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Assessment of Distributed Energy Adoption in Commercial Buildings

Part 1: An Analysis of Policy, Building loads, Tariff Design, and Technology Development

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【論文】

Assessment of Distributed Energy Adoption in Commercial Buildings

Part 1　An Analysis of Policy, Building loads, Tariff Design, and Technology Development

Nan ZHOU[1], Masaru NISHIDA[2], Weijun GAO[3] , and Chris Marnay[2]

業務用建物における分散型エネルギーに関する評価研究

その１　政策、建物の負荷、エネルギーコスト及び技術情報に関する考察

周　　南[*1]　西田　勝[*2]　高　偉俊[*3]　 Chris Marnay [*1]

Abstract

Rapidly growing electricity demand brings into question the ability of traditional grids to expand correspondingly while providing reliable service. An alternative path is the wider application of distributed energy resource (DER) that apply combined heat and power (CHP). It can potentially shave peak loads and satiate its growing thirst for electricity demand, improve overall energy efficiency, and lower carbon and other pollutant emissions. This research investigates a method of choosing economically optimal DER, expanding on prior studies at the Berkeley Lab using the DER design optimization program, the Distributed Energy Resources Customer Adoption Model (DER-CAM). DER-CAM finds the optimal combination of installed equipment from available DER technologies, given prevailing utility tariffs, site electrical and thermal loads, and a menu of available equipment. It provides a global optimization, albeit idealized, that shows how the site energy loads can be served at minimum cost by selection and operation of on-site generation, heat recovery, and cooling. Utility electricity and gas tariffs are key factors determining the economic benefit of a CHP installation, however often be neglected. This paper describes preliminary analysis on CHP investment climate in the U.S. and Japan. DER technologies, energy prices, and incentive measures has been investigated.

Keywords: distributed energy resources, combined heat and power, building energy efficiency, tariff, building loads,

1.　Introduction

Energy consumption in Japan has been following a consistent rising trend, except for periods during the two oil crises. From 1990 to 2000 energy consumption by the residential/commercial sector increased 26.4%, reflecting changes in lifestyle and desire for comfort (METI, 2004; ANRE, 2004). In Japan, which depends on imports for most of its primary energy supply, on-site distributed energy systems, including combined heat and power (CHP) systems and renewables, such as photovoltaics and wind turbines have grown more important and is widely expected to spread to increase the efficiency of energy consumption and to address global environmental problems. Additional benefit may be gained from distributed systems through clusters of DER and loads in the same geographic area.

The Ministry of Economy, Trade and Industry (METI) is laying down a new Long-Term Energy Supply and Demand Outlook to 2030 and an interim report was released in June 2004. The Japanese government suggests more decentralized energy systems, and the new outlook includes a distributed generation development scenario where in the share of self generation in total electricity supply exceeds 20% in 2030 (METI, 2004).

While economics is a key to the implementation of DER, an economic optimization design tool based on technology information and current tariffs and policy has not yet been developed in Japan. This research conducts a survey of the potential for DER utilization and the installation of renewable energy in Japan. As part of this research, a database of DER technologies, Japanese energy tariffs, and prototypical building energy loads has been developed and can be used for energy conservation research.

The Distributed Energy Resources Customer Adoption Model (DER-CAM), developed by the Lawrence Berkeley National Laboratory (LBNL) of the United States is an optimization tool for DER technology selection. DER-CAM minimizes the annual energy cost of a given customer, including DER investment costs,

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based on input data consisting of DER technology cost and performance, electricity and natural gas tariffs, and end-use energy loads such as space heating, cooling, hot water, and electricity only. DER-CAM reports the optimal technology selection and operation schedule to meet the end-use loads of the customer.

This paper describes the preliminary research on DER investment climate in Japan and the comparison to that in the US. The assessment of the optimization results using DER-CAM will be reported in a separate paper.

Building Loads

1.1 Hourly Building Loads Profile

Detailed knowledge of energy end-use loads is important for selecting an appropriate DER system. In Japan, when designing CHP systems, estimates of energy consumption intensities of various building types are typically obtained from the *Natural Gas Cogeneration Plan/ Design Manual 2002* (Kashiwagi, 2002). This manual reports annual energy consumption and proportion of consumption by month and hour. Hourly loads can be estimated from this data. It is derived from actual buildings throughout Japan, and although not differentiated by climate, it was used for this research.

Examples of hourly load shapes (cooling and space heating) for an office building are shown in Fig. 1 and Fig. 2). Significant seasonal differences can be seen in cooling and space heating load, which is attributed to the variable typical climate in Japan. The cooling electricity loads are 150 -200 kW during the summer and 50 -70 kW during fall and spring, while the space heating loads are approximately 500 - 600 kW with a peak load of 974 kW in the winter[1]. Although not shown in the figures, the electricity loads vary from 300-400 kW throughout the year. The hot water loads mostly occurs around noon with a peaks at 32 kW in the winter.

2.2 Selection of Building Size

The five prototype buildings considered are: office building, hospital, hotel, retail, and sports facility. Fig. 3 show the average distribution of construction floor area distribution for various building types in Japan. This data is from The Ministry of Construction's (present Ministry of Land, Infrastructure and Transport) "Construction Data and Statistics Annual Report". Most office buildings are below 5,000 m^2 but there are many above 10,000 m^2 and under 2,000 m^2. The results of a survey of Kyushu area buildings is shown in Fig. 4 (Nishida,1997). Most sports facilities in this survey are between 3,000 and 5,000 m^2. Most hotels are larger than 10,000 m^2, and most hospitals are smaller than 7,500 m^2, but there are also many buildings over 20,000 m^2. There are similar numbers of commercial buildings

[1] Both electricity and NG use are reported in kW

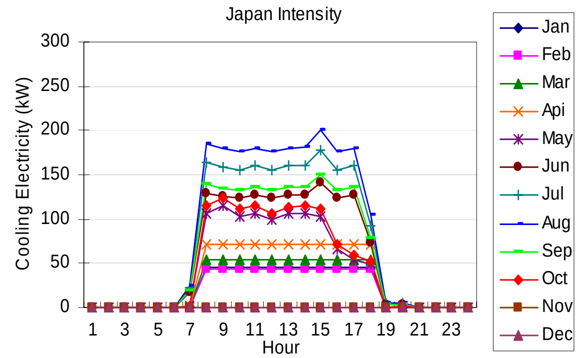

Fig. 1. Cooling Electricity Load

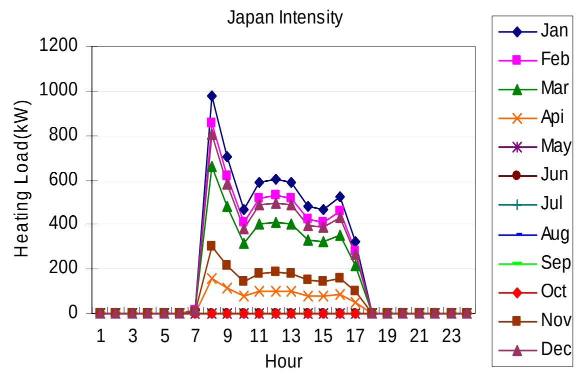

Fig.2. Heating Natural Gas Load

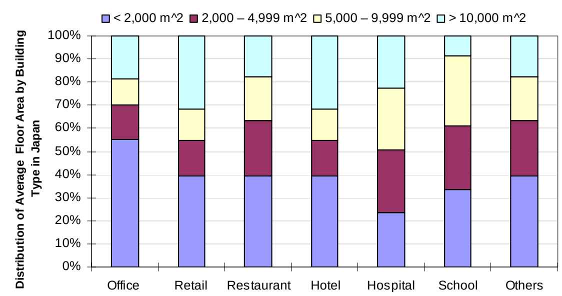

Fig.3. Distribution of Average Construction Floor Area by Building Type

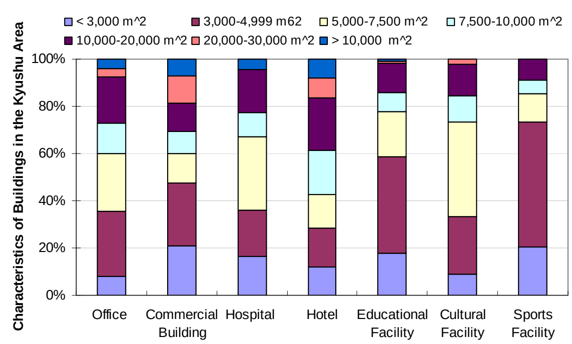

Fig.4. Characteristics of Buildings in the Kyushu Area

from 5,000 to 10,000 m^2 and over 10,000 m^2. Research has shown that buildings are smaller in Kyushu than in other areas.

3. Comparison of Utility Tariffs in Japan and the U.S.

Utility electricity and gas tariffs are key factors determining the economic benefit of the CHP installation. Unlike the U.S., tariff structures and rates do not vary much from utility to utility in Japan.

Table 1 shows the electricity tariffs of several facilities in the U.S., and equivalent tariffs for Kyushu Electric Power Co,.INC. Bailey, 2003 reports a range of U.S. rates.

In Japan, there are three main components to each commercial building monthly electricity bill:

1. a fixed customer charge ($/month);
2. a demand charge proportional to maximum power consumption during the month ($/kW-month) (a typical monthly demand charge is around 10-18 $/kW-month in 2004); and
3. a time-of-day and seasonally varying energy charge ($/kWh) (the energy price ranges from 0.08 to 0.18 $/kWh for on-peak power, and 0.04-0.05 $/kWh off- peak in 2004, which is close to the level of the more expensive U.S. regions).

Table 2 shows the comparison of gas tariffs in selected U.S. facilities and CHP rates and seasonal rates for Saibu Gas.

Table 1 Comparison of Electricity Tariff in Selected U.S. site and Japanese Site

		Pharmingen	San Bernardino USPS	Wyoming County Community Hospital	Comercial Tariff of KYUSHU Elec.Co,.INC		
		Torrey Pines, CA	Redlands, CA	Warsaw, NY	Commercial Electricity (office)	Commercial Electricity with Peak Hour (hotel,hospital)	Commercial Electricity with Peak Hour II (24hour building)
Electricity Rates Structure	Summer months	May-Sept	June- Sept	May- Sept	Jul- Sept		
	Summer On Peak hours	11h-18h	12h-18h	07h-21h	13h-16h		
	Summer Mid Peak hours	06h-11h, 18h-22h	08h-12h, 18h-23h	21h-22h	8h-13h, 16h-22h		
	Summer Off Peak hours	00h-06h, 22h-24h	00h-08h, 23h-24h	00h-07h, 22h-24h	00h-08h, 22h-24h		
	Winter months	Jan- Apr, Oct- Dec	Jan- May, Oct- Dec	Jan- Apr, Oct- Dec	Jan-Jun, Sept-Dec		
	Winter On Peak hours	17h-20h	08h-09h	07h-21h	13h-16h		
	Winter Mid Peak hours	06h-17h, 20h-22h	09h-21h	21h-22h	8h-13h, 16h-22h		
	Winter Off Peak hours	00h-06h, 22h-24h	00h-08h, 21h-24h	00h-07h, 22h-24h	00h-08h, 22h-24h		
Energy Price ($/kWh)	Summer On Peak	0.15	0.20	0.07	0.12	0.18	0.11
	Summer Mid Peak	0.11	0.11	0.07	0.12	0.15	0.09
	Summer Off Peak	0.09	0.09	0.04	0.12	0.04	0.04
	Winter On Peak	0.15	0.12	0.07	0.11	0.18	0.11
	Winter Mid Peak	0.10	0.12	0.07	0.11	0.14	0.08
	Winter Off Peak	0.08	0.09	0.04	0.11	0.04	0.04
Power Price (Demand Charge)	Summer Peak	7.84	19.75	8.54	10.00	10.00	18.58
	Winter Peak	7.48	0.00	8.54	10.00	10.00	18.58
Coincident Demand Charge ($/kW at the utility system peak)	Summer	20.38	0.00	0.00			
	Winter	6.44	0.00	0.00			
Peak Power Charge ($/kW peak monthly usage at any time)		0.00	7.26	0.00			
Standby Charge ($/kW DER Capacity)		0.00	6.60	0.00			
Facility Charge ($/month)		43.50	299.00	16.00			

Table 2 Comparison of Gas Tariff in Selected U.S. site and Japanese Site

	Comercial Gas Tariff of SAIBU Gas CO.							Pharmingen	San Bernardino USPS	Wyoming County Community Hospital
	Commercial HVAC B Contract (Large scale buildings)			CHP System Program				Torrey Pines, CA	Redlands, CA	Warsaw, NY
Month	Flow Rate ($/kJ)	Energy Charge ($/kJ)	Demand Charge ($/mon)	Flow Rate ($/kJ)	Maxmum Demand Season Charge ($/kJ)	Energy Charge ($/kJ)	Demand Charge ($/mon)	cost ($/kJ)	cost ($/kJ)	cost ($/kJ)
January	9.97E-04	9.72E-06	1166.67	1.72E-04	2.27663E-07	9.6177E-06	250	5.26E-06	6.27E-06	4.19E-06
February	9.97E-04	9.72E-06	1166.67	1.72E-04	2.27663E-07	9.6177E-06	250	4.99E-06	5.30E-06	4.19E-06
March	9.97E-04	9.72E-06	1166.67	1.72E-04	2.27663E-07	9.6177E-06	250	5.14E-06	5.28E-06	4.19E-06
April	9.97E-05	9.72E-06	583.33	1.72E-04	2.27663E-07	9.6177E-06	250	4.40E-06	5.40E-06	4.19E-06
May	9.97E-05	9.72E-06	583.33	1.72E-04	2.27663E-07	9.6177E-06	250	4.94E-06	6.09E-06	4.19E-06
June	9.97E-05	9.72E-06	583.33	1.72E-04	2.27663E-07	9.6177E-06	250	4.71E-06	5.64E-06	4.19E-06
July	9.97E-05	9.72E-06	583.33	1.72E-04	2.27663E-07	9.6177E-06	250	4.82E-06	4.19E-06	4.19E-06
August	9.97E-05	9.72E-06	583.33	1.72E-04	2.27663E-07	9.6177E-06	250	5.28E-06	3.91E-06	4.19E-06
September	9.97E-05	9.72E-06	583.33	1.72E-04	2.27663E-07	9.6177E-06	250	5.39E-06	4.19E-06	4.19E-06
October	9.97E-05	9.72E-06	583.33	1.72E-04	2.27663E-07	9.6177E-06	250	5.31E-06	3.73E-06	4.19E-06
November	9.97E-05	9.72E-06	583.33	1.72E-04	2.27663E-07	9.6177E-06	250	5.60E-06	4.06E-06	4.19E-06
December	9.97E-04	9.72E-06	1166.67	1.72E-04	2.27663E-07	9.6177E-06	250	5.99E-06	5.94E-06	4.19E-06

Accurately comparing the cost of natural gas in Japan and the US is difficult because of the different tariff structure. However, natural gas tariffs in Japan are roughly two to three times higher than in the U.S. Even the favorable rate for cogeneration sites is still higher than typical U.S. rates. The rate for buildings with cogeneration has an around 0.0306 $/kWh energy charge, a 64 $/month customer charge, and a 0.00082 $/kWh maximum seasonal charge (a special surcharge on gas consumption from Dec.-Mar.). Additionally, an unusual flow rate charge is also levied monthly in Japan, based on annual maximum hourly consumption (a typical monthly charge is 8.3 $/m3-h). A typical gas price for CHP in Japan is from 0.033 to 0.05 $/kWh. Note that the exchange rate used was that of October, 2003: US$1 = JP 120 ¥.

4. DER Technology Information in Japan and the U.S.

Table 3 shows United States DER technology data collected by Firestone (2004). It is itemized by natural gas engine (GE), gas turbine (GT), microturbine (MT), fuel cell (FC), and photovoltaic (PV). All equipment (besides PV) can be purchased for electricity generation only, and with heat recovery for heating (HX), or with heat recovery for heating and absorption cooling (ABSHX). Numbers at the end of each name in Table 8 refer to the rated capacity of the equipment. Data includes capacity, lifetime (in years), turnkey capital costs, maintenance costs, heat rate, and electrical efficiency.

For this study, data was collected on Japanese DER equipment (Table 4). Fig. 5 compares DER turnkey costs in Japan and the U.S. There is little difference in the range 3,000 kW to 5,000 kW. At higher capacities Japanese prices are lower, while at the lower capacities, Japanese prices are significantly higher.

Table 3 DER Technology Information in the U.S.

Technology	Capacity kW	Lifetime a	Capital Cost $/kW	Fixed Annual Cost $/kW	Variable Annual Cost $/kW	Heat Rate kJ/kWh	HHV Efficiency %
Fuel Cell	200	10	5005	0	0.029	10000	36.00%
Gas Turbine	1000	20	1403	0	0.0096	16438	21.90%
	40000	20	592	0	0.0042	9730	37.00%
Microturbine	28	10	2263	0	0.015	15929	22.60%
	100	10	1576	0	0.015	13846	26.00%
Natual Gas Reciprocating Engine	30	20	1044	0	0.02	13080	27.52%
	1000	20	720	0	0.009	10588	34.00%
	5000	20	695	0	0.008	9730	37.00%
Photovoltaic	10	30	8740	12	0	0	100.00%
	100	30	7840	12	0	0	100.00%
Fuel Cell with Heat Recovery for Heating	200	10	5200	0	0.029	10000	36.00%
Gas Turbine with Heat Recovery for Heating	1000	20	1910	0	0.0096	16438	21.90%
	5000	20	1024	0	0.0059	13284	27.10%
	10000	20	928	0	0.0055	12414	29.00%
	40000	20	702	0	0.0042	9730	37.00%
Microturbine with Heat Recovery for Heating	28	10	2636	0	0.015	15929	22.60%
	76	10	1932	0	0.015	14876	24.20%
	100	10	1769	0	0.015	13846	26.00%
Gas Engine Heat Recovery for Heating	30	20	1442	0	0.02	13080	27.52%
	100	20	1350	0	0.018	12000	30.00%
	300	20	1160	0	0.013	11613	31.00%
	1000	20	945	0	0.009	10588	34.00%
	5000	20	890	0	0.008	9730	37.00%

Note: cost for maintenance and operating

Table 4 Japanese DER Technology Information

Technology	Capacity (kW)	Lifetime (a)	CapCost ($/kW)	Maintenance Cost ($/kW)	Power Generation Efficiency (%)	Total Efficiency (%)	Heat Recovery Efficiency (%)	Annual Operation Hour(h)
Gas Engine	10	15	3333	0.02	26	82.5	56.5	4000
	210	15	2083	0.03	32.6	86.8	54.2	4000
	610	15	1667	0.02	40.8	75	34.2	4000
	815	15	1500	0.02	40.8	74	33.2	4000
	2383	15	1083	0.02	41.1	74.8	33.7	4000
Gas Turbine	3770	15	917	0.01	27.5	72.1	44.6	7000
Gas Turbine CHP	3370	15	1187	0.01			47.8	
	4420	15	980	0.01			51.4	
	5300	15	865	0.01			50.9	
	7260	15	758	0.01			47.5	
	9090	15	688	0.01			48.7	
	10310	15	647	0.01			49.4	
	1090	15	1529	0.01			46.2	
	1270	15	1378	0.01			30.4	

Note: Only With Waste Heat Recovery

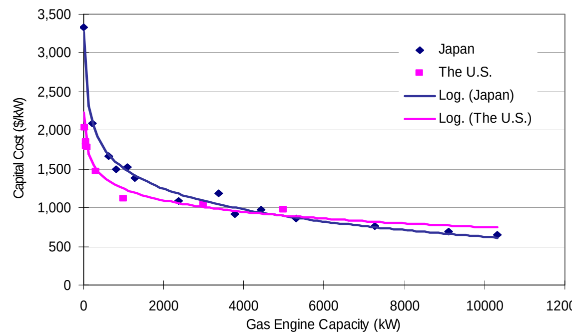

Fig.5. Comparison of CHP costs in Japan and the U.S.

5. Incentives for DER Installation

5.1 The U.S. DER Incentives

There is no single incentive for DER installation in the U.S., rather it varies by state and region, and can include rebates and low-interest loans. Historically under federal law and Federal Energy Regulatory Committee (FERC) regulations, individual states determine incentives for qualifying facilities (QFs) which includes larger (>~1 MW) CHP plants in their state. Small scale CHP is entirely under state and local jurisdiction on incentives may include rebates on DER project costs, energy tariff reductions, or utility purchase of excess electricity. Determining which incentives were available to each site proved difficult. In the work by Bailey (2003), organizations contacted included FERC, the New York State Public Service Commission (NYPSC), the Long Island Power Authority (LIPA), KeySpan, the California Energy Commission (CEC), the California Public Utilities Commission (CPUC), Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), and various energy consultants.

Clearly, presentation of any comprehensive picture of U.S. DER incentives is not possible here, so that example programs one from California, one from New York and one federal are described.

5.1.1 CPUC

As part of California Assembly Bill 970, the CPUC introduced a statewide self-generation incentive program in September 2000. It provides financial incentives to customers that install new qualifying self-generation equipment to provide all or a portion of their electricity needs. Funding of $125 million annually statewide provided is for self-generation up to 1 MW. The program is administered by PG&E, SCE, SoCalGas and the San Diego Regional Energy Office (SDREO, serving SDG&E customers).

Eligible technologies include MTs, FCs, PVs, small GTs, wind turbines, and internal combustion engines that meet the following criteria:

· At least 5% of the power system's total energy output is in the form of useful thermal energy.

· Where useful thermal energy results from power production, the useful electrical output plus one-half the annual useful thermal energy output equals not less than 42.5% of any natural gas and oil energy input.

· In the case of microturbines, small gas turbines, and internal combustion engines, the following power quality and reliability requirements must be met:

· The self-generating facility must be designed to operate at a power factor between 0.95 power factor loading and 0.90 power factor leading.

· Sites with greater than 200 kW generating capability must coordinate maintenance schedules with the local utility, and in general, can only schedule maintenance from October to March, or only during off peak or weekend hours between April and September.

Funding from this program is available as a secondary source after other sources have been fully tapped. The CPUC funding limits are decreased by the amount of alternate funding. In other words, the limits set out by the CPUC represent a cap to funding available to qualifying sites in California. It is assumed, therefore, that the test sites located in California that indicated they are applying for or have received CPUC self-generation funding are qualifying facilities, and will receive funding up to the limits set by the CPUC in this program(Table 5).

Table 5 CPUC DER Incentives

Incentive Category	Incentive Offered	Maximum % of Project	Minimum System Size	Maximum System Size*	Eligible Technologies
Level 1	$4500 / kW	50%	30 kW	1.5 MW	PVs, FCs operating on renewable fuel, and wind
Level 2	$2500 / kW	40%	None	1.5 MW	FCs operating on non-renewable fuel and utilizing
Level 3	$1000 / kW	30%	None	1.5 MW	MTs, small GTs, internal combustion engines, using sufficient waste heat recovery and meeting reliability criteria

* Maximum system size 1.5 MW, but rebate funding only available up to a 1 MW cap

5.1.2 New York State Funding for Energy Efficiency and DER

In New York State, the NYPSC has implemented a system benefits charge (SBC) applied to all electric rates to provide a fund for the purposes of increasing energy efficiency and providing public goods programs. The program has been expanded to include transmission and distribution issues due to the increasing difficulty of providing energy services to "load pockets." 75% if funds collected by the SBC are distributed to the New York State Energy Research and Development Authority (NYSERDA), and the remainder goes electric utilities for their own programs. NYSERDA's programs are called "Energy$mart" and include low interest loans, and targeted energy efficiency programs for schools, agriculture, homes, communities, and pollution control and monitoring for air water and solid waste emissions.

NYSERDA offers funding for projects that demonstrate the use of DER technologies in industrial, commercial, municipal, and institutional organizations. NYSERDA's DER programs provide approximately $12 million annually statewide for 2002 through 2006 (Table 6).

Table 6 NYSERDA's DER program

Funding Allocation	2001	2002-2006	Total
Distributed Generation Combined Heat and Power	$8,637,233	$58,445,839	$67,083,072

5.1.3 Climate Change Fuel Cell program

The DOD's Climate Change Fuel Cell program was initiated in 1995 and provides up to $1,000/kW for fuel cell installations with a capacity of at least 3 kW. The fund is administered through the US Army Corps of Engineers Construction Engineering Research Lab (CERL). The funding level for fiscal year 2002 was expected to be $3 million.

5.1.4 Incentives Applied in Selected Sites

Table 7 shows several incentives that apply to different sites as shown above. Although overall numbers cannot be cited, many sites still can receive incentives.

5.2 Incentives in Japan

Subsidies also exist in Japan. As shown in Table 8, CHP systems are eligible for a rebate of 1/3 to half of installation costs; and an interest rate is as low as 1.5% from both national and local governments. Most of the incentives are provided by The New Energy and Industrial Technology Development Organization (NEDO) and METI through various programs.

6. Conclusions

This paper described preliminary analysis on CHP investment climate in the U.S. and Japan. Comparison on DER technologies, energy prices, and incentive measures has been investigated. Electricity prices did not differ significantly, while commercial gas prices in Japan are much higher than in the U.S. For smaller DER systems, the installation costs in Japan are more than twice those in the U.S., but this difference becomes smaller with larger systems. In Japan, DER systems are eligible for a 1/3 rebate of installation costs, while subsidies in the U.S. vary significantly by region and application. In addition, database on building characteristic and load shape profile in prototypical buildings has been reviewed for future energy research.

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Table 7 Example Subsidies for DG at Selected U.S.Site

	Installed Technology	Project Cost	Grants Received	Cost Share
A&P	60 kW Capstone microturbine CHP for space heating & desiccant dehumidification	$145,000	$95,000	66%
Guarantee Savings Building	3 x 200 kW Phosphoric Acid Fuel Cells, CHP, 350 kW (100ton) adsorption chiller	$4,353,375	SELFGEN, CPUC benefits through PG&E $1.5 million DODCCFC Grant $600,000, $2.6 million loan from United Technologies Corporation (UTC)	48%
AA Dairy	Digester biogas system converted 130kW diesel engine	$363,000	EPA Ag Star $24,000, local Soil Conservation District $120,000	40%
East Bay Municipal Utility District	10 x 60 kW Capstone microturbines,150 ton absorption chiller and CHP	$3,900,000(total funding) $184,522 for absorption chiller and heat exchanger	$855,000 rebate, and $1.9 million low interest loan	22%

Table 8 Example Incentives for CHP in Japan

Program Name	Objective	Content
Energy Conservation Promotion	equipment over 50 kW, efficiency greater than 60%, CHP (any type of fuel)	Interest rate 1.65% Subsidy 50% of investment
The New Energy and Industrial Technology Development Organization (NEDO) : Rational Energy Utilization Enterprise Support Project	Office building ESCO project and using Natural Gas with CHP installation project, must be conducted by private enterprise	Subsidy: no more than 1/3 of cost, up to 500 million ¥
Minister of Economy, Trade and Industry (METI): New Energy Enterprise Support Project	High efficiency natural gas CHP system, Natural gas CHP utilization energy supply equipment	Subsidy: no more than 1/3 of cost, bond covered up to 90%
NEDO: Local New Energy Installation Promotion Enterprise	Local govt. (public) organization: project conducted by local public org. and high efficiency CHP system, Natural gas CHP utilization energy supply equipment	Subsidy: no more than 1/2 of cost