The Destination of Integrated Energy Delivery System - From the View Point of Japanese Experience

Future energy sources, storage technologies, integration of H_2 and electricity systems

August, 20, 2005 PSCC 2005, Liège (Belgium) Tutorial Session

Satoshi Morozumi

Mitsubishi Research Institute, Inc.

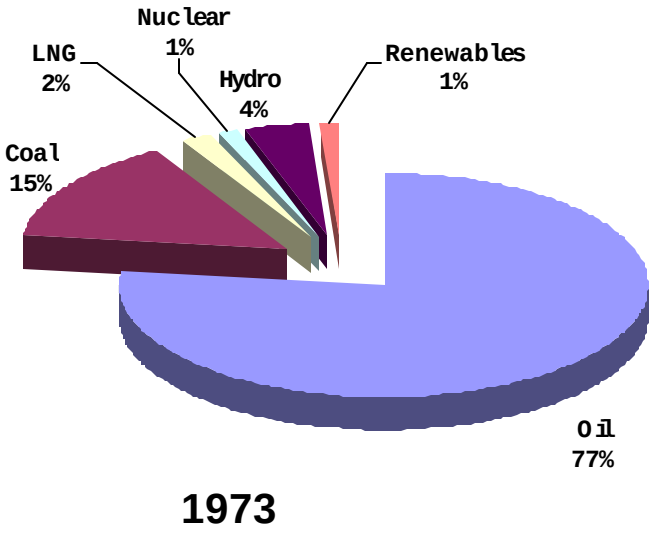
Contents

- Back Ground Information in Japan
- Trend and Future of Renewables in Japan
- Related Japanese technical development projects
- Discussion about application of battery on wind power connection
- Introducing our Micro-Grid Project in Hachinohe city
- My opinion regarding following topics

  * Large Resources vs Distribution Resources
  * Electricity vs H2
  * Heat Pump vs PEFC
  * Deregulation vs Penetration of renewbles

Back Ground of Energy and Power System in Japan

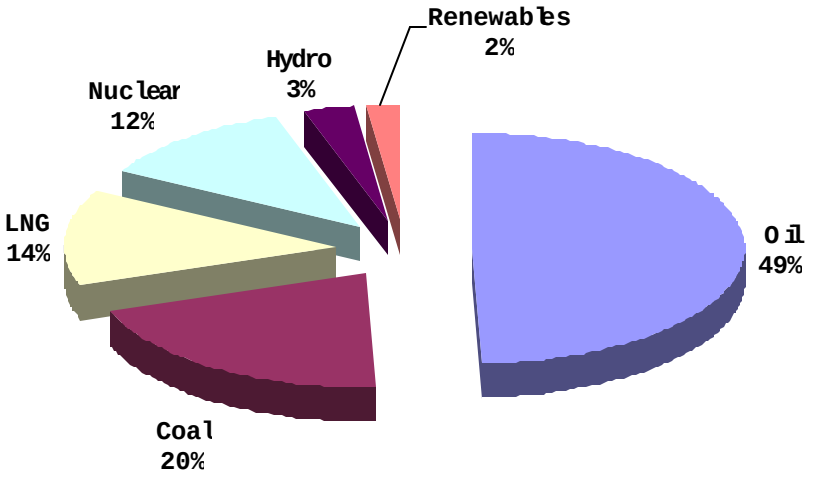
Change of Primary Energy Share in Japan



1973

Japan has continued to achieve diversity of Primary Energy for 30 years.

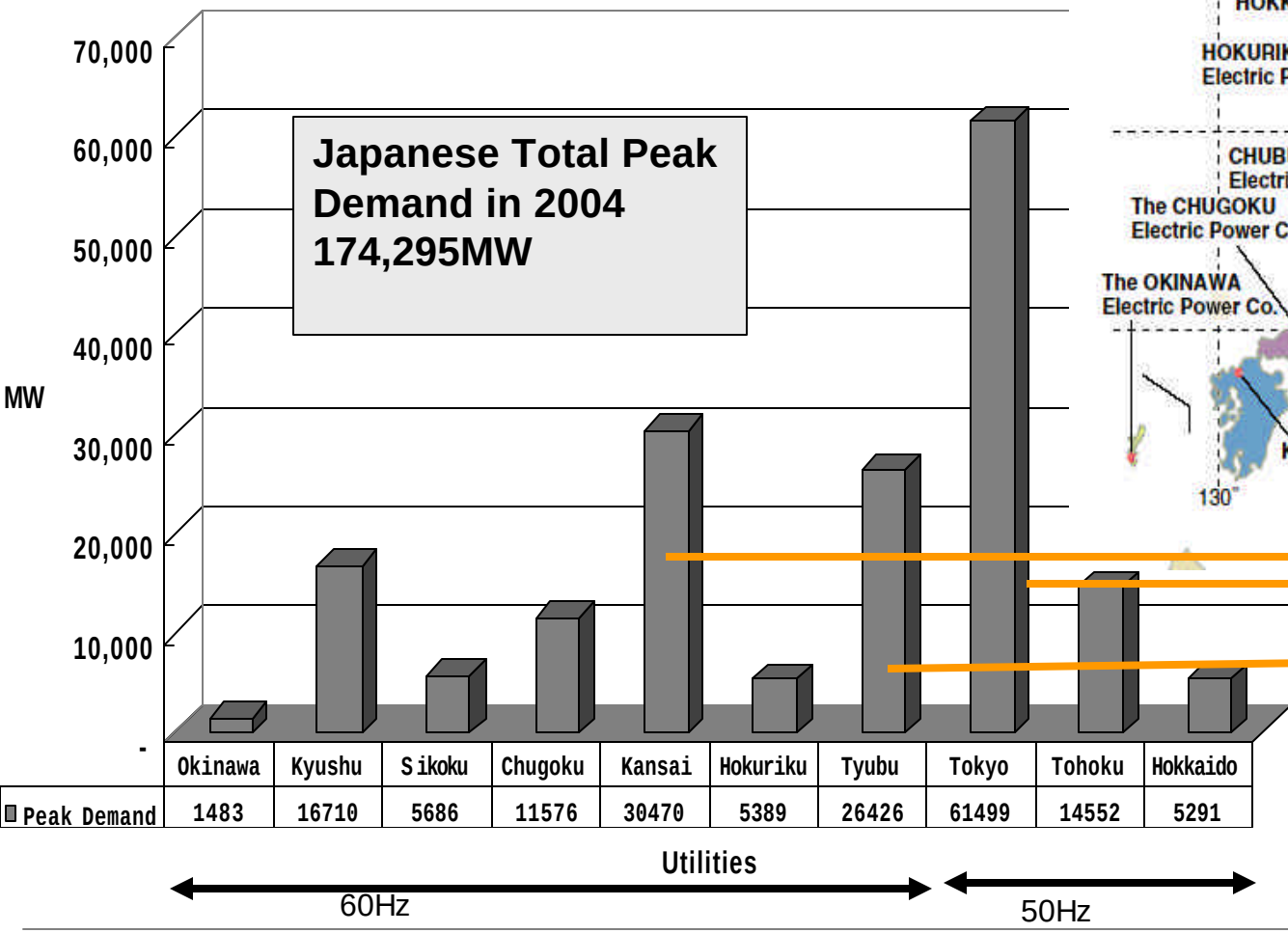
2002



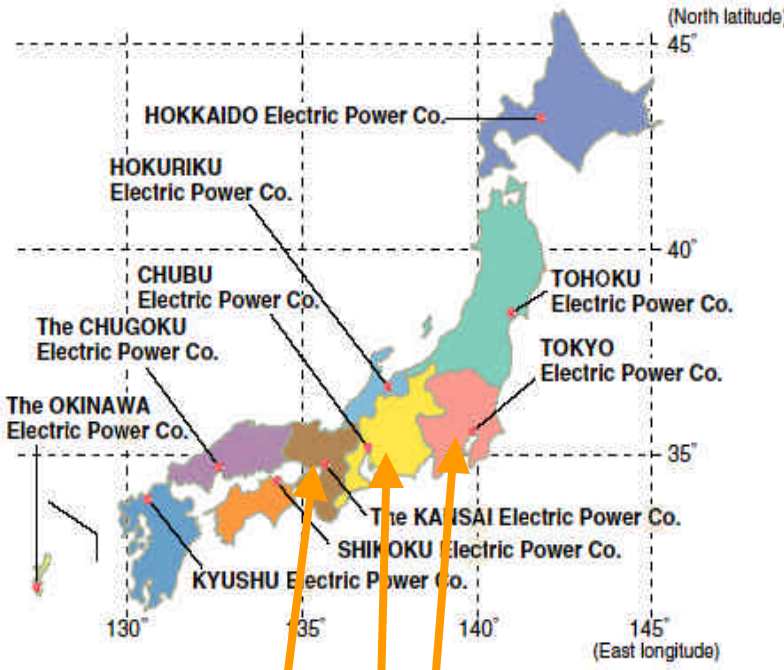
· The destination of integrated energy delivery system

Power System in Japan

Peak Demand in Fiscal Year 2004



The Ten Electric Power Companies by Service Area



· The destination of integrated energy delivery system

Power System Structure in Japan

Large Hydro/
Pumped Hydro

500/275kV Transmission System

Nuclear

Interconnection between utilities

154/77/66kV Sub-Transmission System

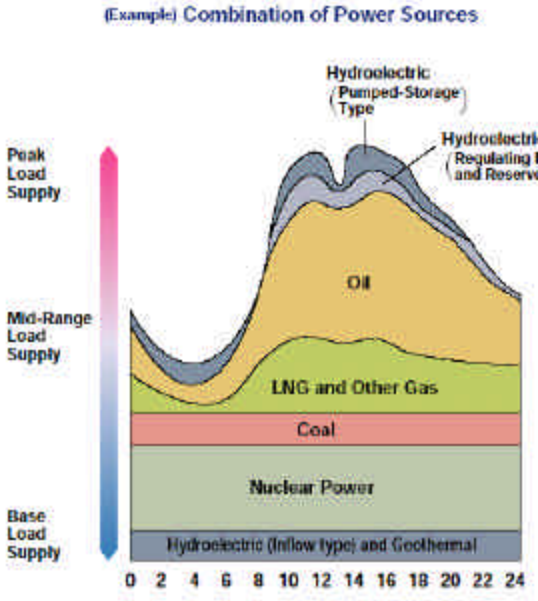
Small Thermal

ge Thermal

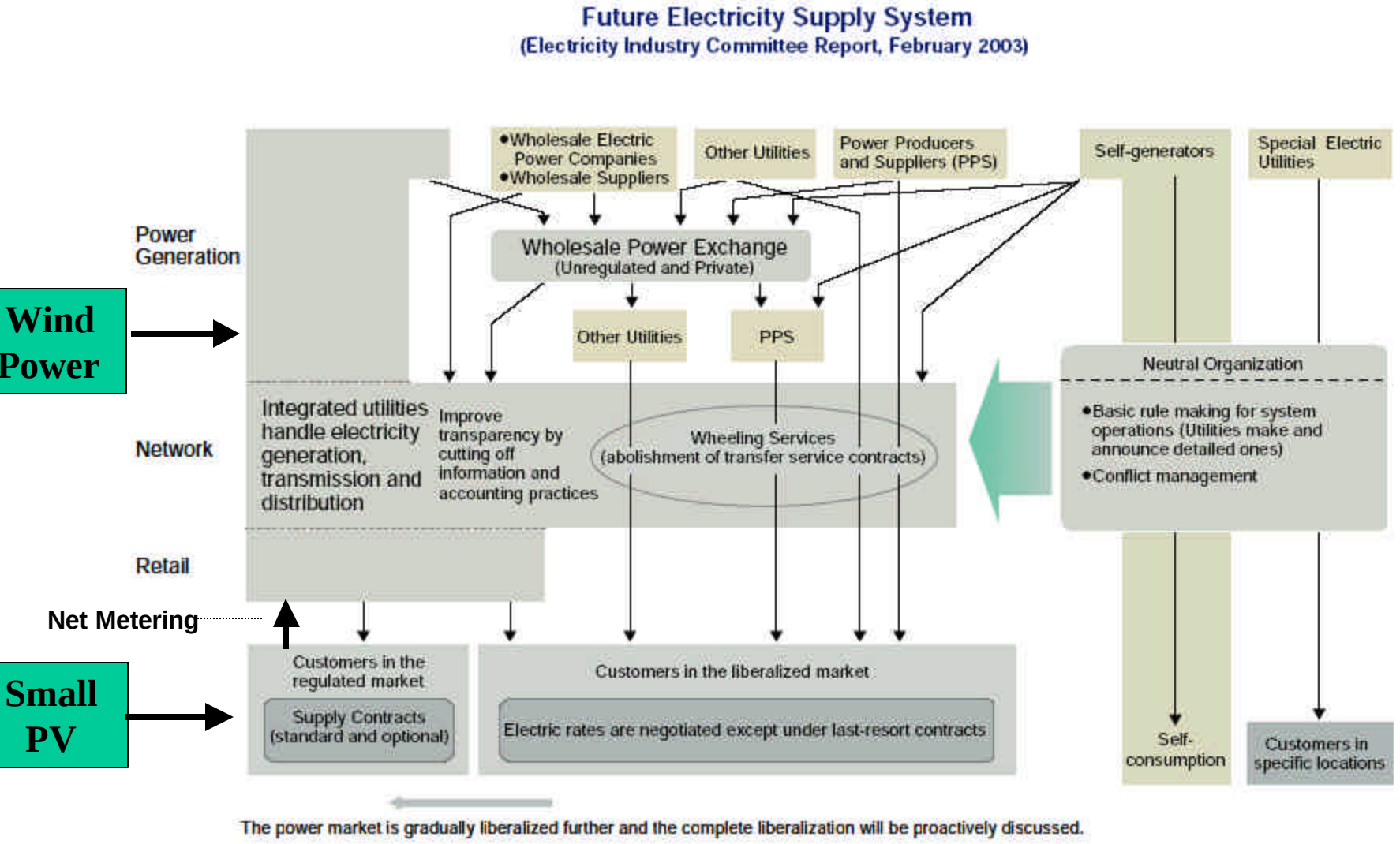
6.6kV Distribution System

Japanese power system consists so called Fish-born (Radial) system

Low Load Factor, Higher Share of Base Load Power Plants



Deregulation in Japan



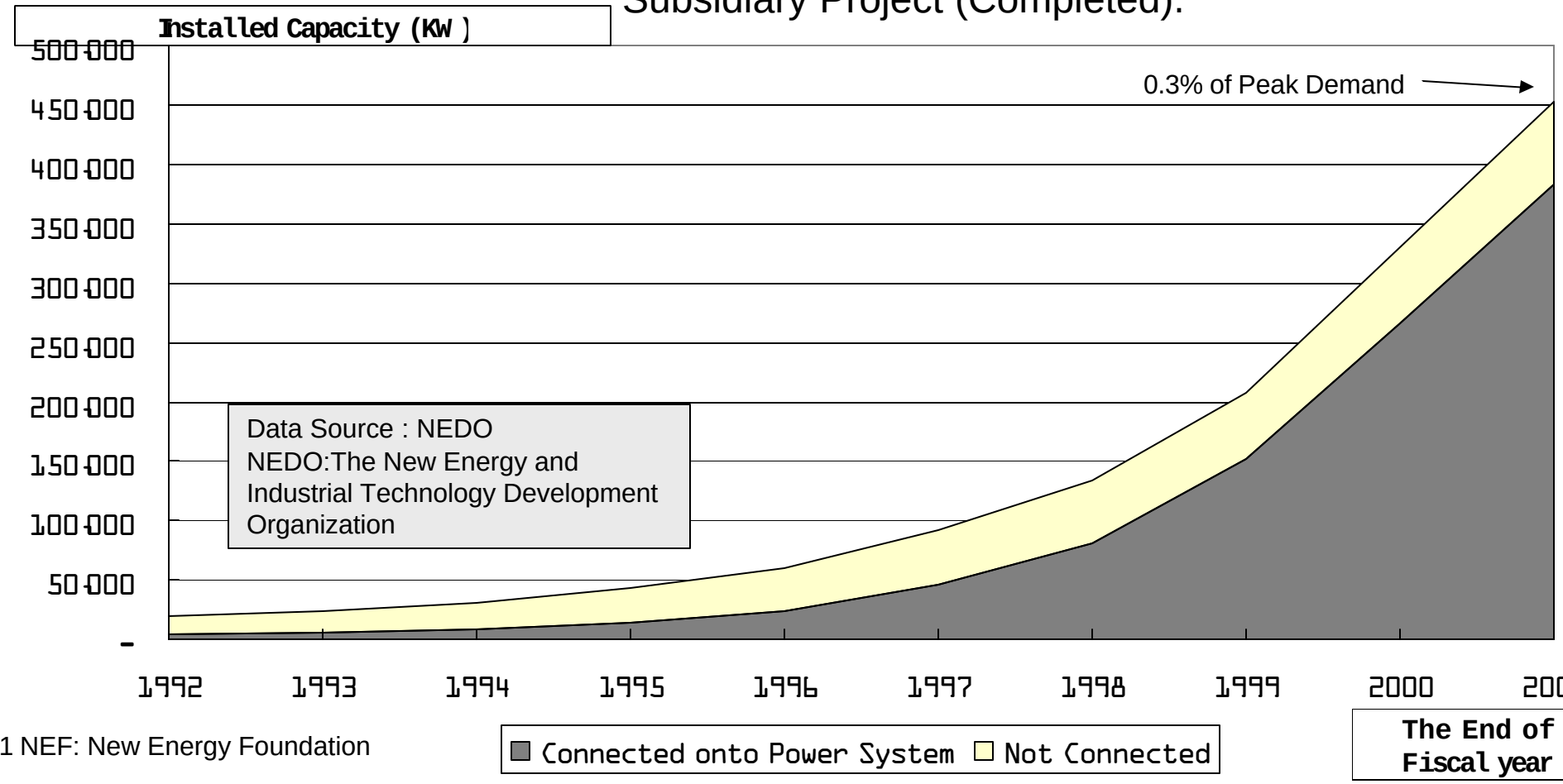
· The destination of integrated energy delivery system

Future of Renewables in Japan

Renewables in Japan - PVs

Penetration of PVs

Connected PVs onto the power systems are increased from middle of 90's Especially by NEF*1 Subsidiary Project (Completed).

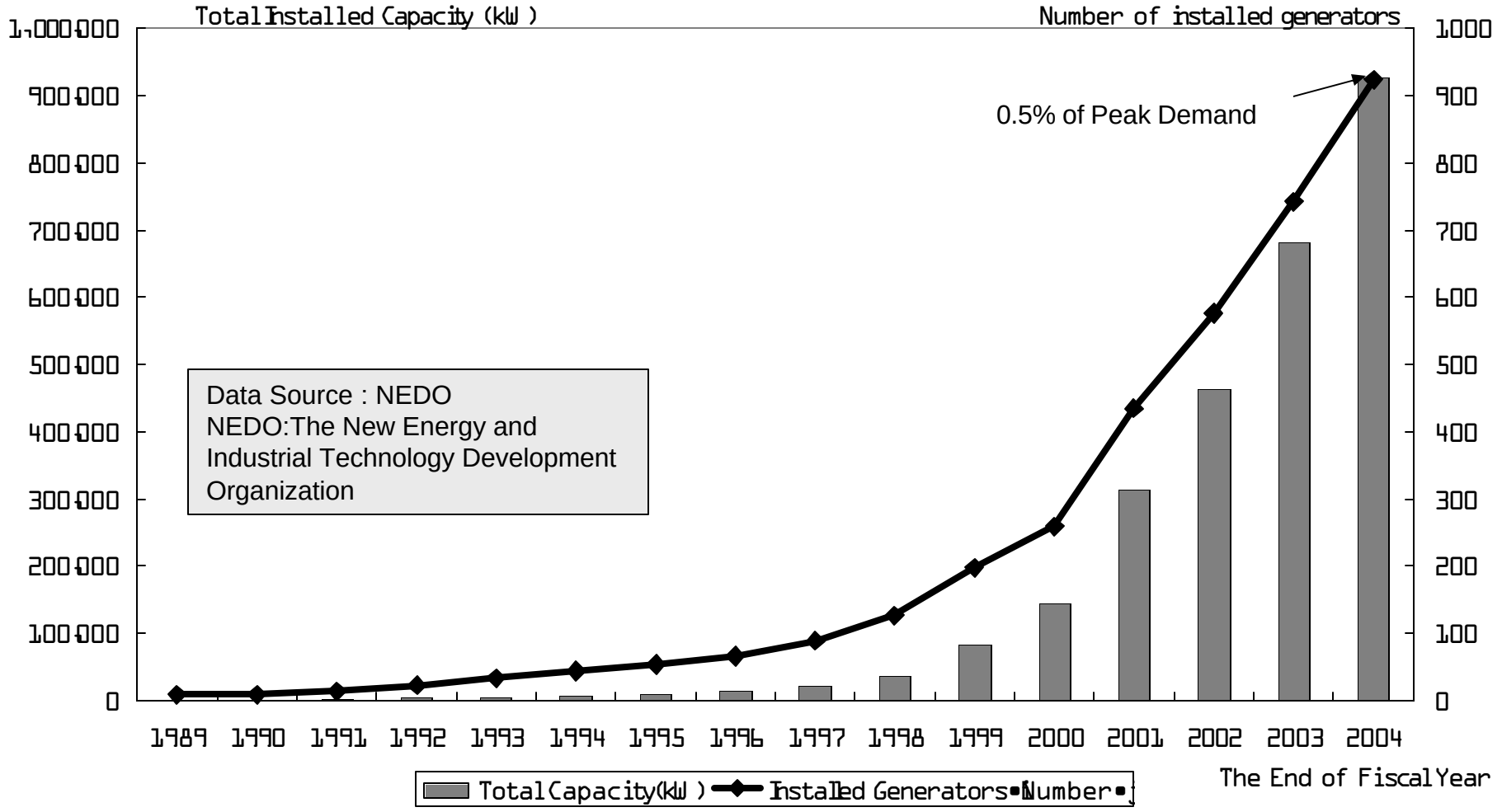


1 NEF: New Energy Foundation

Renewables in Japan – Wind Turbines

Penetration of Wind Turbines

Wind Power marketed in 6 – 7 years ago.
Installed capacity was increased rapidly .



Renewables In Japan - Estimated Generation Cost

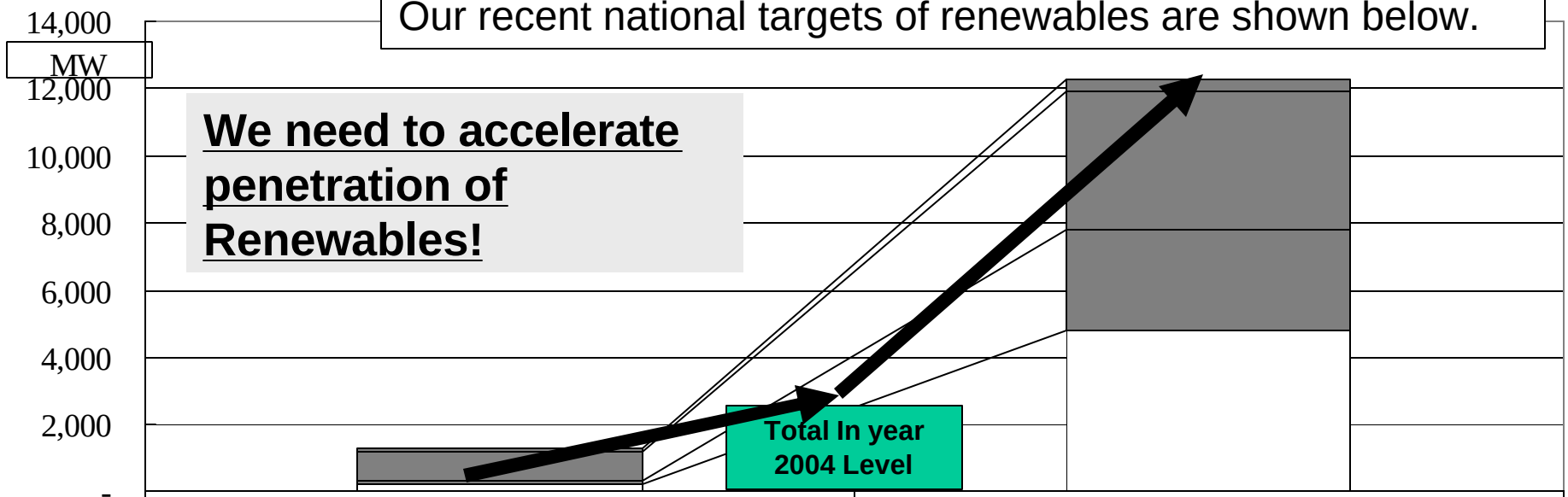
Technologies	Price of generated electricity		
PV - Residential	Average	66.00Yen/kWh	0.49Euro/kWh
PV - Small Office	Average	73.00Yen/kWh	0.54Euro/kWh
Wind -Large Scall	Low	10.00Yen/kWh	0.07Euro/kWh
	High	14.00Yen/kWh	0.10Euro/kWh
Wind -Small and Midium Scall	Low	18.00Yen/kWh	0.13Euro/kWh
	High	24.00Yen/kWh	0.18Euro/kWh
Waste - Large Scale	Low	9.00Yen/kWh	0.07Euro/kWh
	High	11.00Yen/kWh	0.08Euro/kWh
Waste -Small and Midium Scale	Low	11.00Yen/kWh	0.08Euro/kWh
	High	12.00Yen/kWh	0.09Euro/kWh
Utility Thermal Power Plant	Average	7.30Yen/kWh	0.05Euro/kWh
Fuel Cell(PAFC)	Average	22.00Yen/kWh	0.16Euro/kWh

Data Source : METI
METI : Ministry of Economic, Trade and Industry

•Average electricity price for residential Is around 16 - 22 Yen/kWh (Energy charge)

Renewables in Japan – Future Target of Introduction

Our recent national targets of renewables are shown below.



	1999 Actual	2010 Target
Bio-Mass	80	330
Waste	900	4120
Wind Power	83	3000
PVs	209	4820

Renewables in Japan – Drivers for Introduction of Renewables

(1) Subsidies for introduction of renewables

For example, Japanese government has kept subsidy for users who introducing PVs from 1994. (20,000 Yen/kW =~ 200$/kW in 2005)

(2) Adopting "Renewables Portfolio Standard (RPS)"

From year 2003, Japanese Government started RPS system to impose obligation of buying renewable energy on retail entity in electric utility business.

(3) Investing technology development

Japanese government has been budgeting several technical development project to improve distribution generations and these control and management.

Renewables in Japan
– Technical Issues Discussed in Japan

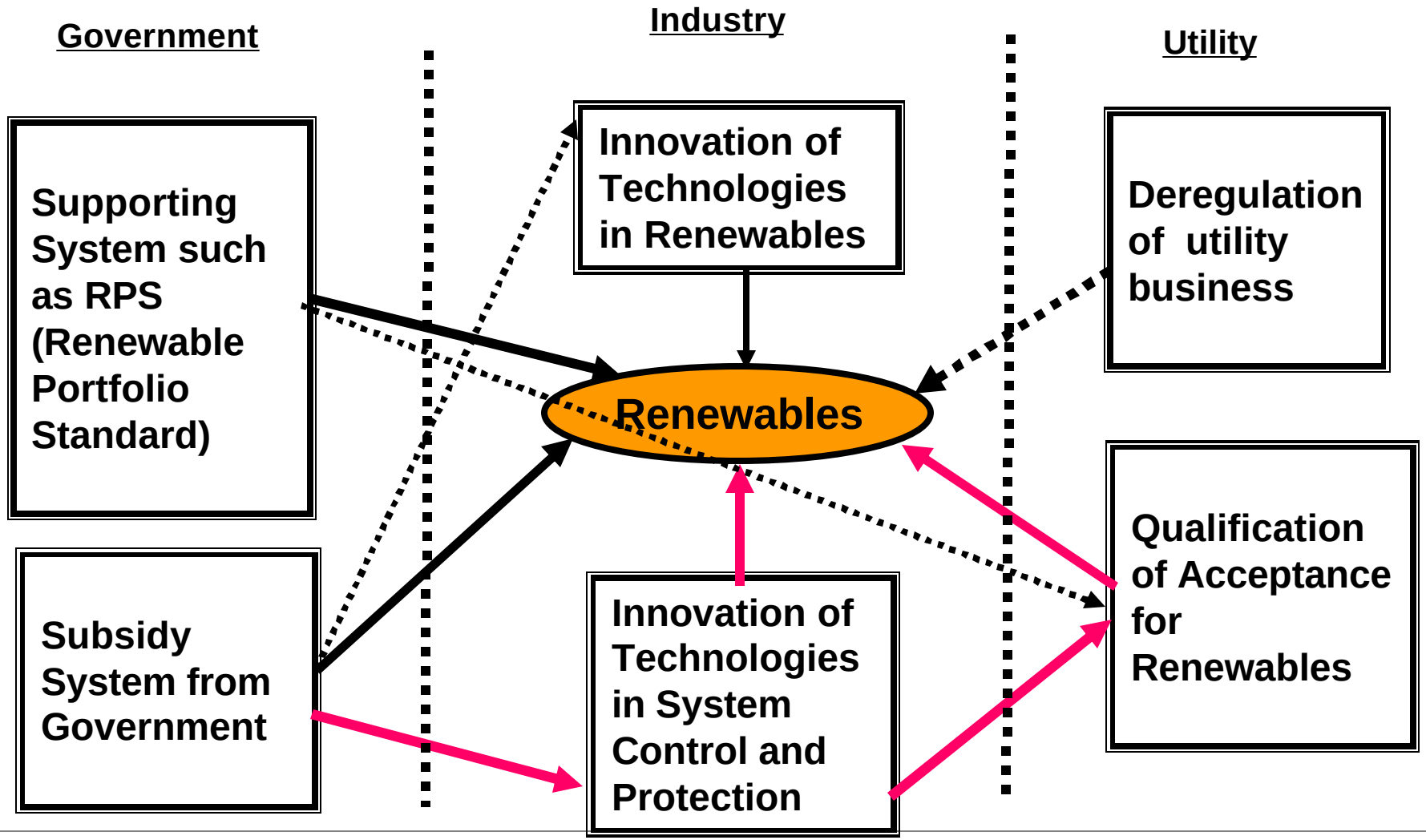
Transmission System

- Wind Turbines are increasing in relatively small utilities' territories in Japan.
- Those utilities are facing the problem of of frequency control and dispatching.

Distribution System

- Radial system operation constrains number of connectable DG on feeder.
- Some new technologies are examined to qualifying those constraint.

Factors Effecting on Penetration of Renewables



Structure of Solving the Issues in Japan

MRI has supported METI by survey and analysis for the wind power studies

経済産業省 Ministry of Economy, Trade and Industry (METI)

Discussing political Issues and Budgeting

NEDO New Energy and Industrial Technology Development Organization

Managing and Promoting Technical Projects

* NEDO will introduce Its project by itself.

Contractor A

Contractor B

Contractor C

Implementing Technical Projects

MRI is implementing a kind of Micro-grid project

The Projects in NEDO

Three Major categories of the Projects

- Industrial Technology Research and Development Projects
- Projects for the Development of New Energy, Energy Conservation and Environmental Technologies
  - **Many Power system related projects are categorized here**
- International Cooperation Projects

The Projects in NEDO

(1)Grid Connection Technology

[1] Demonstrative Project on New Power Network Systems

Two Projects as "(BTB) Power Network Technology" and "Power Supply Systems by Service Level" for Distribution Network

[2] Demonstrative Project of Regional Power Grids with Various New Energies

Three Projects (Aichi, Kyoto and Hachinohe) for demonstrating power balancing in local Grid.

[3] Demonstrative Project on Grid-Interconnection of Clustered Photovoltaic Power Generation Systems

One Project installing and testing behavior of some hundreds PVs in the small area.

[4] Wind Power Stabilization Technology Development Project

Fluctuation control by battery energy system in the wind farm.

The Projects in NEDO

Superconductivity Related Project

(1) Development of Superconducting Power Network Control Technology

SMES development project the third Phase.

(2) R&D of Fundamental Superconducting Application Technologies

The Next Generation Wire development Project

(3) Research and Development of Fundamental Technologies for Superconducting AC Power Equipment

The development project for Superconducting Applications

(4) Research and Development for Superconducting Bearing Technology for Flywheel Electric Energy Storage System

Flywheel with Superconducting Bearing System

The Projects in NEDO

[1] Polymer Electrolyte Fuel Cell Technology Utilizing Hydrogen Energy

Polymer Electrolyte Fuel Cell Program for Utilizing Hydrogen Energy

(1) Development of PEFC Technologies

(2) Development for Safe Utilization and Infrastructure of Hydrogen

……

[2] New Energy Technology

(1) Development of Technology for High Efficiency Biomass Energy Conversion

(2) Solar Energy

(3) Research and Development of Solid Oxide Fuel Cells (SOFC)

(4) Technology Development of Molten Carbonate Fuel Cell (MCFC) Power Generation

……..

[3] Energy Conservation Technology

[4] Environment Friendly Energy Technology **Coal related projects**

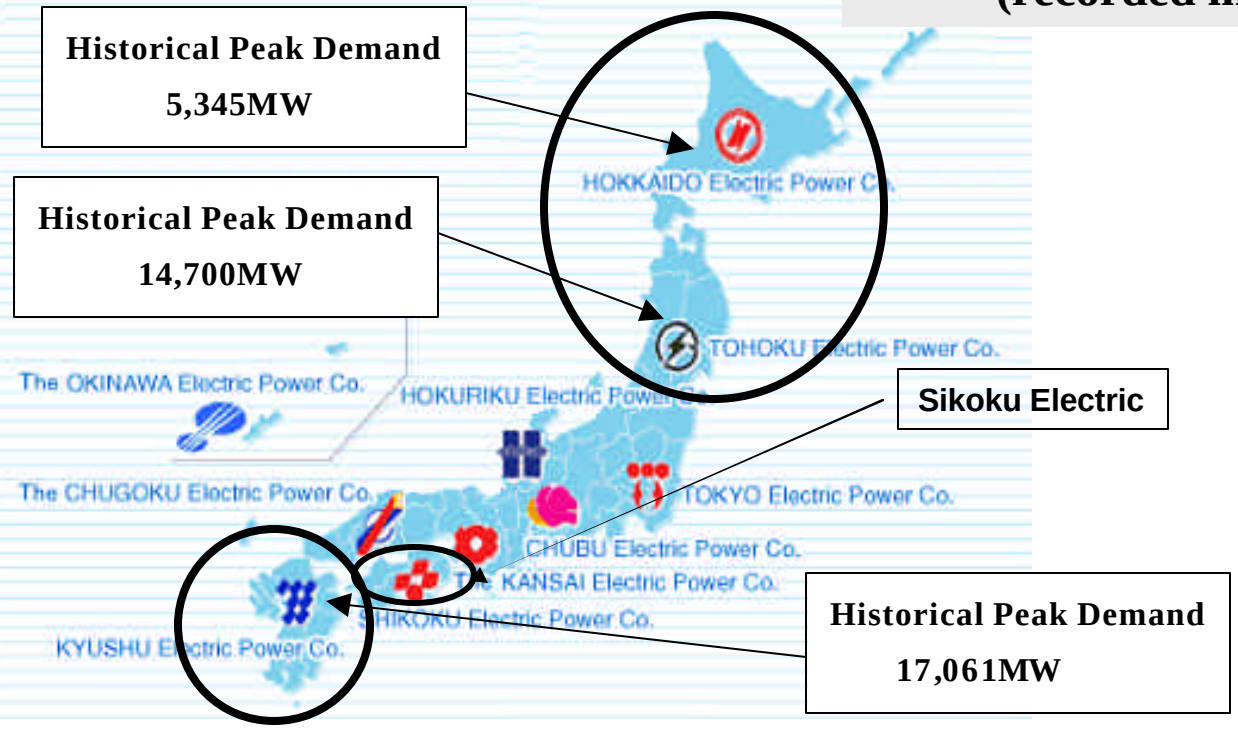
Issues on the Transmission System

- How to increase connectable Capacity of wind power -

Wind Power in Japan

- Installed capacity of wind power (the end of 2003 fiscal year) : 922MW
- Total Generating Capacity in Japanese Power System : About 200,000MW
- Historical Peak Demand : 182,378MW (recorded in 2001 summer)

Surveyed by MRI with support of FEPC (The Federation of Electric Power Company of Japan)

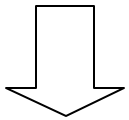


80% of the installed wind power capacities are located in three areas with better wind condition such as Hokkaido, Tohoku and Kyushu.

Hokkaido	170MW
Tohoku	375MW
Kyushu	187MW

Utilities Set Ceiling of Connected Wind Power

- **Hokkaido Electric took the occurrence of fluctuation of frequency into account, and it announced that connected capacity in area is limited as 250MW temporally.**
- **Tohoku Electric also announced its limit as 520MW.**
- **Kyushu Electric offered 50MW of new connection annually, and it will disclose total limits in year 2006.**
- **Shikoku Electric announced its limit as 200MW in this year.**

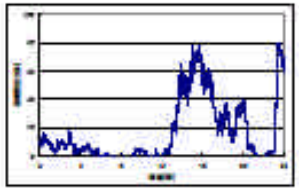


* Utilities Calculated those Results by Analytical Study and Simulation.

METI (The Ministry of Economy, Trade and Industry) held sub-committee from April 2004 to discuss those connection issues of wind power. Under this sub-committee, study teams analyzed characteristics of fluctuation of wind generation and technical countermeasure.

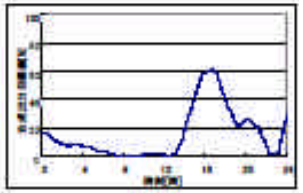
Effects of Battery Energy Storage

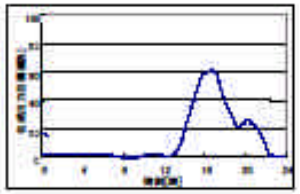
Operation Style 1



Reducing fluctuation of output from Wind Power

Battery

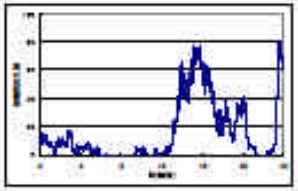




If it is difficult to keep frequency within standard of operation reduction of fluctuation from Wind Power by Batteries is effective.

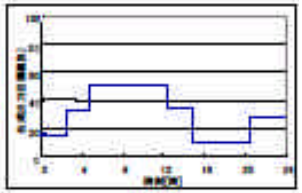
Operation Style 2

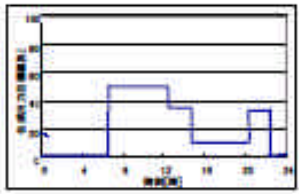
* More Battery needed than “Style 1”



Removing fluctuation of output from Wind Power for a certain period

Battery





If it is difficult to reduce thermal output in low demand period, remove of fluctuation from Wind Power by Batteries is effective.

Reference : METI (Surveyed by MRI)

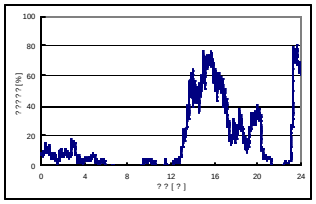
How to Control Batteries?

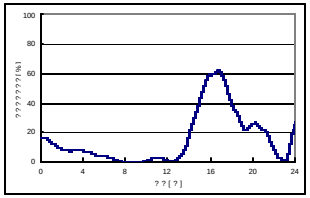
When fluctuation of wind power output must be reduced.

Low Pass Filter

For Example,

Set target output by moving average of wind power output in the past period defined by "averaging time constant".





Wind Power Output

Output of Battery and Wind Power

G

\+

\-

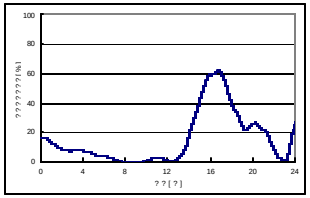
Target Output for Battery and Wind power

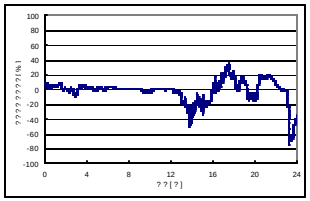
Target output of Battery

Battery Input and Output

Power Converter

Battery





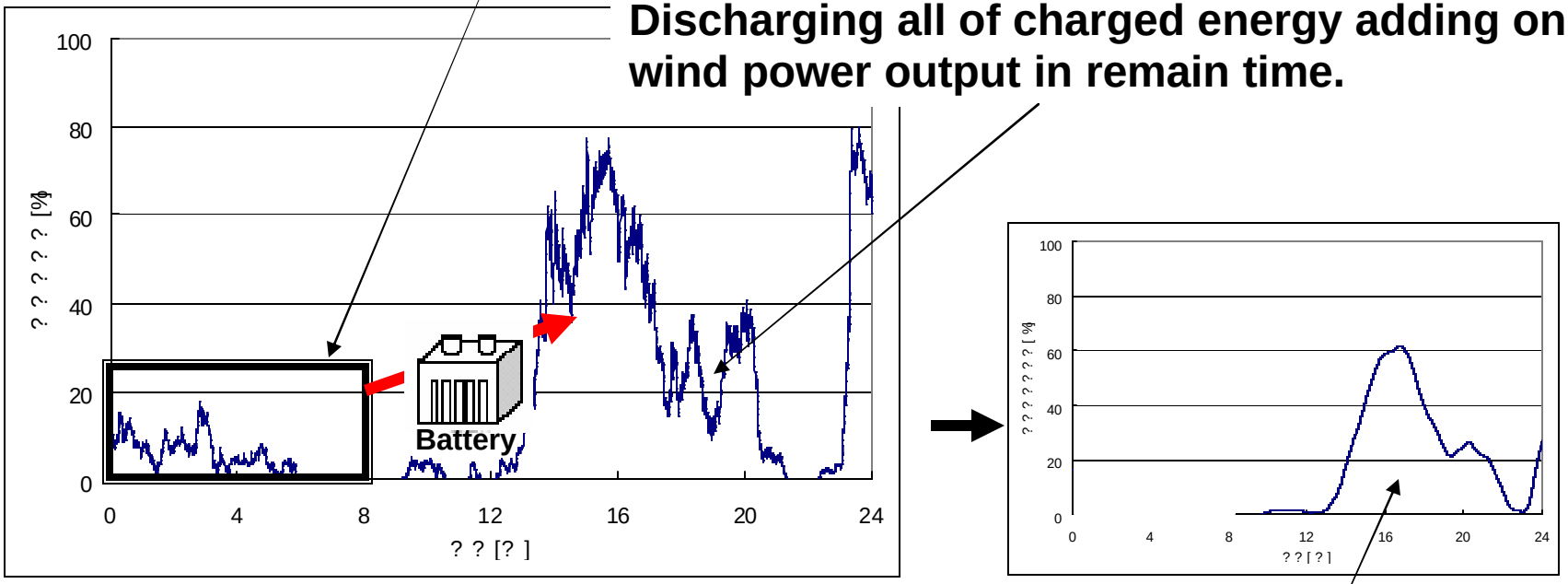
Reference : METI (Surveyed by MRI)

How to Control Batteries?

When capacity of wind power is surplus.

Charging all of generated energy in night time.

Discharging all of charged energy adding on wind power output in remain time.



Smoothing total output by using control shown previous slide

Reference : METI (Surveyed by MRI)

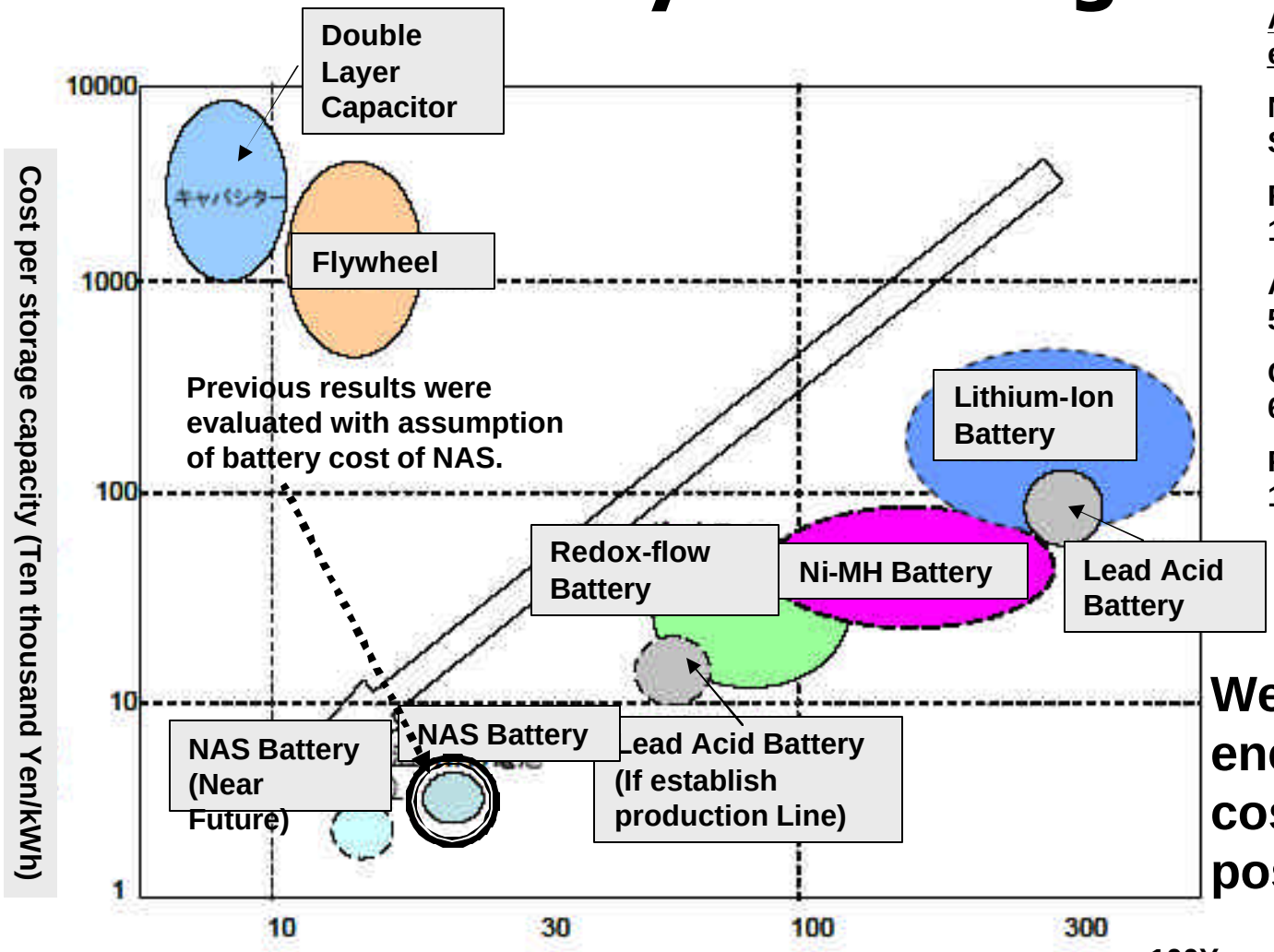
Estimated Effect of Battery Energy Storage

Loss of generated energy is estimated as a few %

Reduction of fluctuation within 20 minutes / Effective duration of avoiding reduction of thermal output	40% / 20 Minutes	70% / 20 Minutes	100% / 20 Minutes
	Averaging time horizon : 10Minutes	Averaging time horizon : 120Minutes	Fully absorbing output energy from Wind Power for 8 hours.
N/A	Installed Battery : 15-20% of wind Power Needed Battery Hour Capacity : 1 Hour Incremental Cost of Wind Energy : 1.8Yen/kWh	Installed Battery : 30-40% of wind Power Needed Battery Hour Capacity : 1 Hour Incremental Cost of Wind Energy : 4.3Yen/kWh	Loss of generated energy is estimated as 9%
8 Hours	Cost of energy from wind power Is almost 10 Yen/kWh. So,Install of battery makes price of energy as twice		Installed Battery : 100% of wind Power Needed Battery Hour Capacity : 8Hour Incremental Cost of Wind Energy : 10Yen/kWh

Reference : METI (Surveyed by MRI)

Evaluation of Battery Technologies



Assumption of stored energy capacity as :

NAS(Sodium-Sulfur) :7.2 Hours

Redox Flow : 1- 8 Hours

Acid Battery: 5 Hours

Capacitor : 6-8 Seconds

Flywheel : 15 Seconds

We need low energy storage cost battery as possible!!

100Yen =~ 1$

Data Source : METI (Surveyed by MRI)

Future of Wind Power Connection Issues

- Sub-Committee held by METI resulted support of battery will increasing connected capacity of wind power.
- To achieve national target of installed wind capacity, battery can contribute more effectively than disconnection of wind power in the required period by system operator.
- Technical problem are;
  - > Developing cheaper and large scale storage technology
  - > Demonstration of battery operation, especially “Fully absorbing” operation.
- Institutional problem is;
  - > How to compensate the cost of battery to wind firms

* By press, METI is planning to create subsidy program for battery.

Future of Wind Power Connection Issues – Another Solution -

- Still, Share of wind power on the total capacity of power system in Japan is very small as 0.5%.
- Therefore, if larger utilities can absorb fluctuation of wind power in smaller utility through interconnection between utilities, discussed issues can be qualified.
- However, Japan is on the way of the liberalization of electric power sector.
- The organization (Electric Power System Council of Japan) responsible about the establishment and coordination of the rule of network has just started in February 2004. Moreover, a wholesale market (Japan Electric Power Exchange) was established in November 2003.
- This methodology will be discussed after year 2007, when the next discussion about liberalization will start.

Issues on the Distribution System

- From Experience of our Micro-Grid Project

Issues discussed in Japan

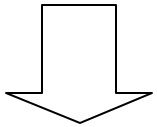
- To encourage introduction of distributed generation, especially renewbles on the distribution system, several problem are discussed such as shown below.

> Because Japanese distribution systems were principally developed for radial operation of system. Relay and voltage control system are allocated with directional character on the distribution line. Therefore, Japanese distribution system dislike reverse power flow.

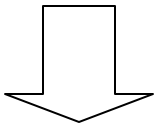
> Japanese guideline for connection of DGs is rigorous. To avoid island operation of DGs, DG is required to prepare protection equipment. Also, distribution lines are applied no-grounding or grounding with resistance, so equipment for detection of faults become relatively expensive.

Issues discussed in Japan

> Utilities want to keep quality of electricity. They concerned about disturbance of DGs from the viewpoint of power quality.



Japanese government promoting several technical development and demonstration project regarding distribution network control and management.



One of those project is *"Regional Power Grid with Renewable Energy Resources Demonstrative Project in Hachinohe" funded by NEDO(Sub-Government Organization)*

Overview of Hachinohe Regional Power Grid Project

- Main purpose of this project is to demonstrate a real Dispersed Energy Supply System which controls the total amount of energy output in response changes in weather condition and demand.
- This system includes bio-mass boilers and generators, PVs, small wind power and battery storage controlled by demand-supply management system.
- Jointly undertaken by Mitsubishi Research Institute, Inc., Mitsubishi Electric Corporation, and Hachinohe city.
- Funded by the New Energy and Industrial Technology Development Organization (NEDO) under the "Demonstrative Project of Regional Power Grids with Various New Energies".

Overview of Hachinohe Regional Power Grid Project - Site

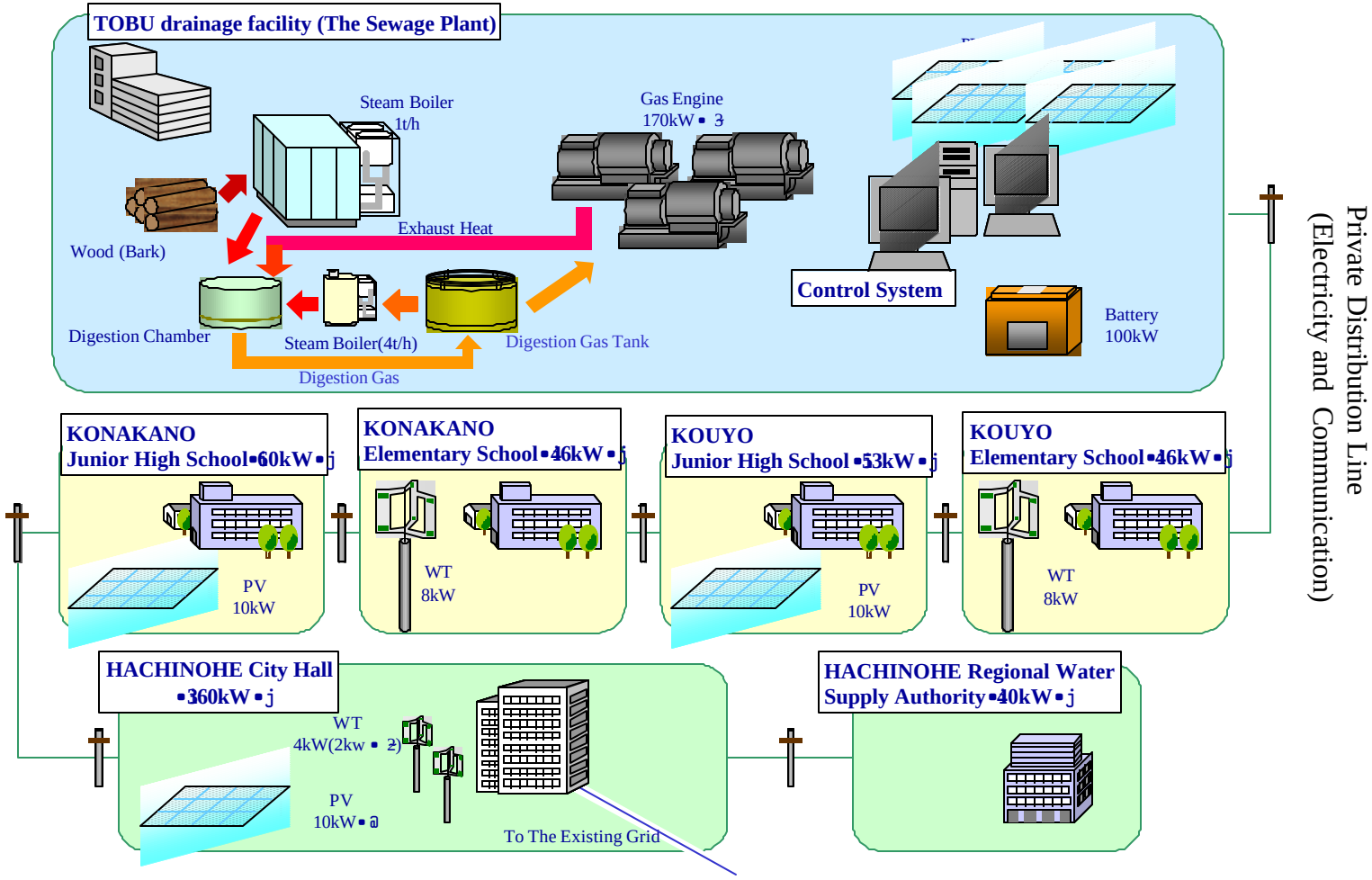
City of Hachinohe

Population : 245,096
Hachinohe is located in southeast Aomori Prefecture and serves as the core city for the northern Tohoku area.

Utility :
Tohoku Electric Power Co.

Photos: Hachinohe City

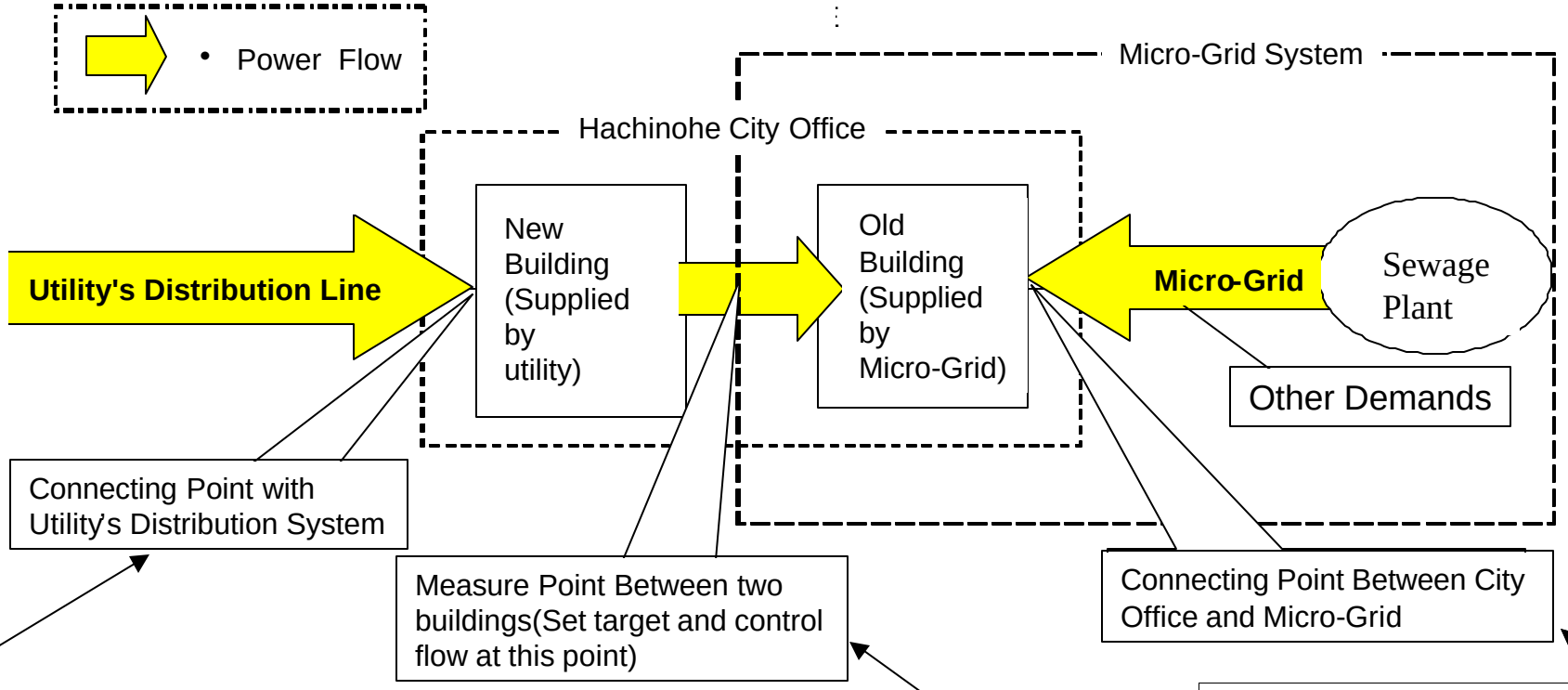
Overview of Hachinohe Regional Power Grid Project - System



Overview of Hachinohe Regional Power Grid Project - Facilities

Facilities	Installed place	Capacity	Role in the System
PVs Totally 80MW	Sewage Plant City Office Junior High Schools (Two)	50kW 10kW 10kW * 2	*Without any control *Absorbed fluctuation and managed power balance by other facilities * Total capacity Is smaller than minimum Load on the system.
Wind Turbines Totally 20MW	City Office Elementary Schools(Two)	4kW(2kW * 2. 8kW * 2	
Gas Engines Totally 510MW	Sewage Plant	170 kW*3	*Main facility supplying electricity *Fuel is digestion gas
Battery Totally 100MW	Sewage Plant	100kW-660kWh	* The regulation capacity for rapid demand change which gas engine can't response.
Wood Waste Burning Steam Boiler	Sewage Plant	1.0t/h	* Warming digestion chamber instead of digestion gas consumed by Gas Engine.
Digestion Gas Burning Steam Boiler	Sewage Plant	4.2t/h	* Warming digestion chamber when digestion gas is surplus or wood burning boiler is stopped.

Overview of Hachinohe Regional Power Grid Project – Principal of Operation

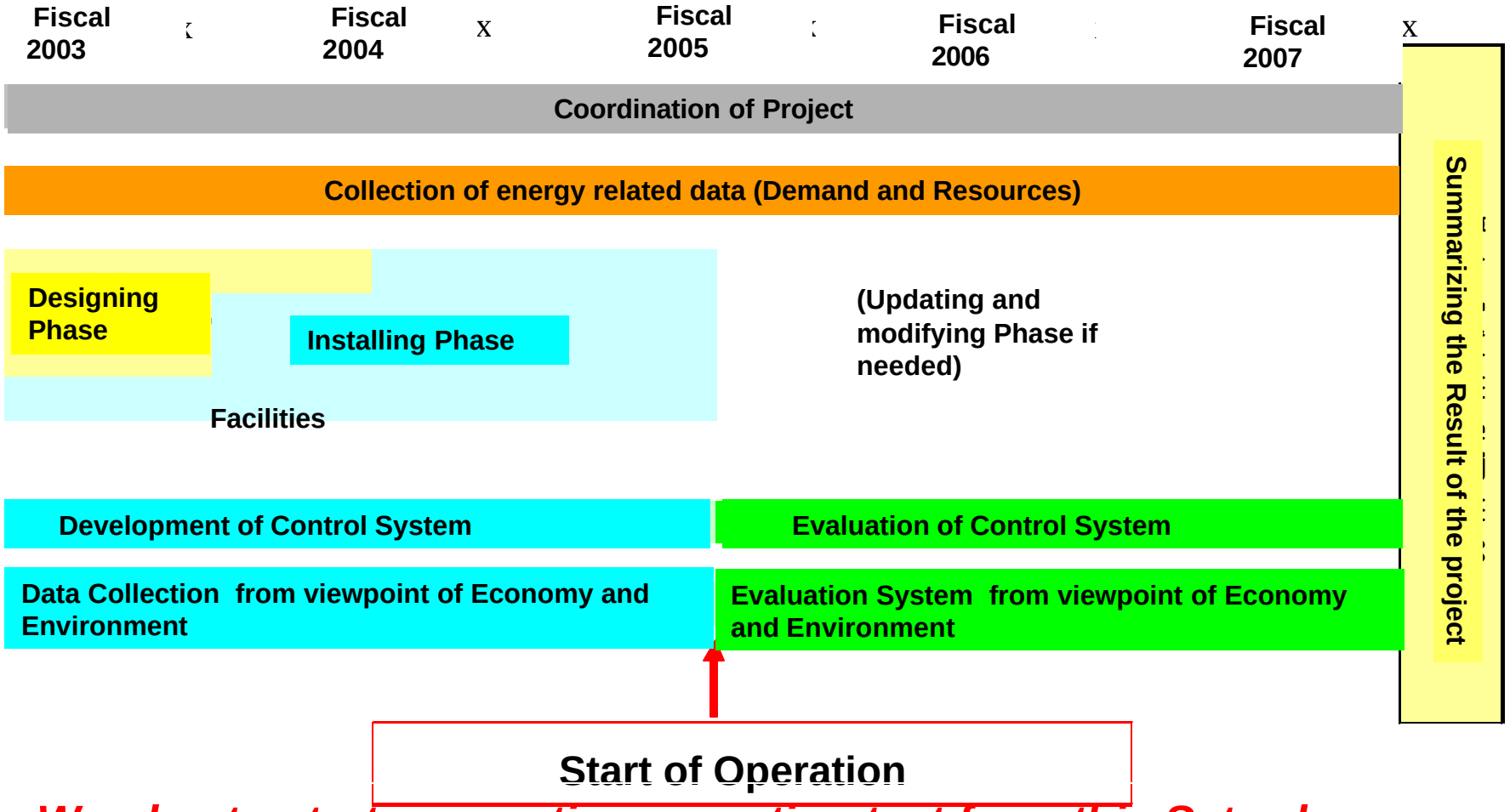


Do not flow power from City Office to Utility Grid. Prohibited by the contract with the utility.

For the purpose of experiment, power flow at this point must be control.

Do not flow power from City Office to Micro-Grid. Prohibited by the contract with the utility.

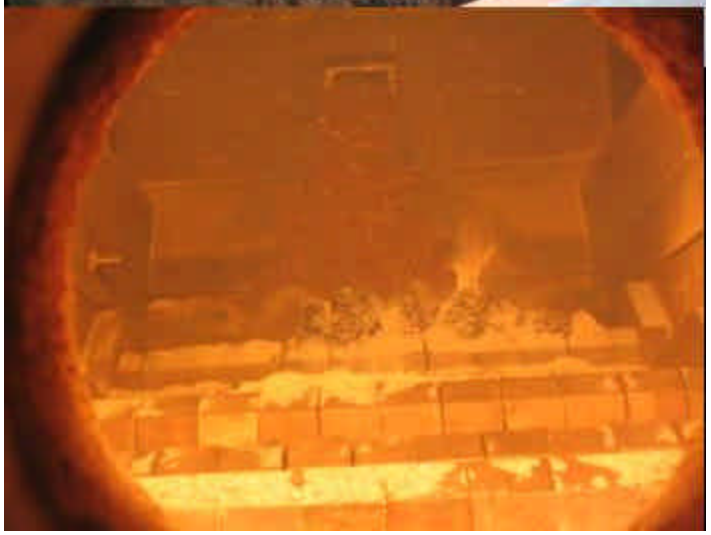
Overview of Hachinohe Regional Power Grid Project – Schedule



We plan to start connecting operation test from this Saturday

Overview of Hachinohe Regional Power Grid Project – Facilities (1)

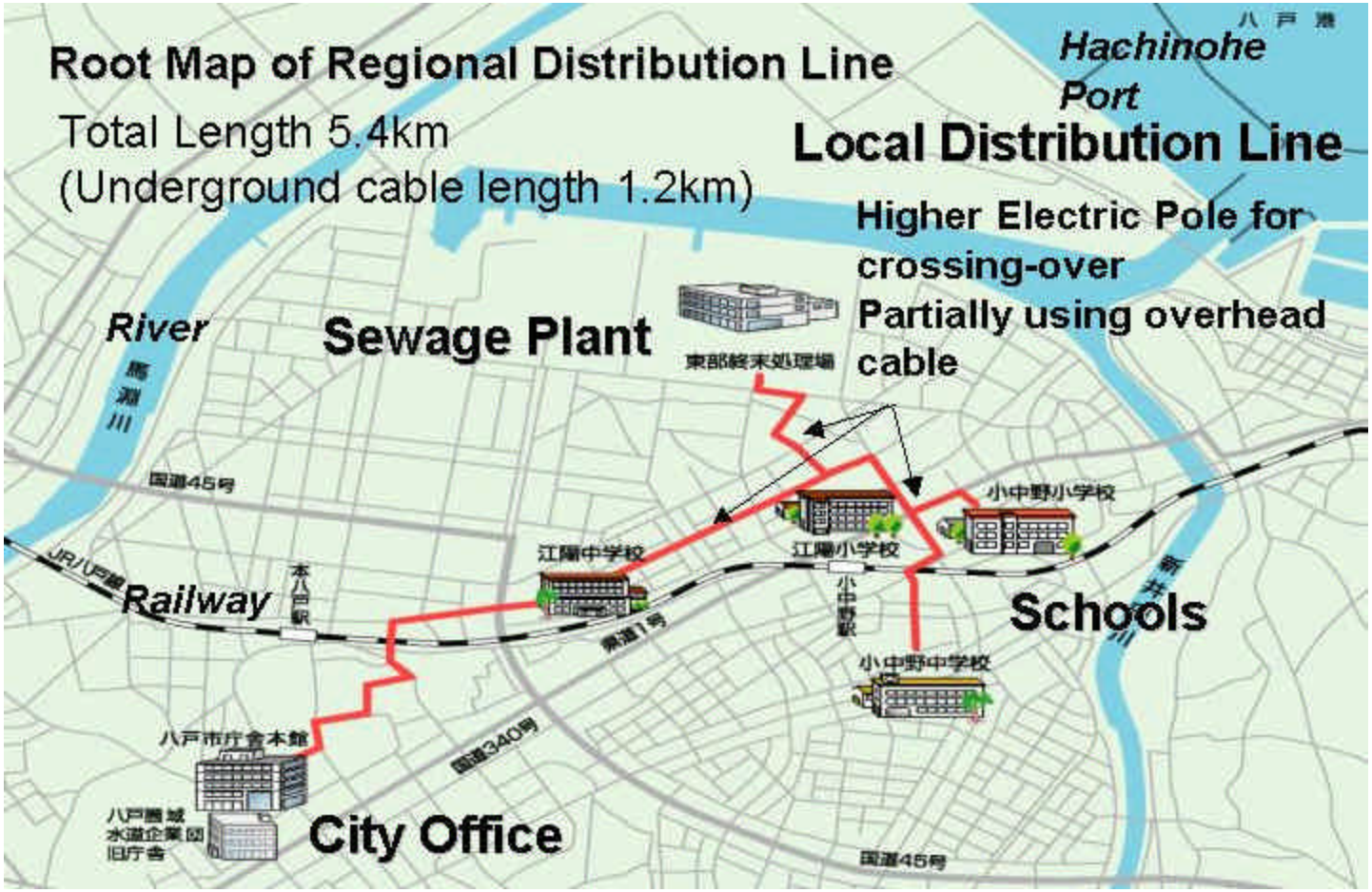
Gas Engines



Wood Waste Burning Steam Boiler

Overview of Hachinohe Regional Power Grid Project – Facilities (2)

Overview of Hachinohe Regional Power Grid Project – Facilities (3)



Overview of Hachinohe Regional Power Grid Project – Control

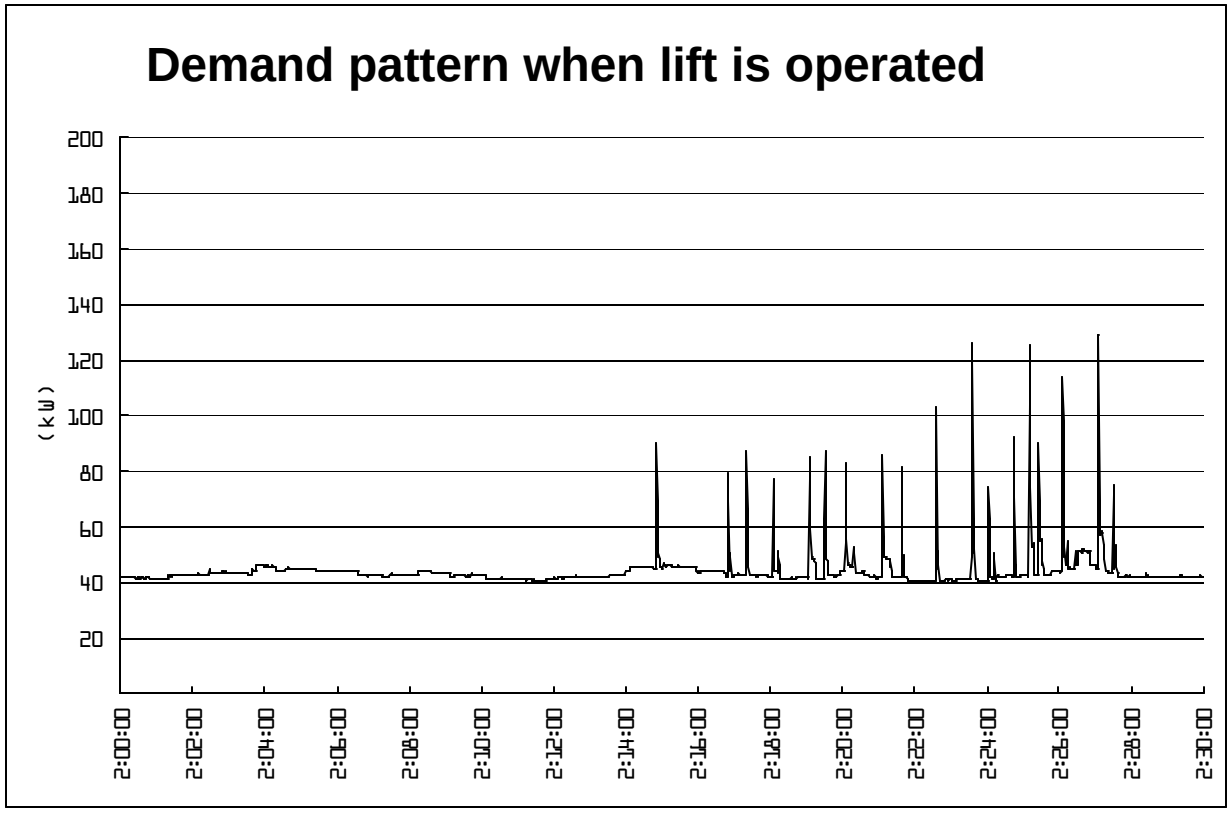
■Central 3 Layered Supply Schedule Planning and Control such as 30minutes/1 week, 3minutes/2hours, 1minutes.

■Adding Local Control when the grid is separated from utility's System.

Server for Control

Extended Knowledge from the Project(1)

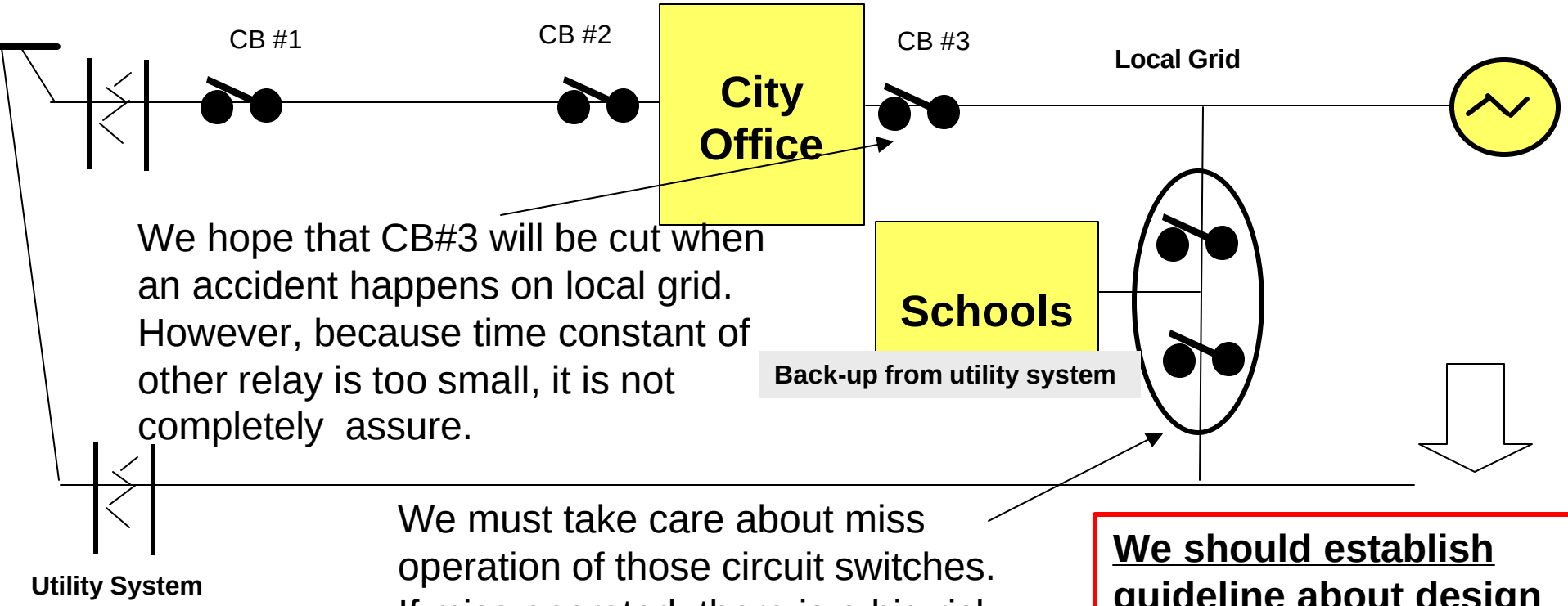
- It becomes difficult to match supply and demand if regional system becomes smaller.



We are considering one more shorter control cycle layer added, for island operation test.
In the small grid, pulsed load is more serious than fluctuation of renewable resources. Also, imbalance of 3 phase becomes larger.

Extended Knowledge from the Project(2)

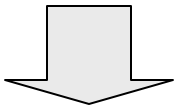
- Creating “Protection” and Coordination of “Relay System” is more difficult than single DG installation.



We should establish guideline about design of micro-grid, especially, regarding protection.

Our Goal of the Project

- The Grid will start operation from this August.
- Officially, Commercial operation will start from October 1st.
- The first half year, the system will be operated connecting with utility system.
- Several test including island operation test will be started in the next fiscal year.



* We will evaluate actual small renewables economical and environmental contribution.

* We will evaluate what are important point when micro-grid is designed. --- What is the minimum requirement of such grid?

Which direction power system technologies are going?

The Needs of large scale Energy Storage!

- From the discussion of wind power connection issue in Japan, the needs of large scale Energy Storage is spotlighted.

In Japan;

- Pumped Hydro Plants have been invested. However, convenient site became difficult to be found now.
- NAS Battery is the cheapest battery with large kWh of the alternatives.
- Still we are looking for other type of battery with low kWh cost.

* Compressed Air Storage may be one of the choice, however we don't have good site inside of Japan.

Large Resources or distribution resources?

- In these years, we have discussed which is better for environment and energy conservation between centralized large scale resources such as nuclear or LNG thermal and distribution generation.

In Japan;

- National government recognizes that DGs can contribute when it is applied as cogeneration.
- Especially, Japanese residential consume large volume of hot water. So, Distributed PEFC(PEM) is now competed with CO2 Heat Pump (COP is almost 3.0).

* Japanese residential more than 200L/60degree-Centigrade in one night.

Micro Grid can help Renewables?

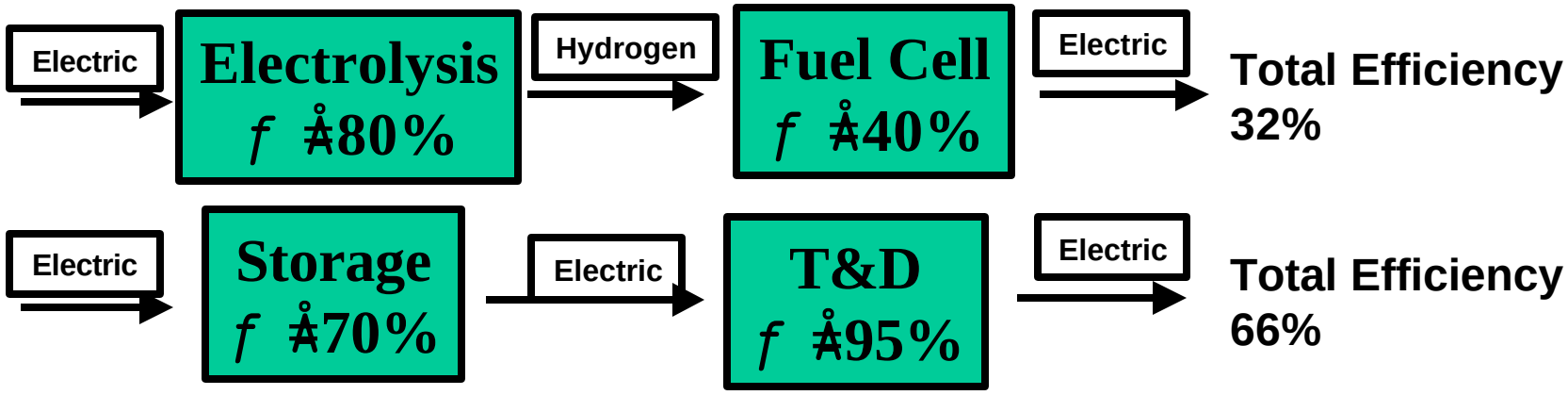
- Discussion of Micro-Grid should be stepped up from conceptual to reality.
- Even though we are promoting a kind of Micro-Grid project, we are worried about economy of those technologies.
- We may investing more special equipment for stabilized system, by fewness of connecting demand and equipment.

In Japan;

- Our project is facing practical issues.
- Japanese government prepare subsidy program for local grid with renewables. However, still people don't know how many thing they must review issues before design.

Hydrogen or Electric?

- Without good hydrogen resource, especially depending on electrolysis, energy storage may be better efficient.



In Japan;

- No good natural resources for Hydrogen.
- Still no good idea for transporting Hydrogen.

* Still we don't have well developed natural gas pipe lines.

- We evaluate only mobile application can be realized.

Penetration of Renewables and Deregulation….

- Unfortunately, deregulation of energy sector has affect on incentive method for penetration of renewables and energy conservation.

In Japan;

- In the discussion of wind power connection, supporting from neighbor utility for absorb fluctuation of wind power output is not discussed, because rule regarding utilization of interconnection line must be discussed on the other stage defined by Electric Utility Law.
- In near future, deregulation and new regulation regarding environment must be conflict.

Conclusion and issues to power system engineers

- Really needed future technologies in power system are still in a mist. However, Even though demonstration projects are not economical, we need trial for knowing actual merit.
- Rule in the energy service and policy regarding environment must be integrated, because energy market and environment market must be both side of coin.
- From our experience, renewbles need to be mature. We met several problem before constructing network system.

  * Short life time of Fuel Cells, higher risk of trouble of renewables than we expected, and difficulty of handling.
- Power system simulation is also important for discussing and evaluating required technologies for those new power system.

* However, we are facing deficiency of simulation tools, especially real time simulation tools for evaluating dynamics of those new power system.