STUDY ON SUSTAINABLE ENERGY MANAGEMENT SYSTEM IN ILC, PART-II

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Abstract

This paper is part 2 of the paper submitted to the 2020 Annual Meeting of the Particle Accelerator Society of Japan. The previous paper summarized and introduced the basic concept of Green ILC activities in the Tohoku region and specific activities in line with this concept. Since then, both domestic and international policies have been announced with the specific goal of achieving carbon neutrality by 2050. Naturally, Green ILC activities must also be based on these targets in accordance with this policy. Our activities have been organized into the following three categories. (1) Promotion of energy-saving technologies. (2) Increasing the ratio of renewable energy in cooperation with local communities and improving energy management technologies such as waste heat energy recovery. (3) Additional efforts to enhance absorption of global warming gases derived from ILC operations in cooperation with local communities. In order to achieve this goal, it is important to operate our agriculture, forestry, and fisheries industries in a smarter way, and the construction and long-term operation of the ILC must serve these goals. This paper will report in detail on item (3) in particular.

INTRODUCTION

A major change that has occurred in the two years since the presentation of Part 1 of this paper [1] at the 2020 Annual Meeting of the Particle Accelerator Society of Japan (Hereafter referred to as PASJ) is that the goal of achieving carbon neutrality by 2050 has been clearly stated both worldwide and also in Japan. Assuming that the ILC will be operational in the late 2030s, that is only a decade or so before the above goal. Therefore, it is essential to proceed with ILC construction based on the 2050 carbon neutrality target. For this purpose, it is necessary to show numerical targets, i.e., visualization of CO_2 emission and absorption.

The starting point for activities related to Green ILC is to know how much CO_2 would be emitted through operation of the ILC facility. For this purpose, it is necessary to know the conversion factor of how much CO_2 is emitted according to the amount of electricity used by operating the ILC. The local power companies publish the conversion coefficients every year. The preliminary value for FY2021 announced by Tohoku Electric Power Company is 0.482 kg-CO_2/kWh [2]. Assuming ILC peak power of 120 megawatts and annual power use of 700 million kWh (depending on operating hours), the annual CO_2 emissions from the ILC would be 337 kilotons. The basis for calculating the conversion coefficient between electricity consumption and CO_2 emissions is composited from the types of power generation facilities. The coefficient becomes smaller as the ratio of renewable energy improves. The details of this are also shown in the reference [2]. The path to a realization of a carbon-neutral ILC can be briefly summarized as reducing emissions by 337 kilotons and increasing CO_2 absorption, which can be summarized as below.

(1) Promote the development of energy-saving technologies and return the benefits of these technologies to society. Further development of superconducting accelerating cavities and improving the power efficiency of klystrons are examples.

(2) Efforts to increase the ratio of renewable energy and development of waste heat energy recovery technology.

However, it is difficult to reduce CO_2 emissions to zero by these two efforts alone. In addition, the following third effort is needed:

(3) We inevitably need a mechanism to absorb CO_2.

Of the three efforts summarized above, (1) would be an internal effort of the ILC itself. However, (2) and (3) cannot be achieved without cooperation with the local community. Therefore, Green ILC activities must be closely coordinated with local communities. Then, who will increase CO_2 absorption? It would be the primary industry of agriculture, forestry, and fisheries. Among these industries, forests would be the trump card for increasing CO_2 absorption.

CO_2 EMISSION

CO_2 emissions by industry type for each basic municipality are estimated by the Ministry of the Environment and published on its website [3]. Since the proposed ILC site is in Ichinoseki City (hereafter referred to as IC), Iwate Prefecture, we checked the data for IC from [3]. It is 871 kilotons in FY 2018. We encourage all participants in this conference to check the actual situation in the area where their facility is located. As mentioned in the previous section, the annual CO_2 emissions from the ILC in operation

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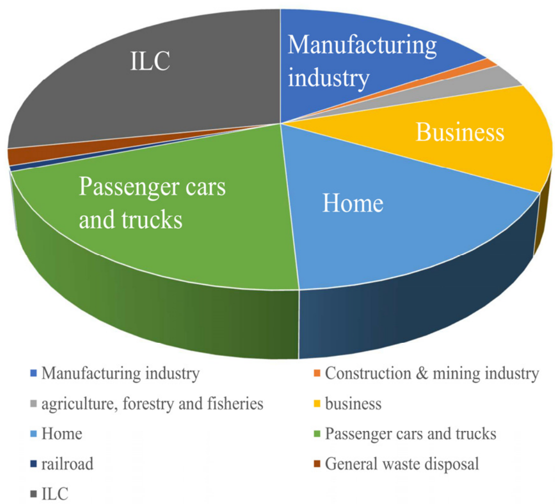

Figure 1: CO_2 emissions from the ILC added to the IC data for FY 2018.

would be 337 kilotons. Figure 1 shows the CO_2 emissions from the ILC added to the IC data for FY 2018.

Adding the emissions from ILC to the 2018 IC data, the total CO_2 emissions are 1,210 kilotons, in which ILC's contribution amounts to 27.9%.

CO_2 ABSORPTION BY FORESTS AND REALIZATION OF A CARBON-FREE SOCIETY TRIGGERED BY THE ILC

Estimations by the Forest Utilization Division, Forest Development Department, Forestry Agency

Each tree in a forest absorbs CO_2 from the atmosphere through photosynthesis, and grows by storing carbon while generating oxygen. The Forest Utilization Division of the Forest Development Department of the Forestry Agency has estimated the amount of CO_2 absorption by forests, which is summarized below [4]. The amount of CO_2 absorbed and stored by each tree is different, so to simplify the discussion, we will limit this summary to cedar forests. It is estimated that a properly managed 36–40-year-old cedar planted forest fixes approximately 302 tons of CO_2 /ha. Such artificial cedar forests are estimated to absorb about 8.8 tons/year/ha of CO_2. Since the ILC emits 337 kilotons of CO_2/year, 38,000 hectares of such managed artificial cedar forests would be needed to absorb this amount. Trees absorb the most CO_2 when they are growing. Therefore, forests must be properly maintained. At the same time, this will lead to proper management of the forest industry.

CO_2 Absorption Analysis by IC Forests

We first analyse forests in the IC: the total forest area in the IC is 66291 hectares, of which planted forests account for 31392 hectares, or 47.4 %. Most natural forests are hardwoods, with a small amount of red pine. The species composition of planted forests is shown in Fig. 2.

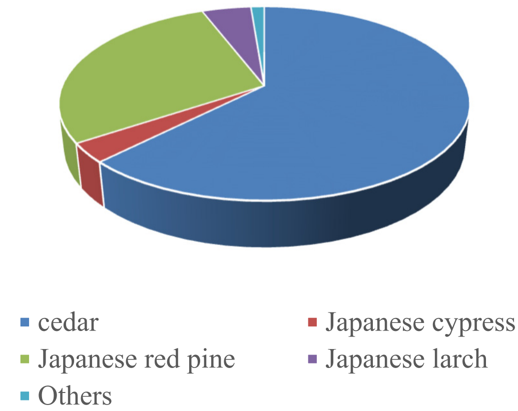

Figure 2: Composition of planted forests in IC by species. Cedar is the most abundant, followed by red pine. These two species make up most planted forests.

Based on the forest management status in the IC, H. Kikuchi, advisor to the Agriculture and Forestry Division of the IC, estimated the annual sequestration of CO_2, considering tree species, age, and forest management status [5]. The result is an annual CO_2 sequestration of 303.53 kilotons. Dividing this by the total forest area of the IC yields an average absorption rate of 4.58 tons/year/ha. This value is only 52% of the calculation by the Forestry Agency mentioned above. This means that there is much room for improvement. This absorption is also less than the amount of CO_2 released by the ILC and is only 25% of the total CO_2 emissions of the IC when the ILC is in operation.

So far, we have clarified the figures for CO_2 emissions and absorption in the IC. Based on these visualized figures, we must now consider how to reduce the amount of CO_2 emitted and increase the amount of CO_2 absorbed.

We propose to explore a path to achieve carbon neutrality with a clear numerical target.

Collaboration between ILC and the Community to Achieve Carbon Neutrality

There are two central challenges with the Green ILC activities in cooperation with the local forest industry based on the premise of achieving carbon neutrality by 2050. (1) To increase the amount of wood used in the construction of ILC-related facilities such as laboratories, offices, etc. as much as possible. (2) To increase the use of wood as much as possible in the town planning process triggered by the ILC as shown in Fig. 3. A further generalization would be to increase affinity with the local forest industry in ILC-related town planning.

For item (1), we have already compared the construction of a laboratory with a floor area of 6,000 m^2 in a mixed wood/RC structure with a steel/RC structure in joint research between private industry and Iwate University and the results were reported at the PASJ conference in 2018 [6]. In this case, we considered the use of locally sourced lumber (red pine produced in northern Iwate), with

Figure3: Community-driven town planning triggered by the construction of the ILC.

sawmilling and construction carried out by a local company. It was found that there were no technical problems at all in constructing such a large experimental hall with a mixed wood/RC structure. In the case of the steel frame, the only option is to procure material from outside the prefecture. A comparison of construction costs showed that a mixed wood/RC structure was slightly more advantageous than a steel frame/RC structure. In addition, the economic ripple effect and the amount of induced employment are much more favourable for the wood/RC mixed structure. It is important not only to evaluate the economic ripple effects of the project, which was done in 2018, but also to look at it from the perspective of the balance between CO_2 emission and absorption. The volume of red pine logs used in this estimation is 3.8 km^3. According to data from the Iwate Prefecture Ministry of Agriculture, Forestry, and Fisheries [7], conifer log production in the prefecture is 1,238 km^3, so the volume of logs used in this estimation is equivalent to 0.3% of the total production in the prefecture. That's how effective it is in expanding the use of red pine. On the other hand, when steel frames are used, CO_2 emissions must be taken into account not only during steel production, but also during import of raw materials from overseas and transportation within Japan. In other words, increasing the use of wood and reducing the use of steel frames has a dual effect in terms of reducing CO_2 emissions.

The basic policy regarding item (2) is summarized as follows. The ILC is Japan's first large-scale international research institute. Referring to the case of CERN, we estimate that the number of ILC-related researchers, engineers, business people, and their families will eventually increase to several thousand. The number of people will vary for each phase of the ILC design, construction, and operation. In addition, the number of spin-off companies are expected to continue to increase, so the population surrounding the ILC facility is expected to grow even more from several thousand people. Town planning to accommodate these people coming from other countries and staying for long or short periods of time is an important challenge. It should be considered that one of the characteristics of the area surrounding the ILC is that it is a vast region blessed with various types of excellent natural environments. Moreover, it is equipped with infrastructure such as highways, public roads, Shinkansen trains, and airports. In order to take advantage of the diverse hobbies and interests of foreign residents and the unique environment described above, we propose a decentralized town planning approach. An example is shown in the figure above.

The first step is to make one community unit the size of 200-300 houses. Also, ILC-related people and local residents will be able to live together. It must respond to the region's declining birthrate and aging population. All houses will be constructed of wood, with high airtightness and thermal insulation, and an energy centre will be set up in one location to distribute hot and chilled water to each house. The heat source of the energy centre will be designed to take advantage of local resources, such as biomass, solar power, and hot springs. A design code should be established for the residential design to achieve a lush greenery unified streetscape. All building materials will be locally sourced, and local companies will be employed for design, construction, and maintenance. Assuming a wood usage of 25 m^3 in an average wooden house (120 m^2), the total usage for 300 houses would be 7.5 km^3. Assuming that logs required would be twice that of sawn lumber, the total amount of logs would be 15 km^3, which is four times that of the large laboratory described in the previous section.

The communication environment will incorporate the latest technology to meet the "Digital Rural City National Concept" which is the basic policy of the Japanese government aimed at bridging the urban-rural divide through digital technology [8].

GLOBAL PERSPECTIVES

According to a recent book by Bill Gates, total global warming gas emissions are 51 billion tons/year [9]. The breakdown in order of emissions is as follows: manufacturing, including cement and steel production (31%), electricity (27%), agriculture and livestock (19%), transportation and traffic (16%), and heating and cooling (7%). On the other hand, according to data compiled by the Japan International Research Center for Agricultural Science based on data from the Food and Agriculture Organization of the United Nations, the total area of forests in the world in 2020 will be 4.06 billion hectares, which is decreasing every year [10]. Of course, there are many other mechanisms besides forests, such as the oceans, land, and other effect, that can be used to absorb global warming gas from a global perspective. These must be studied by experts from various fields. However, from a local perspective, as discussed above, the authors believe that it is important to develop a healthy forestry industry and make efforts to achieve carbon neutrality in each region as much as possible.

SUMMARY

There is no doubt that anthropogenic global warming is progressing rapidly beyond the natural cycles of the past due to the sun's activity cycle and the cyclic variation of tilt of the earth's orbit and axis of rotation. We believe that the simultaneous loss of the Arctic and Antarctic ice sheets is extremely serious, and that the world's goal of achieving carbon neutrality by 2050 is a reasonable and urgent decision. In this case, it is necessary to consider both global and local perspectives as discussed above.

We propose that the goal from a local perspective should be to achieve a balance between CO_2 emissions and absorption in each region. Such considerations should be especially relevant when building large power load facilities such as the ILC. As noted above, such efforts will not produce results for the ILC alone. Collaboration with the community is essential. In order to achieve this goal, it is important to make efforts with clear numerical targets.

ACKNOWLEDGMENT

In completing this manuscript, we have benefited from the cooperation of many companies, organizations, and individuals. We are cooperating with the Project Promotion Subcommittee of the Advanced Accelerator Association Promoting Science & Technology, AAA in town planning. In the forest industry, we received a lot of information from Iwate Prefecture's Niwa Lumber, Shibata Sangyo, Maruhi Lumber, and Yamagata Prefecture's Shelter. Mr. Hiroshi Kikuchi of Ichinoseki City's Agriculture and Forestry Division provided detailed information on the city's forest resources and the difficult task of estimating CO_2 fixation and absorption. Mr. Norihiro Kodama of Hachimantai Smart Farm, Inc. gave an information on high-density automated basil cultivation using hot spring exhaust heat. Finally, we received information through study sessions with the following many municipalities: Ichinohe Town, Iwate Town, Hachimantai City, Hanamaki City, Kitakami City, Nishiwaga Town, and Ichinoseki City.

The authors would like to express their deepest gratitude to all of them.

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