Scenarios for Resolving the Disaster-related Energy Supply Shortages

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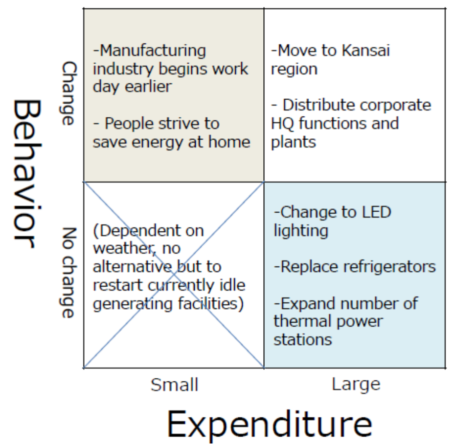
JST Center for Low Carbon Society Strategy

The Center for Low Carbon Society Strategy (LCS) proposes technological and societal scenarios, based on the creation of a low carbon society, to support the reconstruction of the disaster-struck Tohoku region and to avoid power supply shortages caused by power station shutdowns.

In this paper, we study ways to balance power supply and demand, focusing mainly on reducing power shortages in Tohoku and Kanto regions, through scenarios based on the introduction of distributed power sources, mainly using renewable energy, and on power conservation by the household sector.



As power conservation policies, in Fig. 1(2) we show four possible solutions, divided according to how much behavioral change and expenditure will be required. We focused on daily living, which has the greatest potential for power conservation, and especially on the two solutions shown in the lower right and upper left of the diagram.

As a stopgap measure for the summer of 2011, this paper offers a scenario based on a combination of energy conservation and the introduction of distributed generation aimed at allowing society to continue functioning with minimal power interruptions. To achieve this, it will be necessary to ask for the cooperation of all consumers, individuals, industry and business, in the areas served by Tohoku and Tokyo Electric Power Companies. The measures we propose for residential and business consumers (shifting times of use, buying new appliances, energy conservation) should not place an undue burden on daily life, but they do absolutely depend on participation by all residents and corporations. In fact, the power shortages facing us this summer are very serious and in addition to the residential and business sectors, it will also be necessary to press forward with energy conservation measures in industry. It is vital that all sectors be aware of the actions that must be implemented.

[1] *Partially revised on 7 April 2011. Partially revised and business sector evaluation added 12 April. 18 April revision*

corrects misprints.

[2] This was originally created as a 3D matrix with a time axis indicating short, medium and long term requirements, but it is displayed in 2D here for ease of readability. Each quadrant should also be considered in terms of time.

Main Points

- The target of the study is consumers supplied by Tohoku and Tokyo Electric Power Companies.[3]
- We assess three periods: this summer's peak electricity demand (around July 2011), the winter peak (around Feb. 2012) and next summer's peak (around July 2012).
- We plot supplementary power supplies from solar power, wind power, small and medium sized generators and fuel cells. To calculate the total amounts that can be used, we assumed the technically feasible supplies from the surveyed scale of annual production.
- Energy conservation in the residential and business sectors. For the residential sector, we studied three measures: replacing electrical appliances and devices with higher efficiency models, shifting the time of using these appliances, and other electricity saving measures. For the business sector, we studied equipment replacement, halving usage during peak periods and electricity saving with regard to lighting, equipment powered from room outlets (computers etc.), and air conditioning, and electricity saving measures.[4]
- The calculations in this study show that, for the summer period, energy conservation measures by the residential and business sectors could save a maximum of 26 GW[5]. This becomes 22 GW for the case where costs are reduced without equipment replacement, and 13 GW for the case not requiring lifestyle changes (changing times of usage, etc.).
- We find that in order to compensate for power supply shortages, energy conservation will be required by both residential and business sectors in addition to the maximum possible introduction of distributed generation. Even the greatest possible energy conservation by the residential sector through replacing appliances, shifting time of use and electricity saving will not make up the shortfall, but this can be accomplished if the business sector also replaces equipment and shifts time of use. For example, for the 2011 summer period, we find that power shortages could be eliminated using the maximum energy conservation case for both residential and business sectors, or a medium case involving minimized cost for both residential and business sectors, or maximum electricity conservation by business. On the other hand, the minimum energy conservation case results in a shortage of 10 GW. In this case, either the industrial sector would have to cut its power consumption by half or there would be a need for planned blackouts. In view of this, and the negative effects on economic activity, it is clearly necessary to educate both the residential and business sectors in the need for energy

conservation.

- By maintaining a steady rate of distribution and supply, The effect of distributed generation by summer 2011 will be slight, providing just 0.3 GW, but this will rise to 1.3 GW by winter 2012 and 2 GW by summer 2012. That leaves a power shortage of 1.7 GW for winter and 7 GW for summer. On the other hand, if measures taken by both the residential and business sectors can eliminate the shortage, this will leave us with a potential power surplus. In practice, this means that the surplus can eliminate the use of generators with high fuel costs. As this trend toward increased renewable energy supply continues, when the power supply system is fully restored there will be a surplus of generating capacity which can be used to aid reconstruction efforts, for example by supplying power free of charge to industries in the disaster-stricken regions.

[3] *The Tohoku and Tokyo Electric Power Companies in practice flexibly share their generated power so it is necessary to consider their combined total. To show the outcomes more clearly, we have also provided separate totals for each company for the 2011 summer period.*

[4] *For details, see the Reference Section at the end of the paper. Some minor changes in lifestyle will be required, but we do not assume any major changes in the types of devices used. For example, we do not consider changing the type of fuel used, such as replacing electrically powered air-conditioner heaters with gas or oil fueled heaters.*

[5] *GW = Million kW*

Preliminary Scenario Calculations

1. Forecast Power Supply and Demand

Tables 1 and 2 summarize the forecast power supply and demand. Assuming that power supplies are not fully restored by this summer and peak demand is close to that of previous years, there will be a power shortfall of 14 GW. The winter peak will be smaller, but full supply will still not be restored and shortages will continue.

Table 1 Forecast Power System Supply

	July 2011	Feb. 2012	July 2012	
Tohoku Electric	11			GW
Tokyo Electric	50			GW
	61	**64**	**66**	**GW**

(Note) For summer 2011, these figures were compiled by LCS from values announced by Tokyo Electric to the media on March 13, 2011, and from separate announcements by Tohoku Electric. Figures from 2012 are LCS projections.

Table 2 Forecast Demand (Based on past records, assuming no planned blackouts or energy conservation)				
	July 2011	Feb. 2012	July 2012	
Tohoku Electric	15			GW
Tokyo Electric	60			GW
	75	**67**	**75**	**GW**

2. Power Supply from Distributed Generation

Power supply from distributed generation was calculated as annual production totals for the various technologies employed: solar power, wind power, small/medium generators, fuel cells. A time converted operating rate of 20% was used for wind power and solar power (daytime). The total of 0.3 GW by this summer should rise to 2 GW by summer 2012.

Table 3 Forecast Supply from Distributed Generation				
	July 2011	Feb. 2012	July 2012	
Solar power	160 (800)	640 (3,200)	960 (4,800)	MW ※
Wind power	25 (125)	100 (500)	150 (750)	MW ※
Power generators (2kVA)	35	140	210	MW
Power generators (50kVA)	109	437	656	MW
Fuel cells	3	10	15	MW
Total	**0.3**	**1.3**	**2.0**	**GW**

* Figures in ( ) show plant capacity

3. Power Shortages

Table 4 shows the power shortfall between demand and total supply from power systems and distributed generation. This is the amount that will have to be compensated for by demand side energy conservation.

Table 4 Power Supply Shortfall in Various Cases				
	July 2011	Feb. 2012	July 2012	
Case 1: No new distributed generation	14.0 (Tohoku 4.0 Tokyo10.0)	3.0	9.0	GW
Case 2: Small/medium generators only	13.9 (Tohoku 4.0	2.4	8.1	GW

	Tokyo9.9)			
Case 3: With solar, wind and fuel cells	**13.7** (Tohoku 3.9 Tokyo9.7)	**1.7**	**7.0**	**GW**

4. Residential Sector Energy Conservation

In Table 5, we show seven scenarios for the 23.2 million households in the areas supplied by Tohoku and Tokyo Electric Power Companies. The scenarios combine three categories of energy conservation measures (replace appliances, shift time of use, and other power saving) and total savings are calculated for the summer and winter periods. For more details, see Reference 1 at the end of this paper. The maximum savings, implementing all three measures, amount to 8 GW in summer and 20 GW in winter.

Table 5 Summer/Winter Scenarios for Residential Sector Utilizing Appliance Replacement, Time-of-use Shifting, and Power Saving

		Scenario H-1	Scenario H-2	Scenario H-3	Scenario H-4	Scenario H-5	Scenario H-6	Scenario H-7
Energy conservation measures applied	Replace appliances	Yes	No	No	Yes	Yes	Yes	Yes
	Shift time of use	No	Air-conditioning, heating, cooking only	Yes	Air-conditioning, heating, cooking only	Yes	Other than air-conditioning, heating, cooking	No
	Other power saving	No	No	No	No	Yes	Yes	Yes
Conservation in summer period (GW)		**3**	**4**	**6**	**6**	**8**	**5**	**3**
Tohoku Electric		0.5	1	1	1	1	1	1
Tokyo Electric		2	3	5	5	7	4	2
Conservation in winter period (GW)		**3**	**11**	**18**	**14**	**20**	**10**	**5**
Tohoku Electric		1	2	3	3	4	2	1
Tokyo Electric		3	9	15	12	16	8	4

Table 6 shows power shortfalls for various energy conservation scenarios in the residential sector. All scenarios produce a power supply surplus for the winter period, meaning that generators would not be required during peak periods. Residential sector energy conservation will not make up for shortfalls in the summer 2011 period, so measures will be required in other sectors also.

However, by 2012, appliance replacement and some shift in times of use should result in power supply surpluses.

Table 6 Power Supply Shortfalls after Residential Sector Energy Conservation (units: GW)

	Scenario H-1	Scenario H-2	Scenario H-3	Scenario H-4	Scenario H-5	Scenario H-6	Scenario H-7
July 2011	11	10	7	8	6	8	11
Tohoku Electric	3	3	3	3	2	3	3
Tokyo Electric	8	7	4	5	3	5	7
Feb. 2012	-2	-10	-16	-13	-18	-9	-4
July 2012	4	3	1	2	-1	2	4

* Negative values in green indicate surplus supply

5. Business Sector Energy Conservation

Business sector energy conservation measures include:

- Replace fluorescent lighting with LED and halve use during peak hours.
- Halve use of devices powered from electric outlets during peak hours, turn off standby power or use energy saving mode.
- Switch off air-conditioning during peak hours and set cooling/heating to energy saving mode.

For details, see Reference 2 at the end of this paper. Results are shown in Table 7.

Table 7 Summer/Winter Scenarios for Business Sector Utilizing Equipment Replacement, Time-of-use Shifting, and Power Saving

Scenario		Scenario O-1	Scenario O-2	Scenario O-3	Scenario O-4	Scenario O-5	Scenario O-6	Scenario O-7
	Replace lighting	Yes	No	No	Yes	No	Yes	Yes
	Shift time of use	No	Yes	No	No	Yes	Yes	Yes
	Turn off standby power, energy conservation	No	No	Yes	Yes	Yes	No	Yes
	Percentage saved	24%	59%	5%	29%	61%	71%	72%
Summer	Total (GW)	6	15	1	7	15	18	18
	Tohoku Electric	1	3	0.3	1	3	4	4
	Tokyo Electric	5	12	1	6	12	14	14
Winter	Total (GW)	5	13	1	6	14	16	16
	Tohoku Electric	1	3	0.3	1	3	4	4
	Tokyo Electric	4	10	1	5	11	12	13

In the maximum scenario, where all measures are applied, we calculate a maximum reduction in demand of 18 GW in summer and 16 GW in winter. Table 8 shows power supply shortfalls in various scenarios. In summer 2011, power shortages can be avoided through scenarios based on: lighting replacement plus time-of-use shift, and time-of-use shift plus electricity savings. After winter 2012, consistent implementation of either lighting replacement or time-of-use shift will result in power supply surpluses. Turning off standby power or using energy saving mode alone will not prevent power supply shortfalls.

Table 8 Power Supply Shortfalls after Business Sector Energy Conservation (units: GW)

	Scenario O-1	Scenario O-2	Scenario O-3	Scenario O-4	Scenario O-5	Scenario O-6	Scenario O-7
July 2011	8	-1	12	6	-1	-4	-4
Tohoku Electric	3	1	4	2	1	0.4	0.3
Tokyo Electric	5	-2	9	4	-2	-4	-5
Feb. 2012	-4	-11	0.5	-5	-12	-14	-14
July 2012	1	-8	6	-0.2	-8	-11	-11

* Negative values in green indicate surplus supply

6. Conclusion

Table 9 shows the amount of energy conservation possible and the shortfall after implementation of maximum, minimum and intermediate cases combining the residential and business sector energy conservation scenarios outlined in sections 4 and 5.

Four intermediate cases are presented:

- Minimize lifestyle changes: Wherever practicable, no time-of-use shift
- Minimize cost: No replacement of appliances
- Maximize residential conservation: Maximum energy conservation by households, minimum scenario selected for business sector
- Maximize business conservation: Maximum energy conservation by businesses, minimum scenario selected for residential sector

Power supply shortages can be avoided for summer 2011 with the maximum case, the minimum cost intermediate case and the maximize business conservation intermediate case. The minimum case would result in a 10 GW shortfall, and this would require the industrial sector to cut its power consumption by 40%. Considering the negative effects on economic activity, it is necessary for both the residential and business sectors to engage in energy conservation.

Table 9 Power Supply Shortfalls after Residential and Business Sector Energy Conservation (units: GW)

Cases	Maximum case	Minimum case	Intermediate case: Minimize lifestyle changes	Intermediate case: Minimize cost	Intermediate case: Maximize residential conservation	Intermediate case: Maximize business conservation
Residential sector scenario	H-5 Replace appliances, time-of-use shift, energy conservation	H-1 Replace appliances	H-6 Replace appliances, time-of-use shift except for air-conditioning & cooking, electricity savings	H-3 Time-of-use shift	H-5 Replace appliances, time-of-use shift, energy conservation	H-1 Replace appliances
Business sector scenario	O-7 Replace appliances, time-of-use shift, turn off standby power, electricity savings	O-3 Turn off standby power, energy conservation	O-4 Replace appliances, turn off standby power, electricity savings	O-5 Time-of-use shift, turn off standby power, electricity savings	O-3 Turn off standby power, energy conservation	O-7 Replace appliances, time-of-use shift, turn off standby power, electricity savings
Summer total	26	4	13	22	9	21
Winter total	36	5	18	31	21	20
July 2011	-12	10	1	-8	4	-7
Tohoku Electric	-1	2	2	-0.3	2	-0.1
Tokyo Electric	-11	7	-0.4	-8	2	-7
Feb. 2012	-35	-3	-15	-30	-20	-18
July 2012	-19	3	-6	-15	-2	-14

* Negative values in green indicate surplus supply

＜Reference 1＞

This table gives details of the various appliances and equipment used in our energy conservation calculations, and indicates which are involved in each scenario.

- 23.2 million households are affected, 4.23 million served by Tohoku Electric Company and 18.97 million by Tokyo Electric Company.
- Summer daily peak demand is from about 2pm to 3pm, winter peaks are around 9am and 6pm.
- Energy conservation values are set based on manufacturer's values and on the ECCJ Energy Conservation Dictionary.
- Energy conservation per household was calculated by LCS by multiplying the energy conservation per device by occupancy, utilization and possession (or diffusion) rates.

Reference Table 1 Results of Energy Conservation from Residential Sector Electrical Appliances (Midday peak)

		Energy conservation (W/device)	Energy conservation (W/household)	Scenario						
				1	2	3	4	5	6	7
Lighting	Off during peak hrs. (incandescent)	54	16			○		○	○	
	Off during peak hrs. (fluorescent)	12	2			○		○	○	
	Replace incandescent with LED	48	14	○			○			○
	Replace fluorescent with LED	6	1	○			○			○
Air-conditioning	Off during peak hrs. (cooling)	480	112		○	○	○	○		
	Temp. set 1°C higher	50	12						○	○
	Replace with more efficient unit	280	25	○					○	○
TV	Off during peak hrs. (CRT)	87	7			○		○	○	
	Off during peak hrs. (LCD)	49	3			○		○	○	
	Off during peak hrs. (plasma)	204	9			○		○	○	
Personal computer	Off during peak hrs. (desktop)	70	5			○		○	○	
Refrigerator	Replace with more	55	69	○			○	○	○	○

	efficient unit									
Microwave oven	Off during peak hrs.	1000	3		○	○	○	○		
Electric rice cooker	Off during peak hrs.	1400	4		○	○	○	○		
Hot water dispenser	Off during peak hrs.	1000	15		○	○	○	○		
IH stove	Off during peak hrs.	3000	5		○	○	○	○		
Dishwasher/dryer	Off during peak hrs.	1200	14		○	○	○	○		
Heated washlet-type toilet seat	Off during peak hrs.	500	20			○		○	○	
Washing machine	Off during peak hrs.	300	27			○		○	○	
Washing machine/dryer	Off during peak hrs.	800	22			○		○	○	
Vacuum cleaner	Off during peak hrs.	1000	15			○		○	○	
Dryer	Off during peak hrs.	1000	1			○		○	○	

Reference Table 2 Results of Energy Conservation from Residential Sector Electrical Appliances (Morning/evening peaks)

		Energy conservation (W/device)	Energy conservation (W/household)	Scenario						
				1	2	3	4	5	6	7
Lighting	Off during am/pm peak hrs. (incandescent)	54	54			○		○	○	
	Off during am/pm peak hrs. (fluorescent)	12	6			○		○	○	
	Replace incandescent with LED	48	48	○			○			○
	Replace fluorescent with LED	6	3	○			○			○
Air-conditioning	Off during peak hrs. (heating)	500	195		○	○	○	○		
	Temp. set 1°C lower	90	35						○	○
	効率のよい機器へ買い替え	280	25	○					○	○
Electric carpet	Off during peak hrs.	600	98		○	○	○	○		
	Change setting from "strong" to "medium"	100	16						○	○
Kotatsu (quilt-covered table with electric heater)	Off during peak hrs.	600	75		○	○	○	○		
	Change setting from "strong" to "medium"	130	16					○	○	○
	Use more futons (quilt coverings and rugs)	90	11					○	○	○
TV	Off during peak hrs. (CRT)	87	12			○		○	○	
	Off during peak hrs. (LCD)	49	5			○		○	○	
	Off during peak hrs. (plasma)	204	14			○		○	○	
Personal computer	Off during peak hrs. (desktop)	70	8			○		○	○	
Refrigerator	Replace with more efficient unit	55	69	○			○	○	○	○
Microwave oven	Off during am/pm peak hrs.	1000	10		○	○	○	○		
Electric rice cooker	Off during am/pm peak hrs.	1400	63		○	○	○	○		
Hot water dispenser	Off during peak hrs.	1000	15		○	○	○	○		
IH stove	Off during am/pm peak hrs.	3000	15		○	○	○	○		
Dishwasher/dryer	Off during peak hrs.	1200	24		○	○	○	○		
Heated washlet-type toilet seat	Off during peak hrs.	500	20			○		○	○	
Washing machine	Off during peak hrs.	300	89			○		○	○	
Washing machine/dryer	Off during peak hrs.	800	36			○		○	○	

Vacuum cleaner	Off during peak hrs.	1000	25			○		○	○	
Dryer	Off during am/pm peak hrs.	1000	5			○		○	○	

＜Reference 2＞

For the business sector, we do not have data such as equipment usage rate per unit area or office, so we were unable to make the kind of calculations we made for the residential sector. Instead, we used the following method.

- We assumed that the residential sector, business sector, and industrial sector each use one third of the peak power supply.
- From ECCJ data, we can consider business sector energy consumption to be 40% lighting, 30% devices powered from electric outlets and 30% air-conditioning. We will assume that the heat source for air-conditioning is 50% electricity and 50% other fuel in setting our ratios for business sector electrical power consumption.
- We set the possible energy savings for each of these categories, and multiply by the power utilization ratio to derive the percentage reduction in electrical power consumption for each type of equipment.
- We set seven scenarios for different combinations of the three categories: lighting replacement, time-of-use shift (half use, switch off) and electricity saving.

Reference Table 3 Business Sector Reduction in Electrical Power Consumption by Application

	Utilization ratio of energy consumption	Conservation measures	Possible energy savings	Business sector proportional reductions in power consumption
Lighting	47%	Replace fluorescent with LED	50%※	24%
		Switch off half during peak hrs.	50%	24%
Devices powered from electric outlets	35%	Switch off half during peak hrs.	50%	18%
		Turn off standby power, use energy saving mode	10%	4%
Air conditioning	18%	Switch off during peak hrs.	100%	18%
		Set air-conditioner (heating/cooling) to energy saving mode	10%	2%

* In practice, we expect there to also be savings from replacement of halogen bulbs with LEDs, but the data is unclear so we have conservatively set this figure as 50%.