Energy System Integration

"Long-range" Strategic Energy Technology Roadmap
and Power Demand and Supply Planning Tools

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"Long-range" Strategic Energy Technology Roadmap and Power Demand and Supply Planning Tools

1. Energy Technology Strategy
   - "Energy Technology Vision 2100 (Oct. ,2005)"
   - "Energy Technology Strategy Map 2007 (April, 2007)"
   - "The Cool Earth Energy Technology Innovation Plan"

2. Robustness and Energy System Indicator

3. Tool for Energy System Integration
   - Energy system analysis tool
   - PV penetration to a household
   - PV penetration to a power system (time-series)
   - PV penetration to a power system (duration-curb)

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Energy and Environment

- Constraints on energy connect directly to the level of human welfare such as economic activity and quality of life.
- For sustainability, energy strategy should take into account both resource and environmental constraints.
- The key solution for sustainability is technology, which enables enhancement of welfare for more people.

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

Importance of Energy Technology Strategy

Energy technology strategy, in which the role of technologies are positioned and the paths of their realization are identified, is inevitable due to the following reasons:

- Timeframe of resource and environment constraints are from 10s to 100s years, and long lead time of R&D, diffusion, and infrastructure development is required. (Long term)
- Due to the magnitude and timing of constraints and development of alternative technologies, the role and importance of each energy technology can be affected heavily. (Uncertainty)
- Energy system covers huge areas of a social system and there are large number of potential technologies and their portfolio. (Diversification)

Energy Strategies by METI*

- "Energy Technology Vision 2100(Oct. ,2005)" identified the required specification of energy technologies through the backcasting method from year 2100.
- "Energy Technology Strategy Map 2007 (April, 2007)" identified the R&D and diffusion paths of more than 200 energy technologies which contribute the Japan's National Energy Strategy (June 2006), through the forecasting method to 2030, based on the direction of the backcast vision.
- Currently, "the Cool Earth Energy Technology Innovation Plan" is being prepared by a committee for the announcement in the coming March.

*: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry of Japan

Backcasting and Forecasting

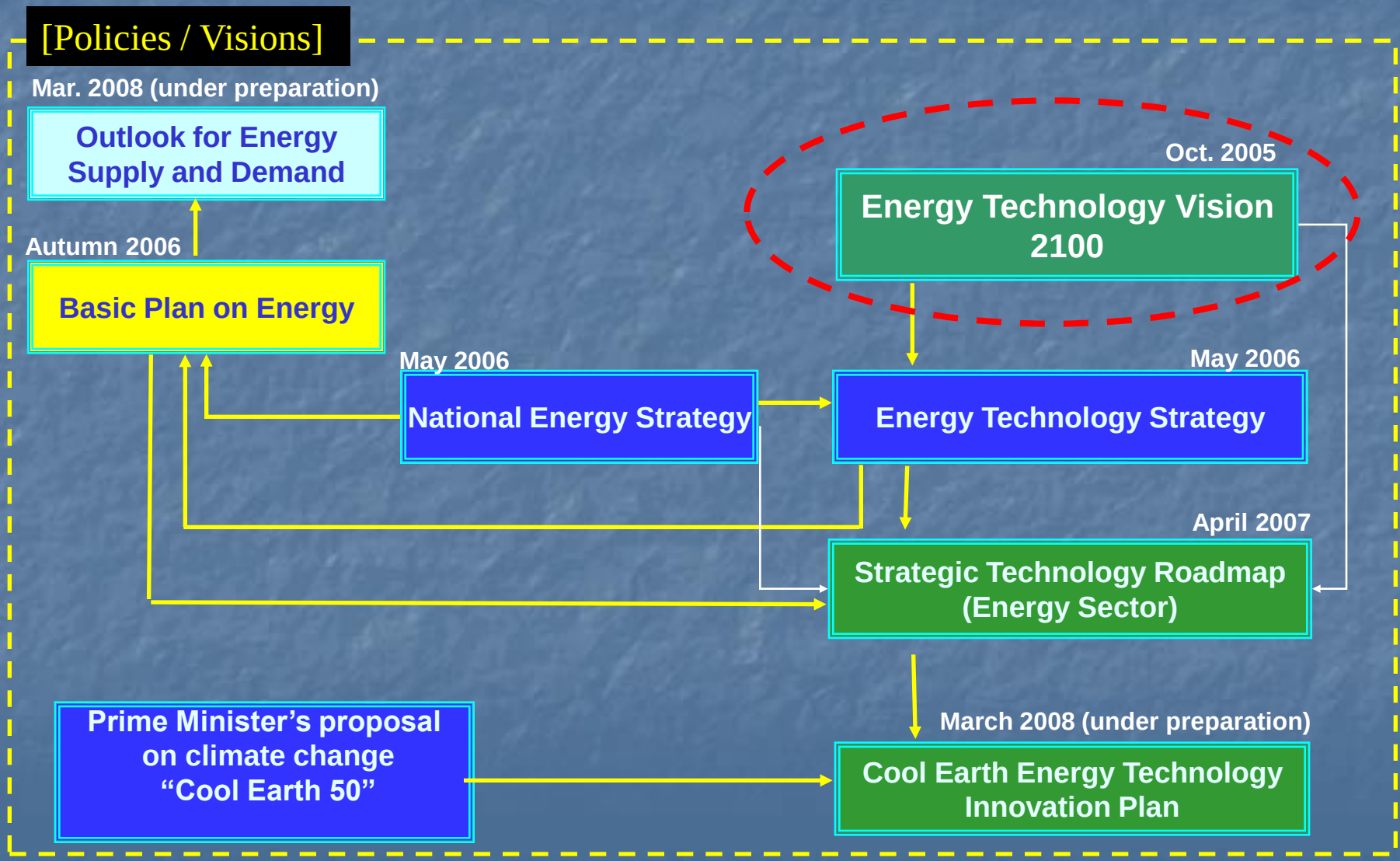
Energy Technology Vision 2100

- Quantitative Target
- Enabling Technologies

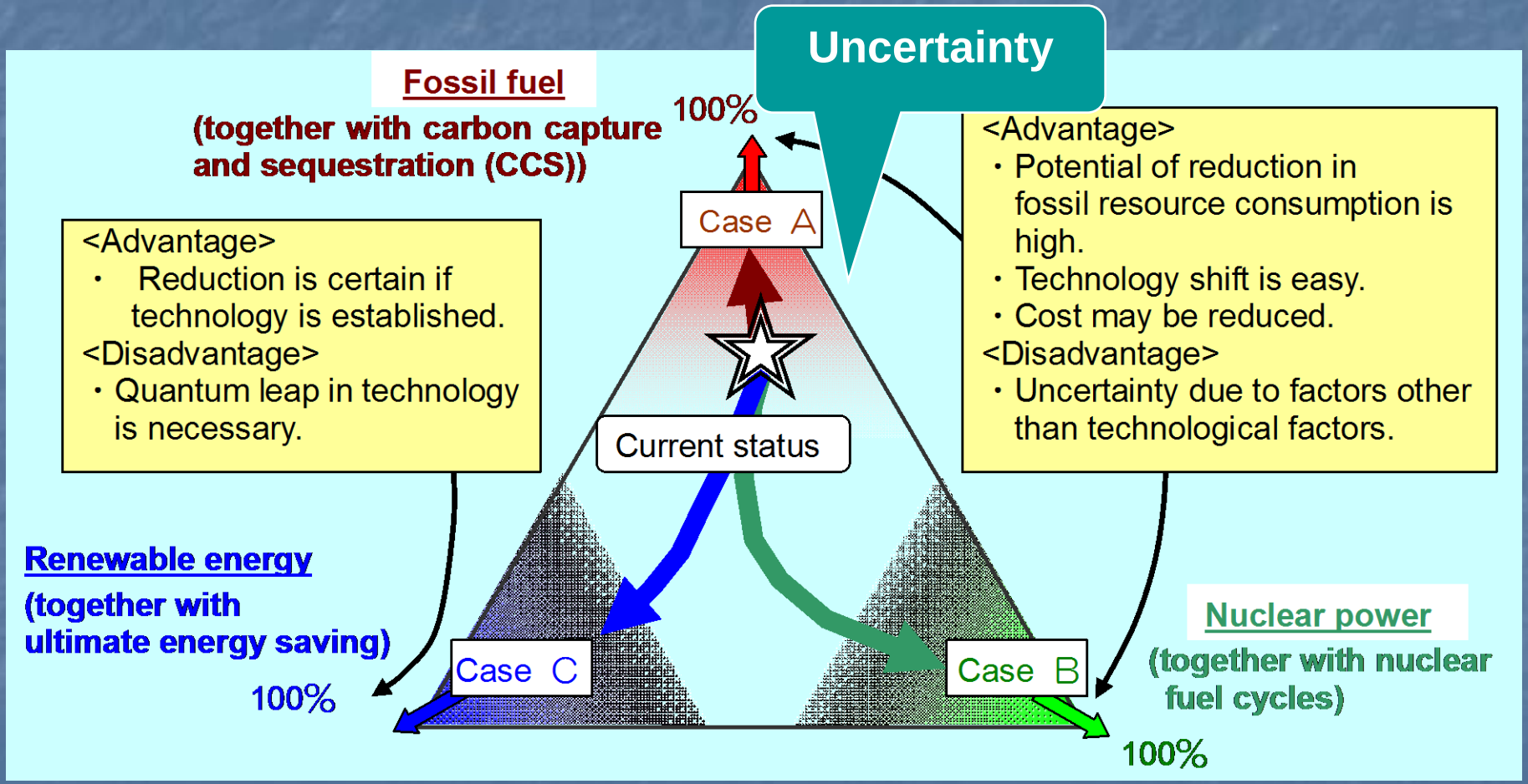
- Desirable Future
- Quantitative Target
- Enabling Technologies

Modified from "Energy Technology Vision 2100", Akai,
2006 International Energy Conference for Sustainable ASIA Institute of Applied Energy

Japan's Energy Policies & Measures



Three Extreme Cases and Possible Pathways



- Cases A & C assume BAU energy saving

"Energy Technology Vision 2100"

Example of a road map :Household, Energy creation

Energy creating technologies
- Various renewable energy sources are introduced depending on individual characteristics of each community such as photovoltaic generation and biomass energy.
- The establishment of the technologies of installation, maintenance, and abandonment are important.
- Energy creating is disseminated to detached houses first, collective housing, and commercial buildings sequentially, according to conditions such as installation space, installation facilitation, and energy cost.

	2000	2030	2050	2100
Energy creating rate*				
Residential	0%	15%	25%	40%
Commercial	0%	5%	10%	30%

*The percentage contribution of energy per unit which can reduce the energy supplied from the transformation sector, compared with total energy demand or utility increases in proportion to

Conversion technologies such as from unused energy to electric power
- The technical hurdles may be high.
- Energy creation will contribute to the "self-sustenance" of electric equipment along with energy saving, but the potential amount of individual energy sou be small.

conversion			
Piezoelectric conversion	Distortion ↔ Electricity	Actuator, s	n
Magnetostrictive conversion	Distortion ↔ Magnetic field	Actuator a	
Bio-photovoltaic	Light → Electron	Biosensor	

Long term

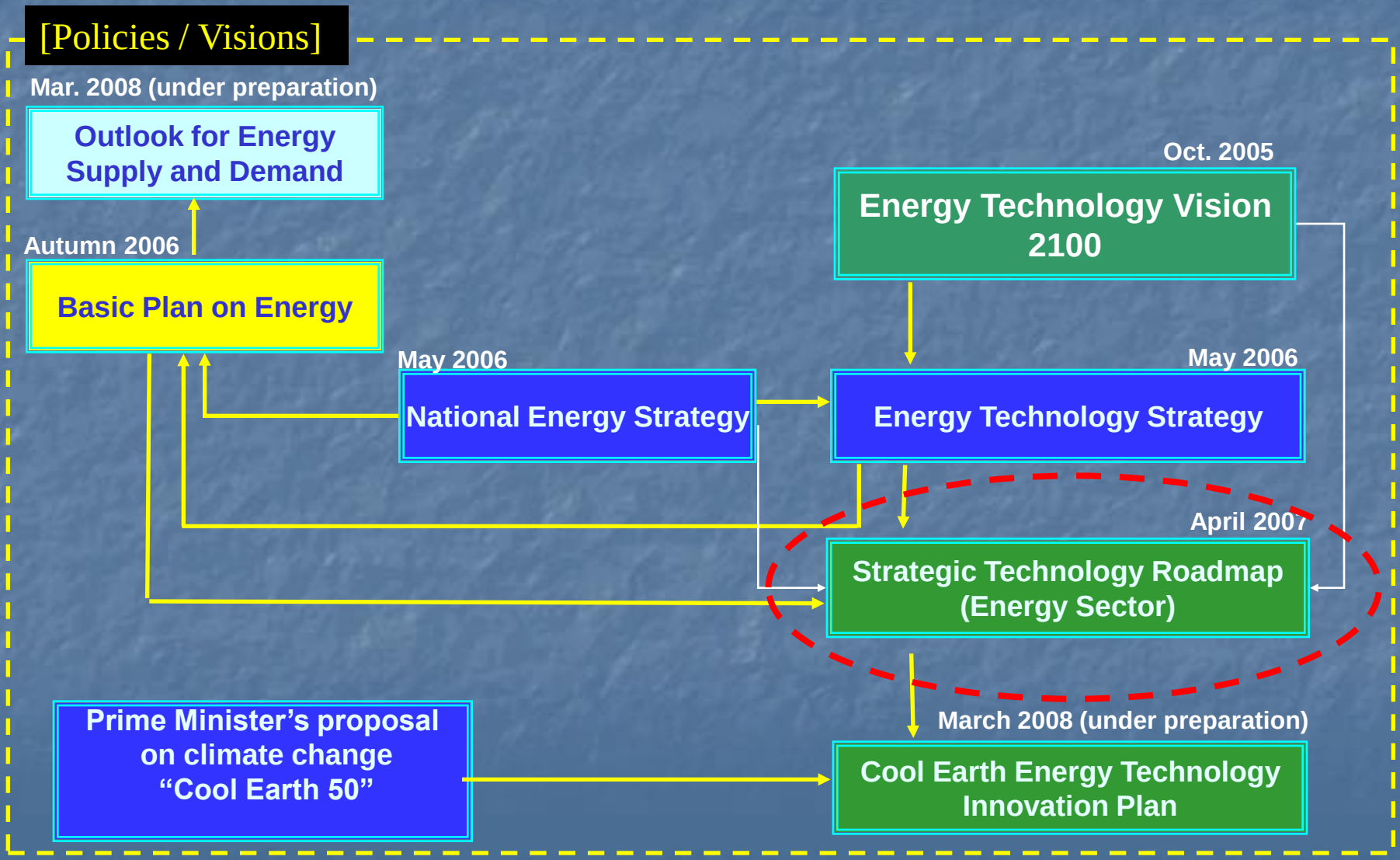
Photovoltaic generation
- Development of several types of solar cells continues for the present, such as crystal silicon, thin film silicon, and dye-sensitized type, etc. The suitable solar cells will be selected from viewpoints of the generation efficiency, productivity, durability, etc.
- The solar module is diversified (lightweight, flexibility, the bifacial photovoltaics, and built-in inverter, etc.) and multifunctioned (sound insulation, thermal insulation, glare proof, etc.) to correspond to various usages and locations. Technological development is also necessary to increase additional value such as integration with construction materials and the material.
- Overall economic improvement is important, by means of more efficiency, cost reduction of the system and installation, adaptive flexibility, standardization of grid connection, increasing efficiency and reducing the cost of connecting equipment.

	Cost reduction and high efficiency	*Module efficiency 22%* *Durability 30 years*	*30%* *40 years*	*40%* *40 years*
Installation facilitation	Flexible solar cell and "see-through" solar cell (curved surface and window)			"PV paint" (all places)

Non-technical factors
- Measures of deployment such as the bounty system.

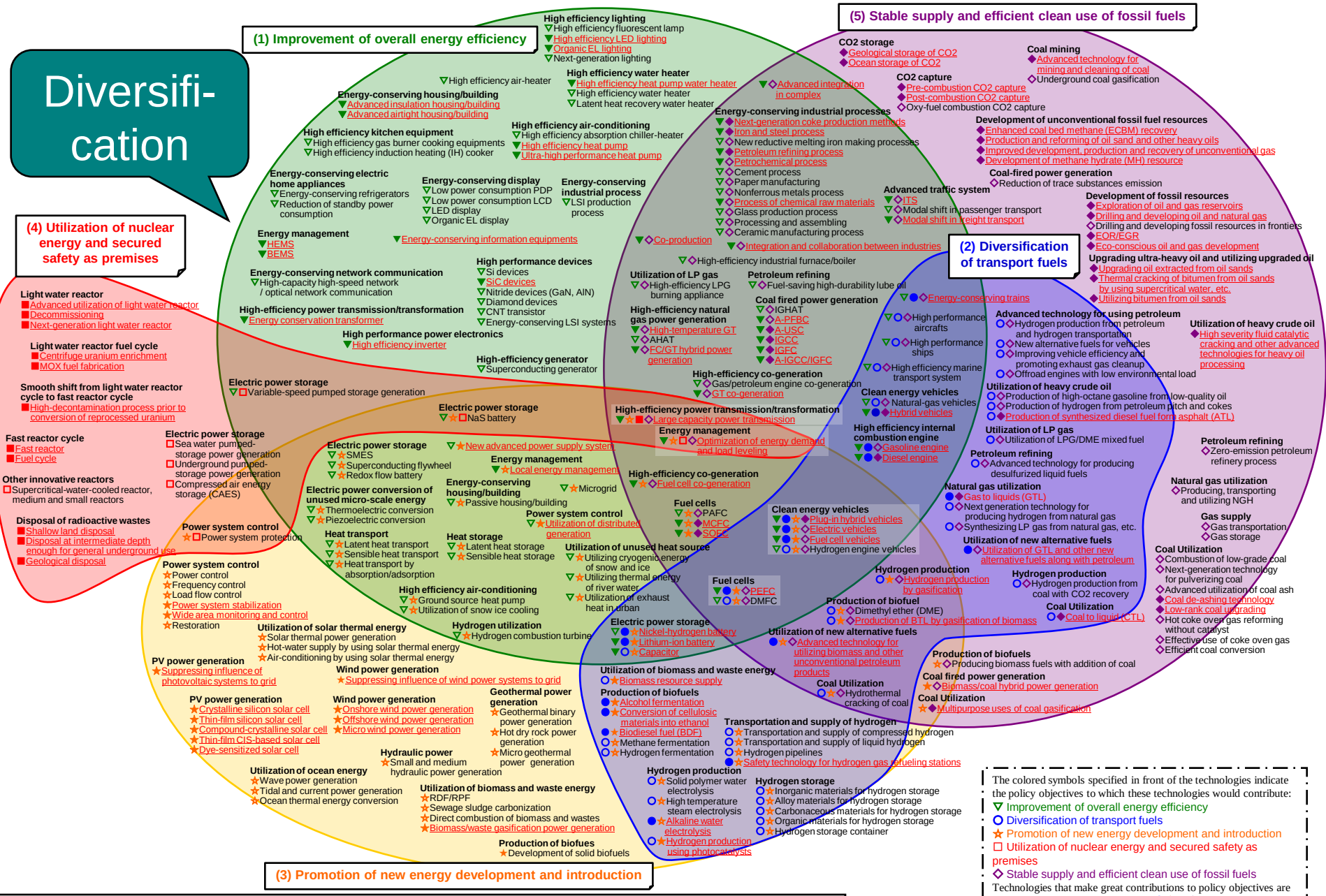
Source: Energy Technology Vision 2100, Institute of Applied Energy and METI

Japan's Energy Policies & Measures



"Energy Technology Strategy Map 2007"

Overhead Map of Energy Technologies



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

"Energy Technology Strategy Map 2007"

(3) Technology Map (Diagram) for Promotion of New Energy Development and Introduction

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

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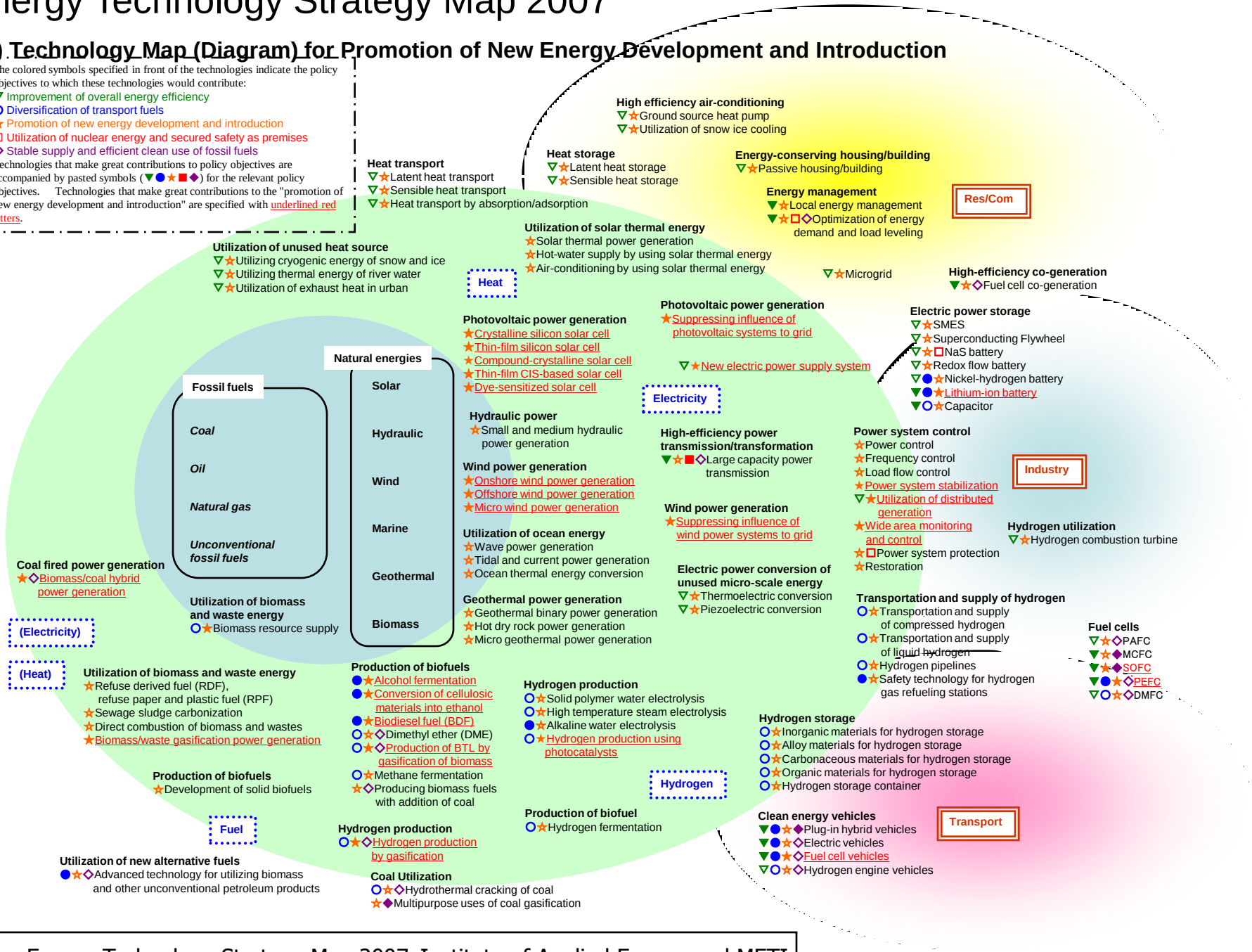
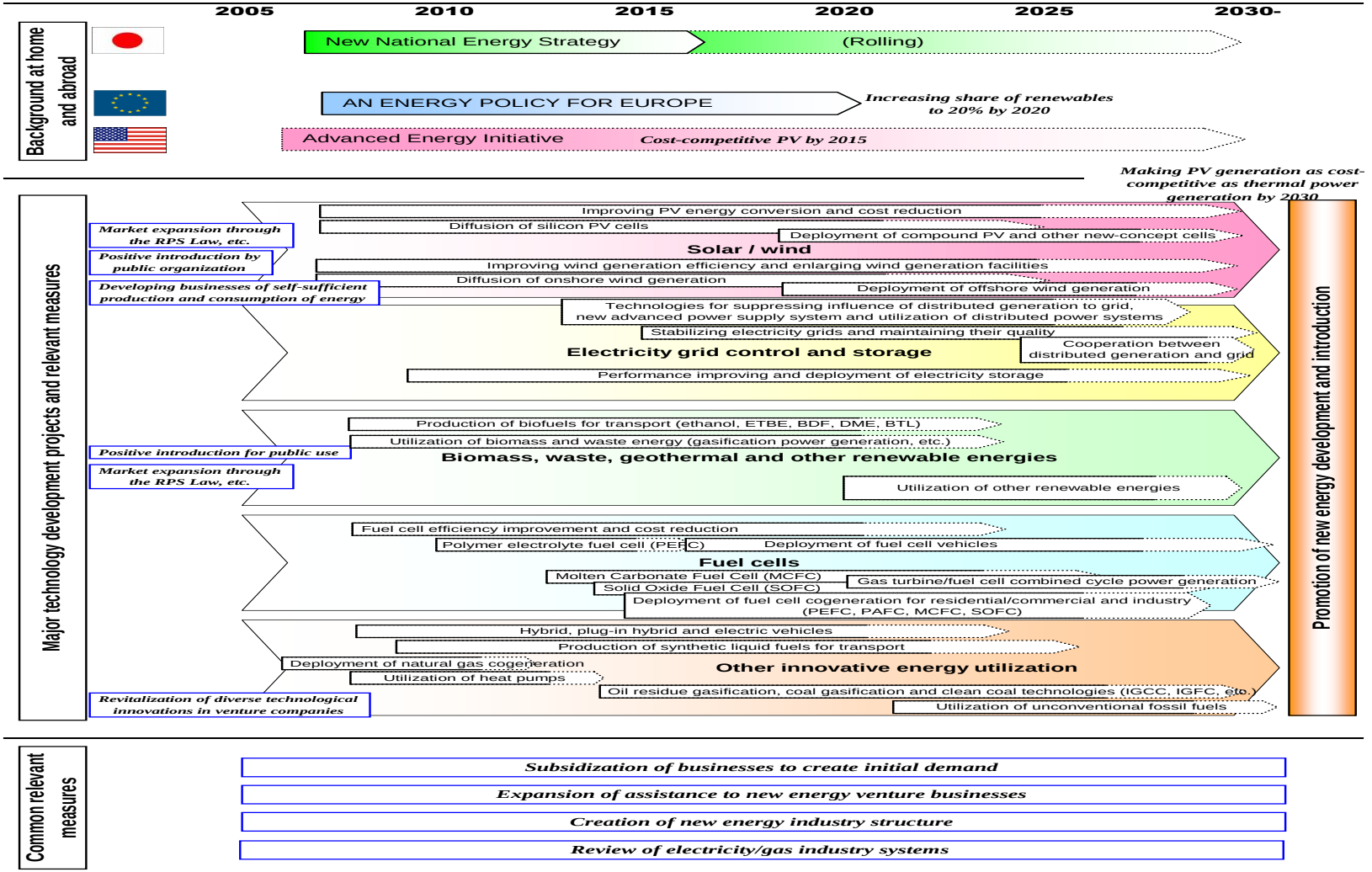


Source: Energy Technology Strategy Map 2007, Institute of Applied Energy and METI

Example of Deployment Scenario

("Promotion of New Energy Development and Introduction")



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

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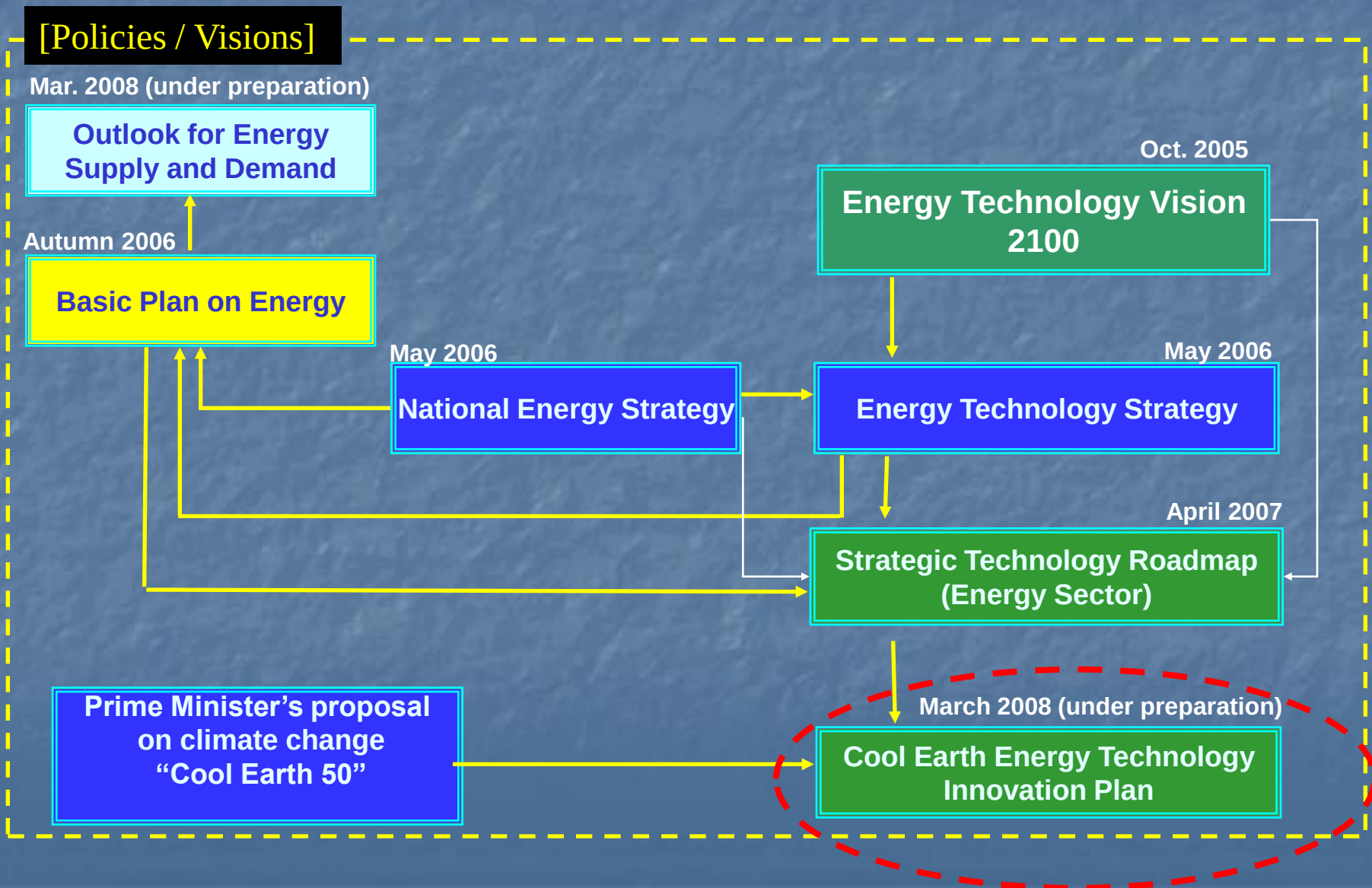


Cool Earth Energy Technology Innovation Plan

Needs for accelera-tion

Source：METI

Direction of Energy System Innovation(1)

- Fossil fuel will play a major role in primary energy supply in the world for a mid-term, and the role of nuclear, coal and renewable energy will increase under the constraints oil and natural gas supply.
- For real sustainability, the innovation to supply-use-recycle system of material and energy is necessary in order to realize total optimization.
- The total optimization should need not only the supply side innovation but also the demand side innovation and energy distribution system innovation.

Direction of Energy System Innovation(2)

- INDUSTRY: Process integration by Coproduction and process harmonization through material storage, recycling –conscious production
- ENERGY TRANSFORMATION: Coal gasification generation, Renewable energy generation, Nuclear generation and CCS, and Biomass utilization
- USE: Various energy saving and energy creation technologies including heat pump (air-conditioning/water-heating), PHEV/EV, distributed generation including PV
- RECYCLING: Waste treatment, water treatment, metal recycling
- SYSTEM: HEMS, BEMS and community EMS

Direction of Energy System Innovation(3)

- The renovation of energy demand-supply structure by innovative technology
  (Energy system integration)

- The renovation of production-demand-reproduction chain (Energy and material metabolism optimization)

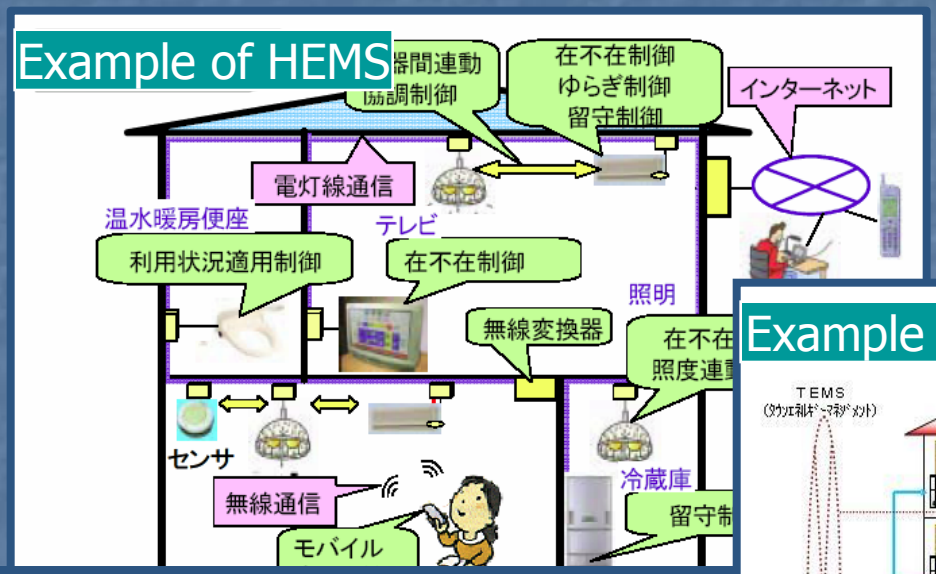
- These renovations are required to occur more earlier than commonly expected.

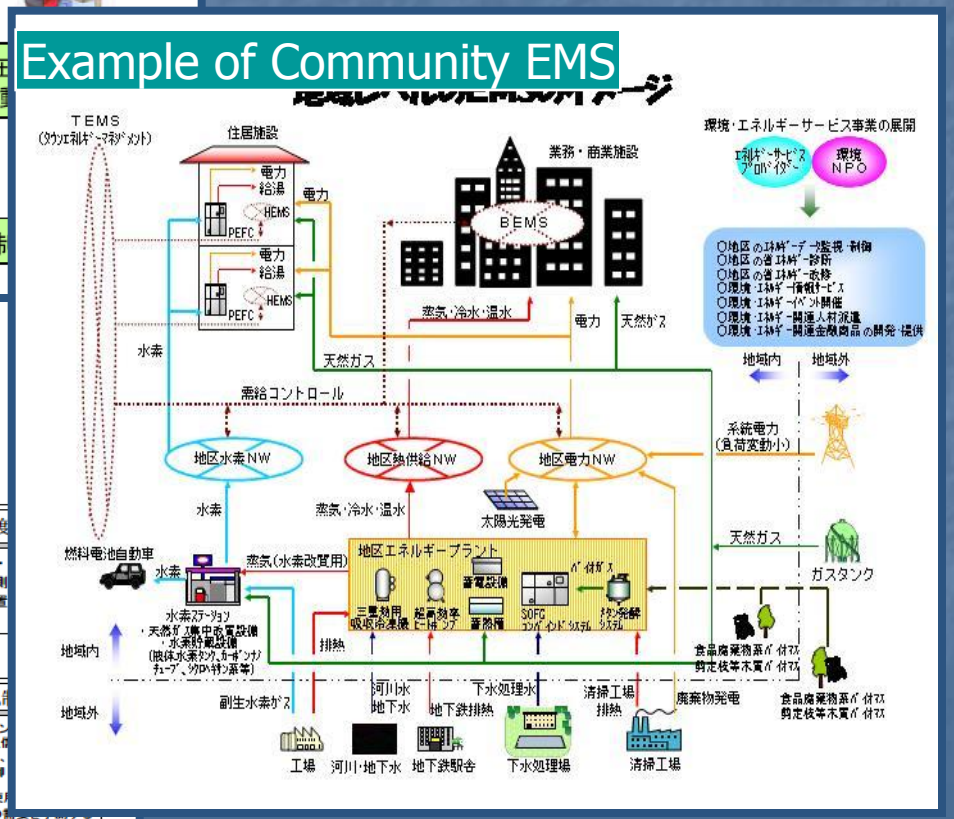
Energy System Integration (1)

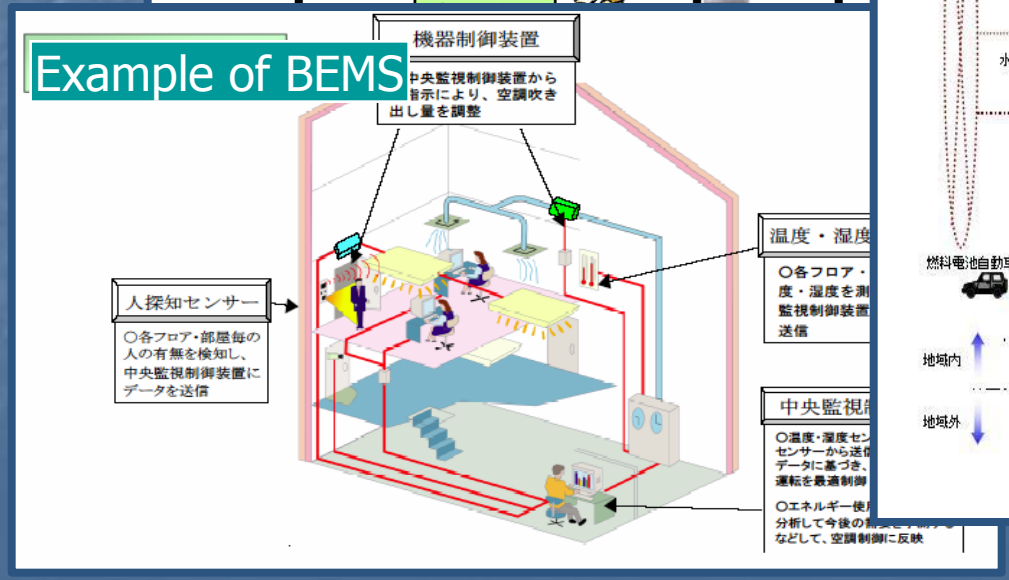
Household, Building, Community:

- HEMS, BEMS and Community EMS, clustered and multi-layered distributed control execute energy management and harmonization with central control
- Secondary energy selection (including vehicle fuel) and innovation of distribution infrastructure
- Integration of regional resource utilization, waste/water treatment and heat/power supply

Energy Management for Energy Integration







Source: Repots of METI

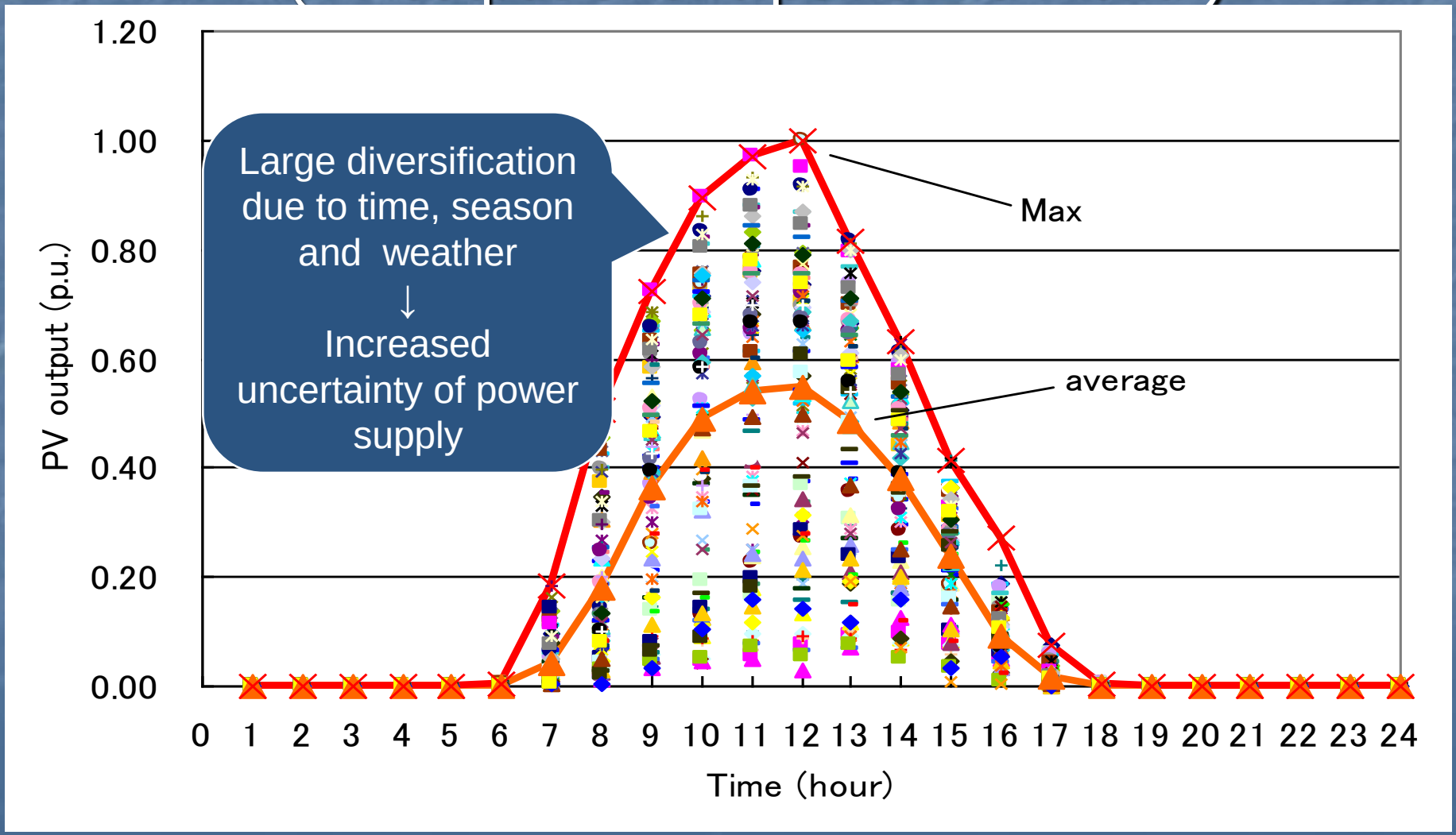
Energy Integration Optimization(2)

National and Regional level:

- Robust and sustainable national energy integration including renewable energy and CCS
- Integration of large scale PV Generation and desalinization plant (water storage from intermittent PV energy)
- Integration of large scale renewable energy generation and energy transport/storage by transmission line or some medium including H_2

And, new uncertainty

Intermittency of Renewable Energy (PV output of one point in a month)



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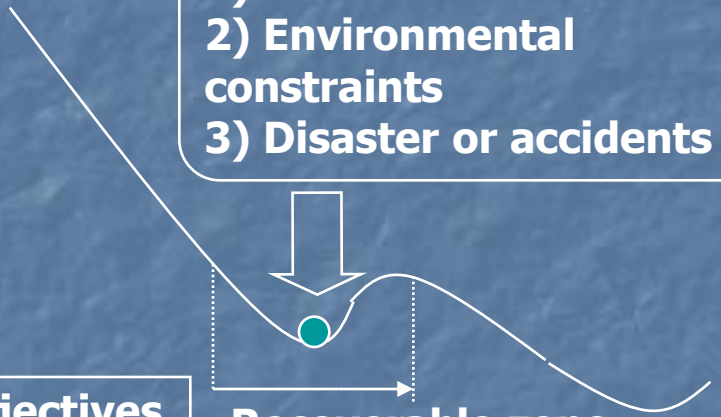
Robustness of Energy System

2) Risks

1) Resource constraints
2) Environmental constraints
3) Disaster or accidents



1）Objectives

Recoverable zone

3) Measures

1) Energy supply security
2) Competitive industry
3) Safe and peaceful life

1) Strategic measures based on energy policy
2) Diplomatic activities for resource
3) Private sector's actions for management risk minimization

Source：Triple 50, university of Tokyo

Example Classification of Risks

Classification	Risk	Primary Measure
Long term supply outage (＞1 year: Change in infrastructure is necessary)	-Resource depletion・price increase -Severe social rejection -Severe environmental constraints	Diversification of primary energy source for risk minimization Reduction of energy demand（Efficiency enhancement）
Short term supply outage (＜1/2year；Mainly measured by stockpile. Limited change in infrastructure）	-Conflicts -Spike of price of resource due to speculation -Social rejection (Short term)	-Resource stockpiling in accordance with demand -Reservation of excessive generation capacity
Short term network infrastructure outage	-Natural disaster Terrorism, Network failure	-Power system reinforcement -Distributed energy source - Reduction of energy demand

Source：Co-study

Energy System Integration: Objectives and Indicators

Example Indicators

Challenge

Sustainable Robustness

- **Connectivity to the target sustainable society in 2100**
- **Robustness at time cross sections**

Primary Objectives (National Policy)

I. Stable energy supply
1)Energy self sufficiency enhancement
(Self-sufficiency rate, Oil dependence rate)
2)Energy use efficiency enhancement
(Primary energy/GDP)

II. Global Environmental performance
(CO2/GDP)
～Fossil fuel dependency rate

III. Supply security in demand side
(Self-assistance, redundancy)

Secondary Objectives (Policy)

1)Reduction of oil consumption (Oil consumption amount)

2)Reservation of excessive generation capacity (Reserve rate)

3)Primery energy diversification (Diversification rate, Substitutability)

4)Specific Energy consumption of each sector (Specific energy consumption)

5)Diversification of fuel of transportation sector and material in industrial sector (Diversification, substitutability)

6)Reduction of CO2 Emission from each sector (Specific CO2 emission)

7)Enough stockpiling (Equivalent stockpiling days)

8)Enhancemnet of Network reliability (Supply interuption probability, Recovery time, Congestion index)

9) Appropriate energy price (Unit price)

Source：Co-study

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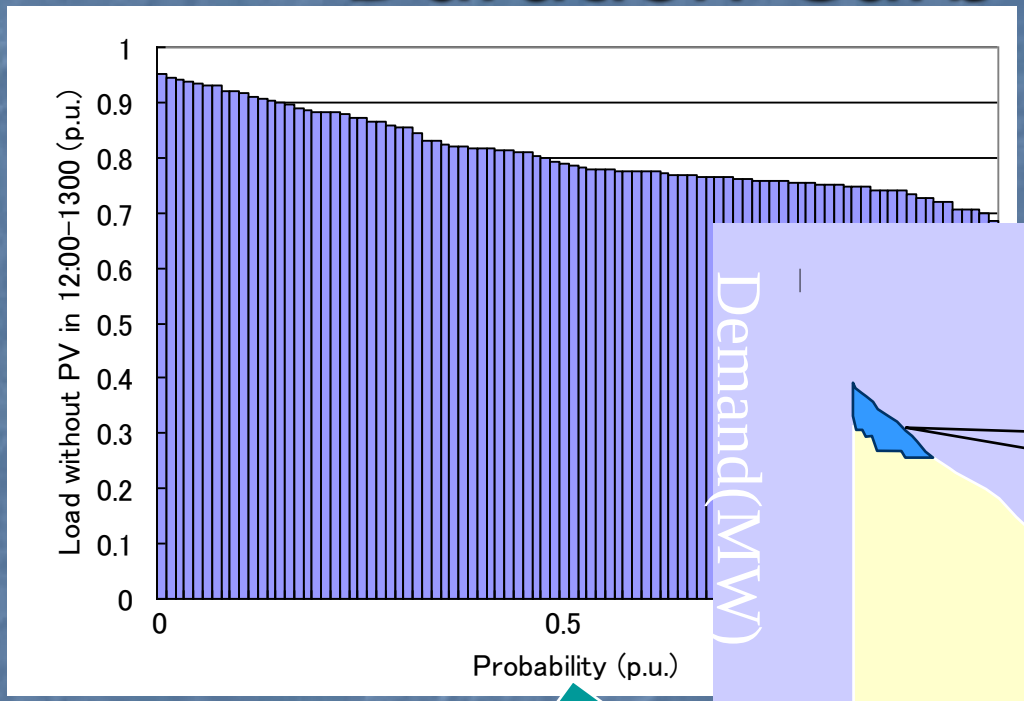
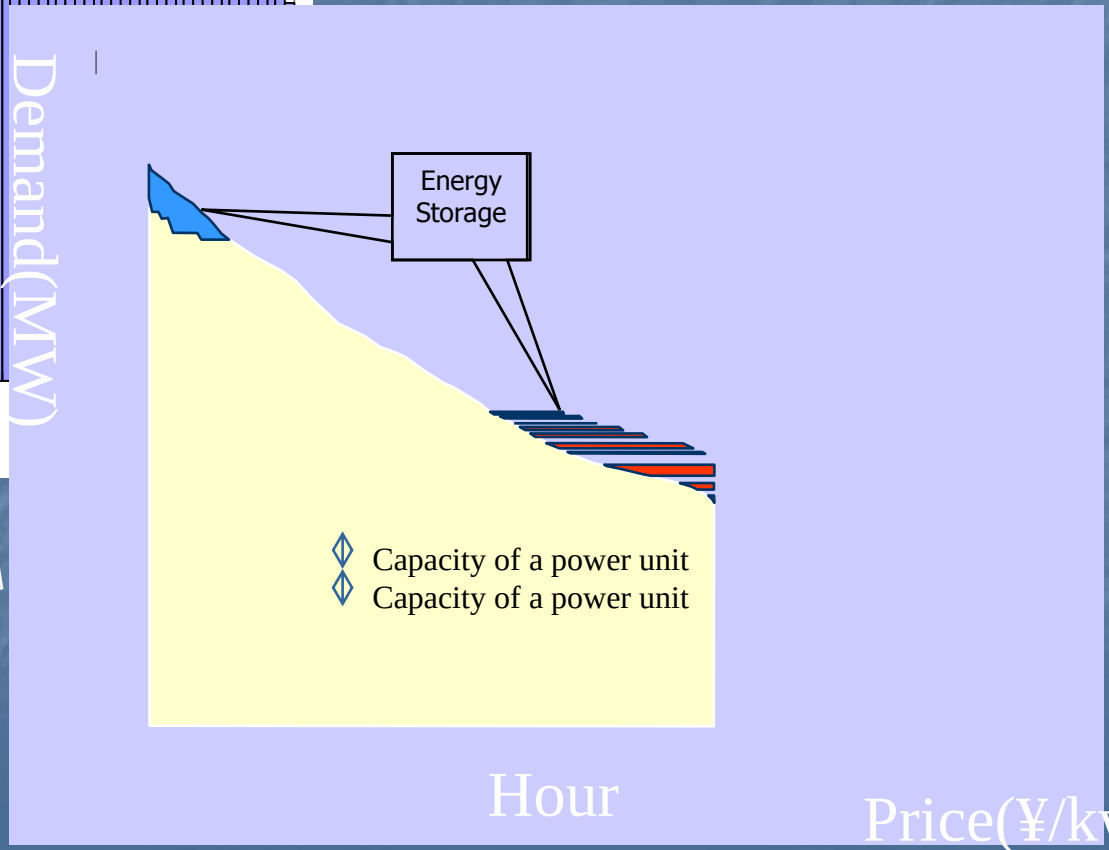
Energy System Analysis Tool
From Strategy to Grand Design

- Energy Balance Analysis
- Material Flow Analysis
- Power Balance Analysis
  Influence of new technologies
  - ✓ Time-Series / Duration-Curb
  - ✓ Single bus / Multi-area / Clustered and Multi-Layer
  - ✓ With / Without Energy Storage
  - ✓ With / Without Demand Control
  - ✓ Central / Decentralized Control

Energy System Analysis Tool
Duration Curb Method in



Time series load data are reordered by magnitude. The load is dispatched to each generation unit by merit order.



Energy System Analysis Tool
Comparison between Duration-curb/Time-series

- Time-series method
  - ✓ Easy to understand
  - ✓ Easy Simulation of sophisticated control
  - ✓ Energy storage can be modeled directly

- Duration-curb method
  - ✓ Effective to include probabilistic features such as plant outage and renewable generation intermittency
  - ✓ The expected amount of energy
  - ✓ Reduced computing resource

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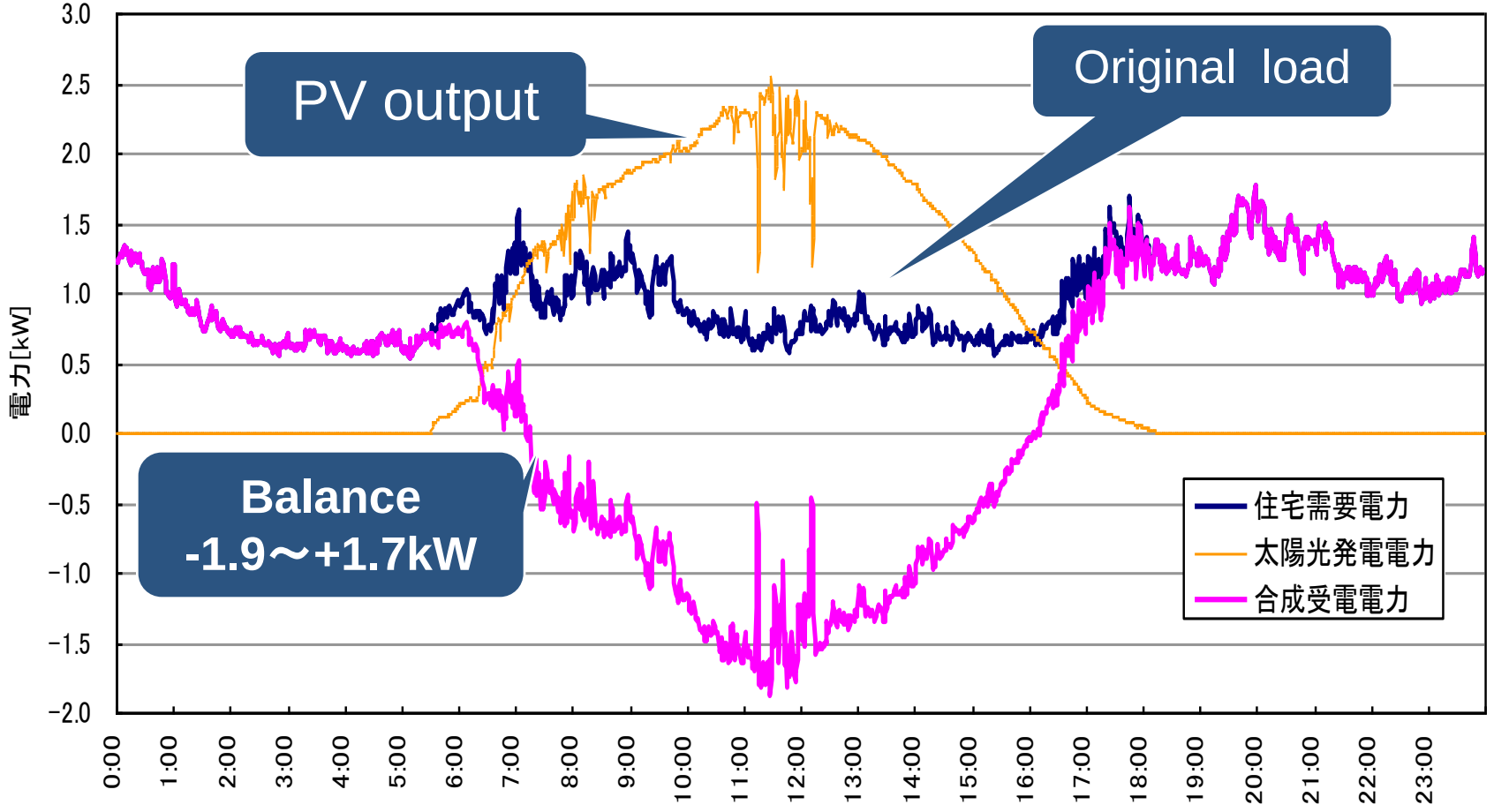
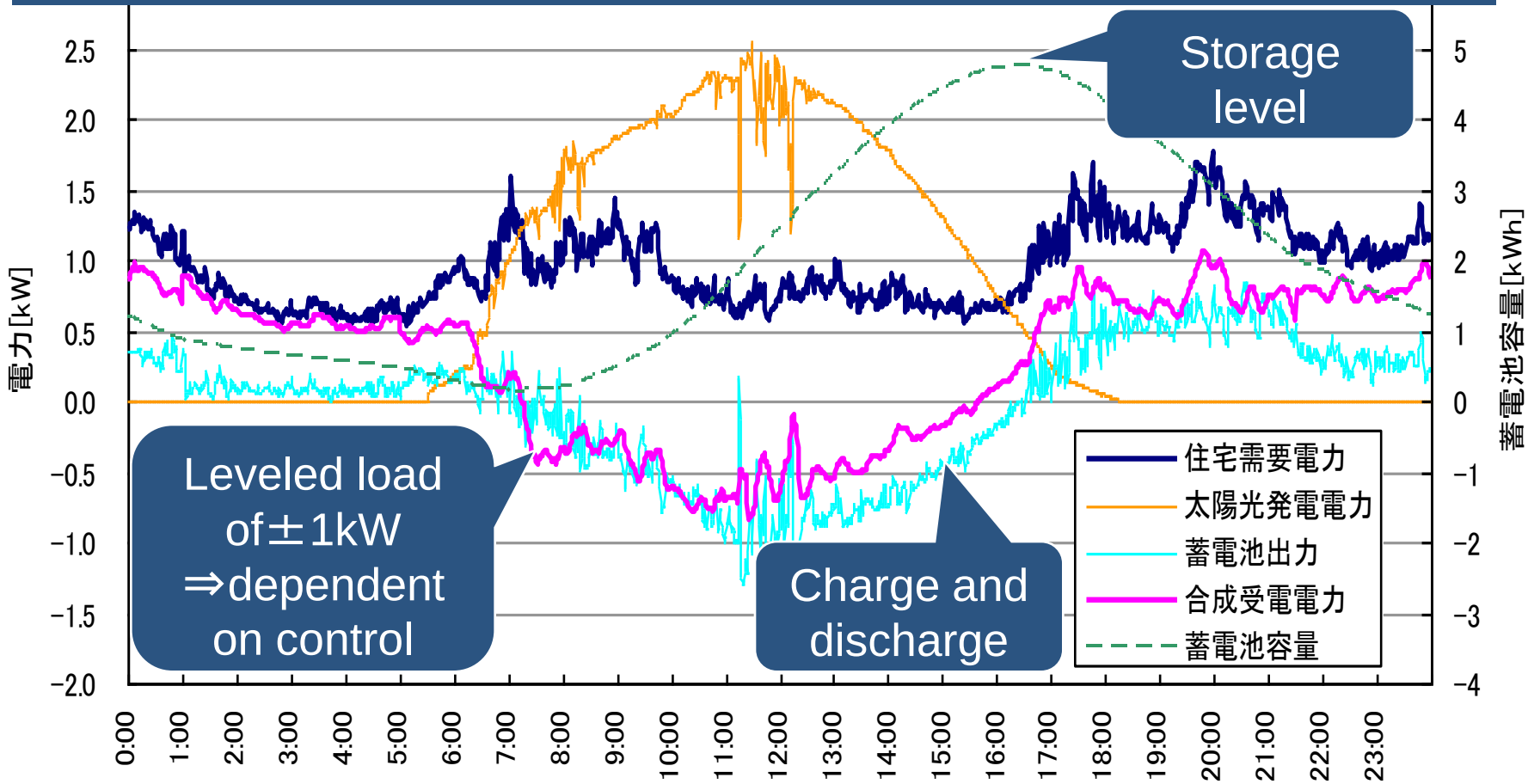
PV Penetration Analysis to a household

Power balance w/ PV and w/o energy storage



PV Penetration Analysis to a household

Power balance w/ PV and w/ energy storage



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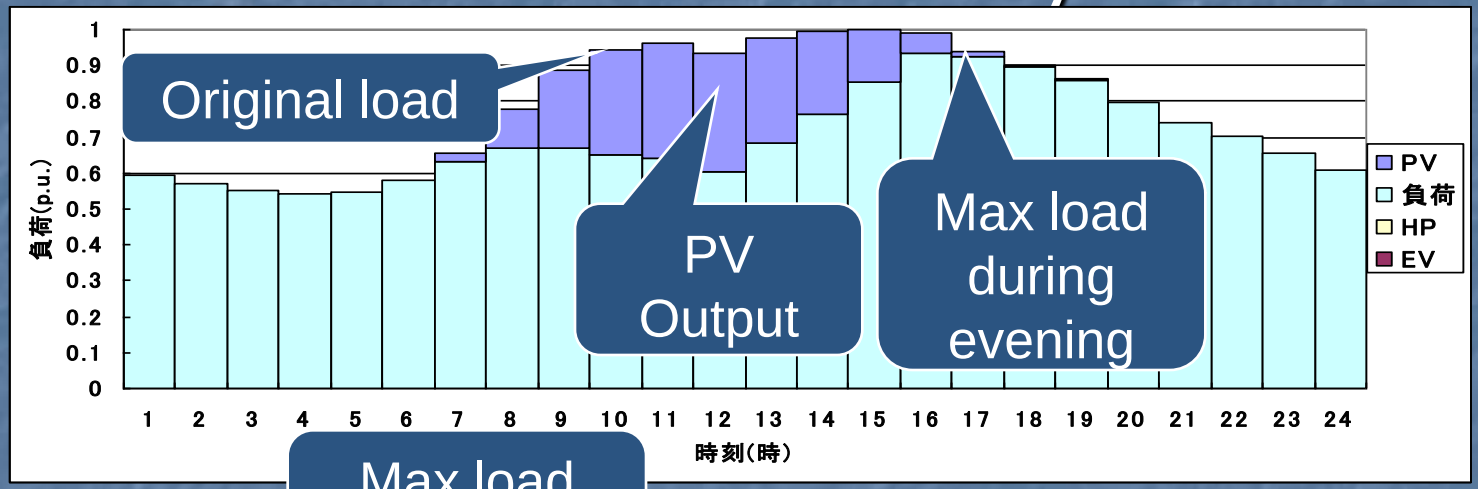
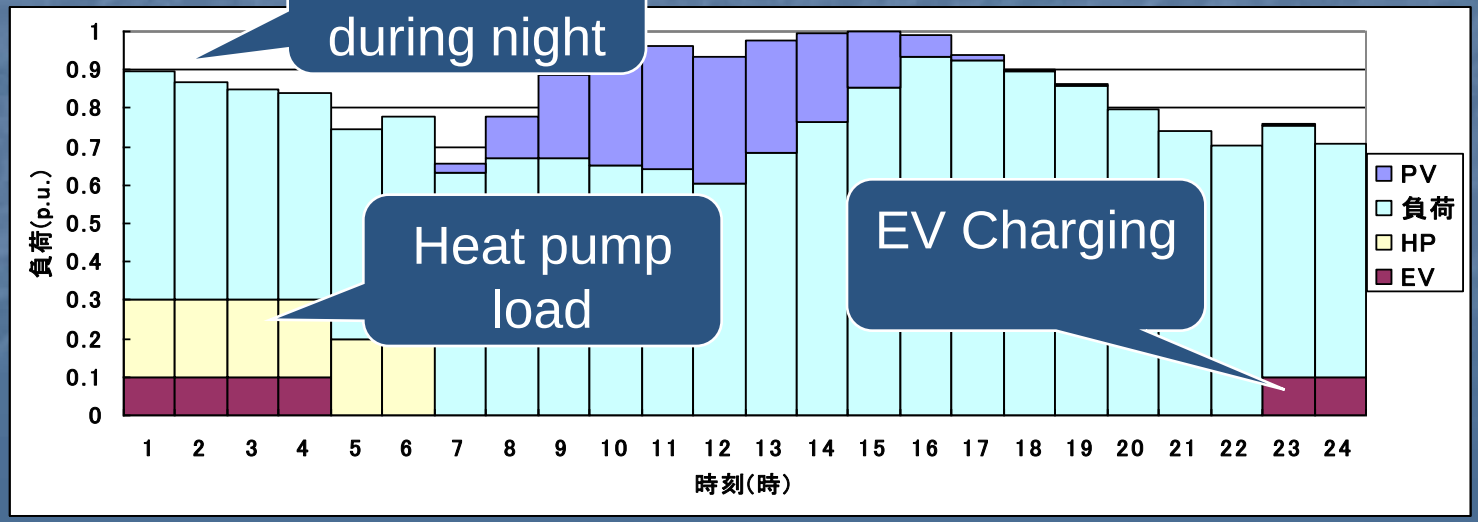
New technologies' Influence on Demand of a Total Power System

Original load
-
PV Output



\+
EV Charge
\+
HP Operation



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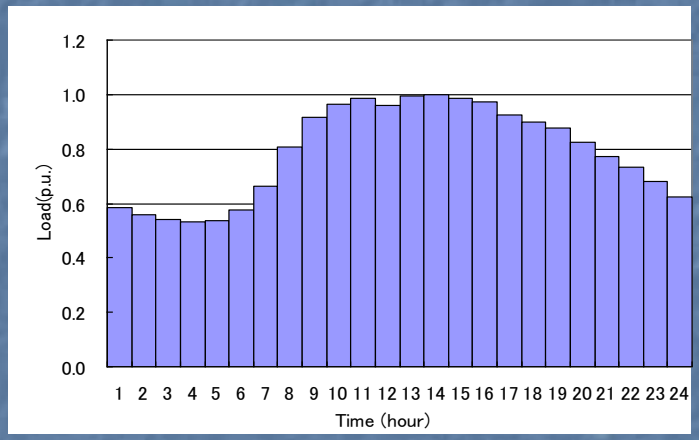
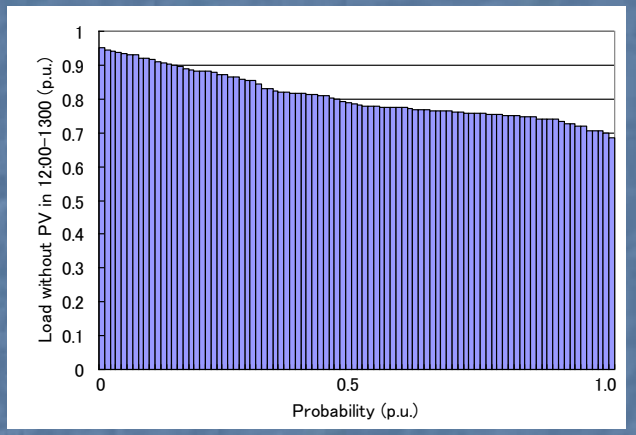
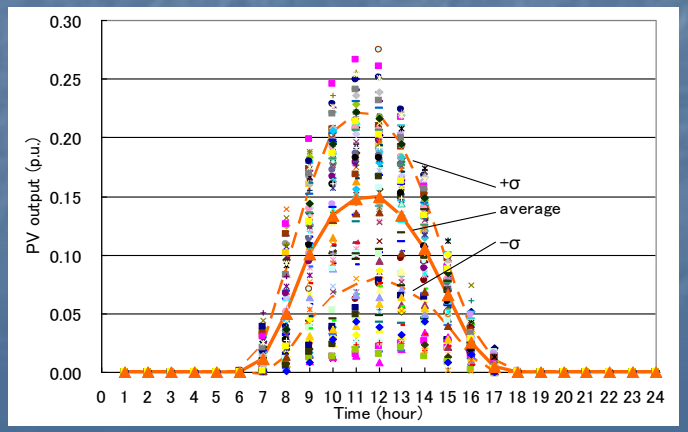
PV Penetration to Power System
Duration Curb (One month)



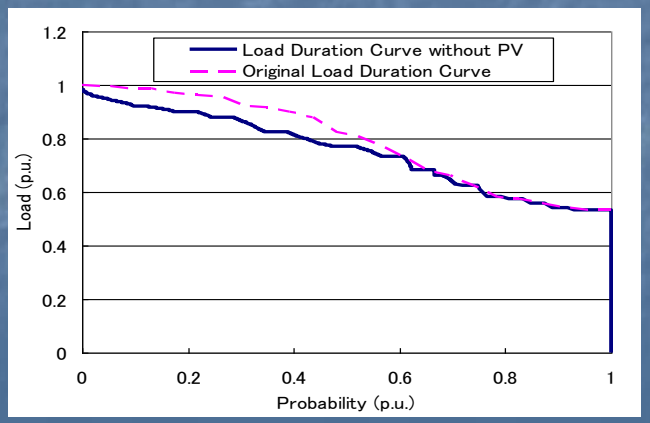
1) 24 hour load data



3) Duration curb including PV intermittency



2) Intermittency of PV output

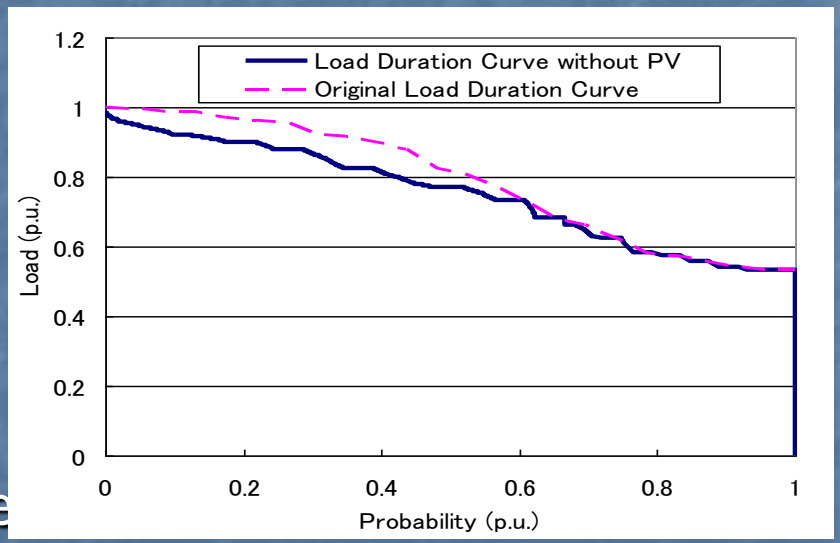


4) Comparison of before and after

How the intermittency affect the system?

Under the Japan's insolate condition and assumed PV deployment level (several % of generation):

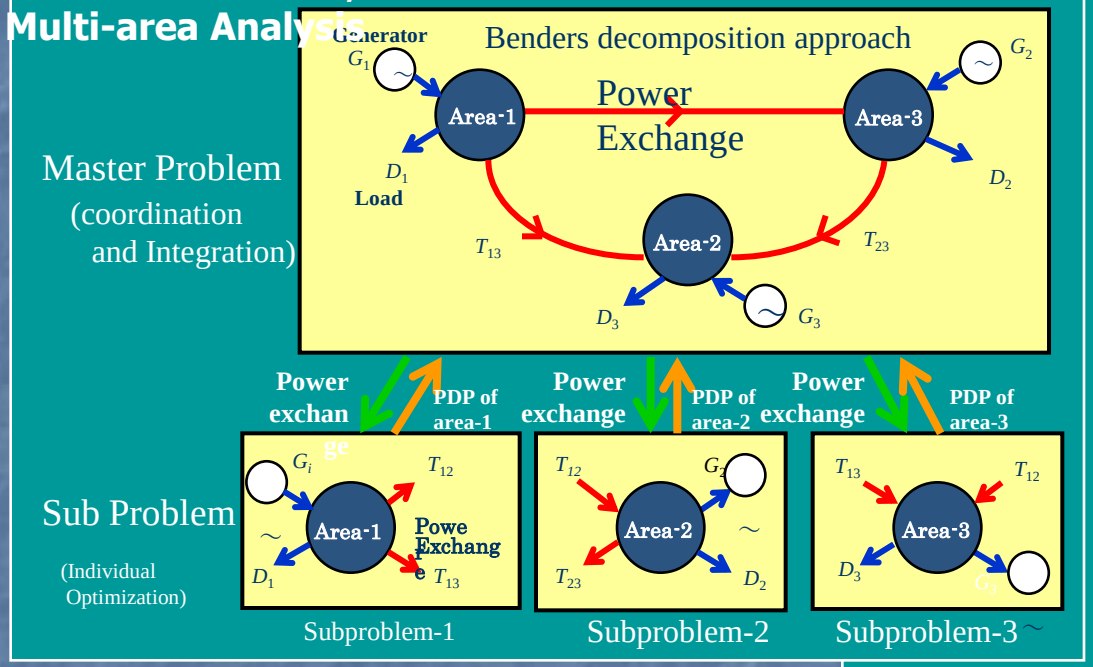
- Equivalent peak load can be slightly reduced.
- Mid-peak load is reduced to the utilization of the generation units of the area will be reduced and change the economy of the system.
- Deployment of energy storage might be a solution.
- Grand design should include the evaluation of distribution infrastructure change* with storage and total economy.



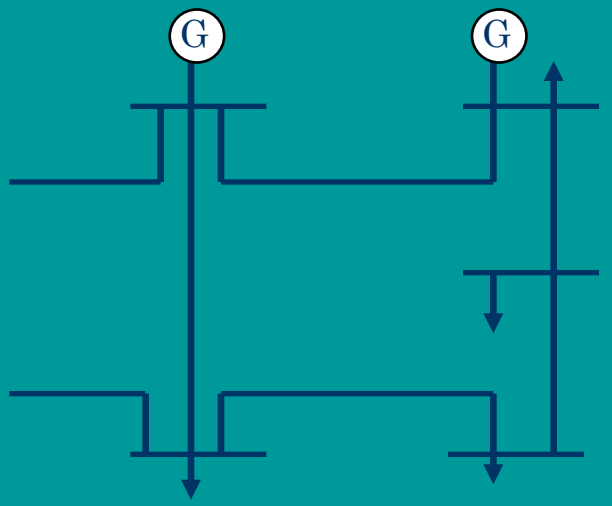
* Some concepts are proposed including "Kosuke Kurokawa, Further considerations on solar community concept consisting of massive roof-top PVs and domestic loads, 22nd EU PVSEC, 2007.

Clustered and Multi-layer Analysis

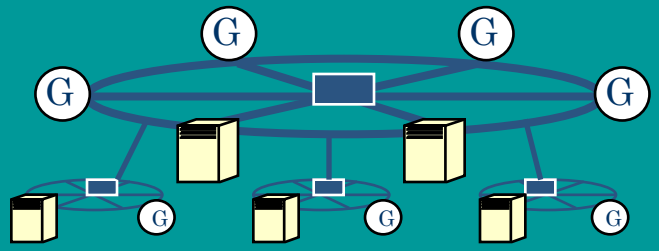
Central controlled, Multi-area Analysis



Central controlled, Composite Analysis



Decentralized control, Clustered, and Multi-layer Analysis



On-going Analysis

Targeting the completion in several months, the following analysis are under way:

- In order to find the realizable solution for 2020 and 2030, Japan's power system demand supply balance is being analyzed by both of the time-series and duration-curb method, under several generation expansion and demand scenarios, including heavy introduction of PHEV/EV, HP, PV, Wind, biomass generation and so on.

- In order to quantify the possible PV penetration level and its contribution for CO_2 reduction, multi-point insolation data processing and Japan's power system demand supply balance is being analyzed with the parameter of the capacity of energy storage.

NEXT STEPS

- Case study and grand design
  - A house with PV, HP, battery, load control and HEMS
  - A power system with new technologies (PV, wind, HP, PHEV/EF, coal gasification generation, energy storage, CCS) and nuclear increase.
  - Clustered and multi-layer power system control
  - Community energy integration utilizing regional resources
  - Case studies of other countries
- Indicators for robust and sustainable energy system
- Energy technology strategy
  - R&D strategy
  - Dissemination Strategy
  - Institutional consideration

Thank you!

エネルギーシステム　インテグレーション

エネルギー技術戦略マップ

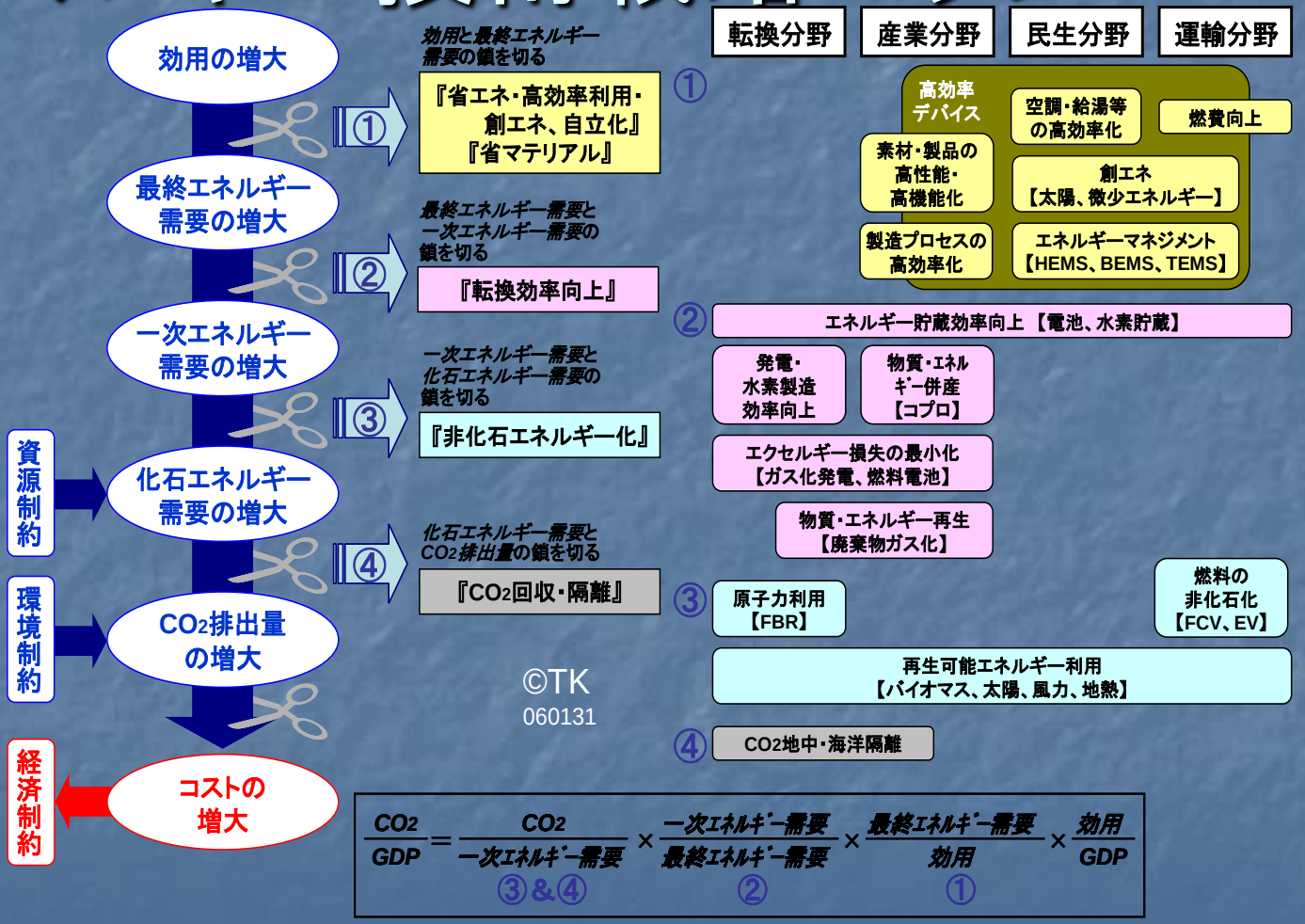
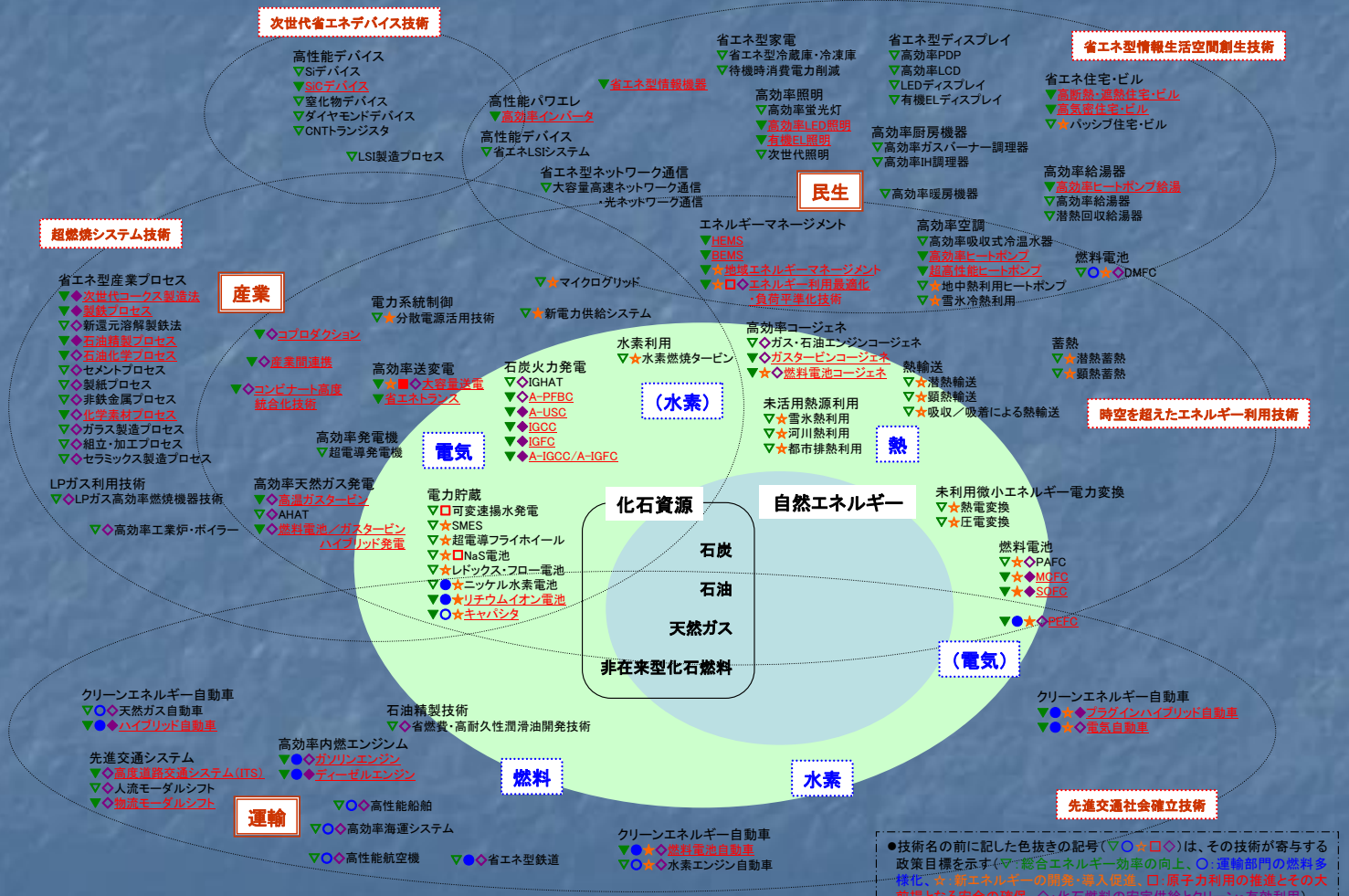


図３　資源制約・環境制約克服のための連鎖脱却と分野ごとの技術の全体像

出典:エネルギー総工研　H17　資源エネルギー庁委託調査 エネルギー技術戦略マップ

エネルギーシステム　インテグレーション

総合エネルギー効率の向上に寄与する技術マップ



●技術名の前に記した色抜きの記号（▽○☆□◇）は、その技術が寄与する政策目標を示す（▽：総合エネルギー効率の向上、○：運輸部門の燃料多様化、☆：新エネルギーの開発・導入促進、□：原子力利用の推進とその大前提となる安全の確保、◇：化石燃料の安定供給とクリーン・有効利用）。

●特に政策目標への寄与が大きいと思われる技術については、その寄与が大きい政策目標を、色塗りの記号（▼●★■◆）で示した。

●「総合エネルギー効率の向上」への寄与が大きいと思われる技術名を、赤字・下線付きで記載した。

①「総合エネルギー効率の向上」に寄与する技術の技術マップ（整理図）

出典：エネルギー技術戦略マップ2007(エネ総工研　H18　資源エネルギー庁委託調査)

メタボリズム最適化に向けて

- 環境/資源制約のもとでのエネルギー・産業戦略、技術開発戦略策定と、発信
  ↑ ↓
- 家庭、ビル、産業、地方、国、地域など多様なケースの資源、需要形態に関するインテグレーションの研究と、発信
  ↑ ↓
- 実現に向けた要素技術の研究・開発の加速

メタボリズム最適化に向けて

- 長期的かつ分野横断、垂直統合などの多様な視点が必要

  ⇒人材育成や産(事業実施箇所)、官(政策策定箇所)、学が連携した取り組みが重要

- 技術、資金、適用など日本の中で完結しない場合が多い

  ⇒ 様々な段階、形態での国際的連携が重要

Energy Management

●BEMS（Building Energy Management System）

●HEMS（Home Energy Management System）

・通信ハードウェア技術・Sensor network　・Energy storage (elec. and hear)連携
・ミドルウェア技術　・Renewable energy coordination
・Load analysis/forecast
・Distributed generator
・DC power distribution
・生活行動予測技術による省エネ協調制御

●地域レベルのEMS（Energy Management System）

飛躍的な省エネ

HEMS/TEMS技術

・HEMS/BEMSおよび地域熱電供給などとの有機的連携技術
・自律分散型の地域エネルギー需給・系統との協調
・Local area EMS
・Community level EMS
・Cluster level EMS

Related Technology

◆PV, House/Building, Lighting, IT appliances, Battery, Power electronics, and others