Development of a Japanese Input-Output Table for Renewable Energy and Smart Grid Systems

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1. Introduction

The Institute for Economic Analysis of Next-generation Science and Technology of Waseda University made a research agreement with The National Institute of Science and Technology Policy (NISTEP) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) aiming at analyzing the economic, social, environmental effects of next-generation technology.

As an initial step, we studied the effect of the spread of power generation using renewable energy and smart grid systems including Building Energy Management System (BEMS), Home Energy Management System (HEMS), Electric Vehicle (EV), Combined Heat and Power (CHP), and Storage Batteries. After the Great East Japan Earthquake, Japanese attention is paid to construction of an energy system that is not only sustainable but also resilient. Introduction of renewable energy is indispensable to construction of such energy system. Furthermore introduction of a smart grid system is indispensable to exploitation of renewable energy. These are our research motives.

2. The method

The existing Japanese Input-Output Table doesn't include renewable energy or smart grid activities. Therefore our first step was to construct a new Input-Output Table for the analysis of renewable energy and smart grid systems. In addition to the existing classifications, the activities shown in Table 1 were added to the original table. The estimation method for each activity is shown in the following section.

In December, 2011, the Energy and Environment Council established in the National Policy Unit under the administration of the Democratic Party set renewable energy introduction targets for 2030. Table2 shows the targets under the assumption of 25% dependence on nuclear power generation. Using the new Input-Output table, we next calculated the direct and indirect effects of construction and operation of renewable

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energy plants and smart grid equipment. Smart grid equipment can be used in various effective ways, and such usage is discussed in section 5.

Table1 New activities added to the new table

Power generation of renewable energy

Photovoltaics	Home use
	Large-scale solar power systems
Wind power generation	Land-based wind power generation
	Offshore wind power generation
Hydro-electric power generation	Efficient use of existing dams
	Subordinate power generation using agricultural-use water
Geothermal energy	Large-scale power systems
	Hot spring binary power systems
Biomass energy	Unused woody biomass
	Methane fermentation gasification power generation
	Generating heat from waste materials
	Generating electricity from waste materials
Energy Management Information Services	

Construction of equipment

Construction of photovoltaics equipment	Home use
	Large-scale solar power systems
Construction of Wind power generation equipment	Land-based wind power generation
	Offshore wind power generation
Construction of Hydro-electric power generation equipment	Efficient use of existing dams
	Subordinate power generation using agricultural-use water
Construction of Geothermal energy equipment	Large-scale power systems
	Hot spring binary power systems
Construction of Biomass energy equipment	Unused woody biomass
	Methane fermentation gasification power generation
	Generating heat from waste materials
	Generating electricity from waste materials
Construction of smart grid equipment	Building Energy Management System (BEMS) equipment
	Home Energy Management System (HEMS) equipment
	Electric-power distribution equipment (SVC, SVR, steel towers, power lines, electric substation equipment, etc.)
	Electric vehicles
	Storage batteries
	Heat pump water heaters
	Combined heat and power

Table2 Renewable energy introduction targets for 2030

	25% of the dependence on nuclear power generation		2010 track-record value	
	GW	TWh	GW	TWh
Photovoltaics	53.40	56.2	3.62	3.8
Home use	40.00	42.1	2.88	3
Large-scale solar power system	13.40	14.1	0.74	0.8
Wind power generation	17.60	33.3	2.44	4.3
Land wind power generation	14.73	25.8	2.41	4.2
Offshore wind power generation	2.87	7.5	0.03	0.1
Hydro-electric power generation	23.78	109.5	21.64	80.9
Large-scale Hydro-electric power generation	11.78	46.4	11.18	44.1
Subordinate power generation by water for agricultural use	12.00	63.1	10.46	36.8
Geothermal energy	2.40	16.8	0.53	2.6
Large-scale power system	1.89	13.2	0.53	2.6
Hot spring binary	0.51	3.6	0.00	0
Biomass energy□	5.52	32.8	2.40	14.4

Source: Energy and Environmental Council

3. Estimation methods for each activity[3]

3.1. Division of power equipment construction activity

In the existing Japanese Input-Output table, there is a section for power plant construction which includes construction of power generation plants and equipment for distributing electricity. We divided that activity into the two elements using accounting reports from electric power companies.

3.2 Photovoltaic (PV) Power Generation

We assumed the existence of two kinds of PV power generation: PV systems for residential use and mega solar power plants. We defined PV power facility construction activities using the following procedure. First of all, the construction cost of the assumed model system and plant was calculated. The generating capacity (kW) and construction cost per kW is based on the findings of the Procurement Price Calculation Committee (FY2012). According to the reference material, generating capacities of the model system and power plant are 4kW and 2,000kW, respectively. In addition, the findings assumed that construction cost per kW for the residential system and power plant are 466 thousand JPY and 340 thousand JPY respectively. Second, the total construction cost is divided into components such as PV modules, power conditioners (or inverters), balance of system (BOS), and construction. The construction cost portion was determined using reports of field tests conducted by New Energy and Industrial Technology Development Organization (NEDO), and the subsidies introduced by the Ministry of Economy, Trade and Industry (METI) (Table3) to reduce the initial costs of

[3] For details, see Nakano and Washizu (2013a,b)

building residential PV systems. In particular, the PV module is subdivided into primary intermediate inputs by using the life cycle inventory (LCI) data from a report by Mizuho Information & Research Institute (commissioned by NEDO), unit price data from the Input-Output Table 2005 by the Ministry of Internal Affairs and Communications (MIC), the Yearbook of Machinery Statistics by METI, and trade statistics by the Ministry of Finance (MOF). The secondary intermediate inputs and gross value added of the PV module activity was estimated using information from the other electronic component activities in the Input-Output Table. Construction was also subdivided into intermediate inputs and gross value added using the information on electricity power facility construction activities from the Input-Output Table. Finally, we made each component correspond with the sector classification of the Input-Output Table.

Operation estimates for PV power facilities were based on a report by the Power Cost Verification Committee and the Procurement Price Calculation Committee (FY2012). According to the report, mega solar plant operations require 3 million JPY for personnel expenses, 1.0% and 0.6% of total construction costs for repair and other costs, and 14.0% of the direct cost for administrative expenses. The operation of the PV system for residential use only needs 1.0% of total construction cost for repairs.

Table3 Cost share of the PV power facility construction (Unit: %, producer's price)

		Residential	Mega solar
PV module		58.6	38.9
Inverter		8.8	6.8
Array rack	Panel rack	3.1	3.9
	H-steel	0.7	0.9
	Junction box	1.3	1.6
Cubicle		1.0	1.3
Measuring instrument	Measuring instrument	0.3	0.4
	Uninterruptible power supply	0.0	0.0
Display		0.2	0.2
Transformer		–	1.9
Power transmission line		–	1.8
Construction		14.6	33.3
Trade margin and freight	Wholesale trade	10.0	7.9
	Retail trade	0.2	0.3
	Railway transport	0.0	0.0
	Road freight transport	0.9	0.7
	Coastal and inland water transport	0.0	0.0
	Harbor transport service	0.1	0.1
	Domestic air transport	0.0	0.0
	Consigned freight forwarding	0.0	0.0
	Storage facility service	0.1	0.1

Sources: NEDO field test report, data from METI subsidy to reduce initial cost for residential PV systems, and the Input-Output Table 2005 by MIC

3.3. Wind power generation

Wind power generation plants can be installed either on land or offshore. According to the report by the Power Cost Verification Committee, land-based wind farms should be on a scale of 20 MW, and off-shore plants should be 150MW. Furthermore, using the unit construction cost detailed in the report, total construction cost will reach 5.5 billion yen for land sites and 73.7 billion yen for offshore sites.

Using a report by the Japan Wind Power Association (JWPA) (see table4), we divided the total costs into the cost of the windmills, electric facilities, installation work, transportation, etc. Using the information from power generation construction explained in section3.1, each cost was divided into an individual sector.

Windmills are classified into two types: geared and gearless. Using the publication "Wind Directions" (Jan/Feb, 2007) (see table5), the cost of the windmill was divided into individual parts, each of which is related to an individual sector.

Finally, we prepared four wind-power-generation equipment construction activities: geared systems on land, gearless systems on land, geared systems offshore, and gearless systems offshore. Each activity is estimated as input per kilowatt generating capacity.

Normal operational activities on wind farms are described in the report by the Power Cost Verification Committee: 1.4% of total construction cost is needed for personnel expenses and repair, 14.0% for administrative expenses, and 0.6% for other expenses. Each of these costs was divided into an individual sector using the average composition of power generation activity on the existing Input-Output table. Operational activities per generating capacity (kW) were calculated for land-based and offshore wind farms.

Table4 Cost composition of wind farm (purchaser's price)

Land-based Wind Farm		Offshore Wind Farm	
windmill	58.4%	windmill	43.7%
electric facilities	6.0%	electric facilities	10.68%
installation of electric facilities	8.4%	installation of electric facilities	7.12%
transportation of windmill	3.4%	transportation	5.2%
installation of windmill	4.7%	installation	7.3%
groundwork	13.5%	groundwork	21.8%
research cost	1.5%	research cost	3.1%
design cost	1.3%		
test run adjustment	1.4%	others	1.1%
others	1.4%		
	100.0%		100.0%

Source: report by the Japan Wind Power Association (JWPA)

Table5 Cost breakdown for windmills (purchaser's price)

	with gear	without gear
Tower	29.44%	26.03%
Rotor blades	24.85%	21.98%
Rotor hub	1.53%	1.36%
Rotor bearings	1.37%	1.21%
Main shaft	2.14%	1.89%
Main frame	3.13%	2.77%
Gearbox	14.45%	0.00%
Generator	3.85%	16.18%
Yaw system	1.40%	1.24%
Pitch system	2.98%	2.63%
Power converter	5.61%	16.53%
Transformer	4.02%	3.55%
Brake system	1.48%	1.31%
Nacelle housing	1.51%	1.34%
Cables	1.07%	0.95%
Screws	1.16%	1.03%
Total	100.00%	100.00%

Source: the European Wind Energy Association "Wind Directions, Jan/Feb, 2007"

3.4. Hydropower generation

Our estimates assume that large-scale hydropower generation facilities would be expanded and new small-scale facilities established. We defined hydropower facility construction activities using the following procedure. First, the construction costs of the assumed model system and plant were calculated. The generating capacity (kW) and construction cost per kW were based on the water cycle committee report by the Japan Project-Industry Council (JAPIC (2008)), the findings of the Procurement Price Calculation Committee (FY2012), the construction cost integration guide by the Agency for Natural Resources and Energy and the New Energy Foundation (ANRE and NEF (2013)), and "Study on Water-power Resources for Power Generation by Unutilized Head" by the NEF (2009). According to those references and reports, the generating capacity of large-scale facilities is 3.69GW (1.71GW from expansion and 1.98GW coming from reviewing operations) and capacity for small- scale facilities is 200kW. The reports presumed construction cost per kW for large-scale and small-scale facilities to be 1.63 million JPY (2.55 million JPY for expansion and 0.82 million JPY for review of operation) and 1.00 million JPY, respectively. Second, the total construction cost is divided into components. The construction cost portion (Tables 6 and 7) was determined using JAPIC (2008), ANRE and NEF (2013), NEF (2009) and Asakura (2013). Construction was subdivided into intermediate inputs and gross value added using the information on electricity power facility construction activities from the Input-Output

Table. Finally, we set each component to correspond with the sector classification used in the Input-Output Table.

Operation estimates for hydropower facilities were based on a report by the Power Cost Verification Committee. According to the report, 20 million JPY is required for personnel expenses in large-scale facility operations, and 0.5% of total construction cost is required for repair costs and 0.2% for other costs. 14.3% of the direct cost would be used for administrative expenses. A small-scale facility would require 7 million JPY for personnel expenses. 1.0% of total construction cost would go to repairs and 2.0% to other costs, and 14.0% of the direct cost would be used for administrative expenses.

Table 6 Cost share of large-scale hydropower facility expansion (As percentage of purchaser's price)

			Share
Land acquisition			3.68
Building construction			0.04
Civil engineering	Extension of dam	Concrete	18.26
		Steel	6.09
		Construction	36.52
	Boring	Concrete	0.02
		Steel	0.02
		Construction	0.17
	Penstock	Concrete	0.01
		Steel	0.01
		Construction	0.06
	Other construction work		3.06
	Equipments		1.94
Electrical insulation work	Waterwheels		0.35
	Generators		0.35
Others			29.43

Source: JAPIC (2008)

Table 7 Cost share of small-scale (<200kW, irrigation) hydropower facility construction (As percentage of purchaser's price)

			Share
Power plant construction			21.2
Waterway and reservoir construction			24.2
Mechanical devices	Foundation work	Excavation	3.9
		Concrete	5.4
		Reinforcement	1.4
		Others	2.1
	Other work		3.7
Electrical facility work	Waterwheels		8.3
	Generators		2.0
	Others	Electric motors	0.1
		Transformers and reactors	0.9
		Relay switches and switchboards	14.0
		Wiring devices and supplies	1.4
		Other electrical devices and parts	1.1
		Electric measuring instruments	1.3
	Installation work		7.3
Transmission line			1.8

Sources: ANRE and NEF (2013), NEF (2009) and Asakura (2013)

3.5. Geothermal power generation

Two types of geothermal power generation were considered: single flash and small binary. Geothermal power facility construction activities were defined using the following procedure. First, the construction cost of the assumed model system and plant was calculated. The generating capacity (in kW) and construction cost per kW were based on the findings of the Procurement Price Calculation Committee (FY2012), the "Study of Potential for the Introduction of Renewable Energy" conducted by the Ministry of the Environment (MOE (2011)), and the "Project to Support Innovative New Energy Technology Ventures" by NEDO. According to the references and reports, generating capacity of the single flash type is 30MW and capacity of the small binary type is 50kW. The reports assumed that construction cost per kW for the single flash type and small binary type are 932 thousand JPY (92 thousand JPY for geothermal-resource survey, 790 thousand JPY for construction, and 50 thousand JPY for transmission lines) and 621 thousand JPY, respectively. Second, the total construction cost is divided into components. The construction cost portion (Tables 8 and 9) was determined using MOE (2011), Hienuki and Hondo (2013), Adachi (2011), Asakura (2013) and NEDO project reports.. In particular, construction was subdivided into intermediate inputs and gross value added using the information on electricity power facility construction activities from the Input-Output Table. Finally, we set each component to correspond with the sector classification used in the Input-Output Table.

Operation estimates for geothermal power facilities were based on a report by the Power Cost Verification Committee. According to the report, 120 million JPY is required for personnel expenses in single flash type operations. 2.2% of total construction costs would be required for repair, 0.8% for other costs, and 16.1% of the direct cost would be required for administrative expenses. According to MOE (2011), 8.1 million JPY would be required for personnel expenses in small binary type operations, while 3.0% of total construction cost would be required for repair and 0.46% for other costs.

Table 8 Cost share of 30MW flash type geothermal power facility construction (As percentage of purchaser's price)

		Share
○Geothermal-resource survey		
Small-diameter		3.6
Production well		3.9
Injection well		1.7
Resource survey service		0.7
○Construction		
Excavation	Production well	14.3
	Injection well	7.9
Land	Land acquisition	2.8
	Land preparation	0.9
	Foundation work	0.4
Road between bases	For production well	2.0
	For injection well	1.3
Transport pipe	For production well	18.7
	For injection well	3.2
Power generation facility	Power plant building construction	1.3
	Foundation work	5.7
	Cooling towers	5.4
	Raw water tank	0.6
	Turbines	4.4
	Generators	1.9
	Condensers	2.8
	Transformers and measuring instruments	5.7
	Auxiliary facilities	5.6
○Transmission line		5.4

Sources: MOE (2011), Hienuki and Hondo (2013), Adachi (2011), and the findings of the Procurement Price Calculation Committee (FY2012)

Table 9 Cost share of 50kW small binary type geothermal power facility construction (As percentage of purchaser's price)

		Share
Power generation facility	Design	2.6
	Equipments	62.3
	Installation work	22.1
	Others	1.5
Transmission line		6.4
Hot water pipe		5.2

Sources: MOE (2011) and the Project to Support Innovative New Energy Technology Ventures by NEDO

3.6. Biomass energy

Two sources of fuel for generating biomass power generation were considered: gas from methane fermentation and unutilized woody biomass. We defined biomass power facility construction activities using the following procedure. First, the construction costs of the assumed model systems and plants were calculated. Generating capacity in kW and construction cost per kW are based on the findings of the Procurement Price Calculation Committee (FY2012) and interviews with people engaged in biomass power generation. According to the reference materials, generating capacity of unutilized woody biomass is 5,700kW.[4] The reports assumed that construction cost per kW is 3.92 million JPY for methane fermentation gas and 479 thousand JPY (410 thousand JPY for power generation facility and 69 thousand JPY for pretreatment and drying facility) for unutilized woody biomass. Second, the total construction cost is divided into components. The construction cost portion (Tables 10 and 11) was determined based on interview content and the Ministry of Land, Infrastructure and Transport (MLIT) report, "Input-Output Table 2005 for the Analysis of Construction Sectors. Construction was subdivided into intermediate inputs and gross value added using the information on electricity power facility construction activities from the Input-Output Table. Finally, we made each component correspond with the sector classification used in the Input-Output Table.

Operation estimates for biomass power facilities were based on a report by the Power Cost Verification Committee and the Procurement Price Calculation Committee (FY2012). According to the report, 60 million JPY would be required for personnel expenses for biomass power operations using unutilized woody biomass, and 3.98% of total construction costs would go to repair and other costs.

[4] We made no assumptions regarding size of power plants using methane fermentation gas.

Table 10 Input coefficients of methane fermentation biomass power facility construction (As percentage of purchaser's price)

	Cefficient
Construction materials	0.06528
Power generation equipments	0.09792
Materials for plant construction (except the above)	0.13056
Others	0.18813
Gross value added	0.51812

Source: Input-Output Table 2005 for the Analysis of Construction Sectors (MLIT), and interviews with people engaged in biomass power generation

Table 11 Cost share of construction of pre-treatment facilities and power generation facilities using unutilized woody biomass (As percentage of purchaser's price)

		Share
○Pretreatment and drying facilities construction		
Metal containers, fabricated plate and sheet metal		0.45
Other metal products, n.e.c.		0.23
Conveyors		3.13
Pumps and compressors		0.11
Other general industrial machinery and equipment		1.96
Chemical machinery		0.32
Sawmill, wood working, veneer and plywood machinery		1.88
Electric measuring instruments		1.46
Construction		5.76
○Electric power facility construction		
Power generation facility	Boilers	19.18
	Turbines	10.59
	Conveyors	1.40
	Chemical machinery	4.23
	Electric measuring instruments	4.62
	Installation work	24.20
Building construction	Administration building	2.46
	Stockyard	4.51
	Others	6.84
Electric construction	Electric wires and cables	1.15
	Metal products for construction	0.54
	Transformers and reactors	0.63
	Relay switches and switchboards	1.85
	Construction	2.52

Source: Interviews with people engaged in biomass power generation

3.7. Smart grid activities

Visualization of electricity usage and automatic control of air-conditioning and lighting through sensor control system can save the electricity consumption of a building or a home, without sacrificing resident comfort. This electricity saving becomes possible using BEMS in buildings and HEMS in homes. Furthermore BEMS and HEMS can ease various variation factors. When those are used as a system for demand response, they can ease variation in electricity demand, which can help stabilize the electricity supply system. When they are used with electric vehicles or heat pump water heaters, they can ease the power variation of renewable energy source such as photovoltaic cells. To use electricity generated by renewable energy sources effectively, it is necessary to install energy management systems.

The Kitakyushu Smart Community Project is actively promoting the installation of BEMS and HEMS equipment. In our study, the BEMS/HEMS configuration refers to that project. BEMS/HEMS installation activities for buildings and homes were added to our new Input-Output table.

4. Effect of constructing renewable energy equipment

As the previous section explained, we prepared construction activities for renewable-energy electricity plants. Before making a new Input-Output table including those activities, we calculated the direct and indirect effects of constructing each plant using the Input-Output Table 2005 and Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables (3EID) by National Institute for Environmental Studies.

Tables 12 and 13 show our results by the open Input-Output model. Tables 12-1 to 12-3 show the effect of power plant construction to reach 2030 target capacity. Tables 13-1 and 13-2 show the specific effects per construction capacity of 1kW. Those implications are as follows.

1. Wind power generation and geothermal energy have large induced effects. The reduction of plant construction costs through economies of scale will increase those effects.
2. A large part of the construction cost of PV power generation originates in the production of photovoltaic cells. Therefore, it is important to reduce production cost of cells.
3. As for small hydro-electric and biomass energy power generation, the induced effect of plant constructions is not as large, but that energy must be utilized in micro-grid systems in villages. For that purpose, local industries integrated into the micro-grid system must be developed. As a result, the induced effect of the operation of generation plant will increase.
4. Large hydro-electric power generation through efficient use of existing dams will

have a high construction cost, but that system can be utilized electrical power conditioning. Because other power conditioning equipment such as batteries are very expensive, effective use of this type system will reduce the cost of the grid-system as a whole.

Table12-1 Direct effect (construction cost) of generation capacity of the 2030 targets

	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)
	polycrystalline silicon cell				thin-film silicon solar cell			
Photovoltaics	21,602,320	1,170,017	307,516,893	5,127,821	21,602,320	1,170,017	181,805,509	5,127,821
Home use	17,297,920	721,898	223,245,429	3,258,193	17,297,920	721,898	129,504,839	3,258,193
Large-scale solar power system	4,304,400	448,119	84,271,464	1,869,628	4,304,400	448,119	52,300,670	1,869,628
Wind power generation	5,091,860	426,729	38,748,264	2,885,696				
Land-based wind power generation	3,696,000	304,716	26,743,812	1,982,567				
Offshore wind power generation	1,395,860	122,013	12,004,452	903,129				
Hydro-electric power generation	7,380,520	785,208	123,373,211	12,093,559				
Large-scale water-power generation	5,840,520	644,652	103,080,613	9,893,568				
Subordinate power generation using water for agricultural use	1,540,000	140,557	20,292,598	2,199,992				
Geothermal energy	1,548,610	129,727	17,403,106	1,437,276				
Large-scale power system	1,231,971	109,565	15,254,318	1,279,898				
Hot spring binary	316,639	20,162	2,148,787	157,379				
Biomass energy	3,654,178	372,054	48,581,355	3,976,827				
Methane fermentation gasification power generation	2,446,080	281,008	37,763,746	3,148,358				
Unused woody biomass	1,208,098	91,045	10,817,609	828,469				
Total	39,277,487	2,883,736	535,622,829	25,521,179	39,277,487	2,883,736	409,911,445	25,521,179

Table12-2 Direct and indirect effect (induced effect from the construction) of the generation capacity of the 2030 targets

	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)
	polycrystalline silicon cell				thin-film silicon solar cell			
Photovoltaics	39,124,960	1,990,857	1,063,632,913	62,696,752	42,192,085	2,089,742	1,028,016,522	69,885,933
Home use	31,546,155	1,395,205	824,483,545	48,372,332	34,178,144	1,480,061	808,056,080	54,541,577
Large-scale solar power system	7,578,805	595,652	239,149,368	14,324,420	8,013,941	609,681	219,960,442	15,344,356
Wind power generation	9,206,205	605,774	205,713,760	16,564,742				
Land-based wind power generation	6,755,757	437,432	151,862,178	12,248,301				
Offshore wind power generation	2,450,448	168,342	53,851,581	4,316,441				
Hydro-electric power generation	11,300,720	970,136	294,528,625	30,264,826				
Large-scale water-power generation	8,743,099	783,730	231,666,144	23,826,513				
Subordinate power generation using water for agricultural use	2,557,622	186,405	62,862,481	6,438,313				
Geothermal energy	2,738,039	178,450	71,255,524	6,051,970				
Large-scale power system	2,147,460	147,354	59,016,289	5,108,751				
Hot spring binary	590,579	31,096	12,239,235	943,219				
Biomass energy	5,709,513	466,495	124,970,599	10,517,063				
Methane fermentation gasification power generation	3,544,148	331,924	80,902,266	6,957,563				
Unused woody biomass	2,165,365	134,571	44,068,332	3,559,499				
Total	68,079,437	4,211,711	1,760,101,420	126,095,352	71,146,562	4,310,596	1,724,485,029	133,284,533

Table12-3 Multiplier (direct effect / direct and indirect effect)

2030	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)
	polycrystalline silicon cell				thin-film silicon solar cell			
Photovoltaics	1.8111	1.7016	3.4588	12.2268	1.9531	1.7861	5.6545	13.6288
Home use	1.8237	1.9327	3.6932	14.8464	1.9759	2.0502	6.2396	16.7398
Large-scale solar power system	1.7607	1.3292	2.8378	7.6616	1.8618	1.3605	4.2057	8.2072
Wind power generation	1.8080	1.4196	5.3090	5.7403				
Land-based wind power generation	1.8279	1.4355	5.6784	6.1780				
Offshore wind power generation	1.7555	1.3797	4.4860	4.7794				
Hydro-electric power generation	1.5312	1.2355	2.3873	2.5026				
Large-scale water-power generation	1.4970	1.2157	2.2474	2.4083				
Subordinate power generation using water for agricultural use	1.6608	1.3262	3.0978	2.9265				
Geothermal energy	1.7681	1.3756	4.0944	4.2107				
Large-scale power system	1.7431	1.3449	3.8688	3.9915				
Hot spring binary	1.8651	1.5423	5.6959	5.9933				
Biomass energy	1.5625	1.2538	2.5724	2.6446				
Methane fermentation gasification power generation	1.4489	1.1812	2.1423	2.2099				
Unused woody biomass	1.7924	1.4781	4.0738	4.2965				
Total	1.7333	1.4605	3.2861	4.9408	1.8114	1.4948	4.2070	5.2225

Calculated from Tables12-1 & 2

Table13-1 Direct effect (construction cost) of 1kW generation capacity

	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)
	polycrystalline silicon cell				thin-film silicon solar cell			
Photovoltaics								
Home use	0.4660	0.0194	6.0142	0.0878	0.4660	0.0194	3.4888	0.0878
Large-scale solar power system	0.3400	0.0354	6.6565	0.1477	0.3400	0.0354	4.1312	0.1477
Wind power generation								
Land-based wind power generation	0.3000	0.0247	2.1708	0.1609				
Offshore wind power generation	0.4915	0.0430	4.2269	0.3180				
Hydro-electric power generation								
Large-scale water-power generation	1.5830	0.1747	27.9389	2.6815				
Subordinate power generation by water for agricultural	1.0000	0.0913	13.1770	1.4286				
Geothermal energy								
Large-scale power system	0.9059	0.0806	11.2164	0.9411				
Hot spring binary	0.6209	0.0395	4.2133	0.3086				
Biomass energy(per generation capacity of 1 kW)								
Methane fermentation gasification power generation	3.9200	0.4503	60.5188	5.0454				
Unused woody biomass	0.4840	0.0365	4.3340	0.3319				

Table13-2 Direct and indirect effect (induced effect from construction) of 1kW generation capacity

	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)	Induced production (million yen)	Induced employment (# of people)	Induced energy (GJ)	CO_2 (t-CO_2)
	polycrystalline silicon cell				thin-film silicon solar cell			
Photovoltaics								
Home use	0.8498	0.0376	22.2113	1.3031	0.9207	0.0399	21.7688	1.4693
Large-scale solar power system	0.5986	0.0470	18.8902	1.1315	0.6330	0.0482	17.3744	1.2120
Wind power generation								
Land-based wind power generation	0.5484	0.0355	12.3265	0.9942				
Offshore wind power generation	0.8628	0.0593	18.9618	1.5199				
Hydro-electric power generation								
Large-scale water-power generation	2.3697	0.2124	62.7907	6.4579				
Subordinate power generation by water for agricultural	1.6608	0.1210	40.8198	4.1807				
Geothermal energy								
Large-scale power system	1.5790	0.1083	43.3943	3.7564				
Hot spring binary	1.1580	0.0610	23.9985	1.8494				
Biomass energy(per generation capacity of 1 kW)								
Methane fermentation gasification power generation	5.6797	0.5319	129.6511	11.1499				
Unused woody biomass	0.8675	0.0539	17.6556	1.4261				

5. On future simulation analysis

Using the activities related to renewable energy and smart-grid systems discussed in section 3, we will make a new Input-Output table including the new activities shown in Table1. Using that table and taking the implications considered in section 4 into account, we will conduct simulation analysis to verify the following points:

(1) Without output control, renewable energy can be used more effectively through the introduction of suitable smart grid systems (HEMS or BEMS), hydro-electric power generation, and installation of excess storage batteries.

(2) A wind power generation system must be accompanied by effective electric power system infrastructure capable of transmitting electricity from regions with lower electricity demands more suited to wind power generation, to metropolitan areas with higher electricity demand.

(3) A micro grid system of farming and fishing villages can utilize small-scale hydro-electric power generation and biomass energy appropriately, and can minimize dependence on system electric power.

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