2nd Imperial College London – The University of Tokyo
Joint Symposium on Innovation in Energy Systems

Sustainable Energy System and Energy Management

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Sustainable Energy System and Energy Management

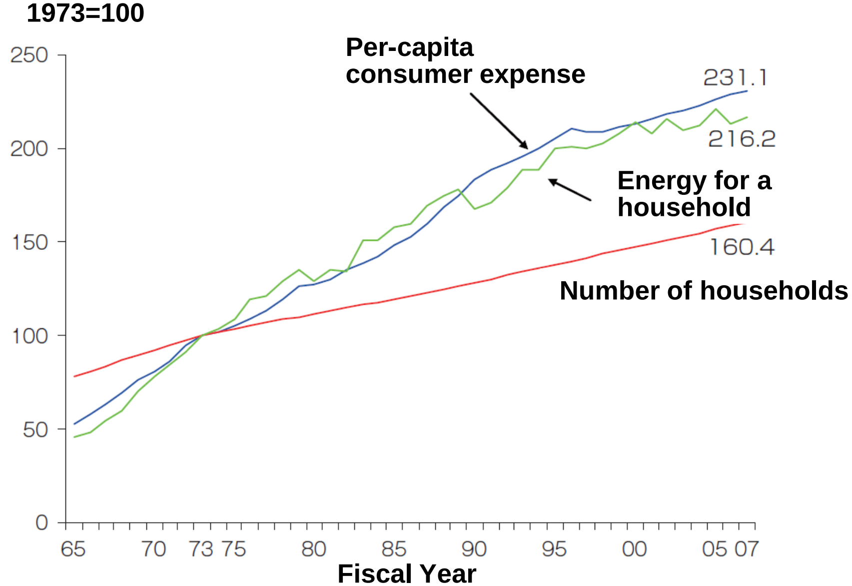
1. **CO2 Reduction Targets in Residential Sector**
   - **Trend of Household's energy demand and supply**
   - **CO2 emission reduction target in Energy Outlook**

2. **Energy Technology Strategy**
   - **Energy Technology Vision 2100**
   - **Energy Technology Map**
   - **PV Road Map "PV 2030+"**

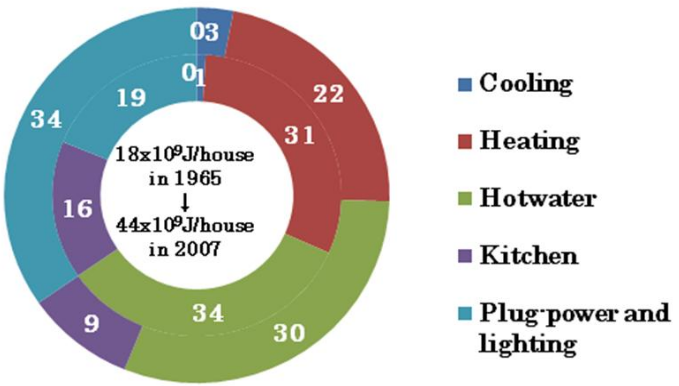
3. **Renewable Energy Integration and Future Power system**
   - **Variation of PV generation**
   - **Smoothing Effect**
   - **Operation planning and augmentation planning**

4. **Centralized/distributed Energy Management**

Households' Energy Demand and Supply Historical Trend

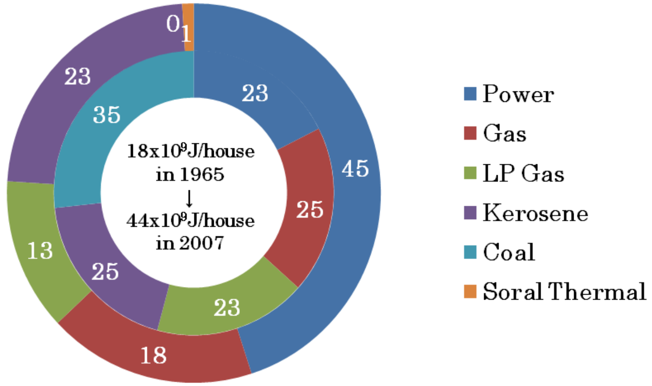


Increase of Households' Energy Demand



Increase of a Household's Energy Demand

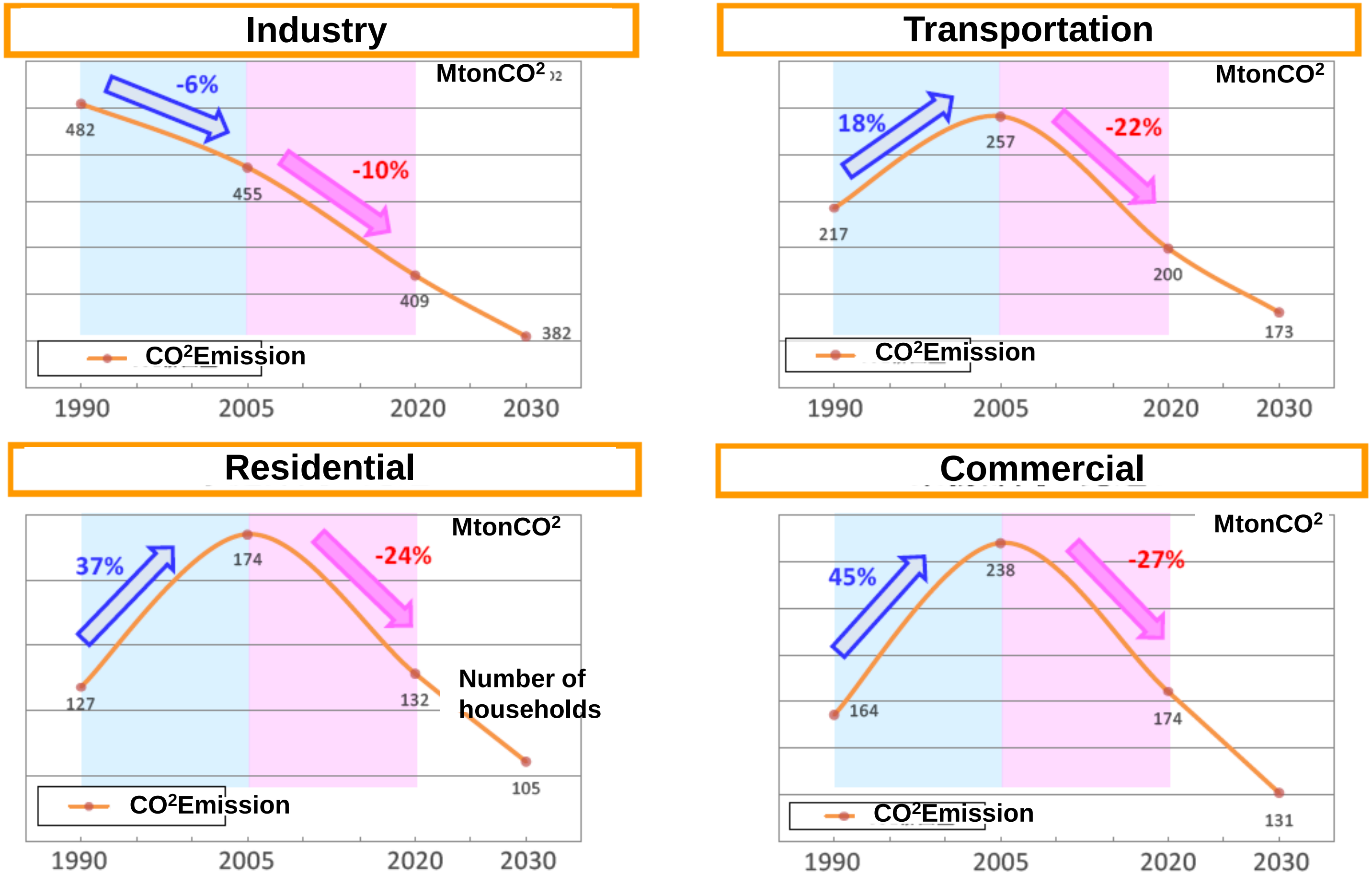
The demand and supply of residential sector of Japan has been steadily increasing through last 40 years through economic growth, change of life style, and new energy utilization technologies.



Change of Energy Supply to a Household

Source : METI Japan's Energy Outlook 2030, Revised

CO2 Emission Reduction Targets in each Sector of Japan



For the aggressive reduction of CO2 emission, the communities which involve the transportation and residential/commercial are the key areas to disseminate technology, improve and keep quality, and adapt life-style.

Source : METI Japan's Energy Outlook 2030, Revised

Critical Technologies for 2020 CO² Reduction Target

Type A : New dissemination

Photovoltaics	:1.4 GW in 2005	⇒ 28 GW in 2020
Innovative Lighting	:0% in 2005	⇒ 14% in 2020
Innovative Cars	:0.6 million in 2008	⇒ 15 million (50% of sales share) in 2020
Efficient IT	:0% in 2008	⇒ 100% in 2020

Type B : Additional acceleration of dissemination

Efficient water heater	: 0.7 million in 2008	⇒ 280 million in 2020
Efficient commercial building:		⇒ 80-90% sales share in 2020
Residential building	: Sales share of 36% in 2007	⇒ 80% in 2020
Efficient appliances	:	⇒ All be Top-Runner certificated.

Type C : Additional Dissemination overcoming social and institutional challenges

Wind Power	: Deployment of 5 times as much as that in 2005 (Park Code, Cost, Bird strike, Low frequency sound)
Biomass	: (Collection and transportation, LCA review, food problem, supply security)
Small hydro	: (Water right, Cost, River code, regional issues)
Geothermal	: (Cost, Park code, Hot spring)

Source : METI Japan's Energy Outlook 2030, Revised

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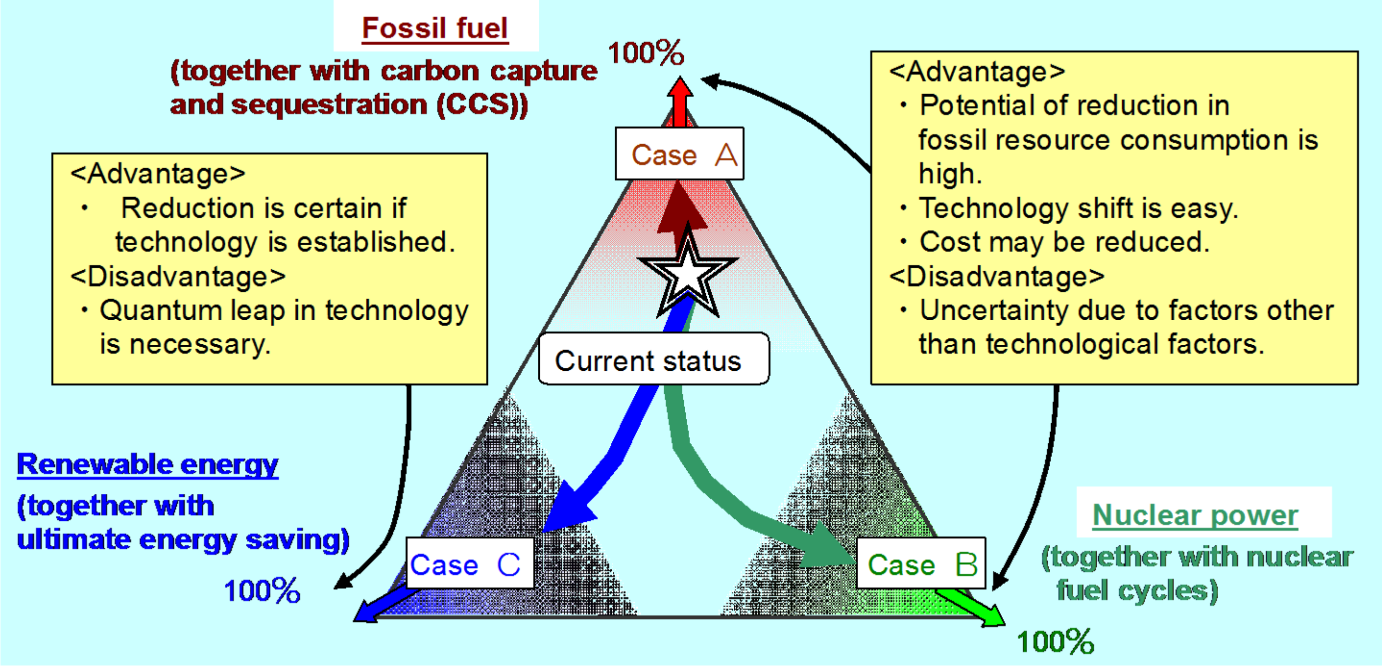
Energy Technology Vision 2100
Extreme cases and possible pathways

In March 2005, the Ministry of Economy, Trade and Industry (METI) formulated the "Energy Technology Vision 2100" as a navigating tool for strategic planning and implementation of research and development investment in cooperation with the people of industry, academia, and public institutions.

The vision, being developed by back-casting of the technology portfolio to overcome constraints in resources and the environment from the year 2100, consists of roadmaps of Residential/Commercial, Transportation, Industry, Transformation sectors.



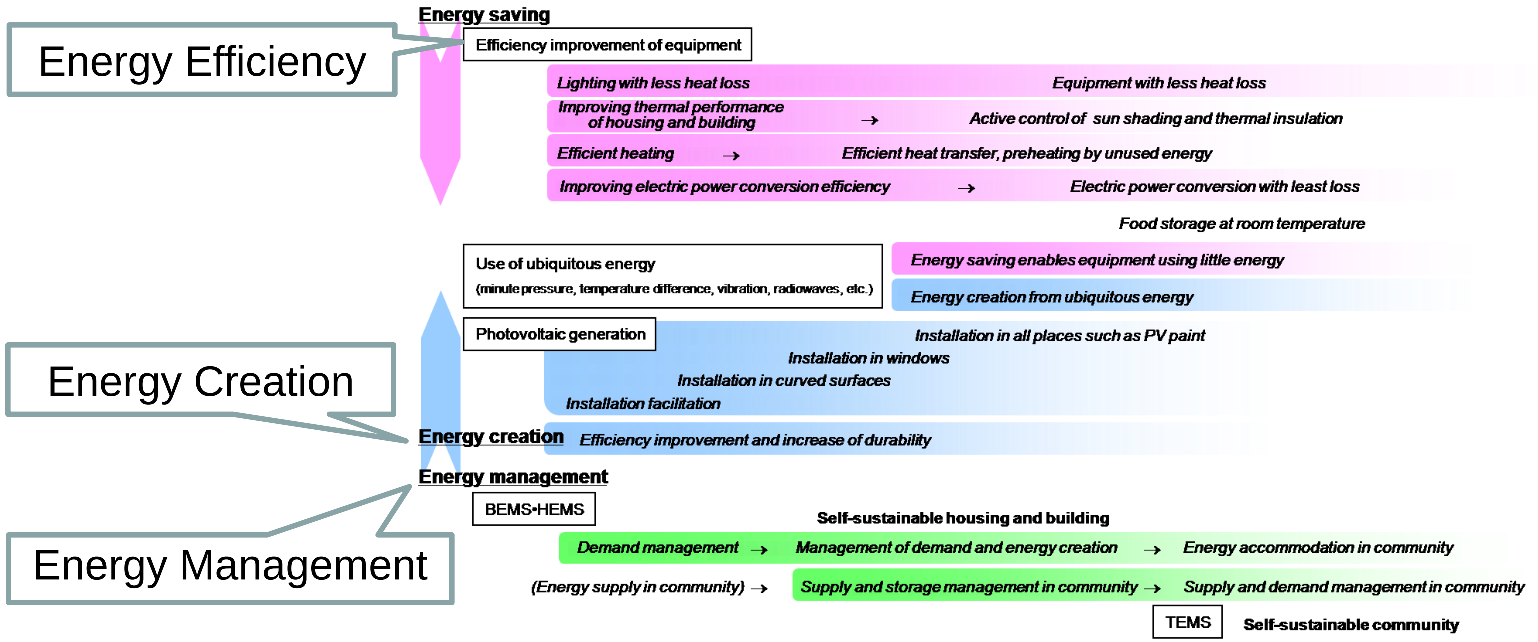
Source: Energy Technology Vision 2100, Institute of Applied Energy and METI

Energy Technology Vision 2100
Energy Technology Strategy of Residential/Commercial Sector

Residential/Commercial sector has three domains of strategy, energy efficiency, energy creation and energy management. It is featured that the energy management should play a important role of not only energy efficiency but also deployment of renewable energy.

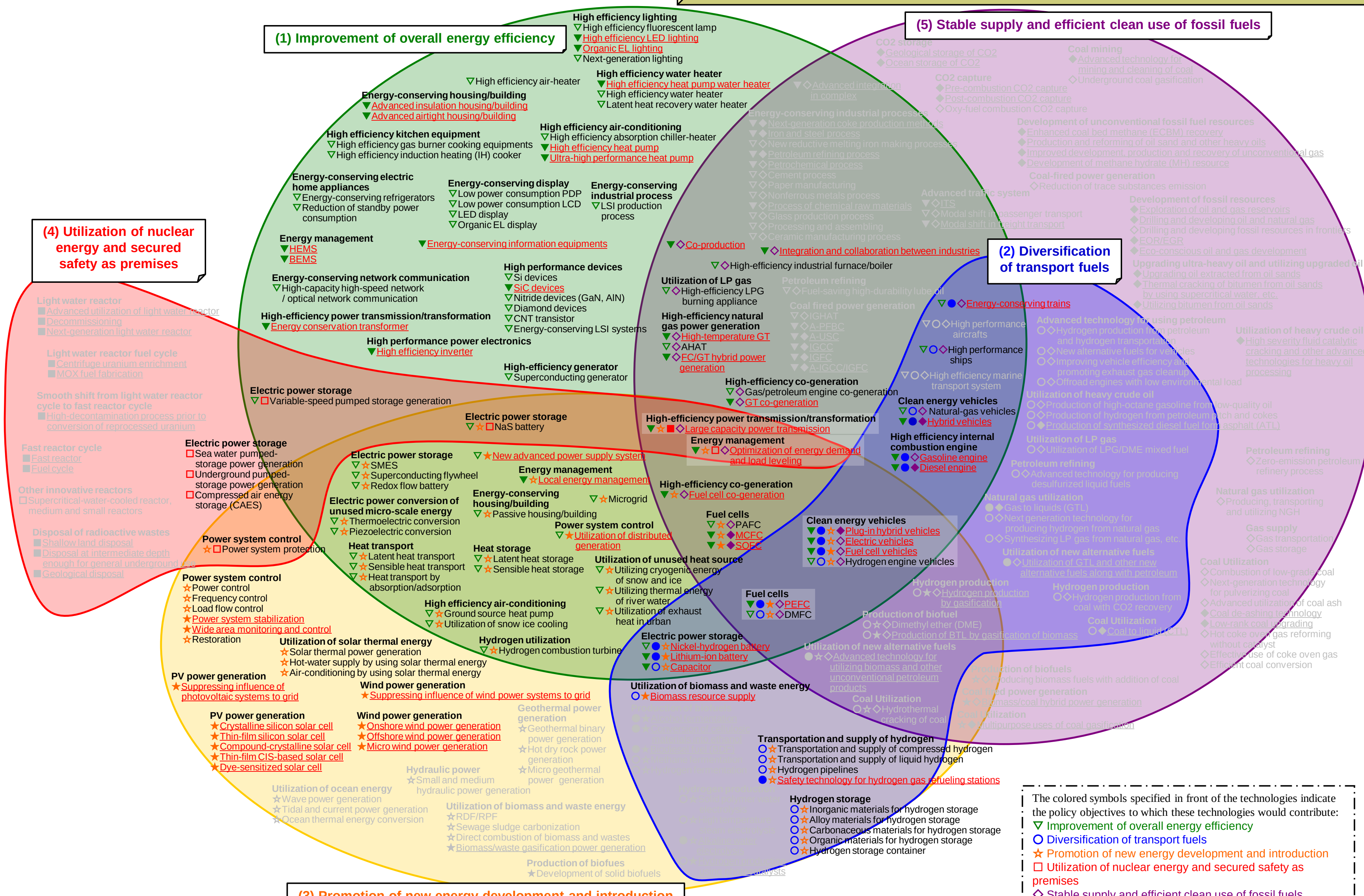
Res/Com		2000	2030	2050	2100
Total energy demand		1 time		1.5 times	2.1 times
Energy supplied from transformation sector*	Residential / Commercial		45% / 35% reduction	60% / 55% reduction	80% / 80% reduction
CO_2 intensity	Residential / Commercial	3.5 t-CO_2/household (1 time) / 118 kg-CO_2/m^2 (1 time)	1.9 t-CO_2/household (1/2 times) / 77 kg-CO_2/m^2 (2/3 times)	1.1 t-CO_2/household (1/3 times) / 40 kg-CO_2/m^2 (1/3 times)	0 t-CO_2/household / 0 kg-CO_2/m^2

*The percentage of reduction of energy per unit should be supplied from the transformation sector, compared with total energy demand increases in proportion to GDP.



Energy Technology Strategy

"Energy Technology Strategy Map 2007"

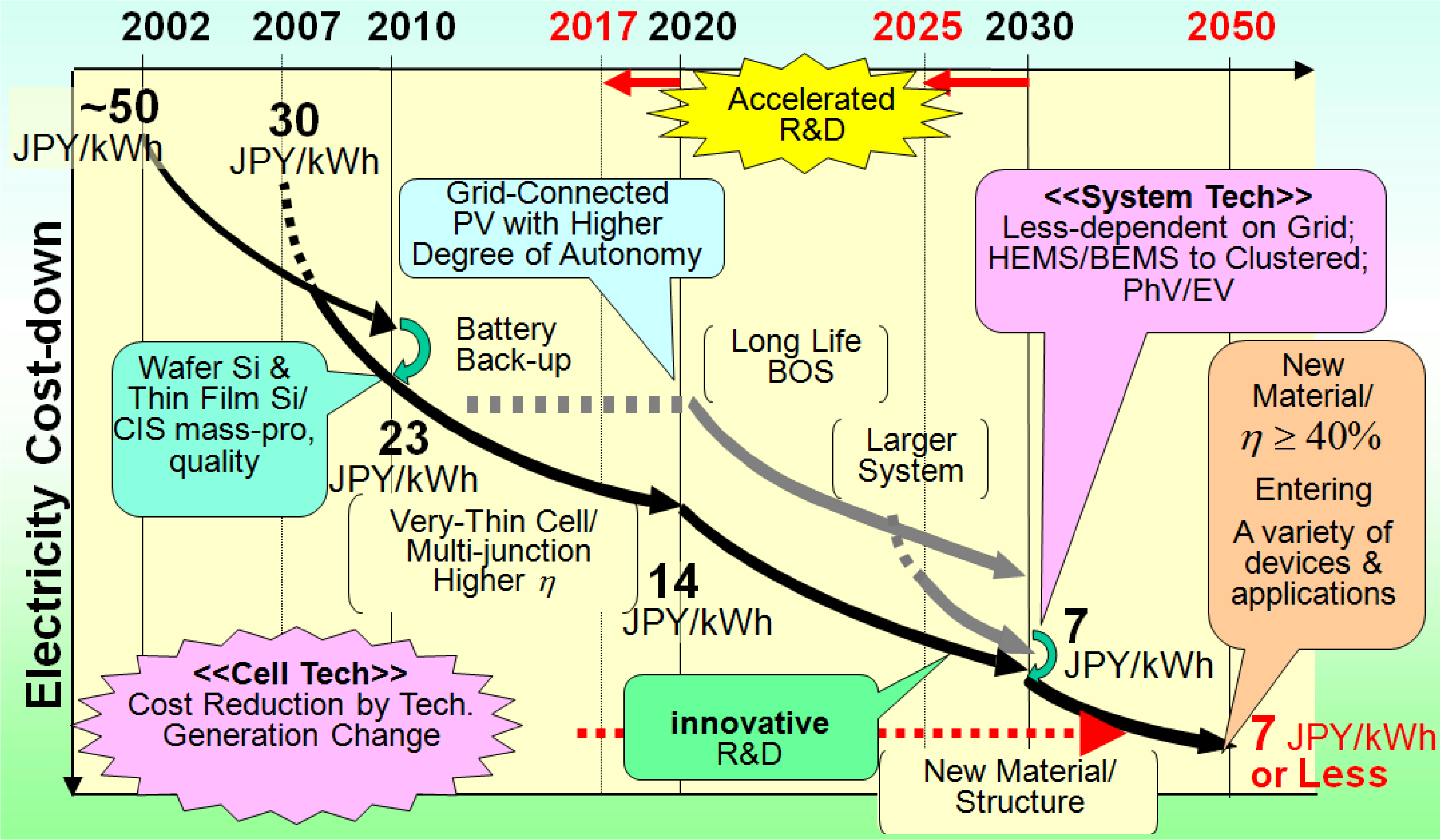


The colored symbols specified in front of the technologies indicate the policy objectives to which these technologies would contribute:
▽ Improvement of overall energy efficiency
○ Diversification of transport fuels
☆ Promotion of new energy development and introduction
□ Utilization of nuclear energy and secured safety as premises
◇ Stable supply and efficient clean use of fossil fuels
Technologies that make great contributions to policy objectives are accompanied by pasted symbols (▼●★■◆) for the relevant policy objectives and specified with underlined red letters.

Source: Energy Technology Strategy Map 2007, Institute of Applied Energy and METI

“PV 2030+”and PV deployment strategy in Japan

For the aggressive reduction of CO2 emission, the communities which involve the transportation and residential/commercial are the key areas to disseminate technology, improve and keep quality, and adapt life-style.



Source : NEDO, PV Roadmap “PV 2030+”

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Variation of Hourly PV Generation

PV generation has a variable feature due to due to change of weather or. Here, the nature is referred as “variable” or “variation”, based on the understanding that it varies but is predictable to a certain extent.

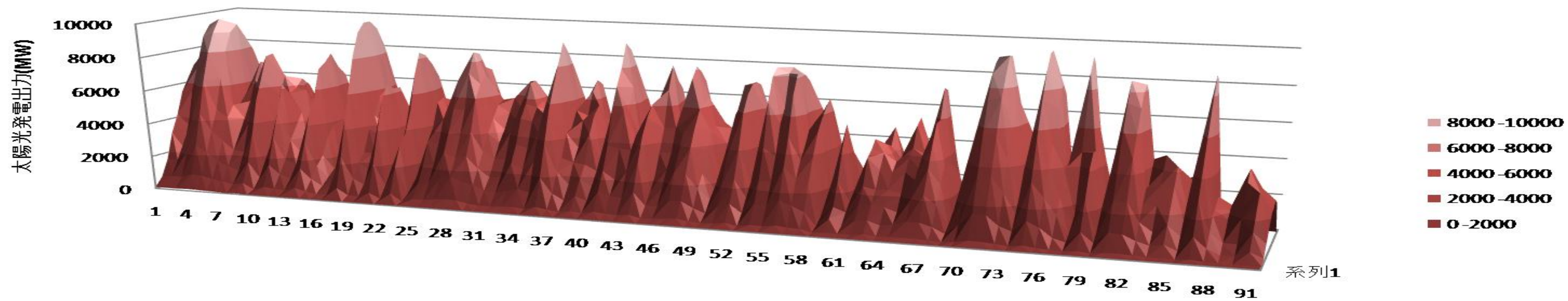


Fig. 24hour PV output variation in 90days in summer

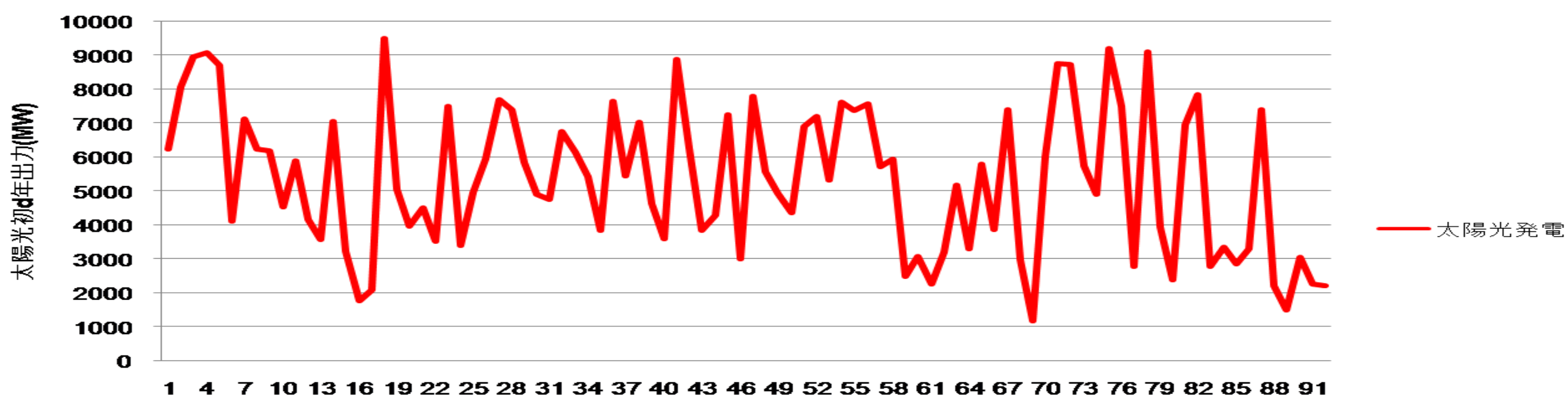


Fig. PV output variation at 14:00 in 90 days in summer

Influence of PV Penetration on Demand-Supply balance

In addition to the existing load deviation, supply capacity deviation, the system have to manage the variation of PV generation.

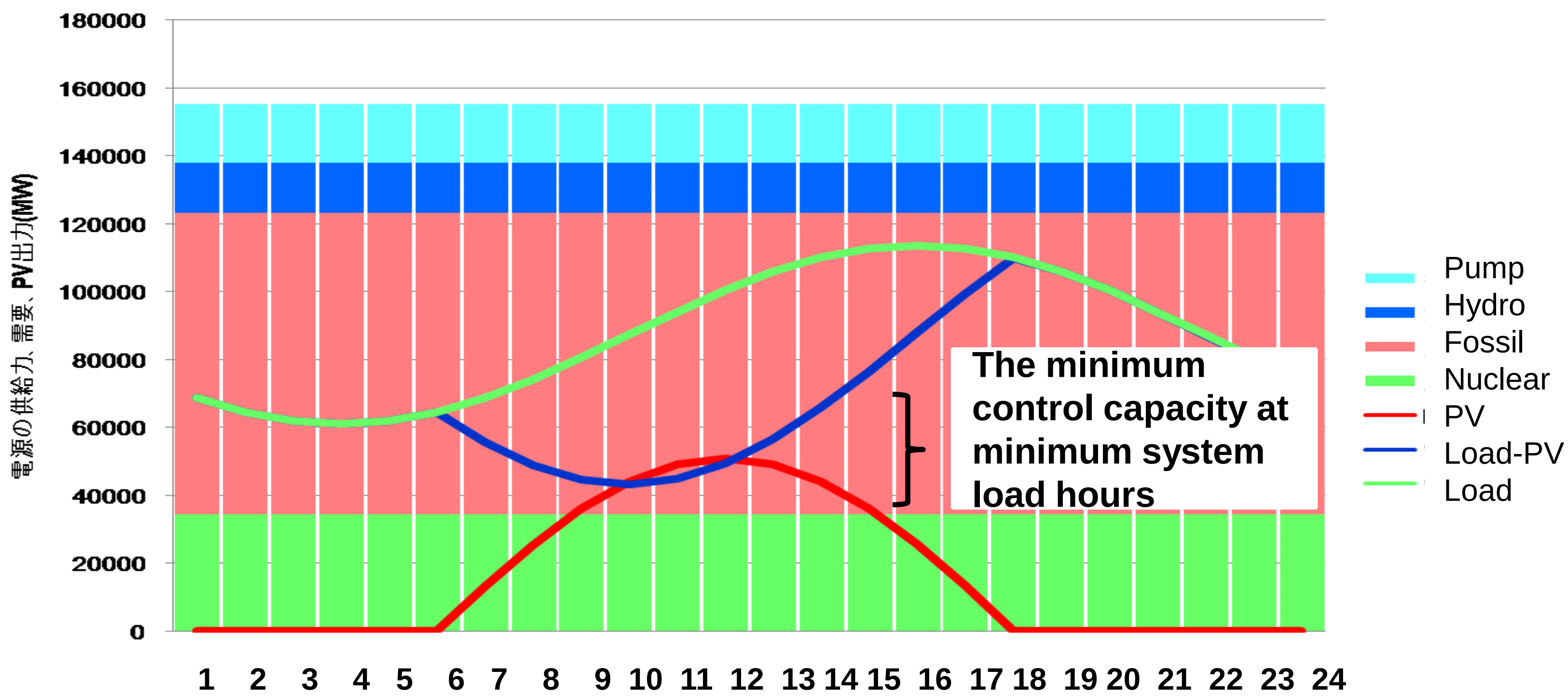


Fig. Comparison of hourly system load, PV generation, and an equivalent load on a holiday in May.

Issues of Renewable energy Integration

The penetration of the renewable energy generation such as PV and wind power will bring about the following impacts on a power system:

Distribution level

- **Voltage fluctuation in distribution network**
- **Power flow fluctuation in distribution network**

Power System level

- **Frequency fluctuation due to power imbalance between supply and demand**
- **Difficulty in generation scheduling**
- **Requirement for new transmission line due to the renewable energy deployment at a new location***
- **Establishment of new generation mix**

***: In case of large scale and concentrated renewable energy deployment such as off-shore wind and VLSPV in desart**

Smoothing Effect of PV output in a broad area

- ✓ **The variation of the total PV output is expected to be proportional to the variation of the total irradiance of the area.**
- ✓ **Total generation output of numerous PV systems in a broad has 1) less variable through the cancelation of each individual's variation and 2) a lower frequency of more than 10 minutes.**
- ✓ **In order to evaluate the smoothing effect, it is necessary to accumulate the insolation or PV generation data of many observing points in a power system for many year.**

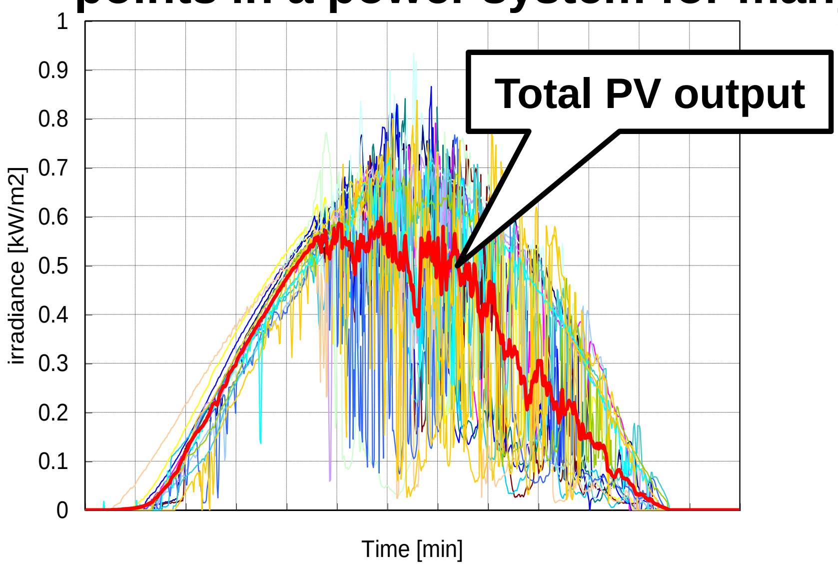
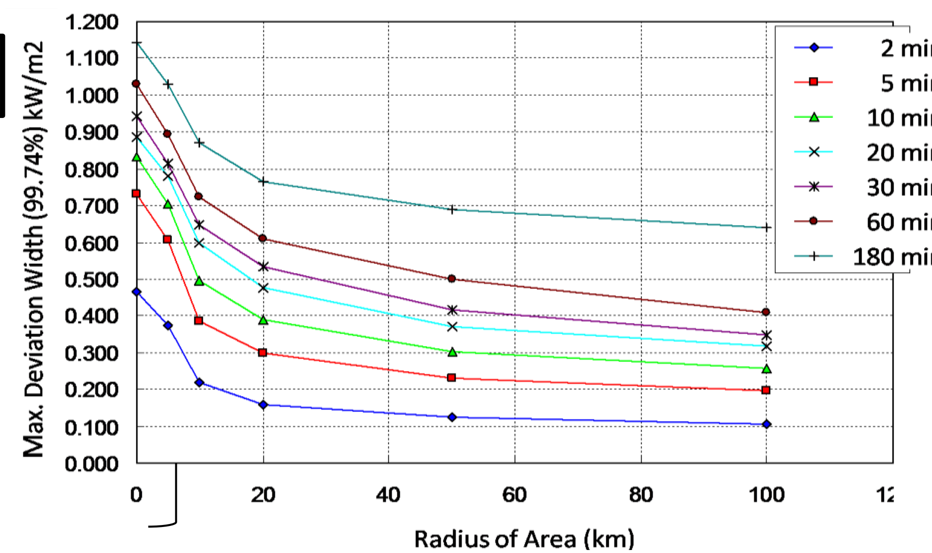


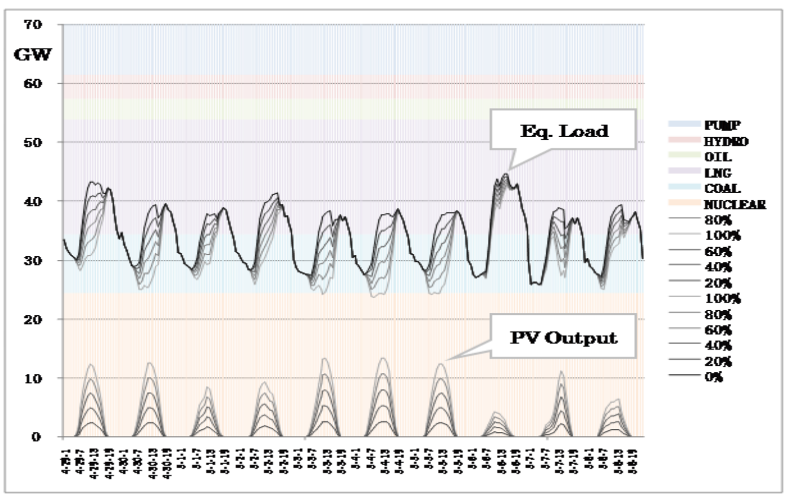
Image of Smoothing Effect



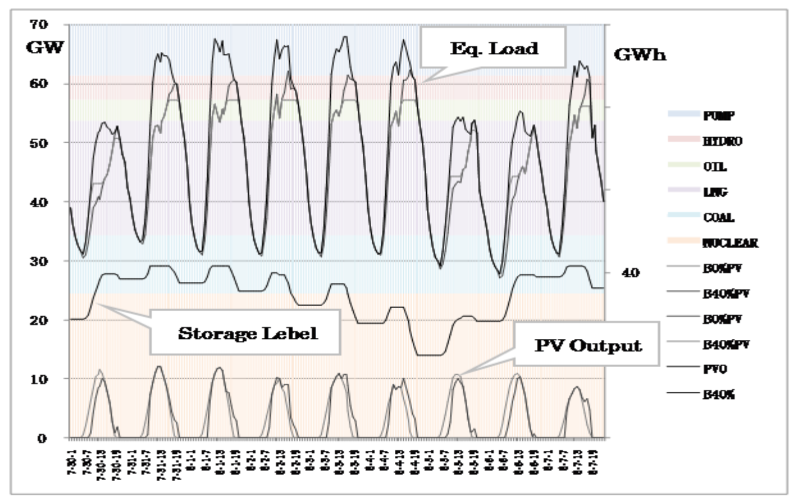
Example of Smoothing Effect in Oosaka-area

Time Series Analysis

- ✓ **The time-series load dispatch analysis evaluates the maximum possible PV penetration into the power system and the required countermeasures.**
- ✓ **In a mid-season when the original load is lowest and insolation is maximum, the equivalent system load indicates substantial dip.**
- ✓ **In a peak load season in summer, PV reduces the system peak load. With power storage, the remaining system peak load in the evening is reduced effectively.**



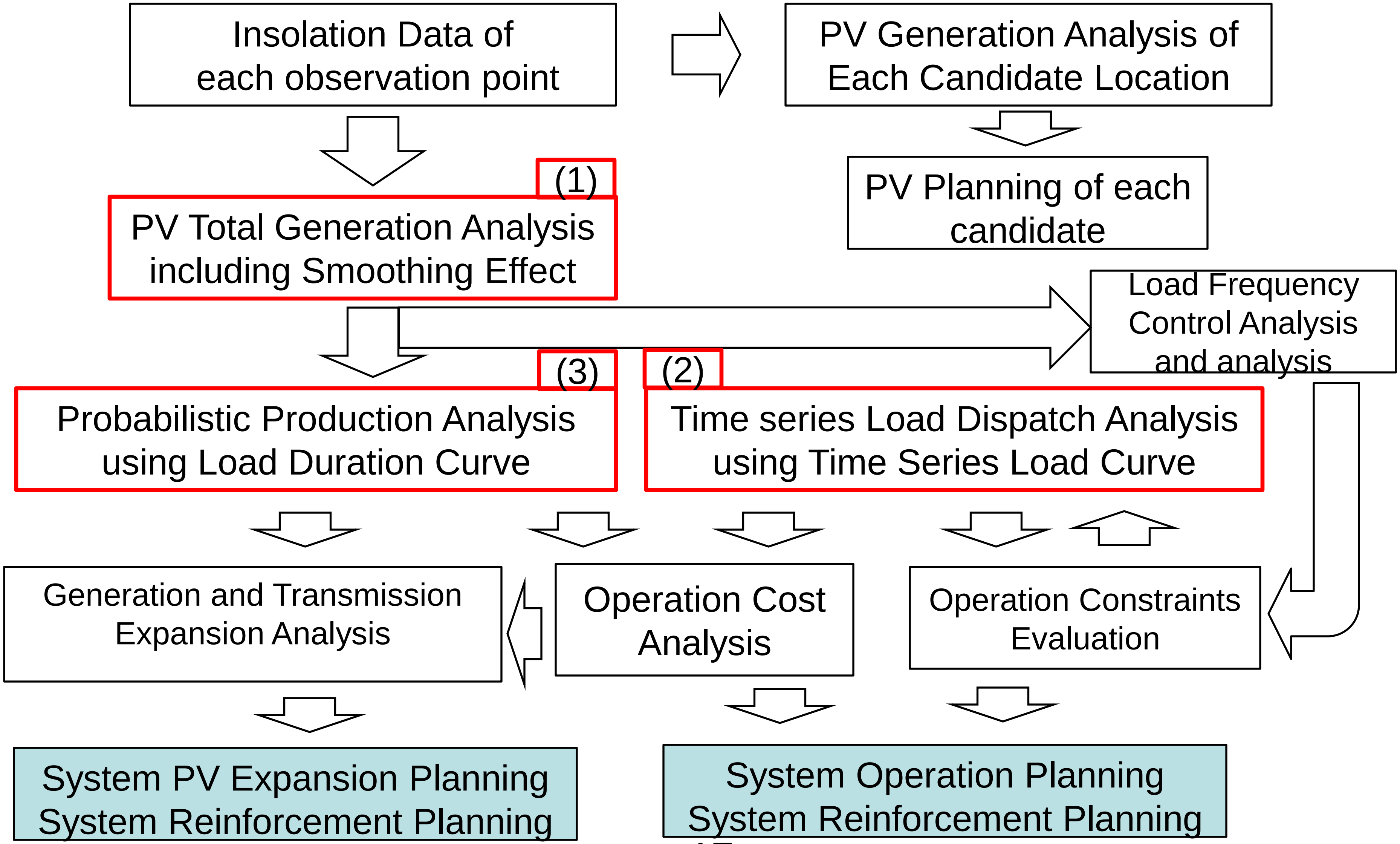
Tokyo-system, May, w/o power storage



Tokyo-system, August, w/ 50% power storage

Equivalent system load including PV

Power System Planning Analysis for PV Integration



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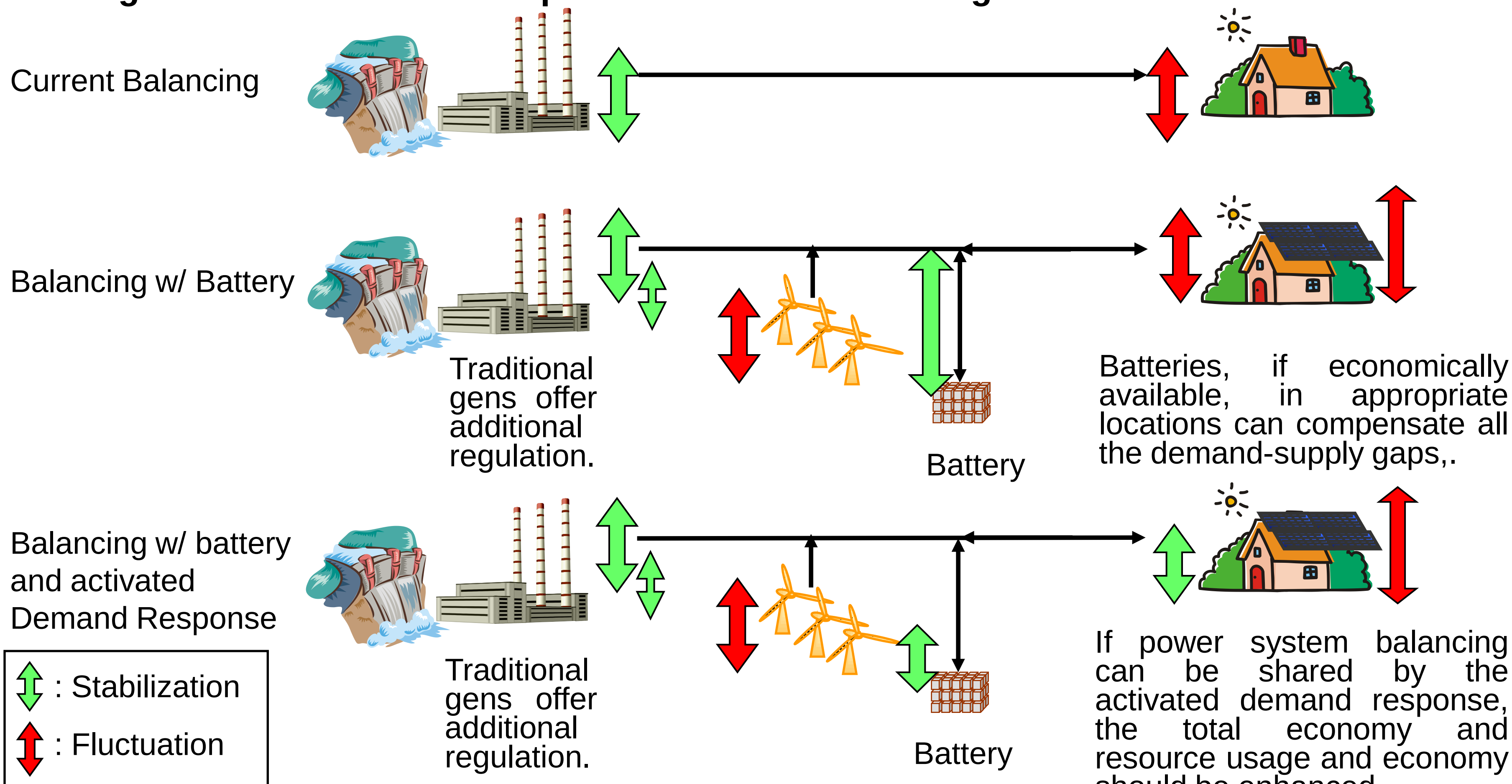
Role of Activated Demand and Storage

The demand-supply balance in a power system is now managed by centralized energy management using major generation units. In the future, when renewable energy generation penetrate into the system, the distributed energy management using activated demand is expected to share the management of the balance.



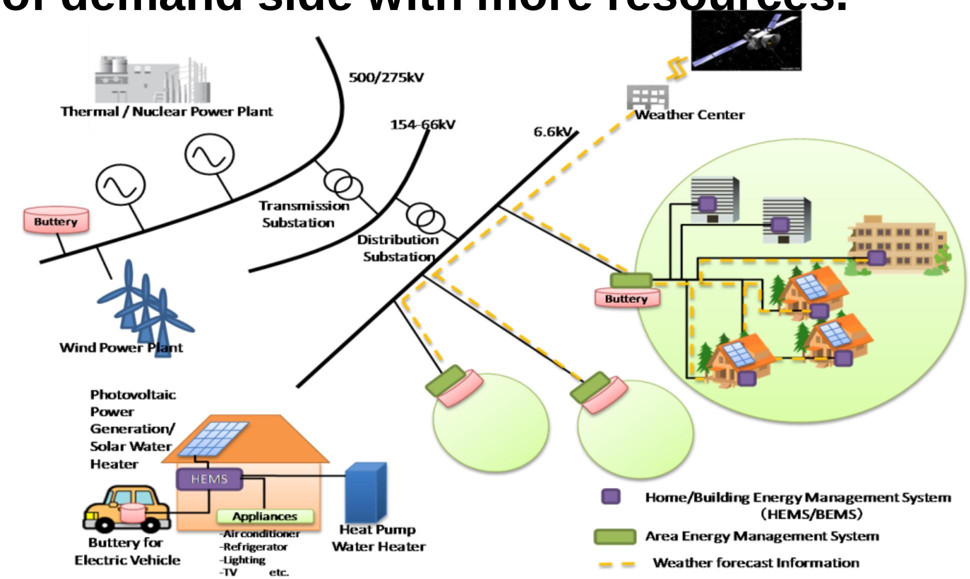
Home, Building, and Area Energy Management

- ✓ **HEMS and BEMS are the appropriate hub for the autonomic and distributed energy management because they can pursue three targets of enhancement of ambient quality, economy and harmonized system demand-supply balance control with a power system**
- ✓ **The distributed energy management autonomously control demand, energy storage and some others.**

HEMS: Home Energy Management System

BEMS: Building Energy Management System

- ✓ **In addition to HEMS/BEMS, Area EMS will be effective to enhance the autonomic control capability of demand side with more resources.**
- ✓ **Area EMS also enables the direct harmonized operation between network (centralized EMS) and demand (de-centralized EMS) to enhance total system quality.**

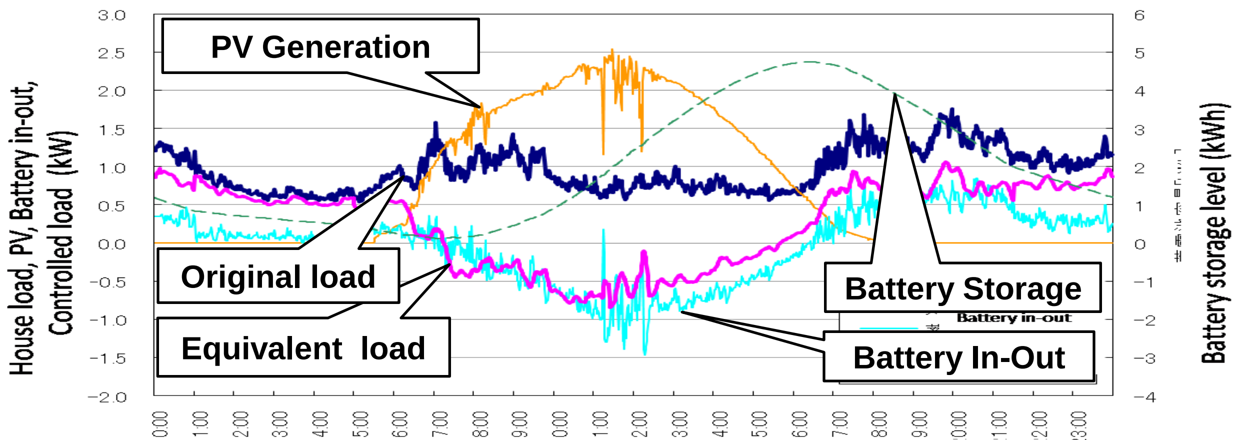


UT CEE Iwafune Lab. Ogimoto Lab.

Centralized/distributed ENERGY MANAGEMENT (1)

- ✓ **In a case of a building without power system connection, distributed energy management is obliged to balance demand and supply within the “node”.**

- ✓ **In a case of a building with power system connection, if under an institutional disincentive to feed power back to a system, distributed energy management prefers to reduce reverse power flow to the system.**



Example of HEMS Control: Minimum reverse flow

- ✓ **In a case of centralized control, the operation of the total power system might be optimized under some optimization policy and the every operation of the system component might be uniquely decided.**

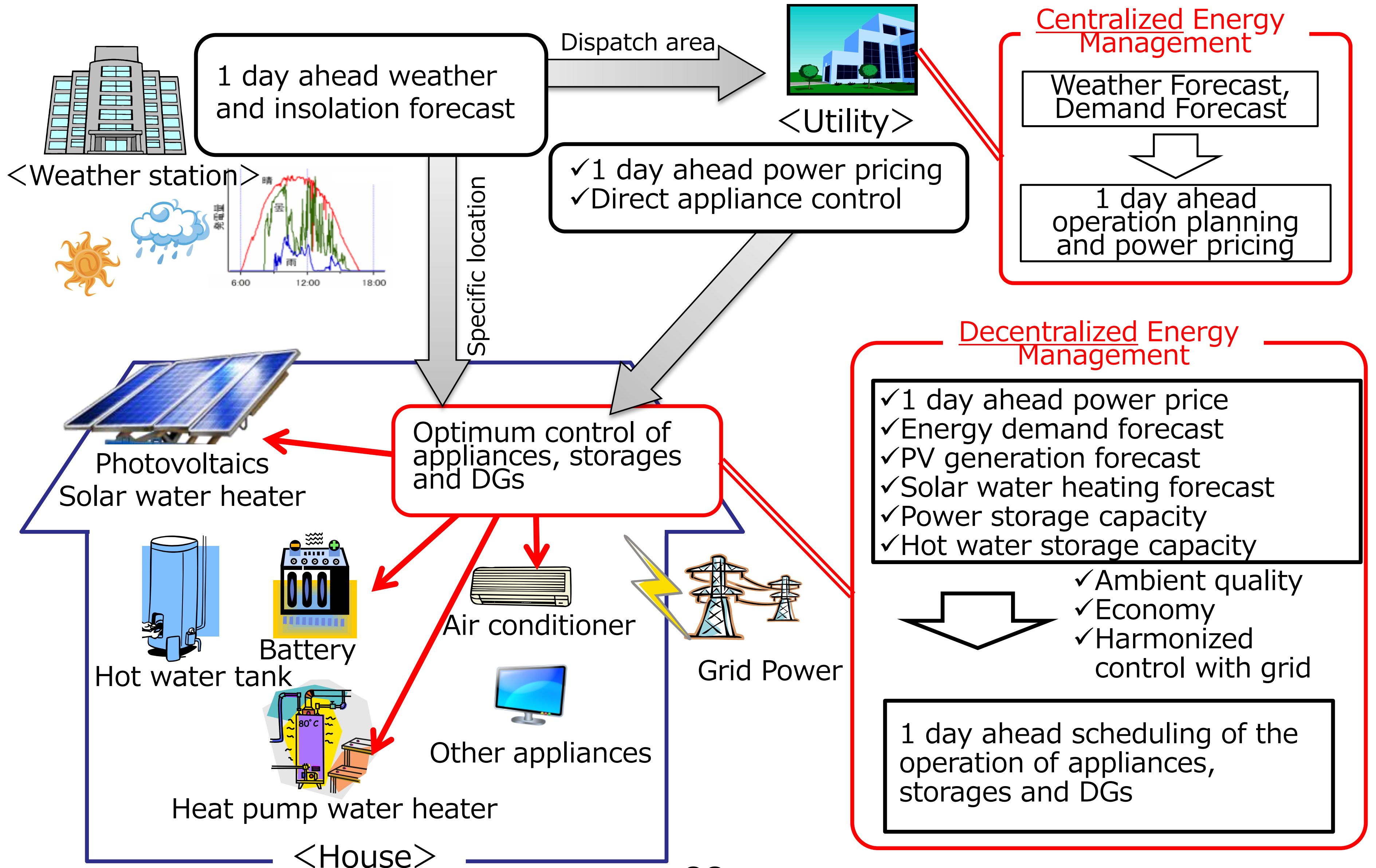
Centralized/distributed ENERGY MANAGEMENT (2)

However, there are many uncertainties in the conditions including the variation of renewable energy generation and component failures of nodes and power system.

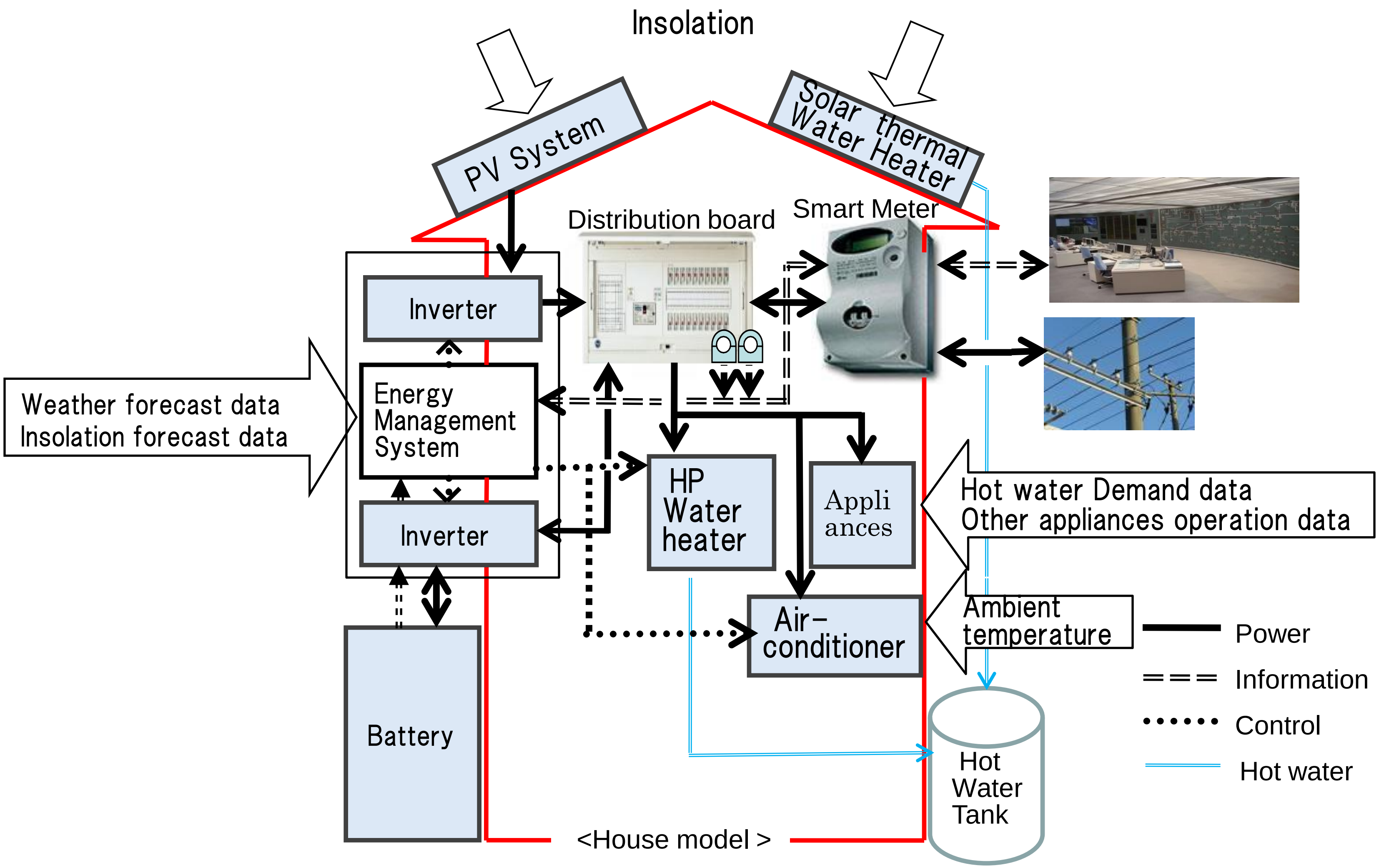
- ✓ **It is unfeasible to collect and share all the information required and to execute the centralized control of the whole system.**
- ✓ **The autonomic distributed energy management system, with the dynamic incentive such as one day ahead pricing, can optimize its control, and power system may change the price in response to the latest situation of the demand-supply balance of the whole system for better operation.**
- ✓ **The centralized Energy Management of the power system can control all the controllable components including demand devices and appliances under special contracts.**

Here, centralized and distributed energy management are expected to realize optimum operation combining direct/indirect control methodology.

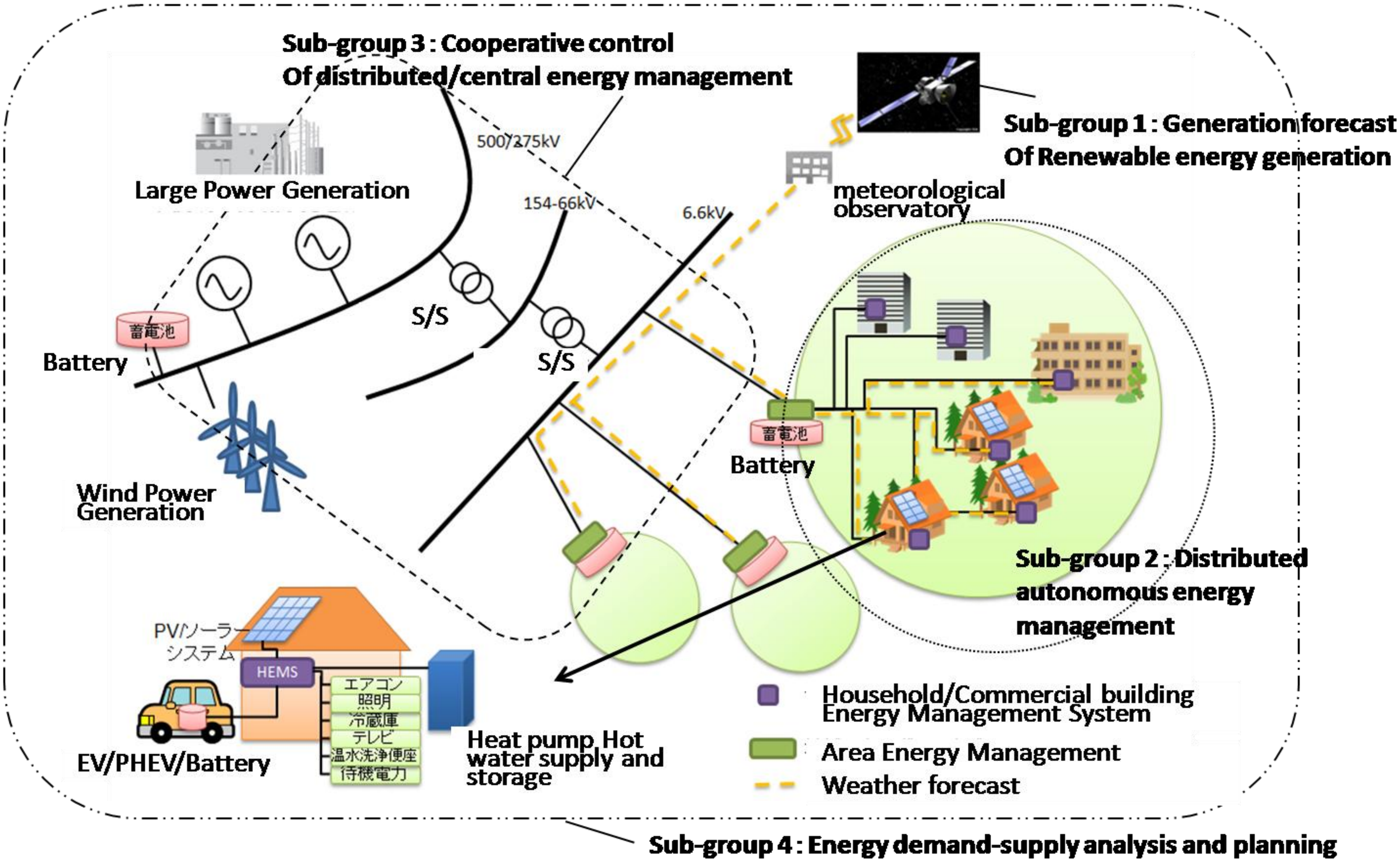
Optimization Model of C/D Energy Management



Simulation Model of Distributed Energy Management



Energy Management R&D Project in Kashiwa-no-ha city



CONCLUSION

- **Residential/Commercial sector will play a crucial role in energy efficiency and CO2 emission reduction.**
- **The deployment of renewable energy generation such as wind power and PV will accompany the variation of their generation, which will have critical impacts on the demand-supply balance of a power system.**
- **Residential/Commercial sector will play a crucial role of demand-supply balance of a future power system through decentralized energy management using activated demand, energy storage and DG.**
- **The total additional requirement for demand-supply balance will be determined by the natural variation characteristics, predictability and smoothing effect of Res generation and power system regulation capability.**
- **Distributed energy management controller will have three roles; enhancement and maintenance of ambient quality, economy and harmonized control with a power system.**
- **We continue to research:1)the optimized operation of the distributed energy management such as HEMS and BEMS of buildings and Area EMS, 2)the optimized interactive operation between centralized and distributed energy managements, and 3) optimum future energy integration.**

Thank you