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Methodologies of energy system research and analysis by world top energy think tanks

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Abstract—Think tanks are mainly engaged in policy research, while having influence on public policies, as well as serving policy makers and the public. Exploring the intelligence research methodologies and applications of the world's top energy think tanks can promote the innovation of Chinese energy think tanks in research methods and can improve the scientificity and objectivity of research results, accelerating the construction of Chinese new energy think tanks. This paper investigates and sorts out the research results and methods of top energy think tanks around the world, and then provides new ideas for the creation of energy think tank research methods suitable for Chinese actual conditions from the strategic and practical levels. The study finds that international authoritative energy think tanks make analysis and predictions mainly through adopting multiple types of investigation method, introducing research models and tools in various disciplines, and combining with visual images, which shows the characteristics of extensiveness, digitizing, and intelligence.

1. Introduction

The "Global Think Tank Report" issued by the University of Pennsylvania has conducted continuous, comprehensive and authoritative research and ranking of think tanks around the world. The report's impact assessment of each think tank is an important standard used to measure the development level and international status of think tanks. Based on the "Global Think Tank Report 2020", and considering the geographical location, property and research fields, we select 7 international authoritative think tanks as shown in Table 1. The selected think tanks cover a number of developed and developing countries to facilitate comparison and fully integrate the analysis of Chinese actual national conditions through learning from each other. From overall view, these think tanks are mainly attributed to official agencies, which have sufficient funds and talent support to provide governments with objective data and scientific suggestions in many fields, including politics and military, society and economy, technology and energy. At the same time, the development of private think tanks can also support successful examples for Chinese corporate think tanks and help them achieve long-term development.



Table 1. Selected international authoritative think tanks

Think tank	Geographic location	Property	Research fields	Link
Rand	America	unofficial	Politics and Military, Technology and Energy	https://www.rand.org/
National Renewable Energy Laboratory (NREL)	America	official	Technology and Energy	https://www.nrel.gov/
Stanford Re-search Institute International	America	unofficial	Politics and Military, Society and Economy, Technology and Energy	http:// http://sri.com/
German Institute for Economic Research (DIW)	Europe	unofficial	Society and Economy, Technology and Energy	https://www.diw.de/
European commission's Joint Research Centre (JRC)	Europe	official	Technology and Energy	https://ec.europa.eu/jrc/en
National Institute of Science and Technology Policy Library (NISTEP)	East Asia	official	Society and Economy, Technology and Energy	http://www.nistep.go.jp/
China Electric Power Planning & Engineering Institute	China	official	Technology and Energy	http://www.eppei.com/

2. Classification of Intelligence Research and Analysis Methodology

Based on the observation and discussion of international authoritative think tanks from research reports and literature investigations, we divided the intelligence research and analysis methodology into four types, including investigation method, visual images, building analysis models, and using tools. These methods have different functions and feature, which are used to analyze and predict specific fields in a targeted manner and provide decision-makers with scientific and objective suggestions.

2.1. Investigation Method

Investigation method includes many forms such as expert surveys, interview surveys, comprehensive system analysis and planning. Nowadays, it is used in all kinds of fields most widely and frequently. What's more, it requires the investigator and the respondent maintain an objective attitude to evaluate and analyze, and the decision-maker has a strategic long-term vision. Only in this way can we obtain the reliable conclusions of practical significance and provides suggestion for future development

forecasts and policy decisions in this field. Among them, the most representative is undoubtedly the RAND Corporation, which pioneered many investigation methods such as Delphi, Gaming and System Analysis Method as shown in Table 2.

Table 2. Investigation methods ^[1]

Method name	Method function	Method characteristics
Delphi (Expert Survey Method)	The opinions of experts have been surveyed many times, and then consulted and revised repeatedly, finally summed up into a basically consistent view as the prediction result.	Reflect group thinking, brainstorming, and cause "thinking resonance". With anonymity and feedback, the results obtained are objective and reliable.
Expert Lens	Based on iterative data collection and group feedback, including the opinions of experts or stakeholders, it consists of four rounds of creative generation, evaluation, discussion, and re-evaluation.	The combination of qualitative and quantitative can determine the potential factors of changes between two rounds of evaluation, with anonymity and ease of use.
Semi-structured Interviews and Focus Groups	Obtain in-depth information through the free expression of the interviewees.	It is a more natural informal interview, which is conducive to stimulating innovative thinking and has high technical requirements.
Multi-mode Interviewing Capability (MMIC)	Integrate multiple survey modes such as telephone interviews, online surveys, self-management surveys, and personal interviews.	A comprehensive information system that uses advanced communication technology for data collection, with diversity and a certain degree of intelligence.
Gaming	Research on the critical issue that how participants find the optimal strategy to maximize their benefits under conflict conditions.	Abstract and pattern complex behaviors, break through the difficulties of analysis under conditions of incomplete and asymmetric information.
Continuous Quality Improvement (CQI)	Adopt four major improvement steps: Plan—Do—Check—Action.	In principle, it emphasizes regular and gradual improvement, while in operation, it emphasizes process improvement, which is continuous, breakthrough and innovative.
Actionable Hot Spot	Use thematic map, Kernel density difference and hierarchical clustering to perform geographic spatial analysis on historical data, identify hotspot clusters and make predictions.	Prioritize key issues and solve the deployment decision and utility maximization issues when existing resources are scarce.

System Analysis Method (SAM)	Use a systematic perspective to conduct thinking under uncertain circumstances, explore possible solutions, and select the optimal path through comparative analysis.	The systematic thinking method symbols the transition of scientific thinking from taking "objects as the center" to "systems as the center", and the instability factors and degrees of freedom in the research are great.
Long-term Policy Analysis (LPTA)	Consider a large collection of scenarios; Look for robust strategies; Achieve adaptive robustness; Conduct interactive exploration.	It can systematically deal with the deep uncertainty of the long-term future and improve the ability of human beings to think about the long-term future.
Assumption-Based Planning (ABP)	It includes five elements: basic assumptions, key assumptions, signs, implementation actions and restraint actions.	The key is to improve the robustness and adaptability of existing plans to help the plan respond to major changes.

2.2. Visual image

Visual image refers to the conversion of data into images, which can be processed interactively. It is mostly used in research path analysis and research results display because of the strong intuitiveness and simplicity. Especially for public reports, visual images are always used in consideration of the legibility and understandability of the public. The specific types are shown in Table 3.

Table 3. Visual image methods

Method name	Method function	Method characteristics
Route Mapping	Composed of simple graphics, tables or text.	It shows the evolution of science and technology under the definite time or conditions, and then identifies key technologies and evolution trends.
Topographic Mapping	The research objects are displayed on the drawings according to the geographical distribution.	Intuitively show the distribution status, range, density and other characteristics of a certain element.
Trajectory Mapping	Monitoring the past and current development status and trends of a certain field in order to predict future development trends based on the obtained trajectory.	Help to judge the development trend characteristics such as development path, development speed and development prospects.
Biomass Energy Atlas	The user inputs biomass energy data on the map, and then collects relevant product and distribution information, and establishes a scientific and rich database.	Combining visual regional resource geographic information and high-level capacity analysis of energy use, it provides a scientific and reliable data basis to help analysis and decision-making in the field of biomass energy.

2.3. Build an analysis model

The think tanks usually build a universal theoretical model for a certain subject area, such as the use of econometric models for quantitative analysis in the economic field. In addition, creating a new model

specifically for a practical problem is also necessary, which can help to research on prototypes more conveniently and obtain the best results through the continuous optimization and adjustment of the model during the research process. It is common to establish analysis models in the research of strategic and policy issues conducted by international authoritative think tanks, as shown in Table 4.

Table 4. Methods of establishing analysis model

Method name	Method function	Method characteristics
Econometric Model	Use mathematics, statistics and computer technology to quantitatively analyze the relationship of economic variables with random characteristics.	It requires a profound basis of economic theory and statistical data in order to deeply explore and simulate the interactive relationship between the research theme and external factors, and then reveal the mutual influence mechanism, which is suitable for various economic researches.
Exploratory Modeling	System analysis; Design scenario; Abstract modeling; Exploratory experiment; Result analysis.	It has a comprehensive and abstract understanding of the problem under the uncertain conditions to help reduce the risk of decision-making.
Robust Decision-making (RDM)	Imagine the implementation under various conditions and build hundreds of models to assist decision-making analysis.	The innovation lies in "reverse analysis".
Discrete Choice Modelling (DCM)	Based on the theory of maximum utility, analyze and predict how human personality affects choices.	It is widely used in the selection behavior of individuals or enterprises.

2.4. Use tools

International authoritative think tanks often realize intelligence and automation of analysis by establishing databases and developing analysis software and platforms. On the one hand, they can select, organize and calibrate basic data to provide easy-to-process raw materials for data analysis and visualization, grasping the accuracy and scientificity of the intelligence analysis work from the source. On the other hand, the open database, software and platforms can facilitate the public to extract information independently, reduce the work intensity of data analysts, and improve the standardization of analysis results. This method is mostly used by official think tanks because it depends on comprehensive, authoritative, and widely recognized data collections, as shown in Table 5.

Table 5. Use tool methods

Method name	Method function	Method characteristics
Portfolio Analysis Tool (PAT)	Weigh the efficiency and cost of different modules, and use algorithm iteration to get the best solution to achieve specific goals.	Innovation is achieved through the ingenious combination of resources, which can be used for the development of military equipment projects.
KIDSASHI	It collects reports issued by more than 300 universities and institutions around the world every day, publishes articles and obtains more feedback information through Artificial Intelligence technology.	The search scope is wide. The update is fast. It is convenient to collect and extract information, and it can build an open database for the public.
EVI-Pro Lite	A large number of simulations are carried out based on detailed data such as private car travel mode, electric vehicle attributes and charging station characteristics.	Focusing on the usage and future prediction of electric vehicles and charging infrastructure in a certain area, which has great practical significance.
System Analysis Model (SAM)	Model and simulate the cost and operating status of renewable energy, provide users with decision-making assistance based on the evaluation of the electricity price and cost.	A free software open to the public that integrates modeling, simulation, analysis, and visual display functions, covering most renewable energy sources such as wind, light, geothermal, biomass and tidal energy.

3. Application of Think Tank Analysis Method in Energy Research

For analysis and prediction in the energy field, NREL mainly uses model construction and visual images. For example, the NZEB concept and indicator system are proposed to evaluate the performance of sustainable buildings in terms of energy performance, and an investment framework is established to formulate energy efficiency strategies to achieve this standard [2]; What's more, NREL created the electric vehicle infrastructure anticipation model (EVI-Pro) and a new tool kit named EVI-Pro Lite to provide support for electric vehicle applications [3]; The System Advisor Model (SAM) is also developed to comprehensively analyze, evaluate and present the power generation, operating conditions, economic benefits, and average costs of renewable energy integrated into the grid. Meanwhile, NREL defined four steps for evaluating energy potential, which is consist of theoretical, geographic, technical and market potential evaluation. According to this step, a power flow calculation model is established and many important parameters including API, IGC, AEP and TOE are calculated to evaluate the tidal current power in the western coast of South Korea, which has determined the key aspects of tidal energy resource potential for South Korea [4]. In terms of visual images, NREL published the "Biomass Energy Atlas" on September 28th, 2010. This tool can obtain the first-class project feasibility identification and biomass energy potential analysis through the information provided by government, state agencies, universities, petroleum transportation industries, research institutions, geographic information system (GIS) companies, private companies, and media. The biomass fuel engineering developers can learn about areas with high concentration of raw materials quickly and easily in order to implement engineering development efficiently. The federal and state policy-making agencies can distinguish

between regional concerns and make better geographic planning decisions by highlighting areas that need for more infrastructure [5].

The German Institute for Economic Research, the Stanford Re-search Institute International, and the Center for European Union Studies usually use econometric models to conduct research on energy policy, economic effects, and future technology forecasts [6]. Specifically, the German Institute of Economic Research established an econometric model based on the ROI indicator to test the relationship between feed-in tariff control policies and renewable energy production, which is used to attain the impact of prices paid to electricity producers, wholesale electricity prices, contract duration, and renewable electricity energy production costs on the rate of return on investment in renewable energy. In addition, DIW also established PPML model for impact assessment of economic geography and energy policy on international energy trade, and SEEEM model for economic effects assessment of energy technology development on increasing investment and driving employment. For example, DIW analyzed the driving factors of solar technology module transactions among OECD member countries through PPML model. The Stanford Re-search Institute International used the "learning curve" to build future energy technology prediction models, such as the power technology futures model (PT-FM), which aims to obtain power generation technologies of coal and natural gas, and scientific forecasts of the efficiency, power generation costs, equipment costs, environmental protection costs and CO₂ emissions. The Center for European Union Studies established the GEM-E3 model to study the macroeconomics and its interaction with the environment and energy systems, and then created a general equilibrium model of energy-environment-economy, which was used to obtain the impact of EU biofuel policy on agricultural market and land use with AGLINK-COSIMO model, ES-IM model and CAPRI model.

As an authoritative organization in the field of science and technology policy research, NISTEP attaches great importance to the application of normative research methods. The "Technology Foresight" and the "Science Map" as its unique research methods have attracted the most attention, which are studied and imitated by many research institutions. NISTEP identifies technology trends from a mid-to-long-term observation perspective through "Technology Foresight". Based on the results of extensive discussions among a large number of experts, the future science and technology picture in the next 15-30 years is obtained to provide direction and goals for the future development. In the "Technology Foresight", NISTEP combined the Delphi, Bibliometric Method, Questionnaire Survey Method, Demand Analysis Method and Scenario Planning Method to forecast and outlook the future energy technology development and the regional green innovation capability [7]. In addition, NISTEP also pays attention to the output of scientific papers, patents and other research activities, relying on Scientometrics, the Essential Science Indicators database (ESI) and visual images to display the research results to the public. In "Science Map 2006", NISTEP used the co-citation relationship of highly cited papers to perform cluster analysis, and display the research field through topographic maps. In "Science Map 2014", NISTEP combined topographic maps, Dot-link maps, and trajectory maps for intelligence research and analysis. Currently, NISTEP is studying the new method named KIDSASHI, trying to realize the integration of knowledge by evaluating and scanning the innovative technology space, and prepare for the prediction of new technologies in the future by collecting and analyzing information.

As a typical representative of Chinese energy think tank, China Electric Power Planning & Engineering Institute mainly uses Actionable Hot Spot to analyze focal issues in different periods. In "China Energy Development Report 2016", it comprehensively explored many key issues such as the environment development, demand analysis, power economic development, power grid development and electricity reform, pointing out China is in the period of energy transition that the government needs to carry out systematic quality improvement and transformation to achieve efficient and coordinated goals [8]. In "China Energy Development Report 2017", it deeply analyzed the consumption of new energy and the construction of the power spot market, reflecting energy development achievements and shortcomings in the past year through a large amount of data and intuitive graphs, and putting forward prospects and relevant suggestions for future energy development through vertical and horizontal comparisons [9]. In "China Energy Development Report 2018", it scientifically predicted future development trends, pointing out that Chinese energy consumption growth rate continues to rebound,

and the energy consumption structure is significantly optimized while the contradictions and problems of energy development still exist. Specifically, the overall looseness of energy supply and demand, the time-period in individual varieties and regional tensions coexist all the time. The task of clean energy replacement is heavy, and the critical core technologies need to be improved [10].

4. Conclusion

The international authoritative think tanks mainly use investigation methods, introduce research models and tools in various disciplines, and combine visual images for analysis and prediction, showing the characteristics of digitizing and intelligence, which represents the new trend of think tank development in the context of the big data era. On the one hand, it can promote the innovation of think tanks in research methods, inspiring them to create and use various models, databases and software platforms, and show the research results to the public more intuitively through images, which contributes to enhancing the scientificity and objectivity of the research. On the other hand, it can provide substantive suggestions for Chinese think tank research methods, especially in the energy field. All in all, we should bear in mind that traditional energy think tanks are faced with huge challenges in upgrading and transformation. The creation of new theories, new methods, and new tools is urgent, which is conducive to promoting the construction of Chinese new energy think tanks.

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