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GUEST EDITORIAL

Fourth International Symposium on Human Survivability: the global energy transformation: a quest for solutions from the perspective of human survivability

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1 Background

The theme of the Fourth International Symposium on Human Survivability was the shift from fossil fuels to cleaner energy sources that has been taking place around the world, or the global energy transformation. The symposium addressed a number of largely unanswered questions such as what should be the balance between the speed and tolerable costs of the global energy transformation. To avoid the dangerous impacts of climate change, we need to reduce our reliance on fossil fuels and use low-carbon sources of energy like the wind, the sun, hydropower, geothermal and nuclear energy. But if we do that very fast, isn't it going to be excessively costly?

Some other questions addressed at the symposium were: (1) Instead of "the shift to cleaner or low-carbon energy sources", should we aim for a transition to 100% renewable energy (mainly wind and solar)? (2) What lessons could be drawn from an international comparison of the energy transformation in UK, Germany, and Denmark? (3) What solutions could be offered to the problem of grid instability that occurs due to the integration of renewables into the electricity system? (4) What solutions could future battery storage technologies offer?

Furthermore, the Fourth International Symposium on Human Survivability aimed to provide a novel perspective on the global energy transformation based on a new integrated field of academic research called "human survivability studies" (HSS). To develop HSS, the faculty members and students at GSAIS strive to learn from

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the history of crises that have endangered the survival of mankind, as well as to analyze present vulnerabilities and future risks. The HSS also adopt a holistic and trans-disciplinary approach that goes beyond the discipline-based style of academic research.

The symposium was organized as follows: First, the Dean of GSAIS, Prof. Shuichi Kawai gave an opening speech about human survivability studies. Then, Dr. Felix Christian Matthes delivered his keynote lecture about the challenges of the transition to a sustainable energy system. After that, we held three plenary sessions where we looked at the global energy transformation from the economic, environmental, and innovation perspectives, respectively. Each plenary session consisted of two presentations by invited speakers followed by a discussion. At the end, we had a panel discussion where we not only summarized various insights generated during the opening and the plenary sessions, but also touched on some issues that we could not discuss before due to time constraints.

2 Summary of the opening session

Prof. Shuichi Kawai, Dean of GSAIS, Kyoto University, gave a definition and framework of human survivability studies (HSS) and explained why we need this new integrated academic field today. According to him, our contemporary society needs a holistic and trans-disciplinary approach because it faces complex social issues that cannot be resolved only with the help of experts in individual scientific disciplines. HSS aim to integrate the knowledge and wisdom of individual disciplines and rearrange those as knowledge and wisdom for survival in practical situations. Although HSS are based on a certain philosophy and methodology, their main focus is on the practical application of knowledge and wisdom for survival. In other words, HSS try to propose innovative solutions to urgent and critical issues such as food security, availability of water and energy, security and regional conflict, pandemic and health care, disaster prevention, etc.[1]

Dr. Felix Christian Matthes, Research Coordinator for Energy and Climate Policy at the Oeko-Institut (Institute of Applied Ecology), Germany, started his keynote lecture with the questions of what is a sustainable energy system and what are the main challenges of the transition to such a system. Among the various challenges, he focused on the problems of costs and public acceptance. Is the energy transition affordable, and how should policy makers design the transition strategy to make it acceptable for the society?

To answer the above questions, Dr. Matthes used some insights from the energy transition at the EU and the national (German) levels. The EU Energy Roadmap 2050 envisages five decarbonization scenarios depending on the policy focus or the type of energy mix: “energy efficiency”, “renewables”, “nuclear”, “carbon capture and storage”, and “diversified options”. At first glance, the scenario with the highest

[1] For readers who would like to learn more about human survivability studies, we recommend the book “Human Survivability Studies: How Can We Use Them for the Education of Future Global Leaders?” (川井秀一、藤田正勝、池田裕一『総合生存学 – グローバル・リーダーのために』、京都大学学術出版会、2015年7月).

share of renewable energy looks also the costliest but the higher costs come mostly from the large capital investments that have to be made. The higher capital investment costs may be partly compensated by lower marginal costs (due to the absence of fuel costs). However, the comparison by cost of different scenarios is complicated because of many "unknowns".[2]

The German case may offer some ideas about how to offset the higher costs of the renewables-based scenario like for instance, using cheaper imported electricity thanks to interconnections with neighboring countries or ensuring that a large majority of the population benefit from the energy transition as small decentralized producers of electricity. But it was unclear from Dr. Matthes' lecture whether the German experience could be applied to other countries as well.

Readers may learn in more detail about the energy transition in Germany from the article of Dr. Matthes that is included in this special issue.

3 Summary of the three plenary sessions

Session 1: "Economic aspects of the global energy transformation"
Moderator: Prof. Yuichi Ikeda, GSAIS, Kyoto University
Speakers: Dr. John Constable, Renewable Energy Foundation, UK, and Prof. Keigo Akimoto, Research Institute of Innovative Technology for the Earth, Japan

In the first presentation Dr. Constable focused on the failures of the energy transition in the UK. From the UK experience we have learned that government subsidies to renewable sources of energy could have certain side effects such as the costly capacity mechanism. For instance, the balancing service use of system costs has increased for the last fifteen years and subsidy cost for CO_2 abatement is still high, i.e., the cost per ton CO_2 ranges from a few hundreds to a thousand US dollars, although electricity generation from renewable energy is increasing and the price of electricity from renewable sources is decreasing. Consequently, the UK government has recently announced a reorientation of its energy and climate policy from the previous renewables-centered policy. Dr. Constable emphasized the need for research and development towards a low carbon transition with tolerable costs.

Prof. Akimoto's presentation discussed the global emission pathways after COP 21 using an economic cost analysis. Most countries submitted their nationally determined contributions (NDCs) before the Paris Agreement towards a post-2020 international framework for tackling climate change. It is highly desirable to have good indicators to evaluate emission reduction efforts on the NDCs. However, Prof. Akimoto showed that no silver bullet indicator was available and that each indicator had pros and cons based on his energy system analysis. The CO_2 marginal abatement costs varied widely across nations, and the required emission reduction efforts also varied widely depending on the chosen indicator. Another point which Prof. Akimoto stressed was "Mission Innovation". That is, doubling government

[2] For instance, it's very hard to predict reliably future storage costs, as well as future carbon prices.

expenditure towards research and development in the field of clean energy. The expected results are innovations in hydrogen and battery technologies that could induce significant changes in the energy system, as well as increases in the share of clean energy with an affordable price.

As a result of the following discussion we concluded that different opinions on the economics of low carbon transitions are attributable to the difference in the indicators used to evaluate emission reduction efforts. In addition, we agreed on the importance of research and development in clean energy technologies such as hydrogen and battery systems.

Readers may learn in more details about the economic aspects of the global energy transformation from the articles of Dr. Constable (with co-author) and Prof. Akimoto (with co-authors) that are included in this special issue.

Session 2: "Environmental aspects of the global energy transformation"
Moderator: Prof. Yosuke Yamashiki, GSAIS, Kyoto University
Speakers: Prof. Brian Vad Mathiesen, Aalborg University, Denmark, and Mr. Yutaka Kamioka, CEO of Satoyama Energy, Inc., Japan

This session focused on the development of renewable energy in the context of the energy transformations in Denmark and Japan. First, Prof. Brian Vad Mathiesen talked about the need to move to a smart energy system where the focus is not so much on the electricity sector but more on heating and transportation. According to him, this strategy for the energy transition is more cost effective, and the goal of having 100% renewable energy in 2050 completely feasible.

The smart energy system is defined as an approach where smart electricity, thermal and gas grids are combined and coordinated to identify synergies between them in order to achieve an optimal solution for each individual sector, as well as for the overall energy system. This includes: smart electricity grids that are more suitable to the integration of intermittent renewable energy sources such as wind and the sun; smart thermal grids (district heating and cooling) to connect the electricity and heating sectors, enabling thermal storage to be utilized for creating additional flexibility and heat losses in the energy system to be recycled; and smart gas grids to connect the electricity, heating, and transportation sectors, enabling gas storage to be utilized for creating additional flexibility (if the gas is refined to a liquid fuel, then liquid fuel storages can also be utilized). At the end of his presentation, Prof. Mathiesen explained briefly about an energy planning tool that can be used to compare various energy transition trajectories while taking into account technological change and the synergies between the electricity, heating and transportation sectors.

The second presentation was given by Mr. Yutaka Kamioka and addressed the development of off-grid renewable energy in Japan. He focused mainly on how the change in the energy system can be encouraged by public involvement inspired by promotion events organized together with the music industry. Mr. Kamioka also talked about his personal activities to introduce off-grid renewable energy through organizing various social events. In addition to the Crying Solar Bear ("SOLABEA") PV systems, the NGO led by Mr. Kamioka initiated the distribution of a small off-grid solar power plants (40 W solar panel with a lithium-ion battery) named "Nano-solar". The latter had a remarkable success, and has been introduced even outside Japan in countries like Kenya. Finally, to find the best way to reform the Japanese energy system, he stressed the need to promote further collaboration between the industrial sector and the academia.

During the discussion, the session chair, Prof. Yamashiki, commented on the costs of electricity generation from large-scale hydropower, thermal power, and nuclear power. Each of them has different environmental impacts, and the proposed solutions are not sufficient to deal with those impacts. In addition, there were questions from the audience to Prof. Mathiesen about how Denmark was different from other European countries and whether those differences could explain the success of the Danish energy transition. Furthermore, Mr. Kamioka replied to questions about the barriers to promoting sustainable energy in Japan.

Session 3: "The role of innovation in the global energy transformation"
Moderator: Prof. Eiichi Yamaguchi, GSAIS, Kyoto University
Speakers: Dr. Lerwen Liu, CEO of NanoGlobe Pte, Ltd., Singapore, and Dr. Ryo Tamaki, CTO of Connexx Systems Corp., USA

The session started with Dr. Lerwen Liu's presentation about how to integrate the three dimensions of innovation, among which she emphasized the importance of social system design innovation. Next, Dr. Ryo Tamaki talked about a technological breakthrough called "shuttle battery", based on the use of Fe particles as an energy source. After the two invited speeches, we had a panel discussion on the following three issues.

1. How to stabilize the power grid by introducing energy storage?
2. How to decrease transmission losses by using the so-called "More-than-Moore" technology?
3. How to eliminate hazardous waste from materials for solar cells?

3.1 Innovation in energy storage systems for the power grid

Dr. Tamaki's shuttle battery consists of SOFC (Solid Oxide Fuel Cell) and iron powder in the reactor. In the shuttle battery, water reacts with iron to produce hydrogen. Generated hydrogen is reacted with oxygen to generate the electric current, continuing cycle until all of the iron is used up. Here, the amount of energy is determined by the amount of iron in the reactor and not by hydrogen volume unlike the conventional SOFC. In other words, hydrogen just functions as an oxygen carrier. Furthermore, this reaction is reversible, so that you can reconvert the iron oxide to the pure iron powder by charging the electricity at midnight.

There is a similar technology invented by Professor Hirao from Kyoto University. He invented a different hydrogen generator by using Ca. Namely, CaH_2 plus water makes chemical reaction to produce hydrogen and Ca-hydroxide. Then, if you add Al into the Ca-hydroxide, you will produce hydrogen and Ca–Al-hydroxide. Finally, you can decompose the Ca–Al-hydroxide by using microwave to make mayenite. He claims that the mayenite can be converted to CaH2, so that this is completely reversible.

Let's compare battery performance. The most advanced Li-ion battery has 500 Wh/L of energy density. This value is about 1/20 of gasoline. Dr. Tamaki's shuttle battery has 7700 Wh/L of energy density, whereas Prof. Hirao's battery has about 3000 Wh/L. Although the latter's energy density is lower than that of the shuttle battery, its specific energy will be higher compared with the former. These two hydrogen batteries could be promising future technologies for the power grid.

3.2 Innovation in power transistors to decrease transmission losses

To make high performance power transistors with higher breakdown voltages, we'd better use semiconductors with higher bandgap, and currently we have two candidates for "More-than-Moore" power semiconductors, namely GaN and SiC. Since the on-resistance must be the lowest to decrease transmission loss of electricity, we can readily judge that GaN is the best material for power transistors. Actually, if you replace the current Si power transistors to GaN power transistors, the power loss will be decreased by more than 80%.

A Japanese venture company is overcoming the cost barrier by inventing a new device principle, PSJ (Polarization Super Junction) for GaN power transistors by utilizing the co-existence of two-dimensional quantum electrons and hole. If successful, that would mean the emergence of a new paradigm for electricity transmission and distribution.

Regarding to the cost, GaN PSJ transistors are almost the best and comparable to Si-MOSFET. Regarding to the speed, GaN-PSJ is comparable to the highest GaN/Si. Regarding to the breakdown voltage, GaN-PSJ is almost equal to SiC. Overall, we can conclude that GaN-PSJ transistors are the best option.

3.3 Negative aspects of innovation in solar cell materials

All semiconductors can be materials for solar cells by making p-n junction diodes, as they absorb light with higher energy than the bandgap. Therefore, to absorb all the visible light, the best bandgap for solar cells is 1.2 eV. Consequently, CdTe should be the best for solar cell materials. Since the cost of making CdTe is tremendously low, an American venture company founded by young scientists started their business only with CdTe and finally succeeded in growing their business quite rapidly.

However, as they are making their CdTe panels in Malaysia, it is possible that they might cause *Itai-itai disease* (cadmium poisoning) due to the presence of Cd. Moreover, as the panel will be broken after some time and disposed of, Cd can generate hazardous waste at the disposal stage.

4 Summary of the panel discussion

Moderator: Prof. Dimiter Ialnazov, GSAIS, Kyoto University

Panelists: Dr. Felix Matthes and the speakers at the three plenary sessions

The moderator, Prof. Ialnazov, asked all panelists to share their views on the following four questions: (1) What did you learn, or wish you could have learned from the other sessions at the symposium? (2) What is your vision of the future energy system? (3) What can Japan learn from the cases of Germany, Denmark, and UK? (4) Do you think that human survivability studies (HSS) can be a useful framework to analyze global energy problems? The following points are also the main conclusions from the panel discussion.

4.1 What did you learn, or wish you could have learned from the other sessions at the symposium?

Although the focus of Session 3 was on technological innovation, we should not forget that technological innovation is only one of the factors that could bring success to the global energy transformation. In reality, we also need a number of social innovations that include various innovative solutions in system design (for example, market design, business models, etc.), as well as the integration of various innovative solutions. To a certain extent, social innovations can help in solving the problem of high costs of renewable energy that was pointed out in Session 1. In addition, cost reduction could come from the learning effects, as a great deal of the costs in the first part of the steep learning curve has already been shouldered by Germany and other countries at the forefront of the energy transition.

4.2 What is your vision of the future energy system?

As for the future energy system, the panelists agreed that it would be more capital intensive and would include a larger share of renewable energy than the present although there were different views on what should be the optimal energy mix. The latter will vary across countries and will also depend on national and regional contexts. It is impossible to propose uniform solutions as the future energy system in a country or a region should suit that country's/region's conditions. Opinions were divided on the question as to whether a larger share of renewable energy in the overall energy mix would be/would not be more expensive.

4.3 What can Japan learn from the cases of Germany, Denmark, and UK?

Obviously, Japan can learn from the cases of Germany, Denmark, and UK by carefully studying the reasons for success or failure in the policy-induced efforts to expand the share of renewable sources of energy. Actually, the feed-in-tariff (FIT) system introduced in 2012 in Japan was based on the German experience, and while the FIT has worked well in Germany, we cannot say the same thing from the Japanese experience. Therefore, we also need to understand better as to how exactly the country's specificity or the national context could influence the success or failure of energy transitions.

Furthermore, the panelists suggested that learning should be done in both directions, e.g., other countries can learn a great deal from Japan's history of improvements in energy efficiency or from the Japanese skills of energy saving and conservation (*sho-ene*, *mottainai,* etc.). As Japan has relatively scarce conventional energy resources, it has always been forced to innovate in the energy sector. Japan should also be more active in the dissemination of advanced knowledge and technology worldwide to make a bigger impact on the global energy transformation.

4.4 Do you think that human survivability studies (HSS) can be a useful framework to analyze global energy problems?

Finally, all panelists were quite positive in their evaluation of human survivability studies (HSS). According to them, HSS can make a great contribution to the global energy transformation if the scholars and graduate students from engineering, natural and social sciences manage to combine “hard” knowledge about technologies or materials with the “soft” side of how people are actually going to use those and what effects will those technologies or materials have on human society. According to some panelists, what may be lacking in HSS is the entrepreneurship dimension. After doing the analysis and making proposals for innovative solutions, the next natural step would be to try to implement some of those solutions, that is, to try to make a real impact on society.

In spite of the fact that some complex questions largely remained unanswered, the Fourth International Symposium on Human Survivability achieved most of its goals, namely, highlighting the relevant results achieved by the scientific community in the field of the global energy transformation, exploring new ideas for innovative solutions, and in providing a fruitful opportunity for dialogue and exchange of ideas towards policy-relevant knowledge.