WNU-SI in Canada

Non Nuclear Technology: Renewables

July 9, 2008

Toshiya NANAHARA

Central Research Institute of Electric Power Industry (CRIEPI), Tokyo, Japan

Future Options for Energy to Cope with CO_2 Problems Except for Nuclear

- Cleaner fossil fuels and their efficient use,
- Renewable energy,
- Energy efficiency in buildings, appliances, transport and industry,
- Carbon capture and storage,

etc.

.source.mostly owing to http://www.iea.org/dbtw-wpd/G8/docs/G8_Leaflet_WEB.pdf

Renewables for Electricity Production

- Hydro: small-scale hydro,
- Solar: photovoltaic, etc.
- Wind: wind turbines
- Geothermal: conventional and innovative
- Biomass: wood chip, biogas, residue, etc.
- Ocean: wave, tide, etc.

High Growth

etc.

Outline of Presentation

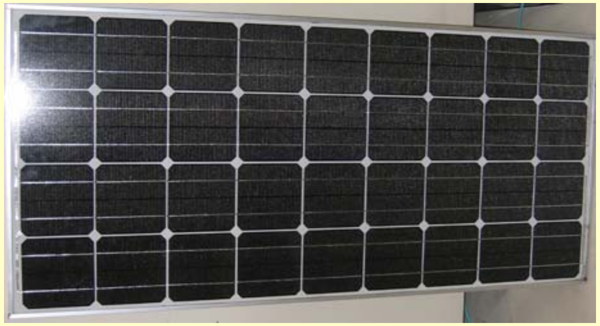
[Main target]

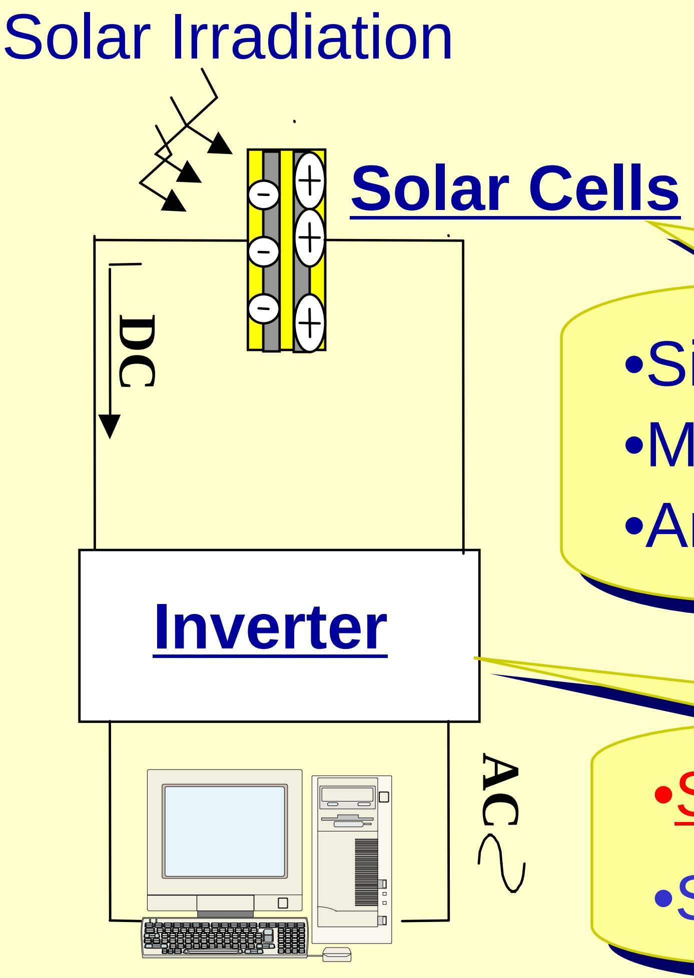
Photovoltaic and wind power

[Outline]

1. Technology outline and recent trend
2. Advantages and disadvantages
3. Characteristics from the viewpoints of electricity grid

Photovoltaics Generation (PV)





- Single crystal
- Multicrystal
- Amorphous

Tradeoff between cost and efficiency

- System Interconnection Type
- Stand-Alone Type

Photovoltaic Generation

[Photo] By courtesy of Dr. Nakaoka

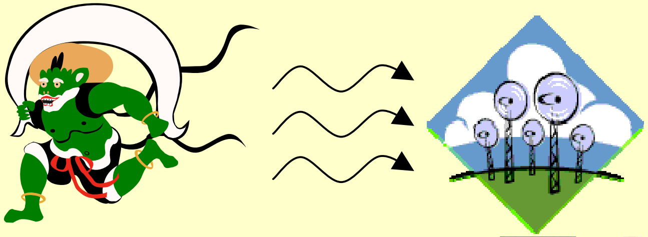
Wind Energy Converter (WEC)

Wind → **Wind Turbine** → **Gear, etc.** → **Generator, etc.** → Electric Output

Mechanical Equipment (Wind Turbine; Gear, etc.)

Electrical Equipment (Generator, etc.)

Fully understanding wind power requires various backgrounds.

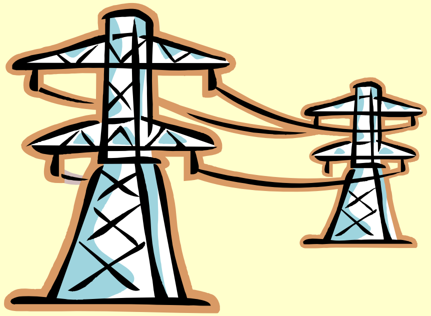


Wind Farm

Otonnrui Wind Farm (Horonobe, Hokkaido)

[Photo] By courtesy of Horonobe Town

Site Suited for Wind Farms

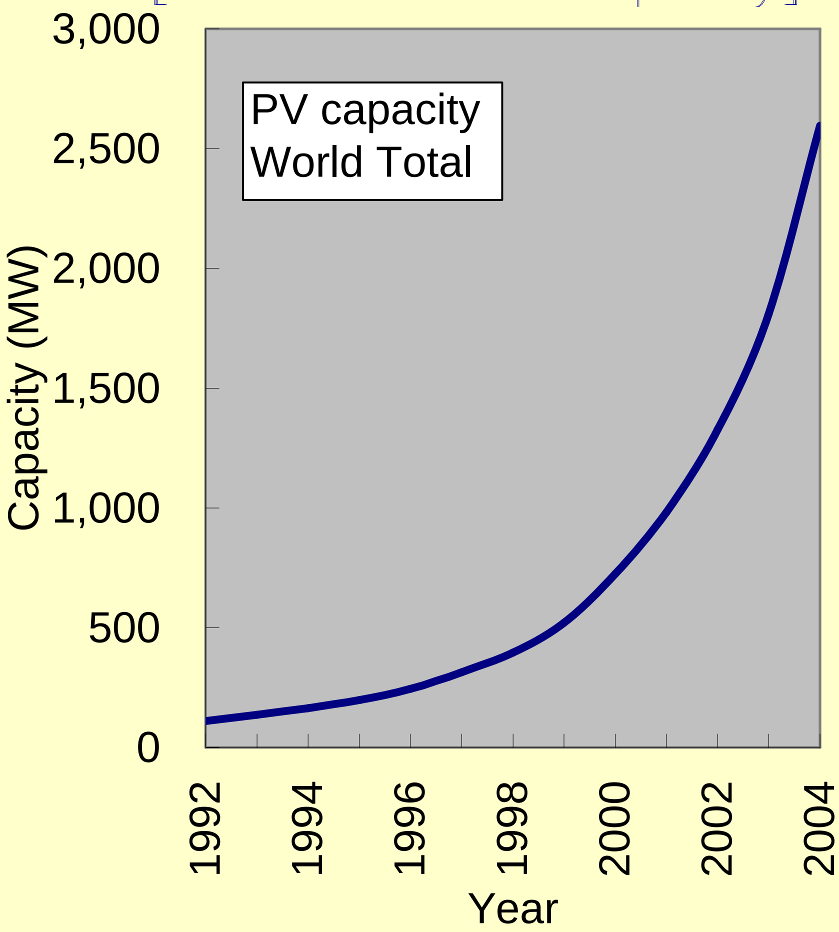


- Availability of wide land,
- Access to a good road,
- Easy access to transmission (or distribution) lines,
- Not-included in natural park,
- High wind speed.

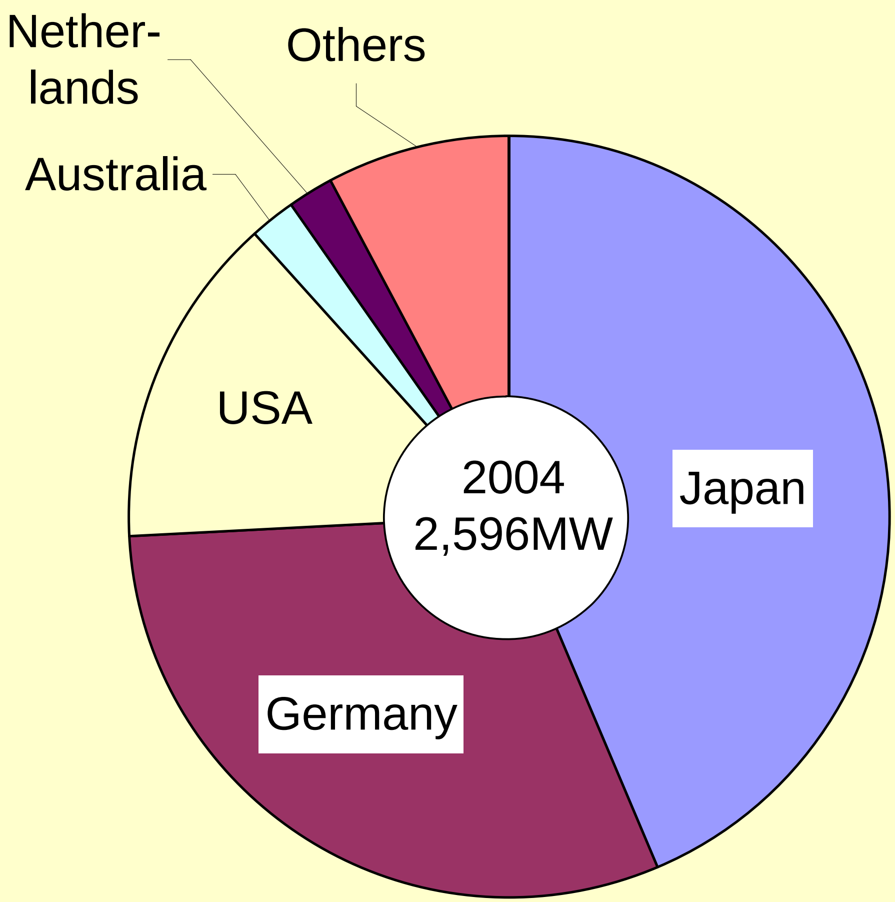
etc.

PV Capacity in the World

[Increase of PV capacity]



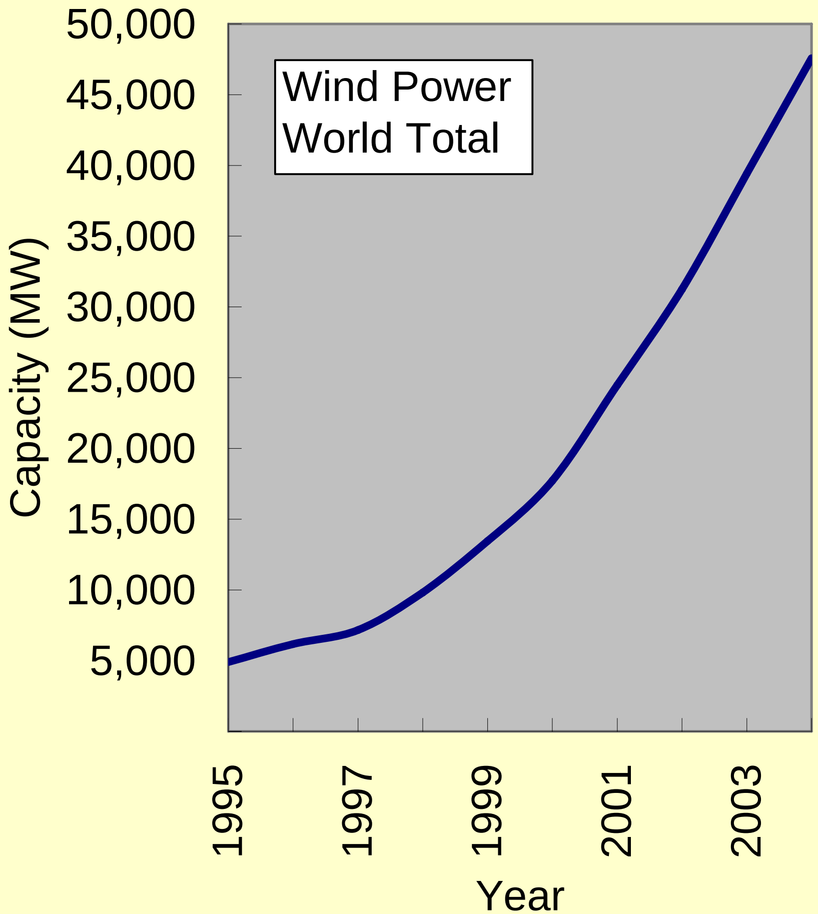
[Global share of PV capacity]



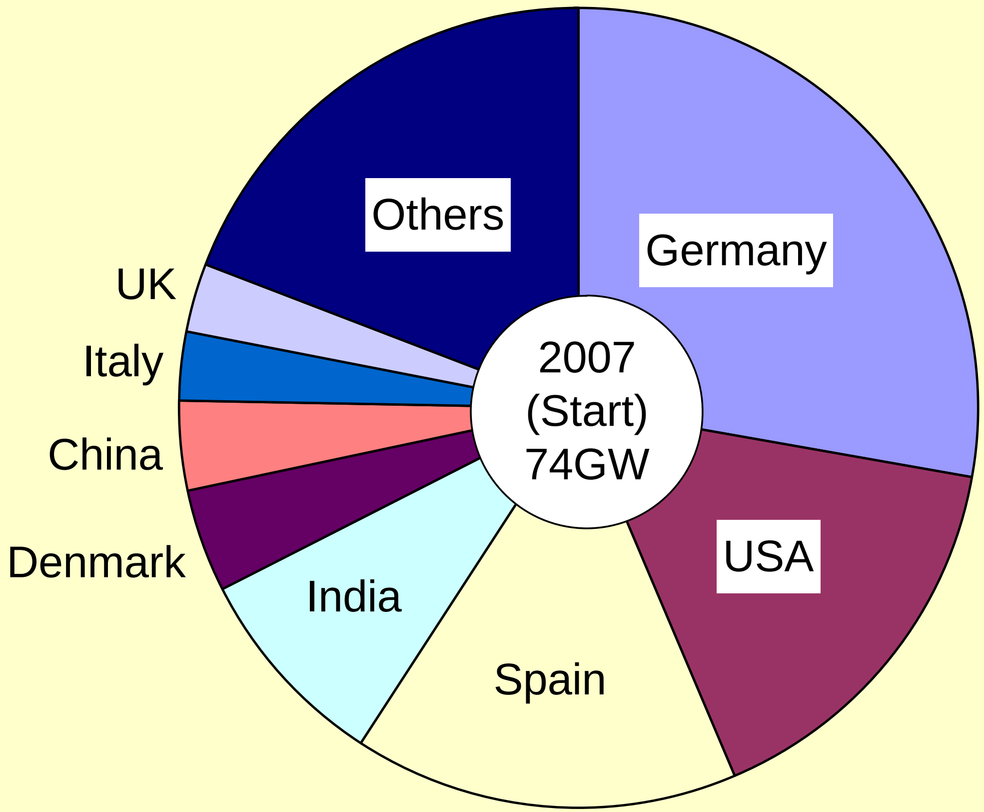
[Data source] NEDO HP http://www.nedo.go.jp/nedata/top.htm

WEC Capacity in the World

[Increase of WEC capacity]

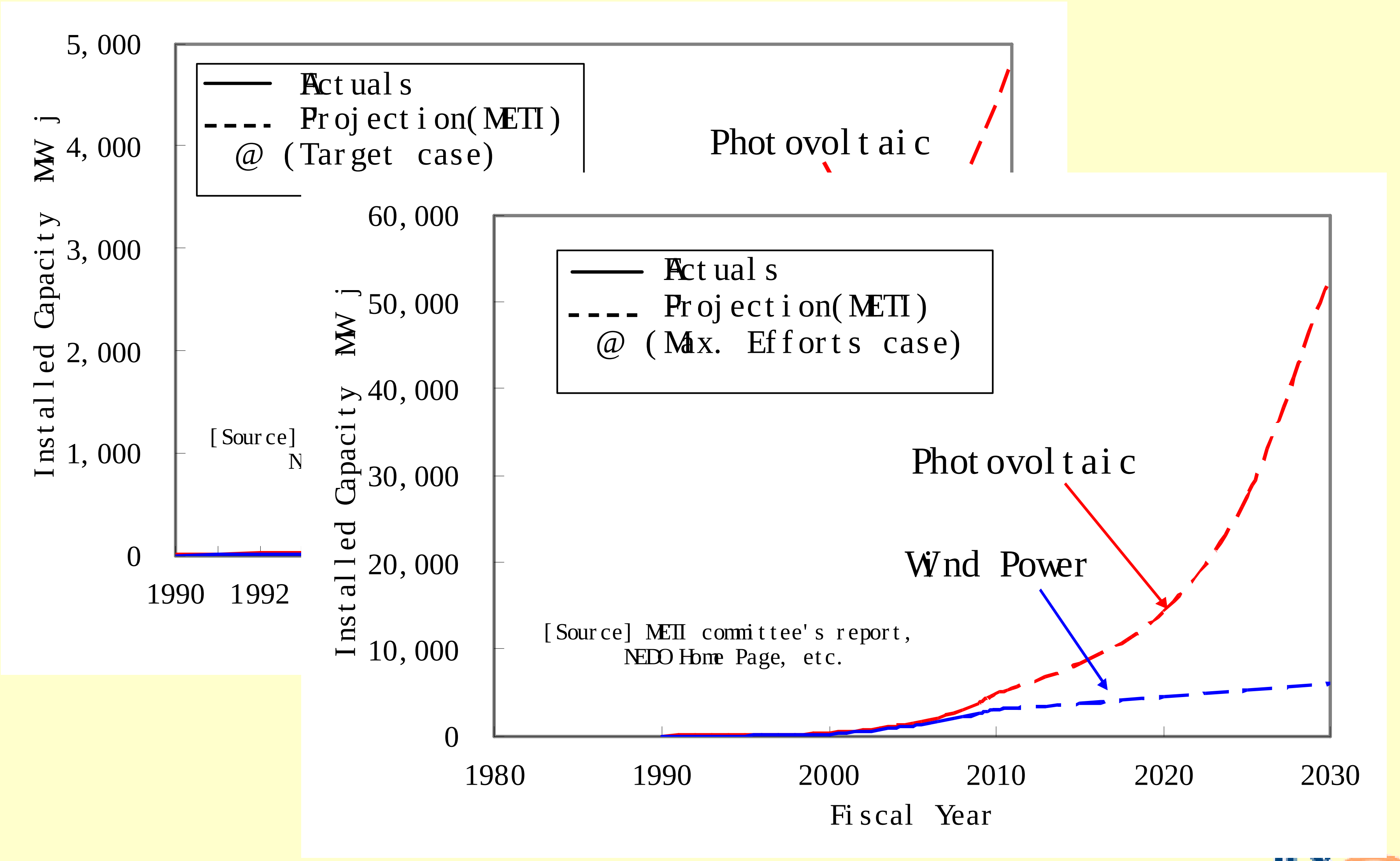


[Global share of WEC capacity]



[Data source] NEDO HP http://www.nedo.go.jp/nedata/top.htm
WindPower Monthly HP http://www.windpower-monthly.com/WPM:WINDICATOR

PV & WEC Capacity in Japan



Key Issues In the Presentation

- Advantages and disadvantages
  - Comparing renewables with the other energy sources could be a highly controversial issue.
- Renewables viewed from electricity grid
  - The other aspects of renewables: distributed generation / intermittent generation.

CRIEPI

Outline of Presentation

1. Technology outline and recent trend
2. Advantages and disadvantages
3. Characteristics from the viewpoints of electricity grid

of photovoltaic and wind power generation.

4. Closing remark

Advantages of Renewables

- **Non-exhaustive carbon-free energy source.**

Generally speaking, they are:

- Supposedly environment-friendly energy,
- More easily accepted by public,
- Technology improvement in recent years, etc.

Disadvantages of Renewables

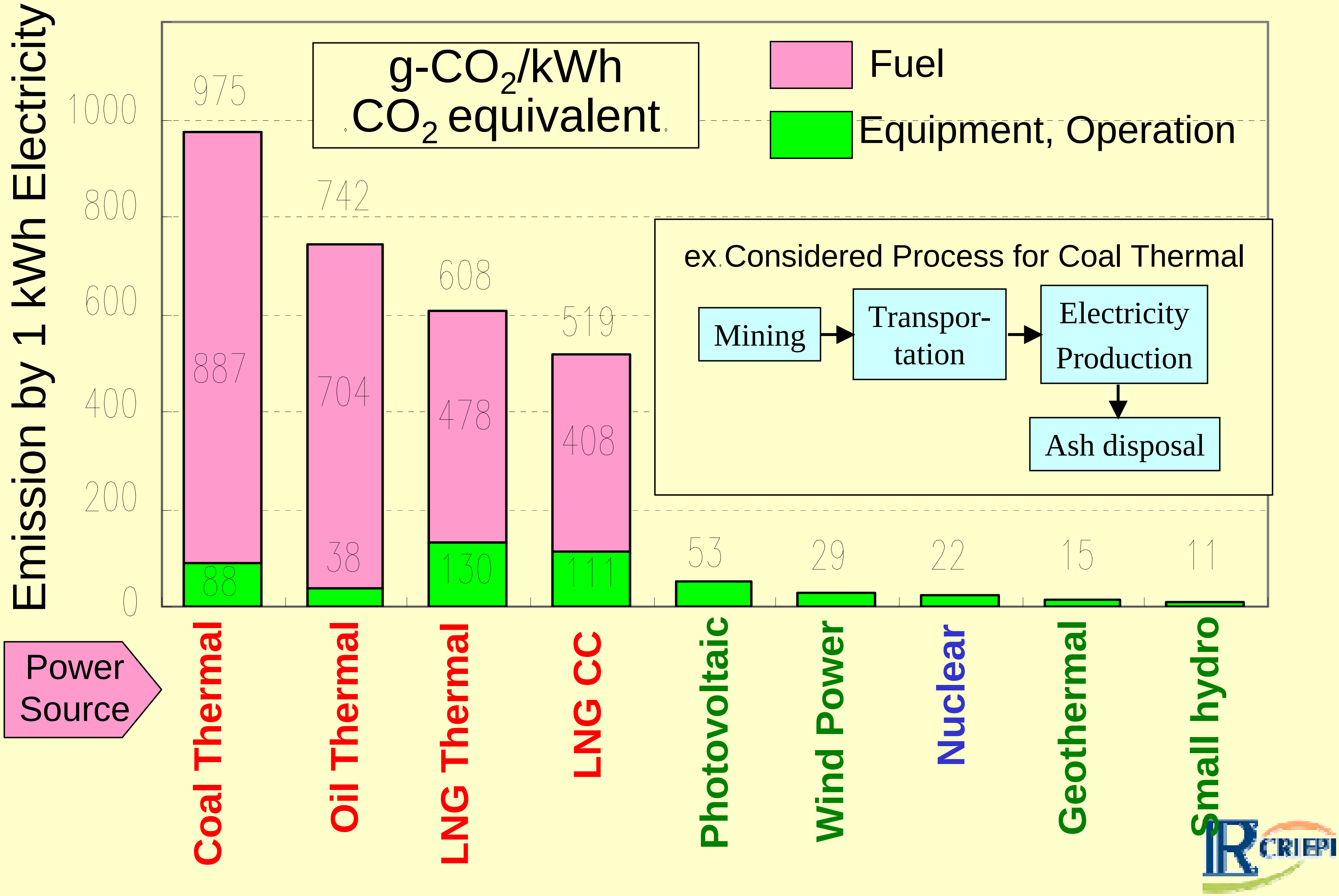
Generally speaking,

- They have low power density;
- Their capacity factor is mostly not so high.

  Thus, they are mostly expensive than conventional energy.
- Their output is unstable;
- They sometimes needs provision for environmental impacts.

etc.

Emission of Power Sources



Required Area for Renewables

20m

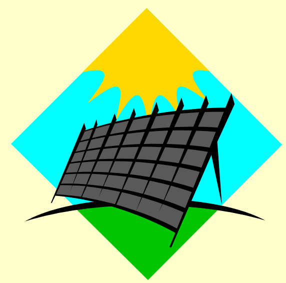
1MW machine
Spacing of WEC: 10Dx3D
...Rotor diameter.
Capacity Factor: 20%

Wind Power

10m

Irradiation
:1kW/m²
Efficiency: 10%
Cap. factor: 10%

Photovoltaic



0.5m

Thermal

Biomas.some ten times area is required

[Note] Required area: area needed for annual average output power of 1kW

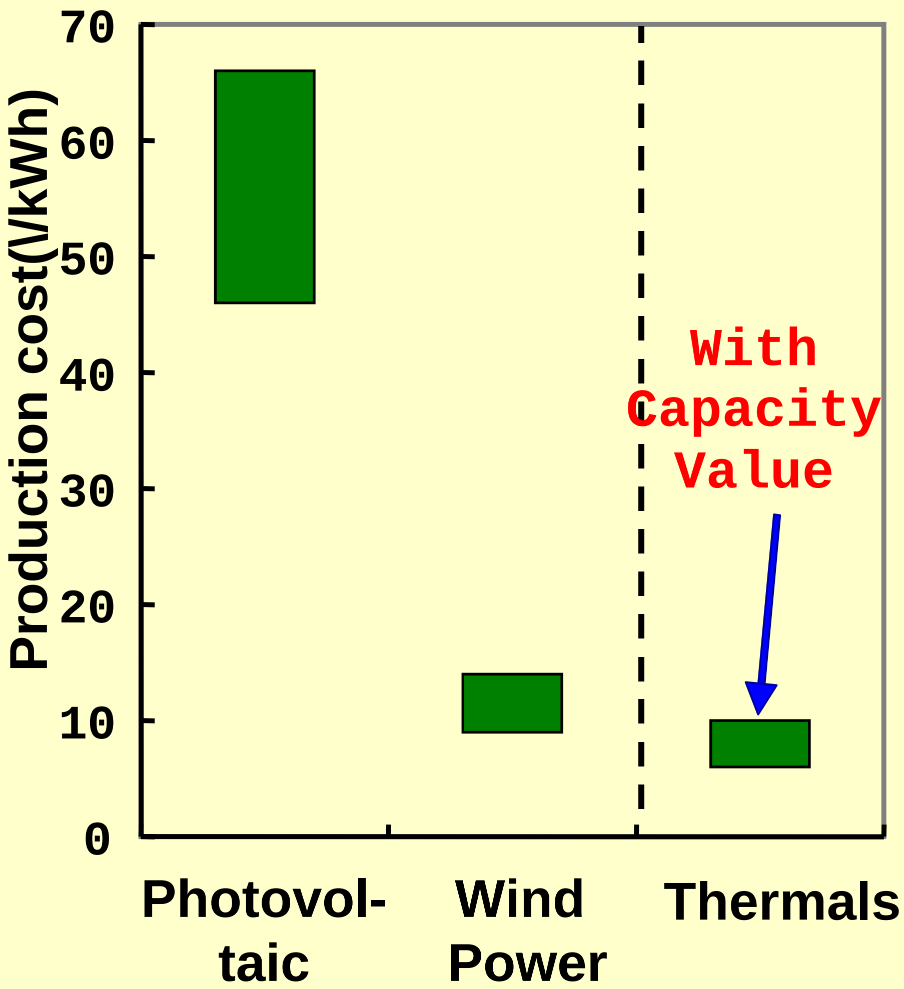
Renewable Energy Capacity Factor

	Required area (order)	Capacity factor
Photovoltaic	10^{-2}kW/m^2	11% (Japan)
Wind Power	10^{-3}kW/m^2	15-30%
Biomas Power	10^{-4}kW/m^2	Depending on fuel availability
Therma	10^{0}kW/m^2	90%

[Note] Required area is calculated with annual average output power.

CRIEPI

Production Cost of Renewables

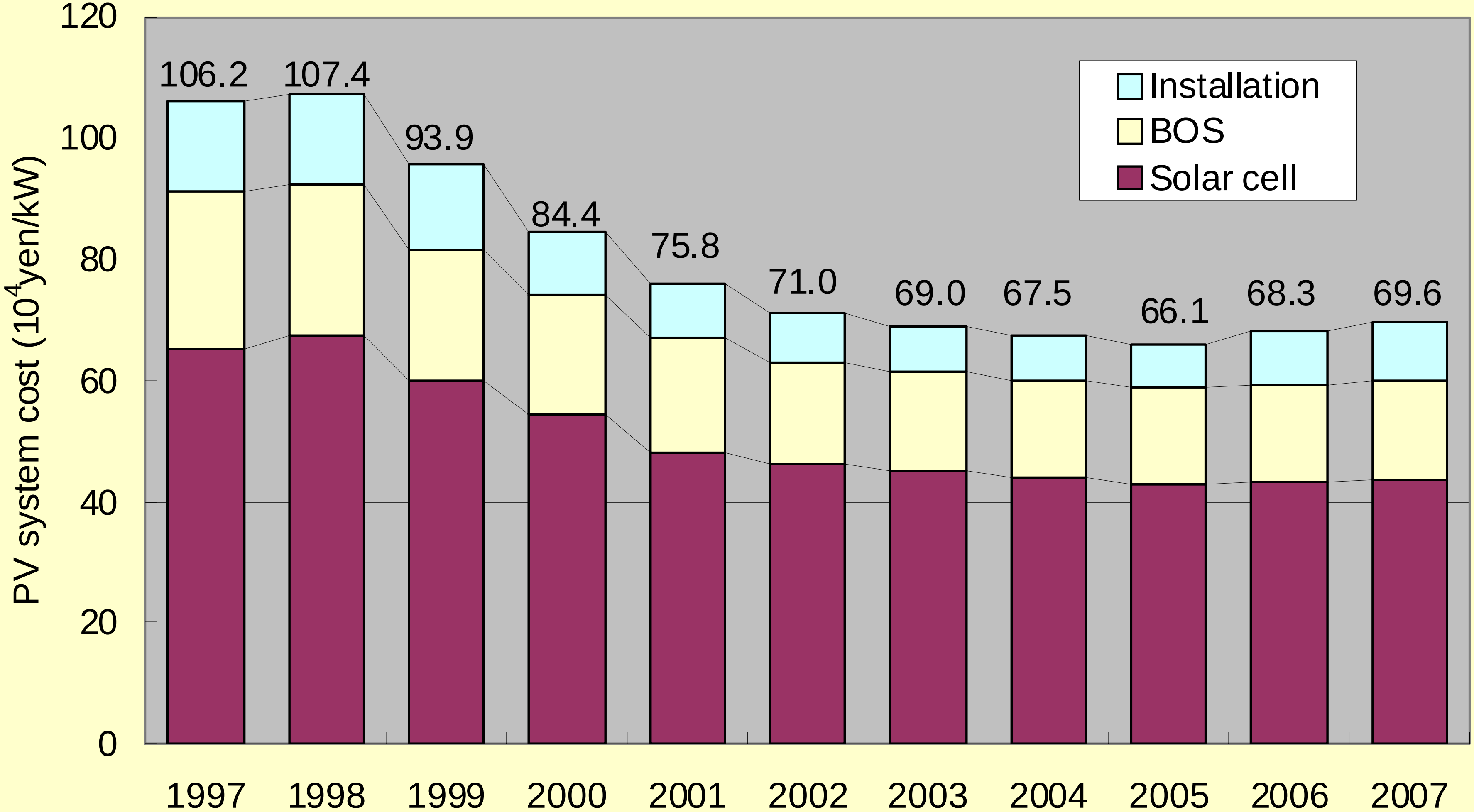


Cost of renewables is decreasing. However, the following measures are generally introduced due to their high cost:

- Institutional measure: feed-in-tariff, renewable portfolio standard, etc.
- Subsidy for installation, etc.

[Data source] New Energy Subcommittee of the Advisory Committee for Energy

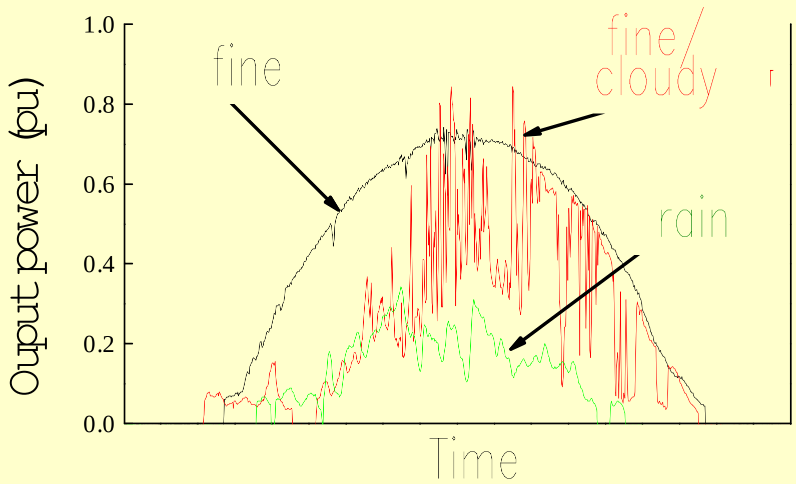
Trends in PV cost



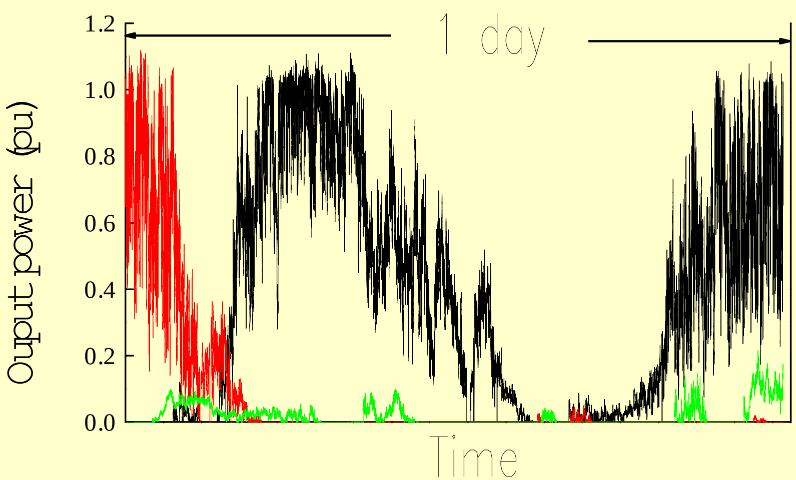
[Data source] NEF HP http://www.solar.nef.or.jp/system/html/taiyou_sys080508.pdf

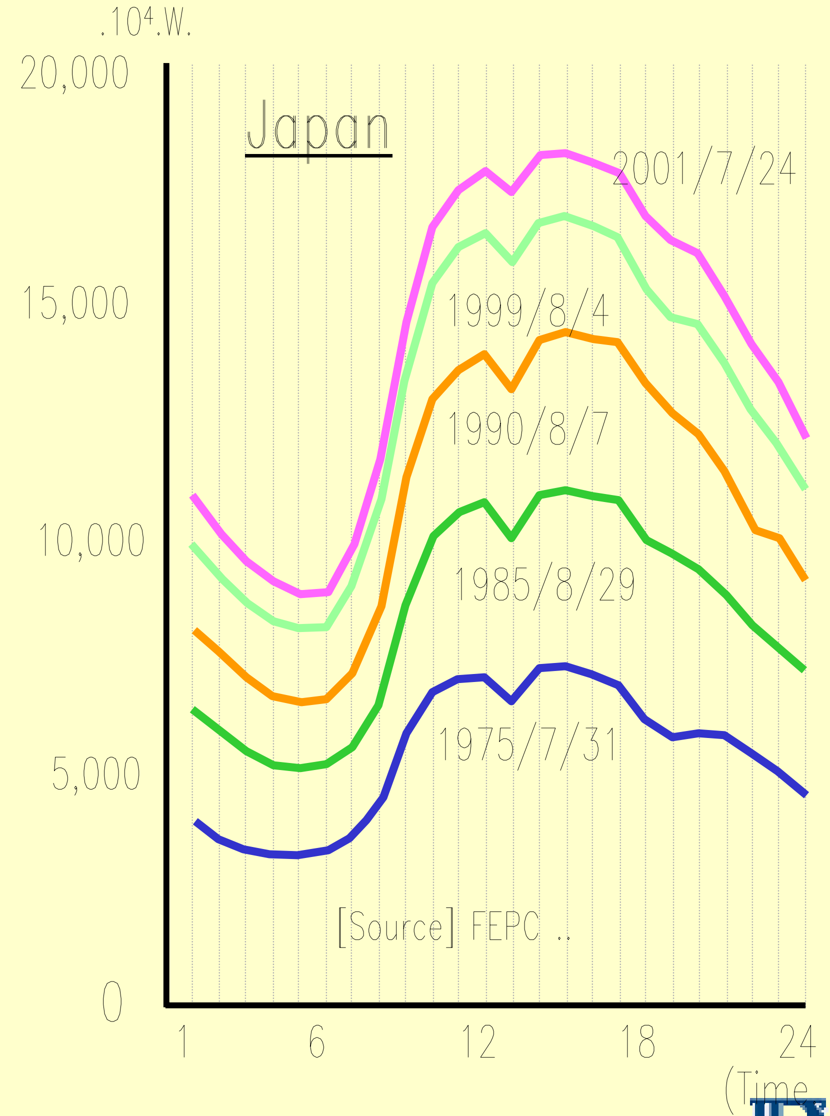
Output of Renewables vs. Elec. Demand

.Photovoltaic.



.Wind Power.

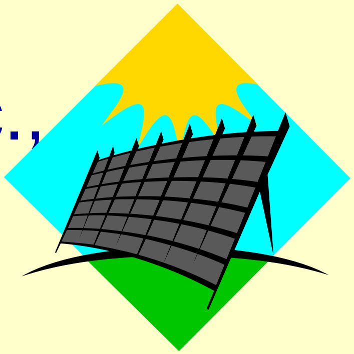




Pros and Cons of Photovoltaics

[Advantages]

- Applicable to various places (residence, etc.),
- Low maintenance requirement,
- Small environmental impact : noise, etc.,
- Familiar to many people, etc.



[Disadvantages]

- Low energy density: solar insolation:1kW/m^2,
- Low capacity factor: about 12%,
- Intermittent output: dependence of on weather,
- Not economically viable, etc.

Pros and Cons of Wind Power

[Advantages]

- Relatively low cost in renewables,
- Larger capacity factor than PV's at a windy site, etc.

[Disadvantages]

- Challenges in harnessing wind,
- Low energy density,
- Intermittent large output fluctuation due to weather,
- Environmental impacts – noise, scenery, etc.
- Windy area ≠ not densely resided area
  → weak grid, etc.

CRIEPI

Challenges in Harnessing Wind

- Turbulence is inevitable.
- Its power is proportional to third power of its velocity.
- Wind turbines are used under severe natural conditions: eg, gust, lightning, typhoon.

- Difficulty in adjusting a turbine to a specific wind conditions,
- Reliability of a wind turbine,
- Requirement of maintenance works, etc.

Closing Remark (pt.2)

- Renewables, as a matter of course, have their inherent pros and cons. *How do you assess them in comparison with the other energy sources?*
- Most renewables take advantage of interconnecting to a power system. This causes another important aspect of renewables discussed later.

Outline of Presentation

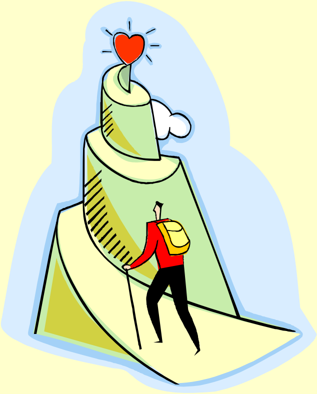
1. Technology outline and recent trend
2. Advantages and disadvantages
3. Characteristics from the viewpoints of electricity grid

of photovoltaic and wind power generation.

4. Closing remark

Action Plan of IEA to respond to the Request of G8 Summit

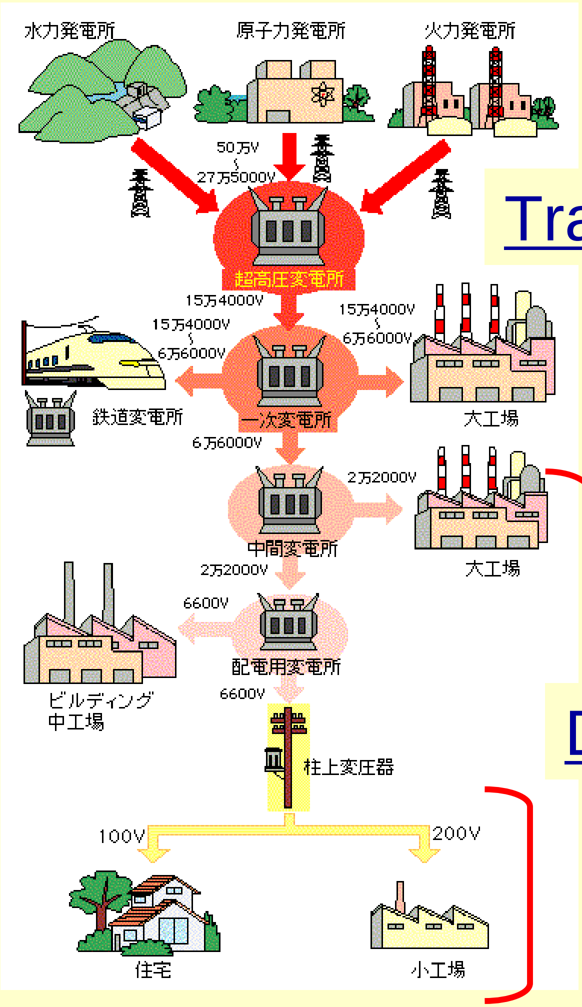
- Cleaner fossil fuels
- Renewable energy: ………….. A dedicated international group of experts …. will speed development of common technical and policy approaches to integrating intermittent renewable energy into electricity grids.
- Energy efficiency in buildings, appliances, transport and industry
- Carbon capture and storage



.source.http://www.iea.org/dbtw-wpd/G8/docs/G8_Leaflet_WEB.pdf

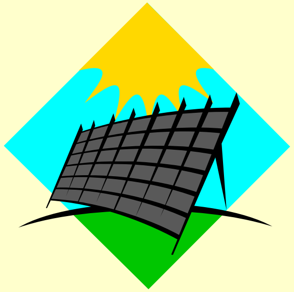
Challenges in Connecting Renewables

- Distributed generators interconnected to weak grid;
  e.g. PVs to low-voltage distribution lines (100/200V)
- Intermittency of output power with difficulties in accurate output forecasting.



Transmission

Distribution



[Source] FEPC ..

Intermittency of Renewables

- Outputs of PV and wind turbines contains large fluctuations difficult to predict.
- Their output could be very low in case of peak demand.

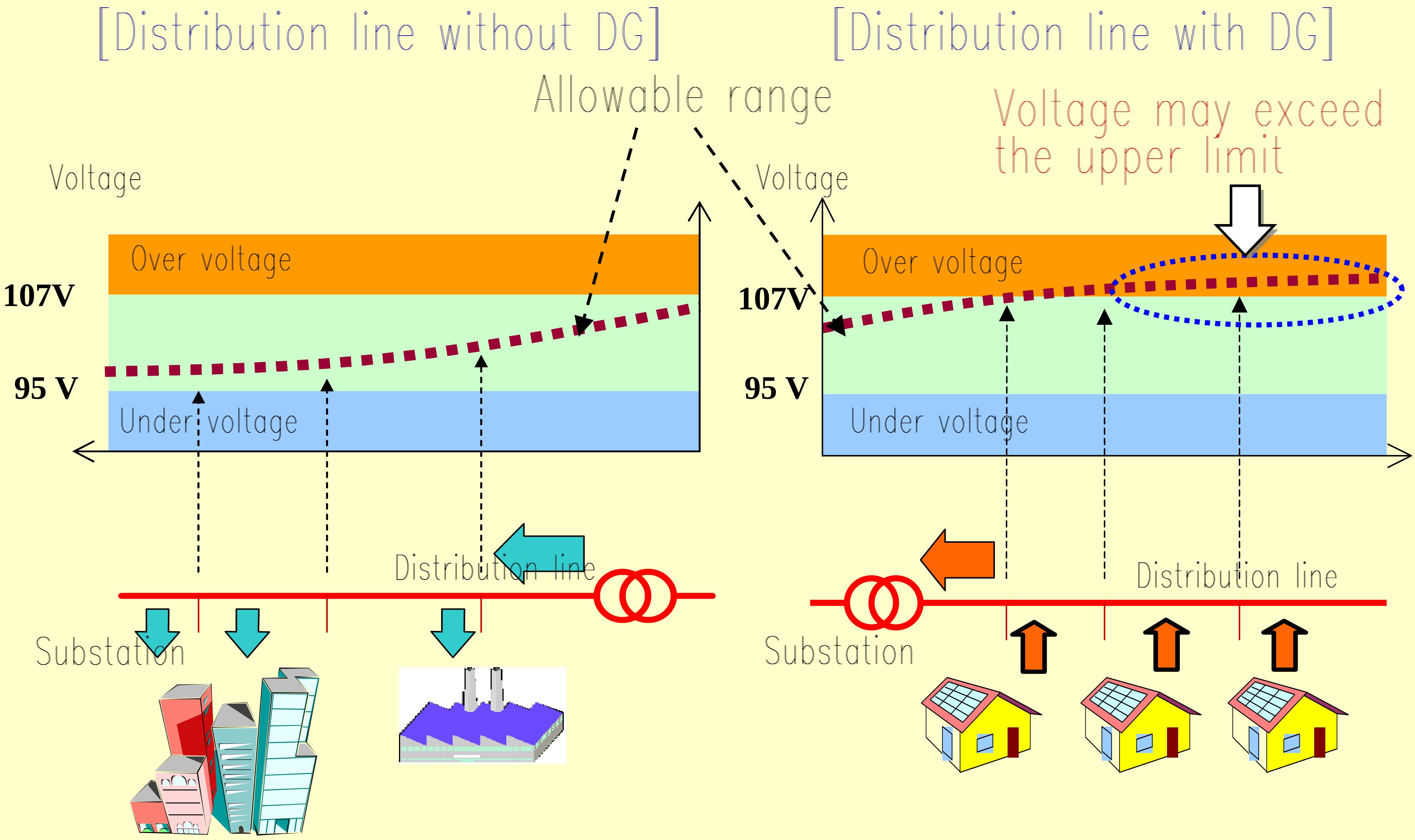
In a power system, supply have to match demand at all times.

Trend in Impacts of Wind Power

penetration	Area of impacts	Major Impacts
small	Local (Distribution)	•Power quality: eg,voltage
↓	↓ Sub-transmission	↓ •Load flow: congestion
large	↓ System-wide (Transmission)	↓ •System security, •Supply-demand-balance

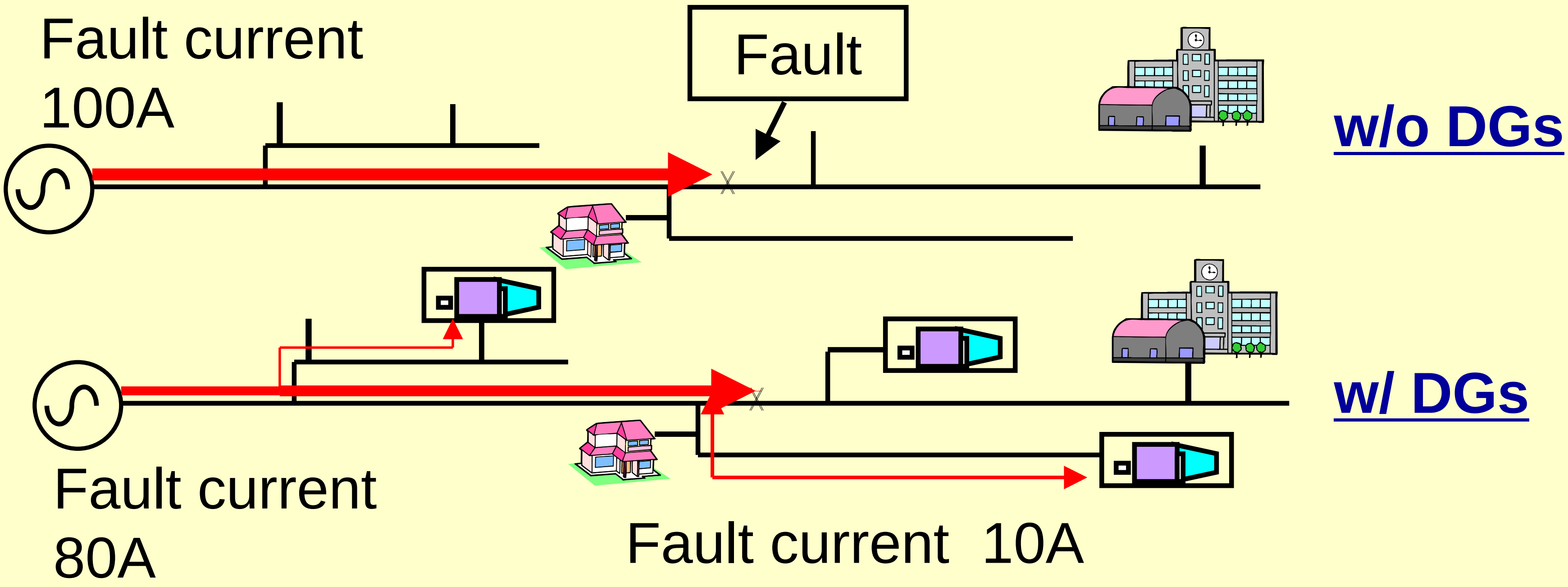
CRIEPI

Local Impacts #1: Voltage Fluctuations

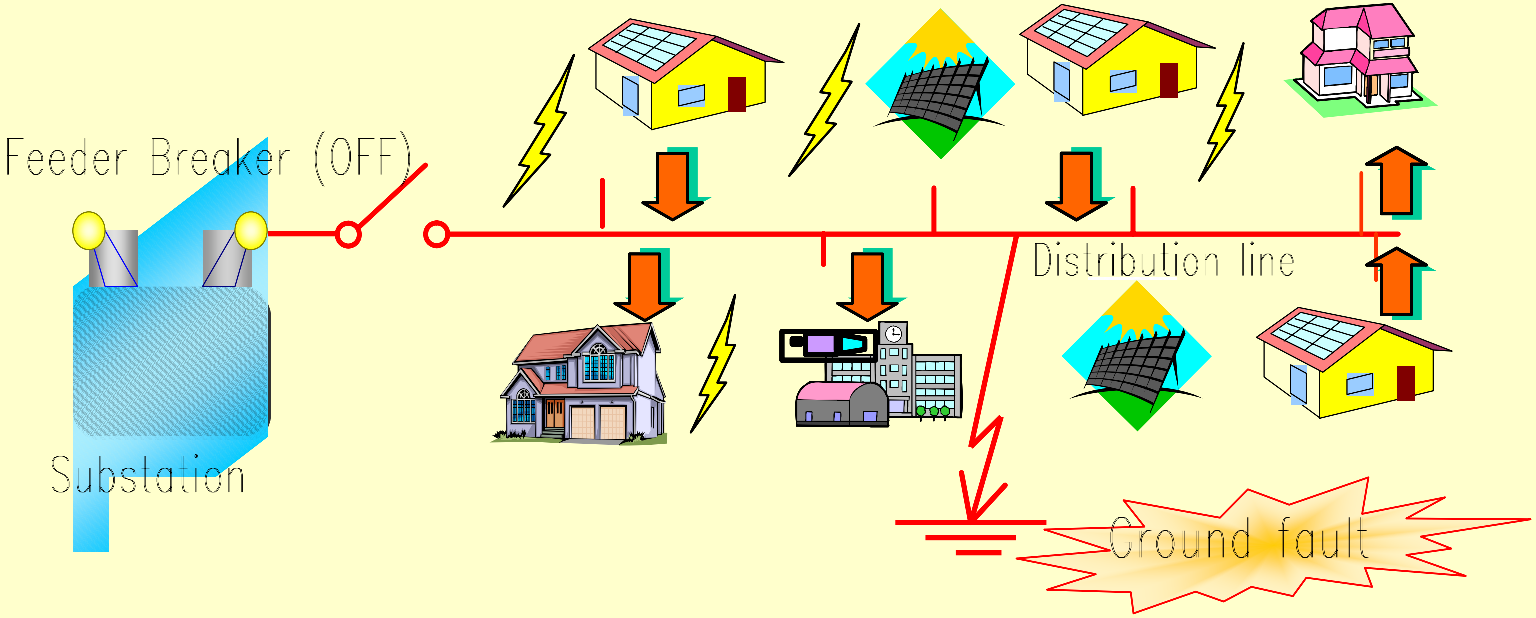


Local Impacts #2: Malfunction of Relay

Change in fault current at a substation → Malfunction of protective relay



Local Impacts #3: Islanding



DGs may continue their operation after a circuit breaker opens. It will hinder system restoration and, in the worst case, the fault cannot be removed.

Penetration that Could Cause the Problems

Expected technical problems	Penetration of DGs problems occur [Note]
◆ *Voltage fluctuation* due to reverse power flow	More than 5 to 20%
◆ Faults can cause -- Increase of short circuit capacity -- Malfunction of a protective relay operation -- islanding	 More than 40% More than 20% More than 20 to 30%

[Note] Penetration rate: ratio to distribution line capacity. They are sample values obtained for the worst case through experimental and simulation studies.

CRIEPI

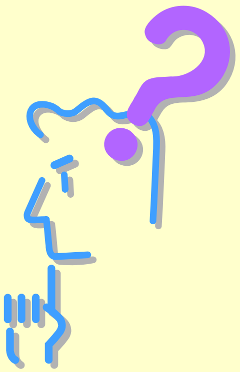
System Impacts #1: Intermittency

- Their large scale integration requires more flexibility (eg, reserve) in a power system.

  ➡ How the flexibility is improved or maintained in a future power system?

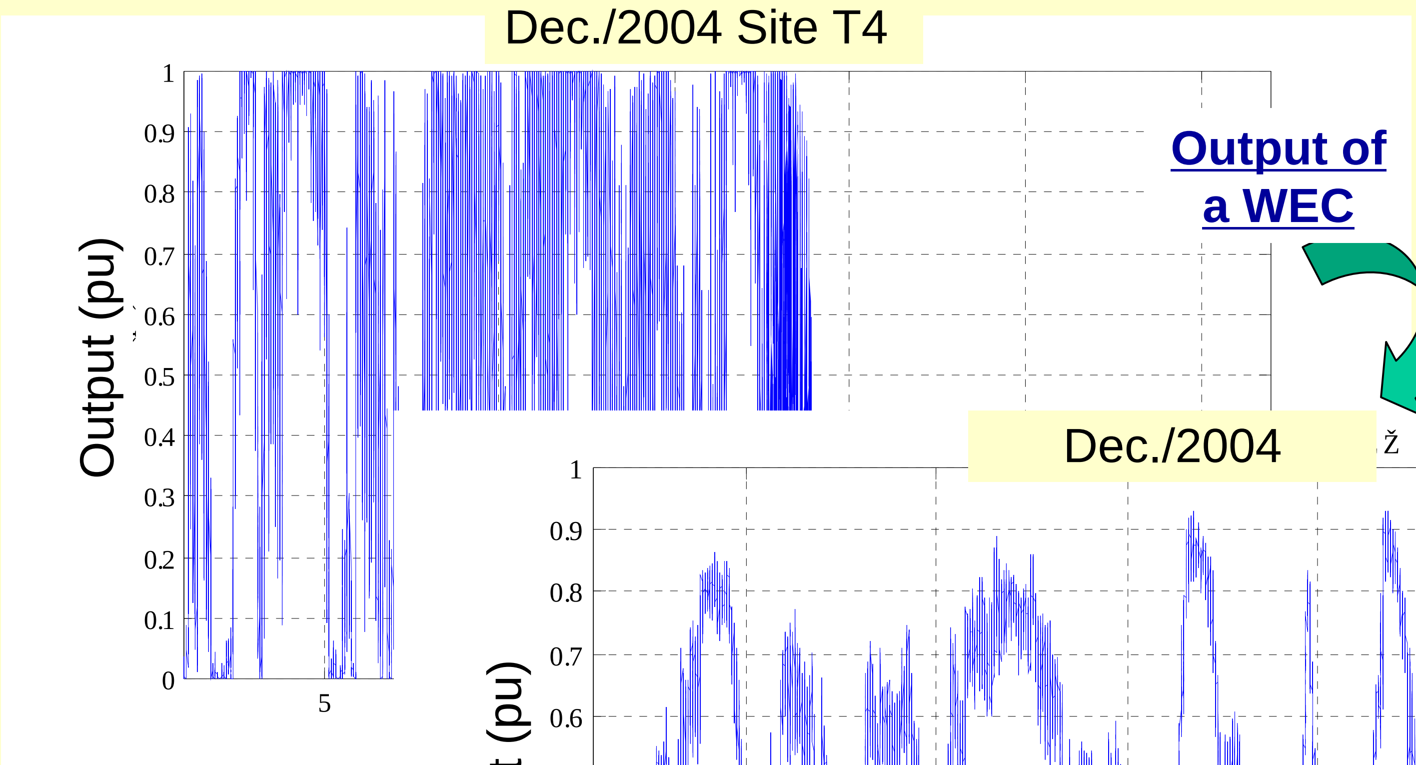
- Capacity value* of PVs and WECs: not so high (controversial issue)

  ➡ Needs for back-up power

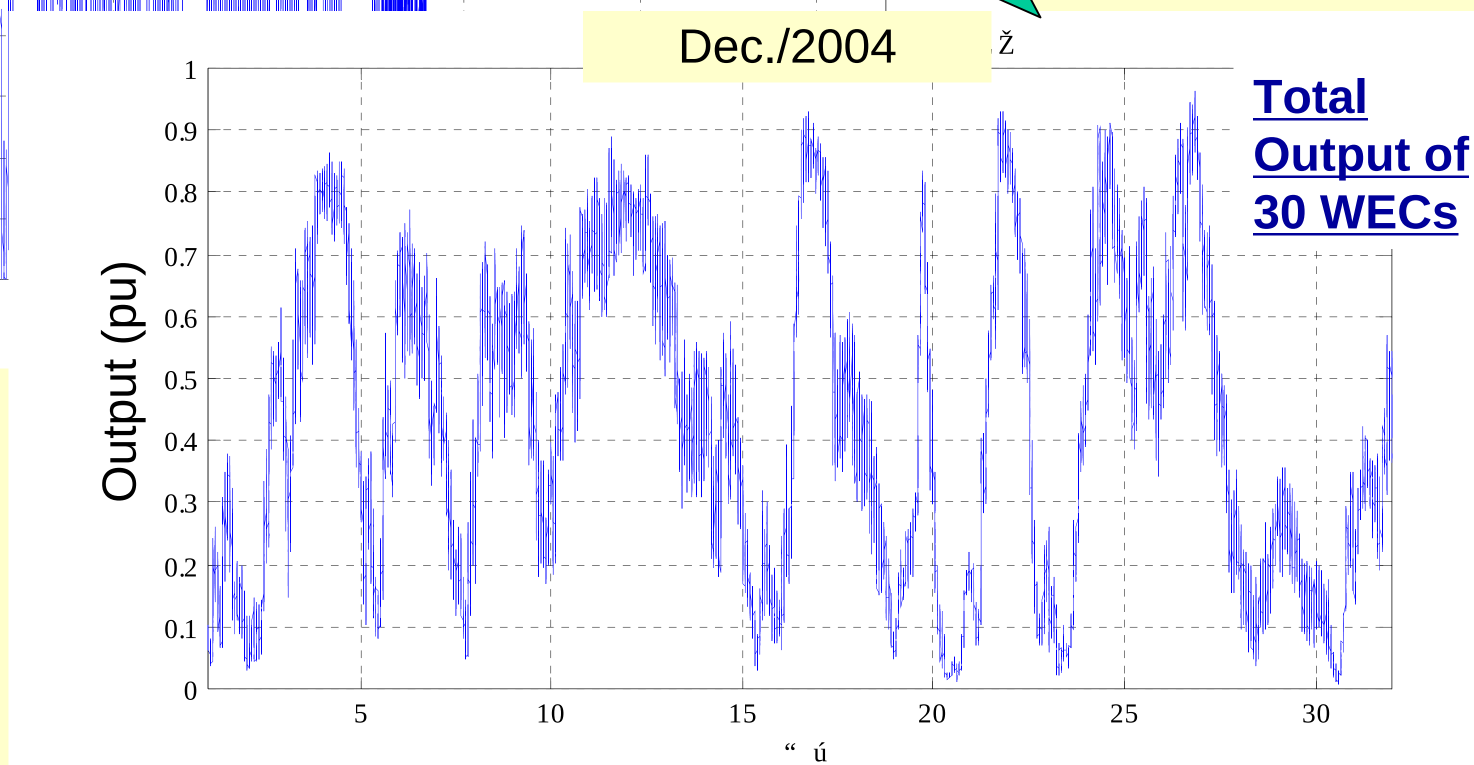


* Capacity value: an index that shows how the power source is reliable when it is needed.

Sample Output of WECs

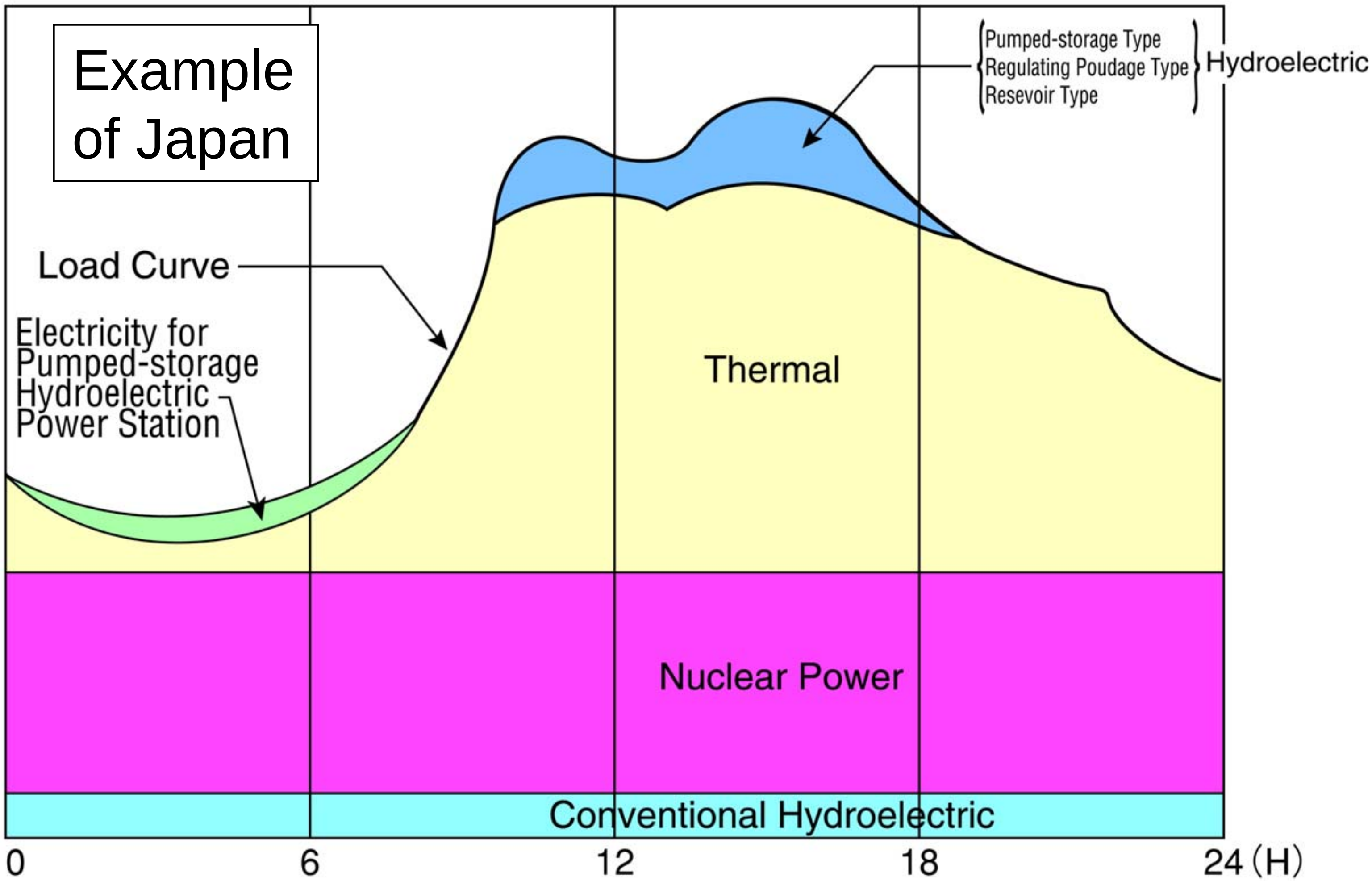


Smoothing



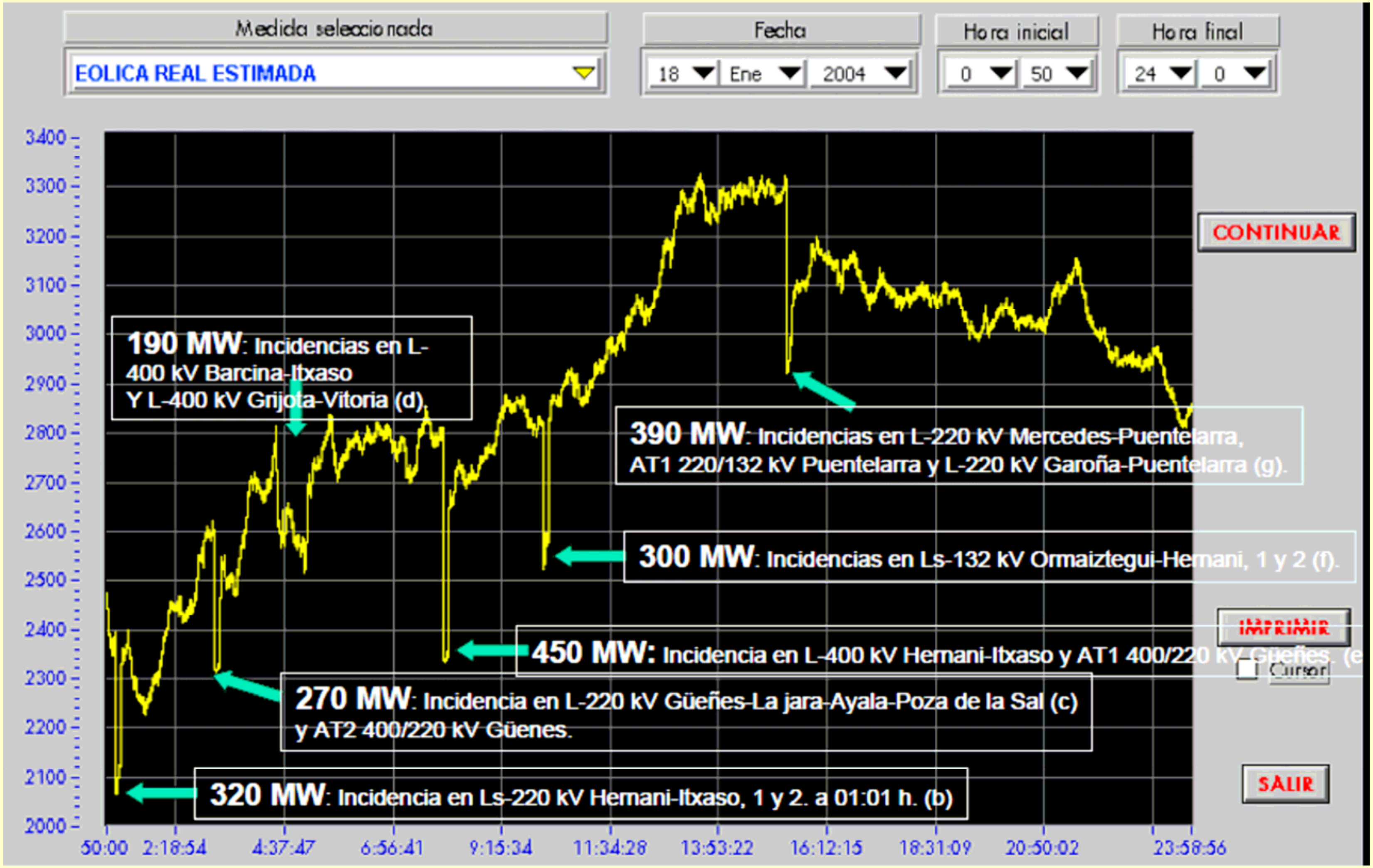
[Source] NEDO report, NEDO-NP-0012

Optimal Combination of Power Sources



(Source) Agency of Natural Resources and Energy

System Impacts #2: Trip Due to Volt. Sag

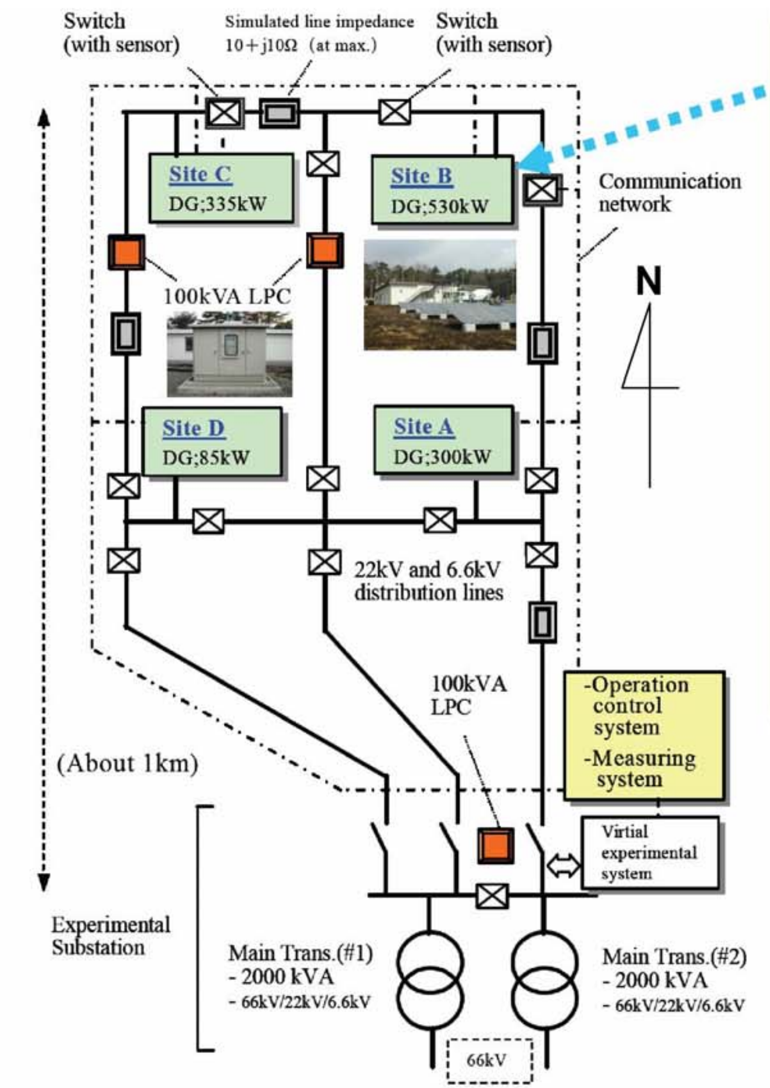


[Source] Juan F. Alonso-Llorente, “Integration of wind Generation within the Power System - Experiences from Spain,” Eolica Mediterranean, Rome, September, 2005.

Impacts and Their Countermeasures

Quant.	Major Impacts	Countermeasures
small ↓	•Power quality: eg,voltage	• Variable speed machine • FACTS (eg, SVC)
	•Load flow: congestion	• Output curtailment • System reinforcement
	•System security	• Fault-ride-through capability
large	•Supply-demand-balance	• Output forecast • Electric storage • Demand response • Hydrogen

Test Facility of DGs in CRIEPI



Whole configuration of the test facility

Distributed power generations in a site

150kW rotating type generator
(simulates WP, Co-generation)

20kW Inverter type generator
(simulates PV,FC, etc.)

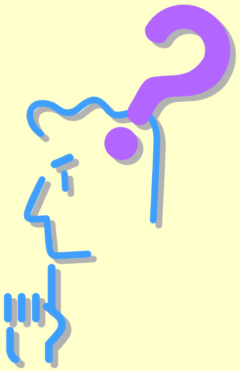
4 to 5 kW power conditioner
for PV power generation

Composition of distributed power generators

Rotating generator	150kW etc.	6 units	600kW
PV system	5kW etc.	16 units	80kW
Simulated FC, PV, Storage battery	20kW 100kW	12 units 3 units	240kW 300kW
MGT	30kW	1 unit	30kW
Total			1250kW

Closing Remark (pt.3)

- Integration of renewables to a power system presents a technological challenge.
- New generation technologies including renewables tend to be not so flexible as conventional ones. *Are there any measures to improve the flexibility of the future generation mix?*



Outline of Presentation

1. Outline and recent trend
2. Advantages and disadvantages
3. Characteristics from the viewpoints of electricity grid

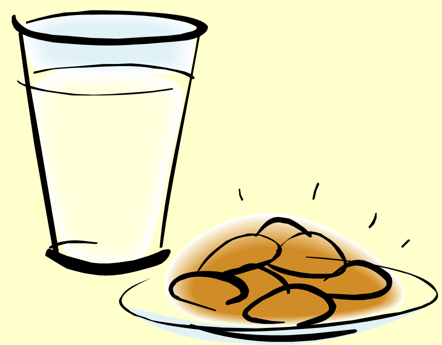
 of photovoltaic and wind power generation.

4. Closing remark

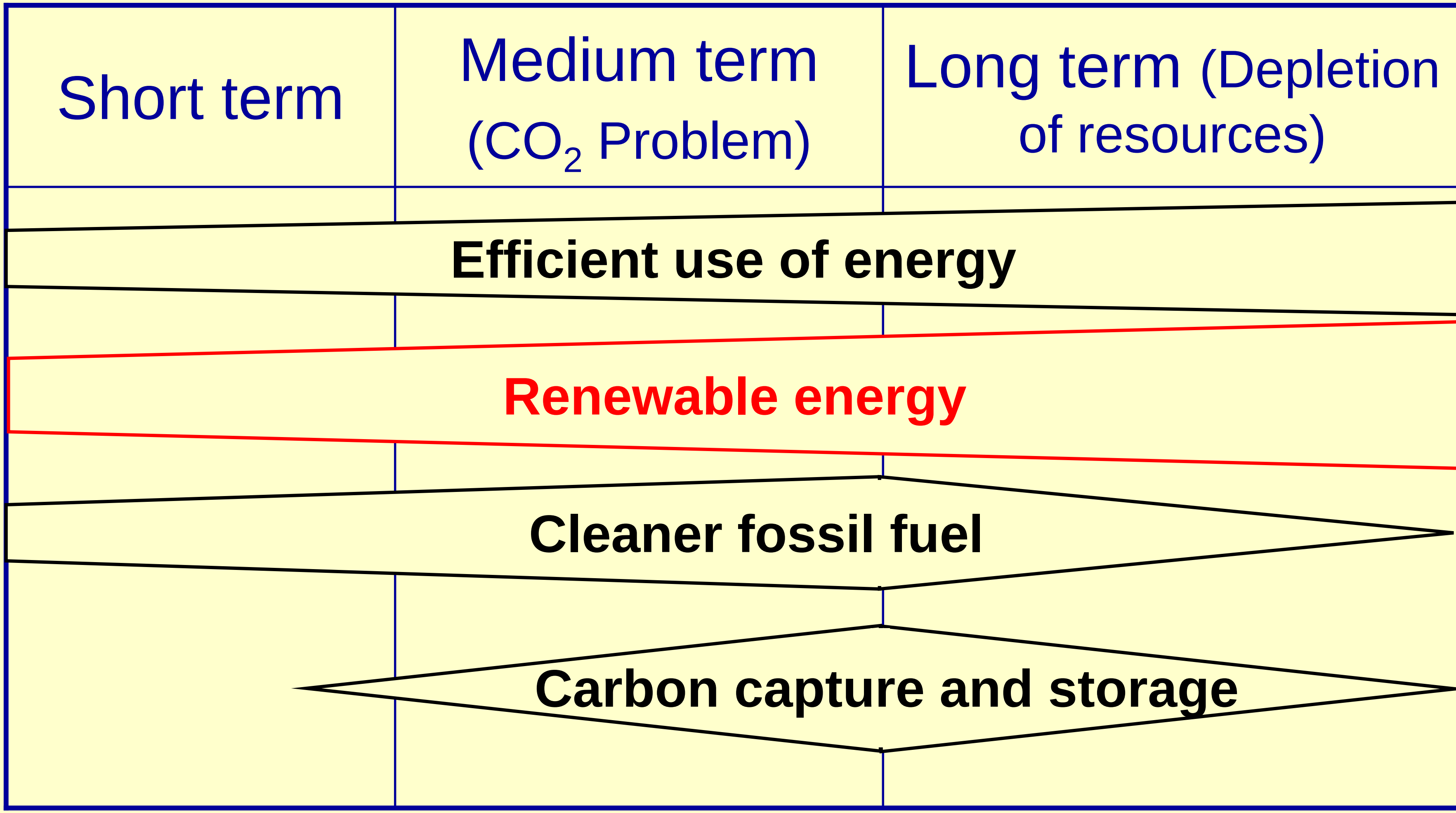
Closing Remark: a Personal View

- Almost all energy technologies will be needed to resolve the future energy problems. Renewables would be surely one of the promising candidates. *What is your scope on the future energy system with nuclear, renewables and other energy sources?*
- System-wide scope would become more important in the future. For example, in assessing the new energy such as renewables, due attention should be paid to power delivery, end-use, etc. aspects.

Thank you very much
for your attention.

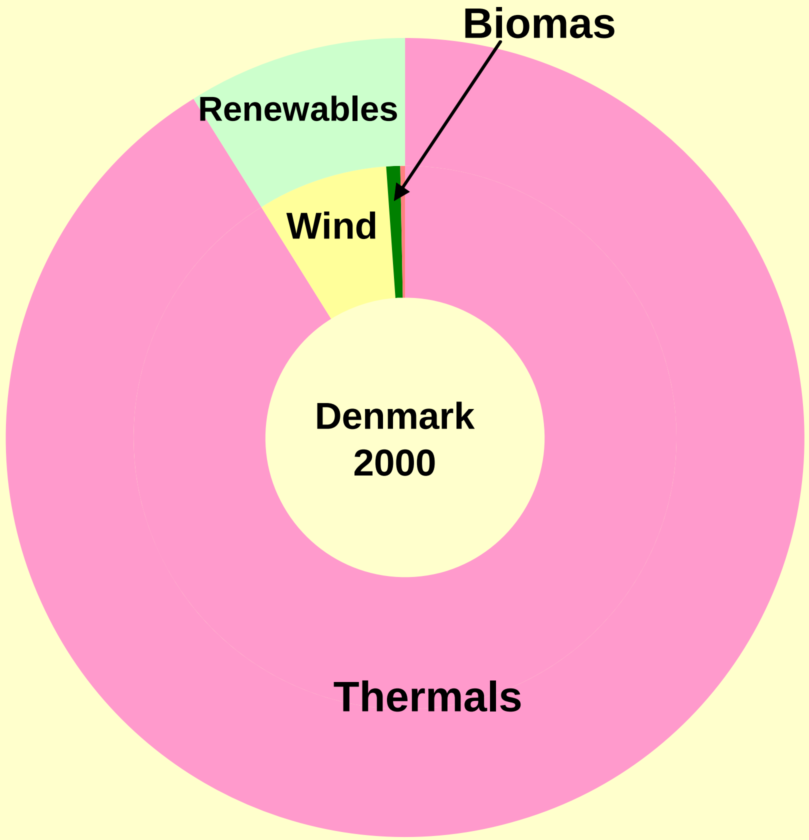


Future Options and Time Span

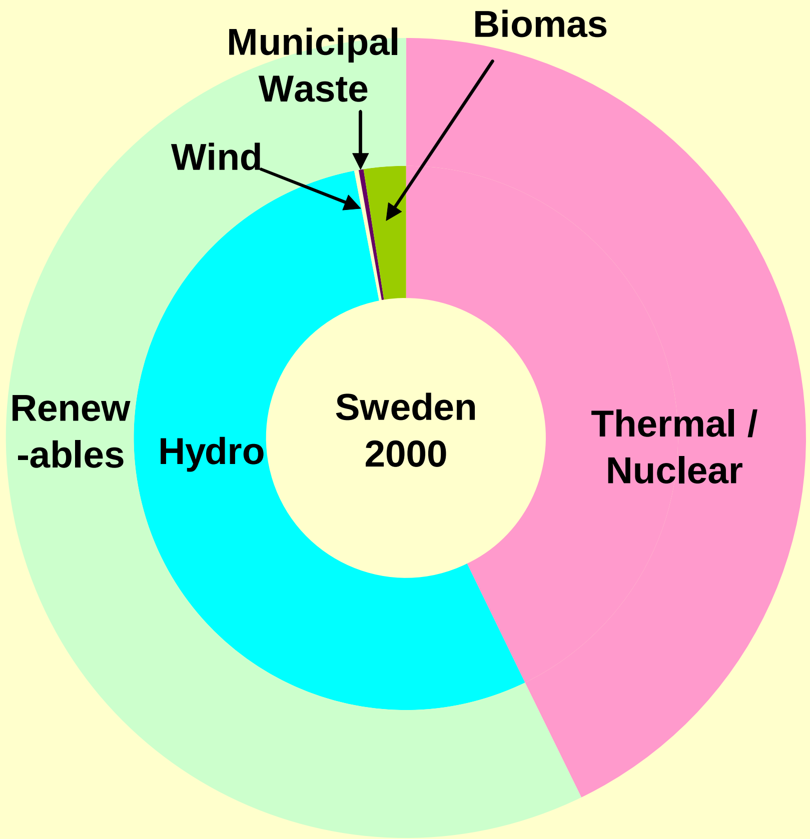


Renewables: Difference among Countries

Electlic energy mix (Denmark)

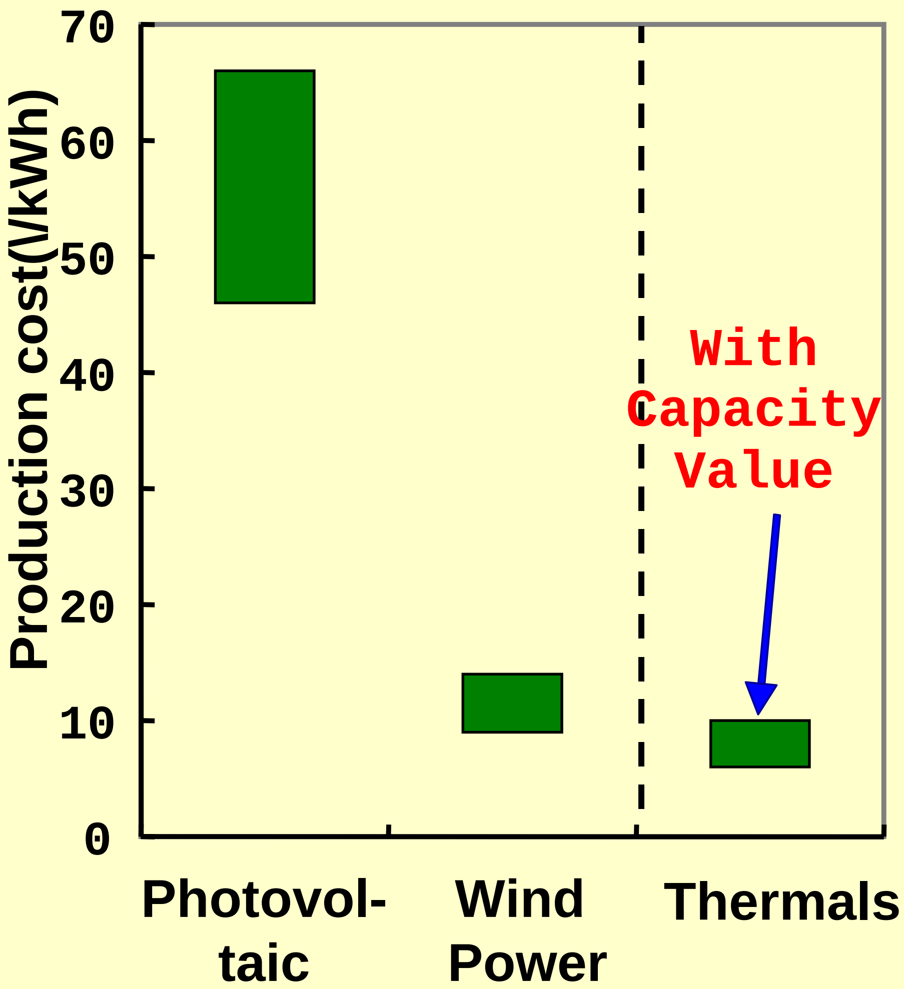


Electlic energy mix (Sweden)



[Data source] IEA, “Renewables Information 2002”

Production Cost of Renewables

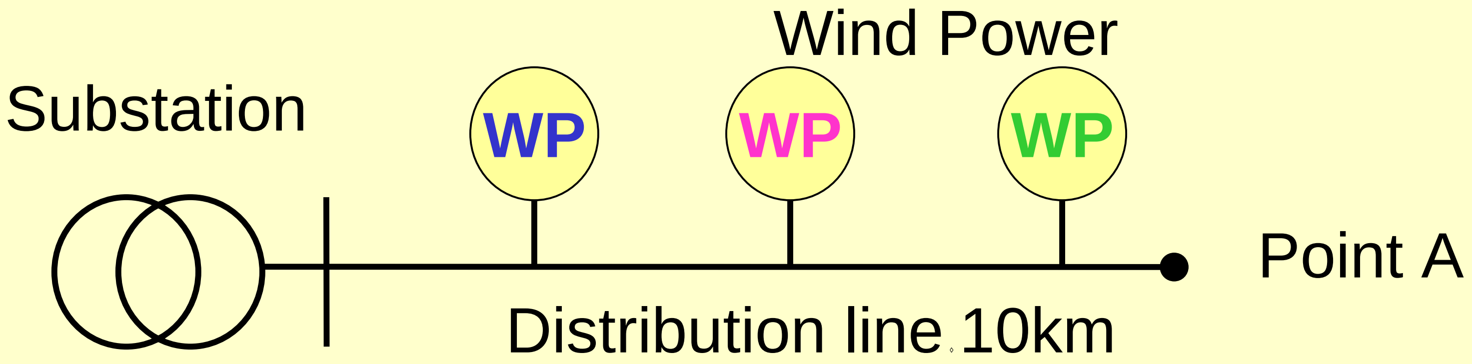


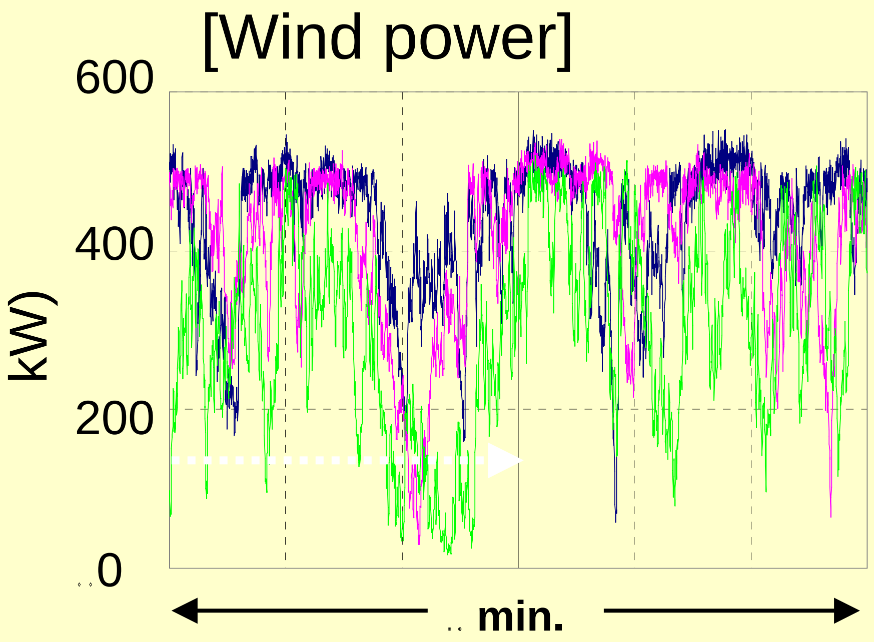
Cost of renewables is decreasing. However, the following measures are generally introduced due to their high cost:

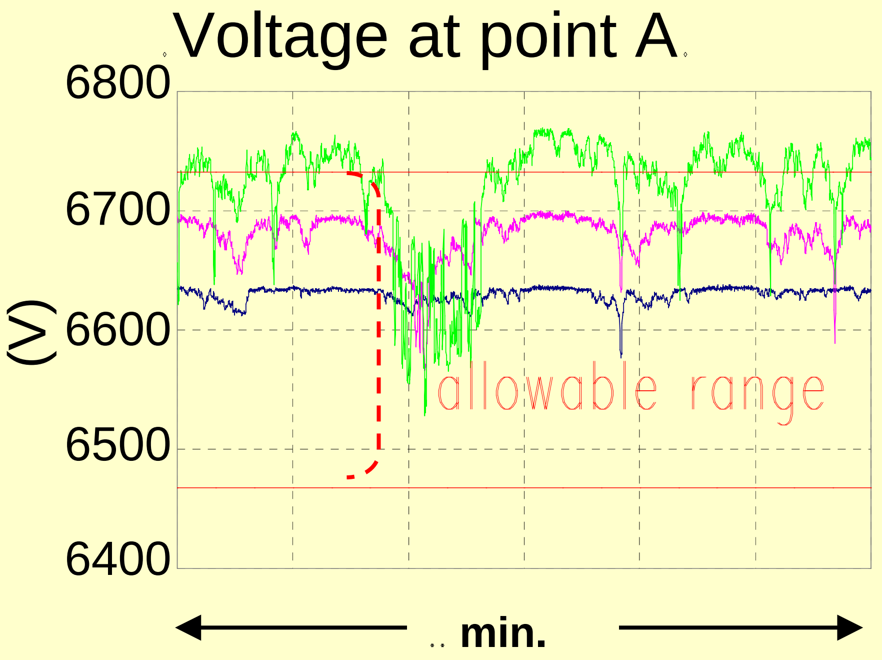
- Institutional measure: renewable portfolio standard, feed-in-tariff, etc.
- Subsidy for installation, etc.

[Data source] New Energy Subcommittee of the Advisory Committee for Energy

Sample Impacts of WEC on Voltage





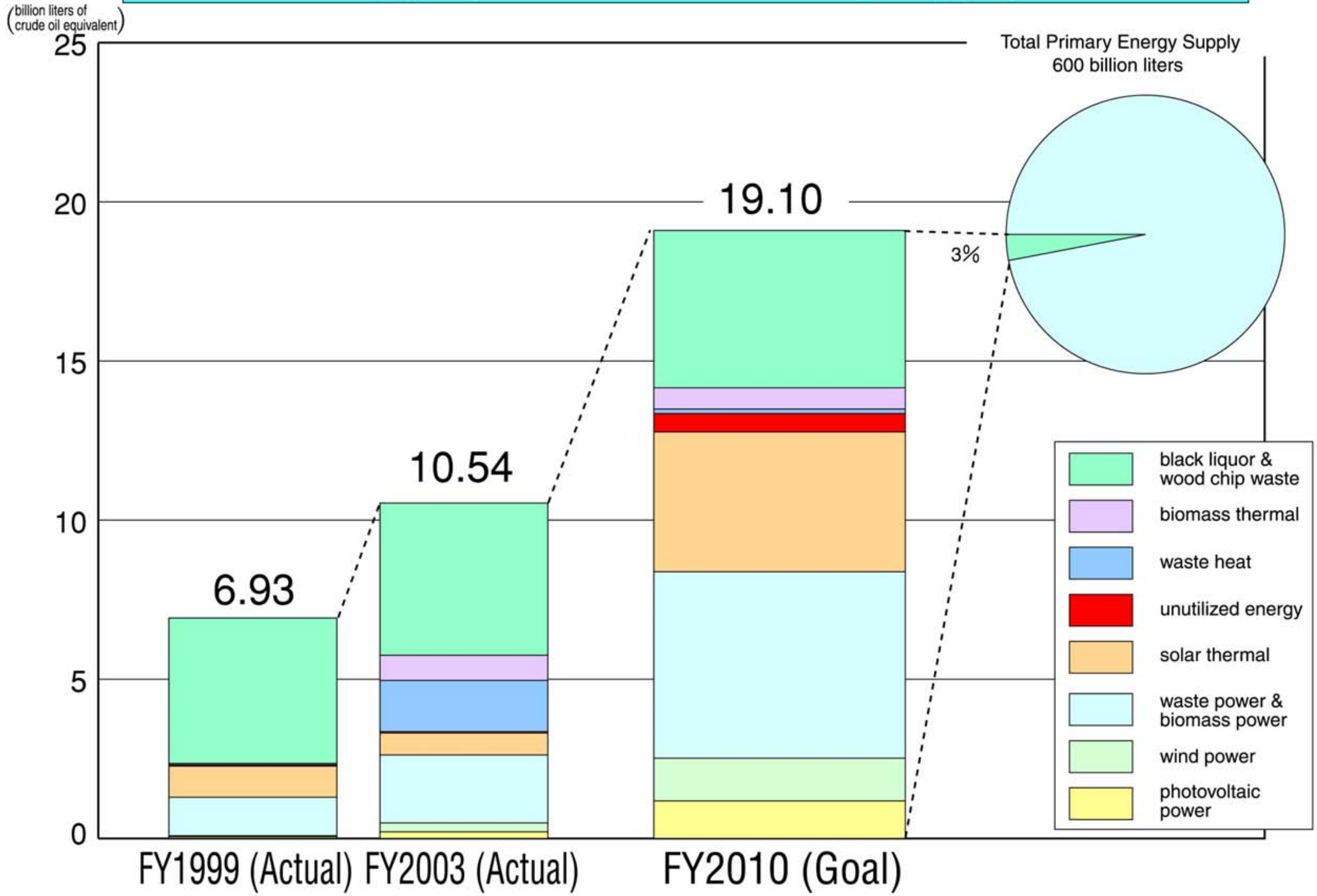


Evaluation of New and Renewable Energies

		Photovoltaic Power	Wind Power	Waste Power	Fuel Cells
Evaluation	Merits	• No fear of exhaustion • Emit no CO_2 or other gases in the process of power generation	• No fear of exhaustion • Emit no CO_2 or other gases in the process of power generation	• No additional CO_2 emission by power generation • Continuously supplied stable power source among new energies	• Emit no SOx or little NOx • High generation efficiency • Not so noisy and can make an entire automatic operation
	Demerits	• Due to low energy density, it needs much larger area than thermal and nuclear power generation for the same amount of power generation • Unstable due to no generation at night and low power output in rainy or cloudy days • High costs on facilities	• Due to low energy density, it needs much larger area than thermal and nuclear power generation for the same amount of power generation • Unstable due to occasional and seasonal volatility in wind directions and speed • Makes noises when windmills rotate • High costs on facilities	• Low generation efficiency • Needs further environmental loads reduction measures such as dioxin emission control measures and ash reduction	• Low durability of cells and low reliability on system • High costs on facilities
	Applied Areas	• Residential • Industrial for factories and commercial buildings etc.	• Private consumption on good wind condition areas and power sales business	• Garbage-fueled power generation (Super Garbage Incinerator/ Power Generation, RDF [Refuse Derived Fuel] Power Generation)	• Widely applied to vehicle, residential and industrial use, and power generation
Results and Goals of Introduction		1. 2005 (Actual) : 1,422MW 2. FY2010 (Goal) : 4,820MW	1. FY2005 (Actual) : 1,078MW 2. FY2010 (Goal) : 3,000MW	1. FY2003 (Actual) : 1,739MW 2. FY2010 (Goal) : 4,500MW	1. FY2003 (Actual) : 7MW 2. FY2010 (Goal) : 2,200MW

(Source) Report of New and Renewable Energy Subcommittee of Advisory Committee for Natural Resources and Energy, June 2001, IEA, NEDO and others

New Energy* (Most Renewables) Supply Outlook



* In this case, new energy is defined as renewable energies that are getting practically used from the technological viewpoint, but is not widely diffused due to their uneconomic performances. Therefore, some renewables such as geothermal, hydroelectric, ocean temperature gradient and wave power are not included.

(Source) Report of Coordination Subcommittee and Energy Supply and Demand Subcommittee of Advisory Committee for Natural Resources and Energy, July 2001 etc.

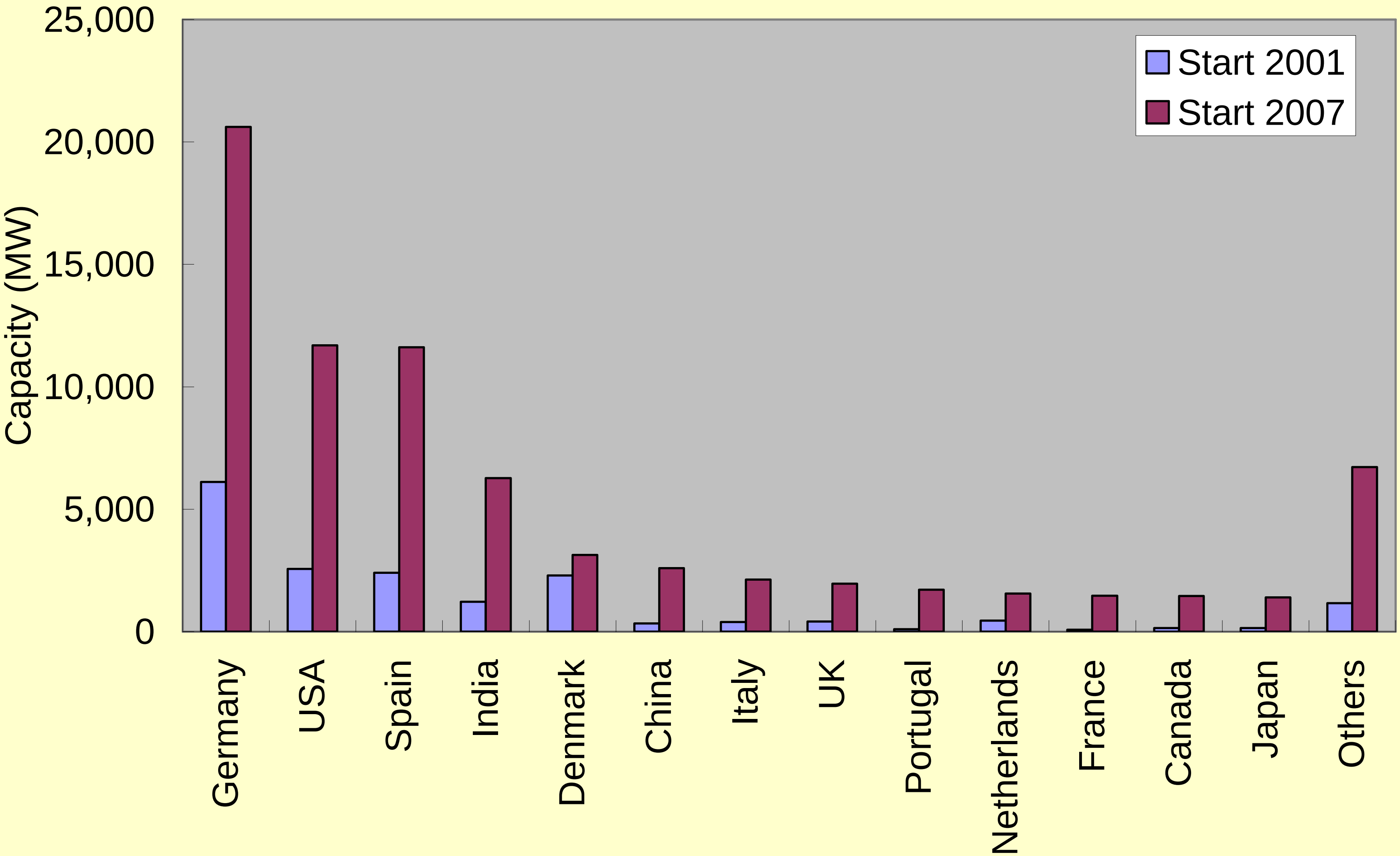
Economic Performance of Photovoltaic and Wind Power

	Photovoltaic Power	Wind Power
Power Generation Cost (*)	[Residential] Average : ￥66/kWh [Non Residential] Average : ￥73/kWh	[Large Scale] ￥10-14/kWh [Middle and Small Scale] ￥18-24/kWh
Site Area (**)	To generate as much power as a nuclear power plant with a capacity of 1GW	
	Approx. 67km^2	Approx. 248km^2
Operation Rate(**)	12%	20%

(Source) Report of New and Renewable Energy Subcommittee, Advisory Committee for Natural Resources and Energy (June, 2001) (*)
Brochure of Agency of Natural Resources and Energy (March, 2002) and others(**)

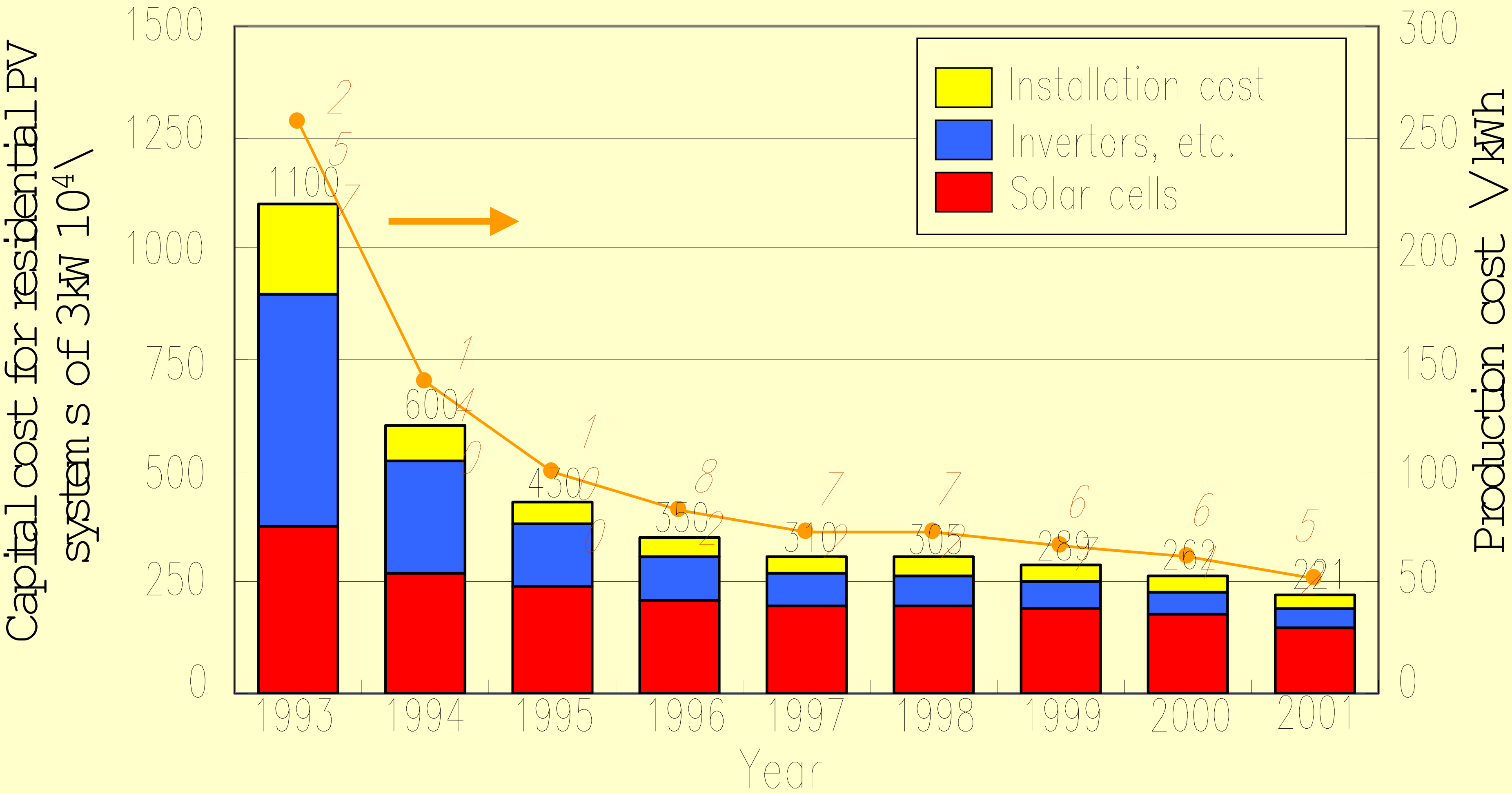
CRIEPI

Wind Power Capacity in the World



.Data source.WindPower Monthly HP http://www.windpower-monthly.com/WPM:WINDICATOR

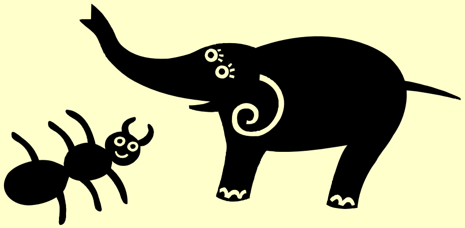
Trends in PV cost



[Data source] NEDO HP http://www.nedo.go.jp/nedata/top.htm

Distributed Generators (DGs): Tentative Definition by CIGRE

- Not centrally planned (by the utility),
- Not centrally dispatched,
- Normally smaller than 50-100 MW,
- Usually connected to a distribution system.



DGs: uncontrollable small generators at the places not previously expected