To Achieve a Low Energy Demand Society through Technological and Social Innovation
－International Model Comparison Project EDITS－

Systems Analysis Group
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1. Introduction

The Paris Agreement in 2015 set a goal to hold the global average temperature increase to well below 2°C above pre-industrial levels and to pursue efforts to limit it to 1.5°C. Then, corresponding to the 2 °C goal as an emission reduction, a so-called carbon neutral (net zero emission) was agreed to balance the anthropogenic emission by sources and the absorption by the sink for greenhouse gases in the latter half of this century. Furthermore, while the demand for early carbon neutrality (CN) was increasing at home and abroad, in October 2020, former Prime Minister Suga declared that Japan would aim for CN by 2050. This is a goal that is consistent with the scenario of controlling temperature rises below 1.5 °C. After that, Japan said in April 2021that it would deepen its emission reduction target to a 46% reduction in 2030 and that it would take on the challenge of further reducing it by 50%. In addition, the 26th Conference of the Parties (COP26) of the United Nations Framework Convention on Climate Change (UNFCCC) has concluded in November 2021, countries agreeing to pursue efforts to limit the rise in global average temperature to 1.5 °C.

To achieve CN, it is crucial to utilize a wide range of emission reduction opportunities such as renewable energy, nuclear power, and so-called Carbon Dioxide Removal (CDR) technology, including Carbon Capture Utilization and Storage (CCUS) and Direct Air Carbon dioxide Capture and Storage (DACCS). On the other hand, it is conceivable that energy conservation will continue to be the most critical issue in reducing CN emissions. In particular, the fusion of digital transformation (DX) and green transformation (GX) can bring about a virtuous cycle of the environment and the economy.

The Intergovernmental Panel on Climate Change (IPCC) published the 1.5 °C Special Report (SR15)[1)] in2018. Various emission routes that achieve 1.5 °C were shown there, particularly the scenario[2)] called Low Energy Demand (LED) drew attention. This scenario shows much less energy than the final energy demand, as shown by regular model analysis. The scenario is said to be possible to contribute not only to climate change countermeasures, but also to the simultaneous achievement of SDGs.

Figure 1 shows the world energy consumption by stage of energy use. Energy is wasted, particularly close to where it is the end-use. Energy is often consumed even though it is unnecessary and does not contribute to the service[3)]. For example, lighting is a classic example and often illuminates even when no one is present. Although motion sensors have become economical in recent years and have come to turn off automatically when there are no people, they are still often lit in vain.

We are not consuming energy for the purpose of consuming energy. As a result of an attempt to obtain a more satisfying service, energy is consumed and CO_2 is emitted. It is essential to determine whether the services we take for granted are indispensable and what services we genuinely need.

In the world, research on the Decent Living Standard (DLS: appropriate standard of living, minimum standard of living) is progressing, and according to the research, the world's end-use energy consumption is about 400 EJ/yr. and would be about 600 EJ/yr. over the year 2050. There are many analyzes that it would be about 400 EJ/yr., which is the same as the current level even with countermeasures for the 2 °C scenario, but some studies say that about 150 EJ/yr. from DLS is sufficient[4]. Indeed, the appropriate level may change since human needs are diverse; however, it is conceivable to be an important study for understanding the factors that cause a gap with actual energy consumption.

Noted that Reference 5) points out that the speed of technological progress of small-scale technology is often seen on the demand side, and while there is a demand for rapid carbon neutralization, it is necessary to take measures on the demand side.

Factors that induce measures on the energy demand side include the significant progress in digitalization technology and the buds of social change, especially among young people in Europe. Under these circumstances, Reference 6) points out the need to strengthen research on the demand side and research progress is expected, with a new chapter focusing on energy demand measures assigned in the sixth evaluation report of the IPCC Working Group 3 scheduled to publish in 2022.

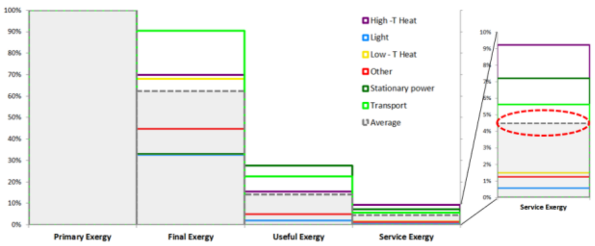

Figure 1 World energy consumption by stage of energy use（assuming100% primary energy consumption）[7)]

This paper introduces the commissioned project “Model Comparison International Collaboration Project on Changes in Energy Demand by Technological Innovation” by the Ministry of Economy, Trade, and Industry (METI). This project is known as EDITS (Energy Demand changes Induced by Technological and Social innovations) and started in 2020, intending to induce a change in society by identifying opportunities for the realization of a low-energy demand society and presenting them as concrete and quantitative scenarios.

2. Possibility of realizing a society with low energy demand in various sectors

We examine the possibility of realizing a society with low energy demand by sector.

2.1. Home appliances

Changes in home appliances are being observed. Figure 2 shows that a variety of home appliances can now be replaced by smartphone functions. In addition, the power consumption of smartphones is becoming much smaller than that of home appliances. Even more important is the "embodied energy" of the product. The energy input at the manufacturing stage of a product is also greatly reduced when it is replaced by a smartphone. Of course, not all functions can be completely replaced, but the addition of other benefits (e.g., ease of mobility) will facilitate the re-placement, resulting in lower energy consumption and CO_2 emissions.

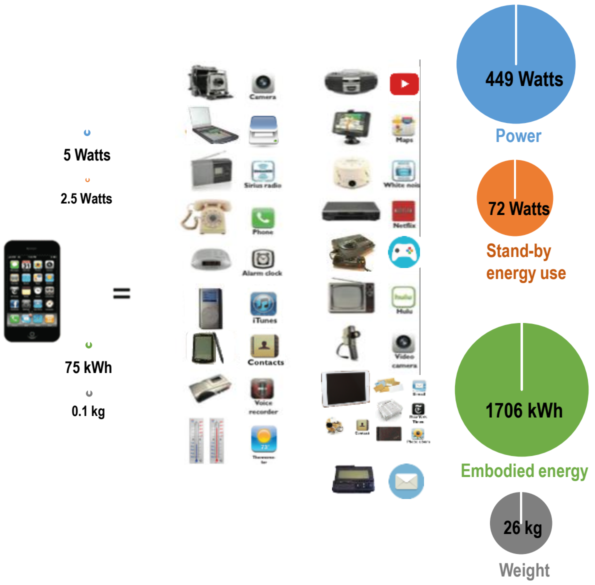

Figure 2 Substitution of home appliances and potential for low energy use[8)]

2.2. Paper medium

Paper has played a major role as a means of circulating information. On the other hand, paper and pulp is an energy-intensive industry that requires a large energy input in the manufacturing process. Figure 3 shows the transition in consumption of printing and writing paper. Recently, per capita consumption of printing and writing paper has been on a downward trend not only in developed countries but also in developing countries. The same trend is observed in the consumption of newspaper rolls. This is thought to be a result of the decline in paper consumption as the IoT progresses, making it relatively easy to obtain information using various digital devices. When digital devices first became widespread, there seemed almost no reduction in paper-based printing, but it appears that the combination of advances in devices and user familiarity is having an effect.

However, the consumption of corrugated paper continues to show an upward trend due to the increase in home delivery and other services.

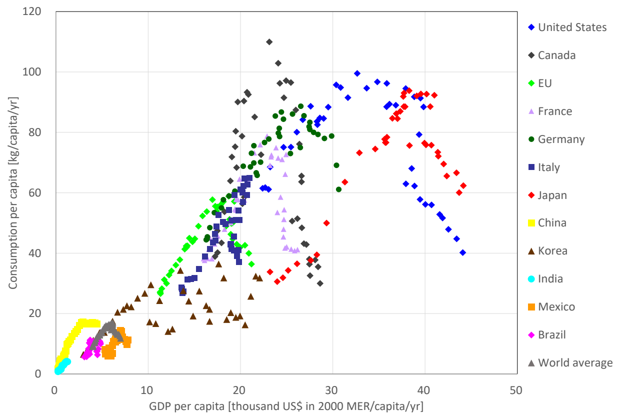

Figure 3 Transition in consumption of printing and writing paper[9)]

2.3. Apparel

Apparel has been pointed out as having a high environmental impact due to its energy consumption from manufacturing to disposal and its short life cycle. For example, the study[10)] shows that the fashion industry is responsible for 8-10% of the global CO_2 emissions (4-5 billion tons per year) to the global environment.

In addition, according to the literature[11)], CO_2 emissions from the use of clothing in European households (washing, drying, ironing, etc.) are estimated to be 530 million tons per year. Although only rough estimates can be made, as the use of clothing and the maintenance of the same garment (how many times it is worn) depend on the choices of the individual consumer, it is estimated that the CO_2 emissions during the use phase of an average T-shirt account for half of its lifecycle emissions. For example, when estimating the life cycle emissions of a cotton T-shirt, if it is washed 50 times, 35% of the CO_2 emissions are attributed to the fiber production and 52% to the use stage. Although natural fibers emit less CO_2 at the fabric production stage than synthetic fibers made from petroleum, the low carbon footprint at the production stage may be offset at the use stage because natural fibers require more energy for washing, drying, and ironing than synthetic fibers.

Recently, apparel sales have been growing dramatically, and the reason behind this growth is the rise of fast fashion. Fast fashion refers to a type of clothing sales chain that emerged in the late 1990s and early 2000s and is characterized by the mass production of clothing that follows the latest design trends in a short cycle and sells it at low prices to encourage mass consumption. It is estimated that 50% of clothes are discarded without being worn, and for many clothes, the utilization rates are low, and those are waiting in the closet to be worn.

The fashion industry is also promoting products that are environmentally and socially friendly. E-Commerce sales allow brand companies to avoid the energy consumption of maintaining physical stores and the need to carry inventory. However, as mentioned above, purchasing clothes through e-commerce without trying them on increases the number of unused clothes that are thrown away because the size does not fit or the image is different. As a solution to this problem, virtual fitting and automatic body shape measurement technologies are being developed.

In addition, the trading of used clothing through the development of internet auctions is effectively the development of clothing sharing, which encourages the matching of supply and demand, improves the utilization rate of apparel products, and reduces waste.

For more information on apparel, please refer to the study [12)].

2.4. Food

GHG emissions from the entire food system, including agricultural and fishery production, food processing, transportation, cooking, etc., were estimated to have accounted for 21-37% of total global emissions[13)]. (These estimations are generally based on flows of products and services; however, it is expected to be even larger if the emissions from constructing fixed capital such as stores, and facilities are included.) On the other hand, it was estimated that roughly one-third of food produced for human consumption has been lost or wasted. The reasons vary by region, with overproduction aimed at maximizing revenues and high levels of waste at the consumption stage being common reasons in middle- and high-income countries[14)]. If food demand can be predicted more accurately by utilizing Information and Communication Technology (ICT), which has made remarkable progress in recent years, it is expected to not only reduce food wastage but also save plastic containers, space in supermarkets, and energy for refrigeration/freezing and transportation, leading to reduced energy consumption and GHG emissions. It could contribute to the simultaneous achievement of the SDGs.

According to our study based on the input-output table for Japan[15)], if the food wastage in vegetable and fruit cultivation, food industries, and households in Japan could be reduced by 50%, it would contribute to reducing total energy consumption in Japan by 0.04–0.08 EJ/yr. (0.2–0.4% of the primary energy supply in Japan) and GHG emissions by 5.9–8.4 million tons CO_2 eq/yr. (0.5–0.6% of GHG emissions). These figures focused on Japan are not so large due to the relatively small ratio of food wastage in Japan. However, if the food wastage could be reduced worldwide, including regions where there is much more potential for food wastage reduction, the impacts would be significant. Our preliminary estimation for the world shows that if the food wastage in the world could be reduced through the assumed measures, the world GHG emissions would be reduced by approximately 1.1 $GtCO_2$ eq/yr[16)]. The regional diversity of the food system is very high, and there is uncertainty in estimating food waste reduction effects; therefore, continuous scrutiny and research are necessary.

2.5. Mobility: Car and ride sharing

Advances in digitalization have a significant effect on mobility. A change called "Connected; Autonomous; Service & Shared; Electric (CASE)" is now taking place. The utilization rate of private cars is estimated to be around 4-5%, and most of the time, private cars are underutilized. This is due to the convenience of being able to travel in a private space at any time and promptly, even at a high cost. However, if fully automated vehicles are realized, even if they become ride-sharing or car-sharing, convenience will not be largely compromised, and they could be available at a lower cost due to higher utilization rates. Therefore, with the exception of some cars as preferences and the like, ride-sharing and car-sharing could advance rapidly. Moreover, ride-sharing can directly reduce the energy consumption of vehicles, and car-sharing can reduce the number of vehicles and the use of materials such as steel and plastic, and lower the energy consumption required for their production. RITE has also conducted quantitative analysis using an integrated assessment model[17).

The OECD/ITF has developed a model based on actual data (population distribution, road and public transport network, weekday trip demand (time of day, OD (Origin-Destination)), trip preferences, etc.)[18). In Dublin, Ireland, the study shows that if all private cars were replaced by shared cars, the current mobility could be supplied with less than 2% of that number of vehicles. If 20% of private cars were replaced (even without EVs), CO_2 emissions would be reduced by 22%.

2.6. Industries: 3D printing

3D printing (additive manufacturing: AM) is making progress. Compared to forming by making molds or modeling by cutting, AM can create complex shapes and, in many cases, can create lighter products with the same strength, which can lead to improvement in material efficiency. In addition, it is possible to manufacture products according to individual needs rather than mass production, and there is a possibility of avoiding mass production and mass disposal.

2.7. Behavioral transformation

Not only technology but also individual behavioral change and the resulting social change are also important. On the other hand, expecting behavioral change alone is unlikely to have a significant impact.

A synergistic effect between technology and changes in social awareness would lead to major social changes. Movements such as ethical consumption will also encourage companies to change their behaviors, and lead to response by society as a whole. For example, the rate of driver's license acquisition has been declining. This will lead to a reduction in the purchase of private cars, which will motivate companies to develop fully automated vehicles.

2.8. Rebound effect

On the other hand, there is a possibility of increased energy demand as a rebound effect.

According to the study[19), it is estimated that the global data center power consumption was 194 TWh in 2010 and increased to 205 TWh (about 1% of the global power consumption) in 2018. Electricity consumption is estimated to have increased by only +6%, whereas the calculated instance for the same period was +550%. The main factors behind the increase in energy efficiency are server efficiency, virtualization, storage drive efficiency and densification, data center infrastructure efficiency, and changes in server types. On the other hand, there is a possibility of the end of Moore's Law, and some studies estimate a significant increase in data center power consumption in the future (e.g., Ref. 20).

The rebound effect is not limited to the direct increase in electricity consumption by the IoT. For example, if fully automated vehicles increase convenience, they may make people switch from trains and buses, triggering new travel demand itself. Furthermore, from a macro perspective, even if consumption decreases in a particular field, it could have a rebound effect where energy consumption and CO_2 emissions increase due to a shift toward other consumption. In addition to the need for comprehensive analysis, it is also necessary to develop comprehensive policies for the real world.

3. EDITS project overview

Against this background and awareness of the problem, EDITS started as a commissioned project of METI in 2020.

3.1. EDITS objectives

The June 2019 G20 Karuizawa Action Plan states that "We recognize the importance of quantitative analysis on a better understanding future energy demand and the role of innovation of both sides driven by digitalization, Artificial Intelligence (AI), the Internet of Things (IoT), and the sharing economy. We encourage efforts to further refine and develop a full-range scenario across the economy for energy and climate models made by the global scientific community and international institutions and frameworks."

The EDITS project aims at the following three points.

1) Build an international research community with a focus on the energy demand side. Share the latest data, concepts, methodologies, and policy analysis on the energy demand side. Through them, deepen discussions on research and policy analysis, and promote mutual enrichment.
2) Develop cutting-edge demand models for environmental and climate policy analysis through international comparisons of methodologies and models. In addition, develop concepts and methodologies across academic, energy, and environmental disciplines, and expand them widely and internationally.
3) Make better policy recommendations through structured model experiments and simulations. Notably, build and leverage models to address new areas and service supplies such as policy making with synergistic effects on the integration of digitalization, sharing economies, SDGs, and climate goals. Evaluate demand-side policy potential impacts and barriers and others, including synergies and trade-offs with other goals of SDGs.

3.2. EDITS research group structure

The following working groups conduct research based on the themes to deepen the research, including the contents introduced in Section 2. Moreover, each theme also plans to be integrated. The coordination of the entire research executes with the International Institute for Applied Systems Analysis (IIASA) cooperation.

【Sectoral Modeling/Analysis/ Consideration】

■ Industry Sector

[Primary Theme] Comparisons between industrial sector models (theoretical, geographical/temporal/biophysical coverage, data availability, understanding of differences in methods, etc.), effects of material efficiency, etc.

■ Building（Household）Sector

[Primary Theme] Comparison between building sector models (regional differences, heterogeneity), the effect of the sharing economy and the impact of smart working on the commercial building sector, etc.

■ Transport Sector

[Primary Theme] Comparison of transport sector models (activity type (passenger/cargo), location (urban/non-urban), vehicle size, mode difference, etc.)

【Data Collection/Organization】

[Primary Theme] Demand-side micro data collection and sharing

【Sectoral Modeling/Analysis/ Consideration】

- Qualitative Scenario Examination/Development

  [Primary Theme] Qualitative scenario construction for low energy material demand in line with 1.5 ℃ goals and SDGs

- Development of Protocol for Model Analysis Comparison

  [Primary Theme] Execution of comparative analysis between models (model analysis comparison utilizing the characteristics of each model)

- Sector Integrated Analysis

  [Primary Theme] Development of evaluation framework based on qualitative scenarios (welfare and feasibility evaluation), etc.

Cross-sectoral themes focus on digitization, equity, lifestyle/behavior change, business models, and theory building.

EDITS
Energy Demand changes Induced by Technological and Social innovations

Figure 4 EDITS Logos(From left to right, Industry, Billing, Transportation, Data and Narrative Working Groups)

The energy demand-side spans various sectors and is diverse from country to country. Therefore, as shown in Table 1, the EDITS project is currently is being pursued jointly by researchers with many specialized fields from many countries and regions to carry out the above themes. In addition, a wide range of researchers other than those listed in Table 1 participate and cooperate with the project.

4. Conclusion

The road to CN realization is steep. Therefore, it is necessary to mobilize all the various measures. Various measures on the energy demand side induced by digitalization can urge widespread use by reducing the barriers, “hidden costs.” The large-scale progress of digitalization is probable to create a "virtuous cycle of environment and economy," accompanied by changes in the consciousness of the younger generation. In addition, it may contribute not only to climate change countermeasures but also to the resolution of various SDGs.

Table1 EDITS participating universities research institutes

Research Institutes	**Description**
International Institute for Applied Systems Analysis (IIASA)	Coordination of the entire project with RITE, formulation of shared scenarios for international model comparison, collection of related information
OECD/ITF	Collection and analysis of transportation sector-related information
Stanford University	Support for formulating shared scenarios for international model comparison
University of Tokyo, Institute for Future Initiatives	Formulation of shared scenarios for international model comparison, coordination with participating organizations and researchers
Lawrence Berkeley National Labs (LBNL)	Collection and provision of various data such as energy demand technology
Utrecht University	Collection and provision of various data such as energy demand technology
Euro-Mediterranean Center on Climate Change (CMCC)	Evaluation of the impact of digitization technology on energy, collection of related information, analysis, and estimation by international model
Tsinghua University	Collection and provision of various data such as model improvement and analysis in China and related energy demand technology
UFRJ/COPPETEC	Collection and provision of various data such as model improvement and analysis in Brazil and South America, and related energy demand technology
Asian Institute of Technology (AIT)	Collection and provision of various data such as model improvement and analysis of India, South Asia, and Southeast Asia, and related energy demand technology
Osaka University	Japanese consumer sector model analysis
University of Wisconsin	US-related data collection, analysis support, impact assessment of digitization technology
University of California、	Data collection and analysis support related

Santa Barbara (UCSB)	to the United States
The Korean Society of Climate Change Research	Collection and provision of various data such as model improvement and analysis related to Korea and related energy demand technology
Central European University	European consumer sector model analysis
University of Natural Resources and Life Sciences, Vienna (BOKU)	Industrial sector model analysis
University of Freiburg	Model analysis of industrial sectors and related information
ISCTE - University Institute of Lisbon	Cross-disciplinary analysis of technology, industry, policy, and related information
Mercator Research Institute on Global Commons and Climate Change (MCC)	Collection and provision of various data such as German model improvement and analysis, related energy demand technology
University of East Anglia (UEA)	Analysis of lifestyle changes in Europe, and related information
University of Groningen	Analysis of the impact of environmental behavior and contextual factors on energy technology and acceptability

This EDITS project continues to provide research results that will contribute to the following IPCC report and promote measures on the energy demand side of governments and companies in each country. The energy demand-side measures, which EDITS considers to be the main target, are not to reduce energy and CO_2 directly but to indirectly reduce energy and CO_2 through changing and optimizing products and services, such as the development of digitization technology. Therefore, it is difficult to recognize directly for the government and society, and there is a possibility that the response may delay. Because of this, the goal of this project is to make the complicated system understandable and quantitatively visible and disseminate it to the government, companies, and society.

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