policies have successfully guided the development of biomass energy, thus reducing the dependence on imported energy, reducing the dependence on oil, improving the commercialization of energy in the country, especially in cities, and successfully making hydropower and other renewable energy sources occupy an important place in the energy structure. However, the study also found that there are some major problems, including (1) due to inefficient energy pricing and energy services, the high energy density in industries such as industry; unreasonable fuel price subsidies, etc. directly lead to low energy efficiency and energy waste. Development of energy-intensive industries; energy prices do not reflect their external environmental impacts. (2) Brazil's high dependence on hydropower brings potential safety hazards to the energy supply. (3) The social problems of energy focus on the affordability and polarization of energy costs. Some rural and urban poor cannot even get the minimum energy supply. (4) The environmental impact of energy is concentrated in sulfur oxides, nitrogen oxides, dust pollution, and the potential environmental

Table 2: Economic domains of EISD sustainable development energy indicators

Topic	Subtopic		Energy indicator	Related parameters
Energy use and production methods Health	Total consumption	ECO1	Total consumption	Energy consumption (total primary energy supply, total final energy consumption, and electricity consumption) Total population
	Overall efficiency	ECO2	Energy consumption per unit of GDP	Energy consumption (total primary energy consumption, final energy consumption, and electricity consumption) GDP
	Supply-side efficiency	ECO3	Energy Conversion and Distribution Efficiency	Conversion system losses include losses in power production and transmission and distribution
	Production	ECO4	Production/Reserve Ratio	Proved developable reserves Total energy production
		ECO5	Production/Resource Ratio	Estimated total resource reserves (including proven and estimated unproven) Total energy production
	Final consumption	ECO6	Industrial energy consumption intensity	Industrial energy consumption Industrial output value added
		ECO7	Agricultural energy consumption intensity	Agricultural sector energy consumption Agricultural output value added
		ECO8	Service industry/commercial energy consumption intensity	Service industry/commercial sector energy consumption Service industry/commercial output value added
		ECO9	Household energy consumption intensity	Household energy consumption Number of households, indoor area, population per household, and ownership of household appliances
		ECO10	Transportation Energy intensity	Energy use in the transport sector (using transport) Passengers and kilometers transported (using transport) Fuel structure
	Fuel Structure	ECO11	Fuel Structure for Energy and Electricity	Primary energy supply, final consumption, power generation, and installed power generation capacity of various fuels Total primary energy supply, final consumption, electricity generation, and installed capacity
		ECO12	Ratio of carbon-free energy in energy and electricity	Primary energy supply, final consumption, power generation, and power generation capacity of all types of carbon-free energy sources Total primary energy supply, final consumption, power generation, and power generation capacity
		ECO13	Ratio of renewable energy in energy and electricity	Primary energy supply, final consumption, power generation, and power generation installed capacity of various types of renewable energy Total primary energy supply, final consumption, power generation, and power generation installed capacity
		ECO14	Terminal energy prices of different fuels and different fields	Energy prices (both with and without taxes/subsidies)
	Energy security	ECO15	Energy import dependence	Energy Imports Total primary energy supply
		ECO16	Strategic fuel reserves/ corresponding fuel consumption	Strategic fuel reserves (such as oil and gas) Strategic fuel consumption

impact of some large dams; while greenhouse gases, forest degradation, and soil erosion are not serious environmental problems in Brazil. (5) In terms of energy infrastructure, it is necessary to expand the transmission capacity of the power grid and strengthen the construction of the natural gas pipeline network.

Secondly, it analyzes the various links between energy and society, energy and economy, and energy and environmental issues, respectively, and then proposes solutions and development strategies to major problems. Especially in the analysis of the relationship between energy and economy, the decomposition analysis method is used to analyze the terminal energy density, and the influencing factors of terminal energy consumption are decomposed into three aspects: activity, structure, and intensity, and the key factors affecting energy consumption are analyzed. In the analysis, some historical influencing factors and the relationship between energy consumption changes have been fully reviewed, and the impact of economic and social factors on energy consumption has been effectively grasped. Then, based on the previous research and analysis, various scenarios for Brazil's energy development policy in the future are put forward and analyzed one by one. The proposed policy options include: Establishing a dedicated national energy efficiency agency; Comprehensively implementing the law on energy conservation standards; Implementing energy efficiency standards for new commercial buildings; Encouraging the development and utilization of renewable energy technologies such as hydropower, wind power, photovoltaic power generation, and bagasse cogeneration; Developing

Table 3: Environmental domains of EISD sustainable development energy indicators

Topic	Subtopic		**Energy indicator**	**Related parameters**
Atmosphere	Climate Change	ENV1	Greenhouse gas emissions due to energy production and consumption per unit of population and GDP	Greenhouse gas emissions caused by energy production and consumption Population GDP
	Air Quality	ENV 2	Urban Air Pollutant Concentration	Air Pollutant Concentration
		ENV 3	Air Pollutant Emissions from Energy Systems	Air Pollutant Emissions
Water	Water Quality	ENV 4	Liquid emissions from energy systems include oil emissions	Liquid Emissions Soil Soil Quality
Soil	Soil Quality	ENV 5	Soil area with soil acidification above critical load value	Affected soil area Critical load value
	Forest	ENV 6	Forest loss due to energy use	Forest area in two different periods Biomass Utilization Status
	Generation and management of solid waste	ENV 7	Solid waste generation rate/output energy unit	Amount of solid waste Energy Production
		ENV 8	Properly treated solid waste/total solid waste	Properly treated solid waste volume Total solid waste
		ENV 9	Amount of solid radioactive waste/unit of energy produced	Amount of solid radioactive waste (cumulative value over some time) Energy production
		ENV 10	Amount of solid radioactive waste to be treated / Total amount of solid radioactive waste	Amount of solid radioactive waste to be treated Total amount of solid radioactive waste

incentives for cogeneration with ethanol fuels and bagasse; Encouraging the construction of natural gas cogeneration plants; Implementing industrial energy-saving targets and sign energy-saving agreements; Improving the energy efficiency of traffic; Improving passenger transport efficiency through transport planning and guiding low energy density transport; Establishing energy security fund for the poor and so on. Finally, these policy recommendations include: (1) internalize the environmental cost of fuels used in automobiles, etc.; (2) implement renewable energy share standards; (3) expand their production and use and promote biomass fuel cogeneration; (4) establish a national energy conservation agency to implement fuel economy or CO2 emission standards for new passenger vehicles; (5) fully implement the Energy Conservation Standards Law. Finally, Brazilian researchers, together with IAEA experts, used the IAEA's energy modeling tools [Energy Demand Forecasting Model (MEAD) and Energy Supply Options Model (MESSAGE)] to forecast Brazil's future energy development scenarios under various energy policy options, and quantify the future values of each indicator. The predicted value of the indicator shows that Brazil's energy development policy is in line with the principles of sustainable development. Increasing the development and utilization of renewable energy can continue to maintain Brazil's economic growth, reduce fossil fuel consumption, and reduce environmental impact.

4. APPLICATION PROSPECT OF EISD INDICATOR SYSTEM IN CHINA

Domestic official energy indicators are generally found in the "China Energy Statistical Yearbook", "Electricity Statistical Yearbook" and statistical yearbooks of various provinces (such as "Zhejiang Statistical Yearbook"). These yearbooks all have basic energy data collection. Each situation focuses on time, but if you need to understand the energy of a certain region (province), it takes time and effort to collect and analyze scattered basic statistical data. If the EISD energy index system is used, a systematic national (regional, provincial) energy index database can be formed, and the social, economic, and environmental issues related to energy can be fully grasped, the historical trend of the development of the indicators can be understood, and the development prospects can be predicted. The index system can be used as a unified metric to compare the level of sustainable energy development in different regions and countries. It is very necessary to establish such an indicator system when energy issues are becoming more and more important.

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