The particularity of the power network incorporating with the aggregation of distributed PV systems

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The particularity of the power network incorporating with the aggregation of distributed PV systems

Part 1:

General Considerations – Particularity of PV

Part 2:

Aggregation of a large number of PV systems

Part 3:

Bulk Systems – LSPV to VLSPV

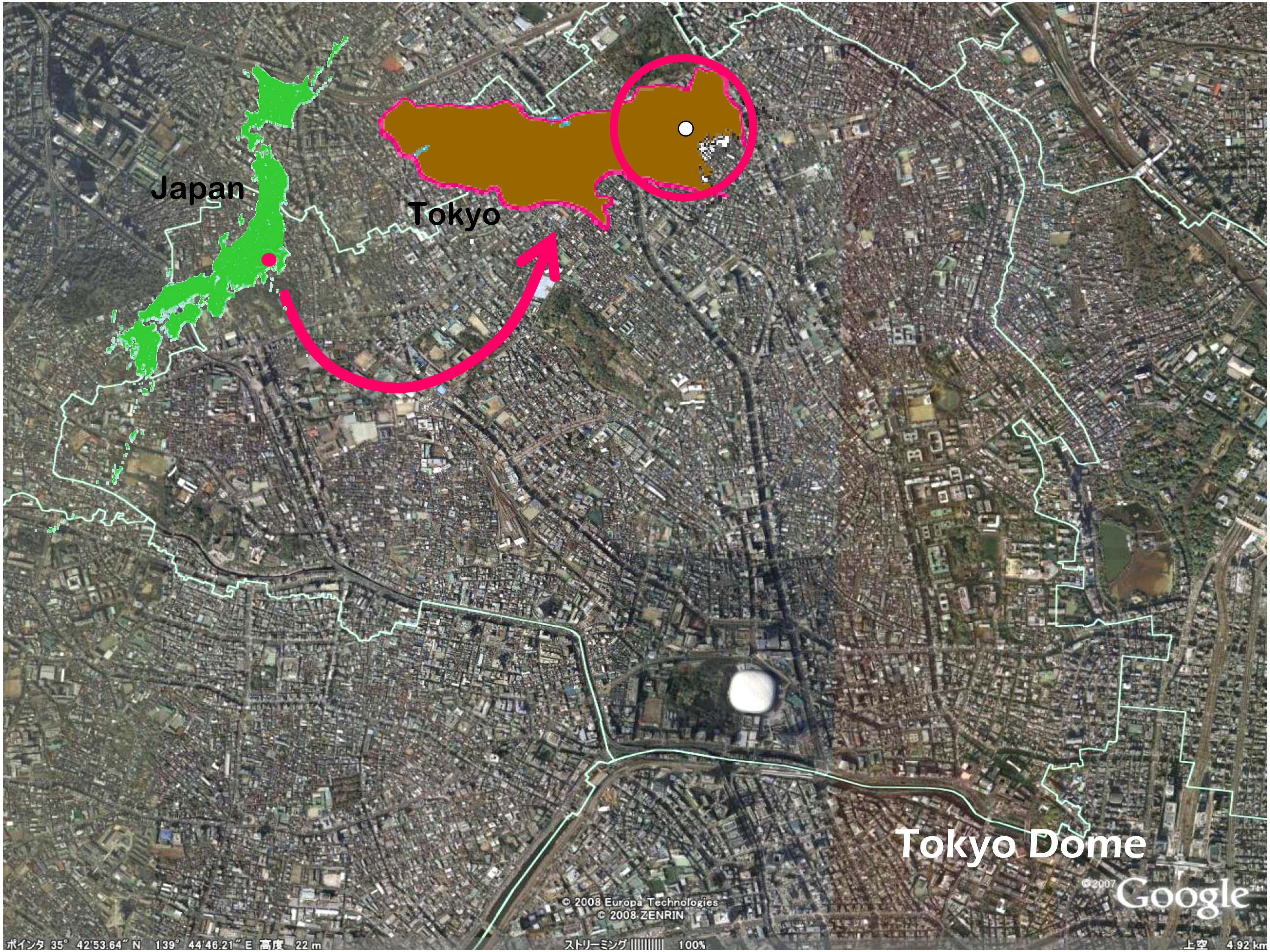
Particularity in Solar PV Power Generation

Broader Area ↓

Longer Term ↓

1. Irregularity:
   - Random fluctuation for seconds, minutes to hours by cloud movement
     can be equalized over a broader area
2. Regularity:
   - Daily change by earth rotation: day and night
     can be equalized by east-west inter-tie
   - Seasonal change by orbital motion
     can be equalized by north-south intertie
   - Limited capacity factor < $2800/8760 \times 100$ %
     $\approx$30 % terrestrially max
3. Universality:
   - almost Everywhere Accessible: peaceful energy
   - terrestrial max: 2800 kWh/m^2 in Sahara
   - however, rather evenly distributed: e.g., 1400 kWh/m^2 in Japan; 1200 kWh/m^2 in Central Europe

NEDO's City of Ota Project


Japan
Tokyo
Tokyo Dome
© 2008 Europa Technologies
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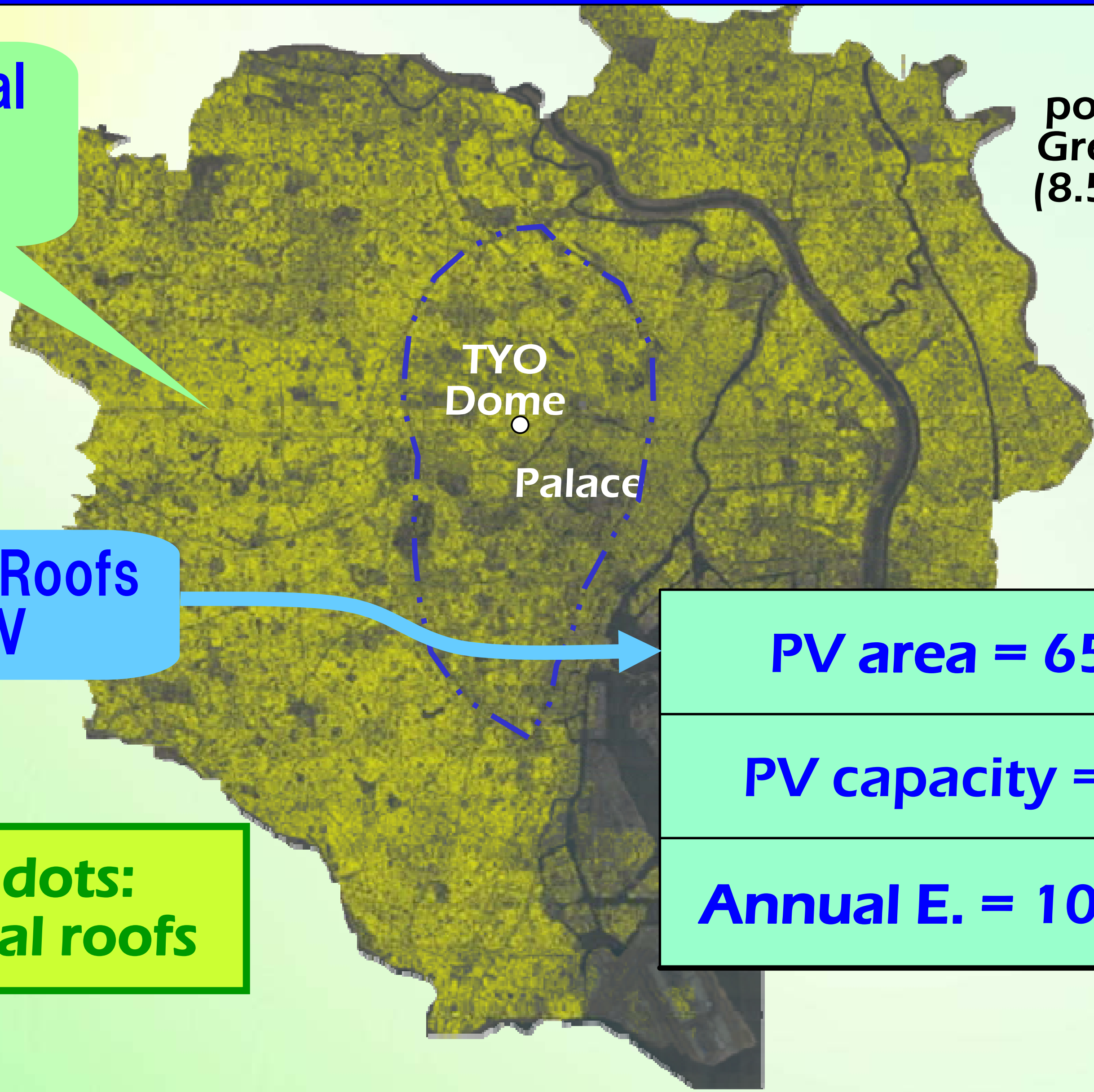
ポインタ 35° 42'53.64" N 139° 44'46.21" E 高度 22 m
ストリーミング 100%
上空 4.92 km

Residential PV Potential
Central Tokyo (23-Wards)



Residential Roofs ・ 20%

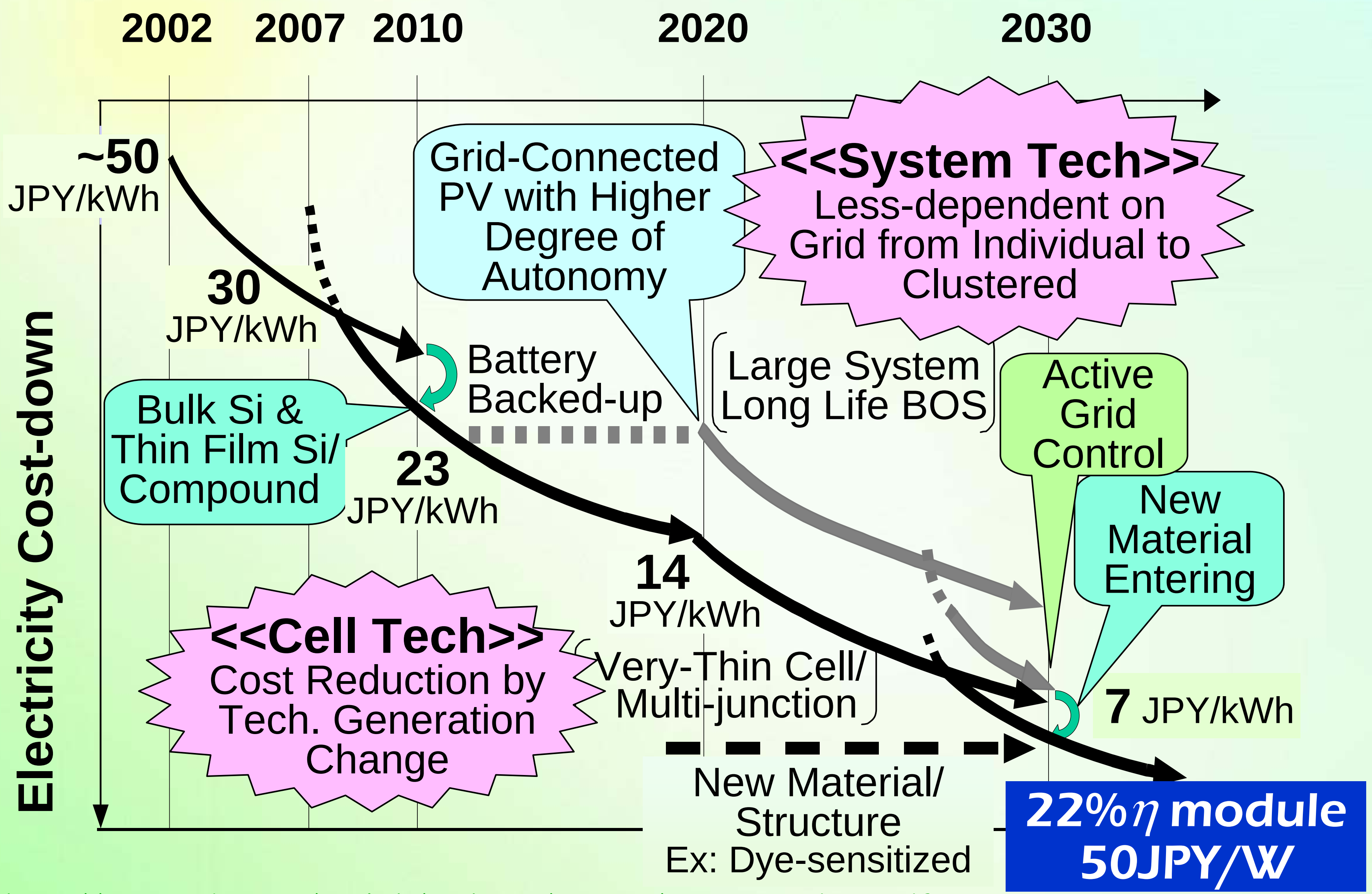
A Half of Roofs for PV

72% population in Greater Tokyo (8.5 / 11.8 Mln)

PV area = 65.0 km^2
PV capacity = 9.7 GW
Annual E. = 10.8 TWh/Y

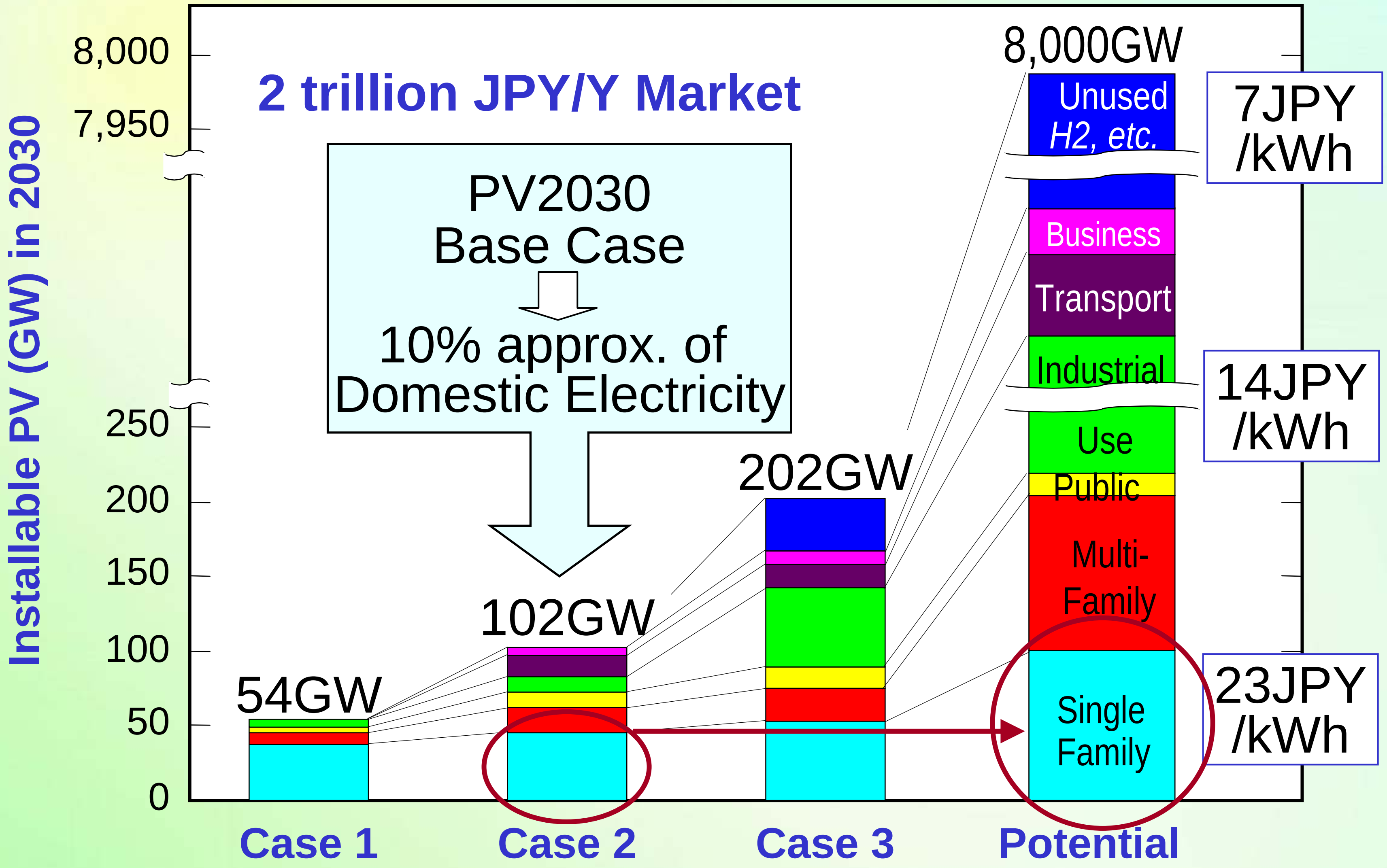
yellow dots: residential roofs

PV2030 Roadmap

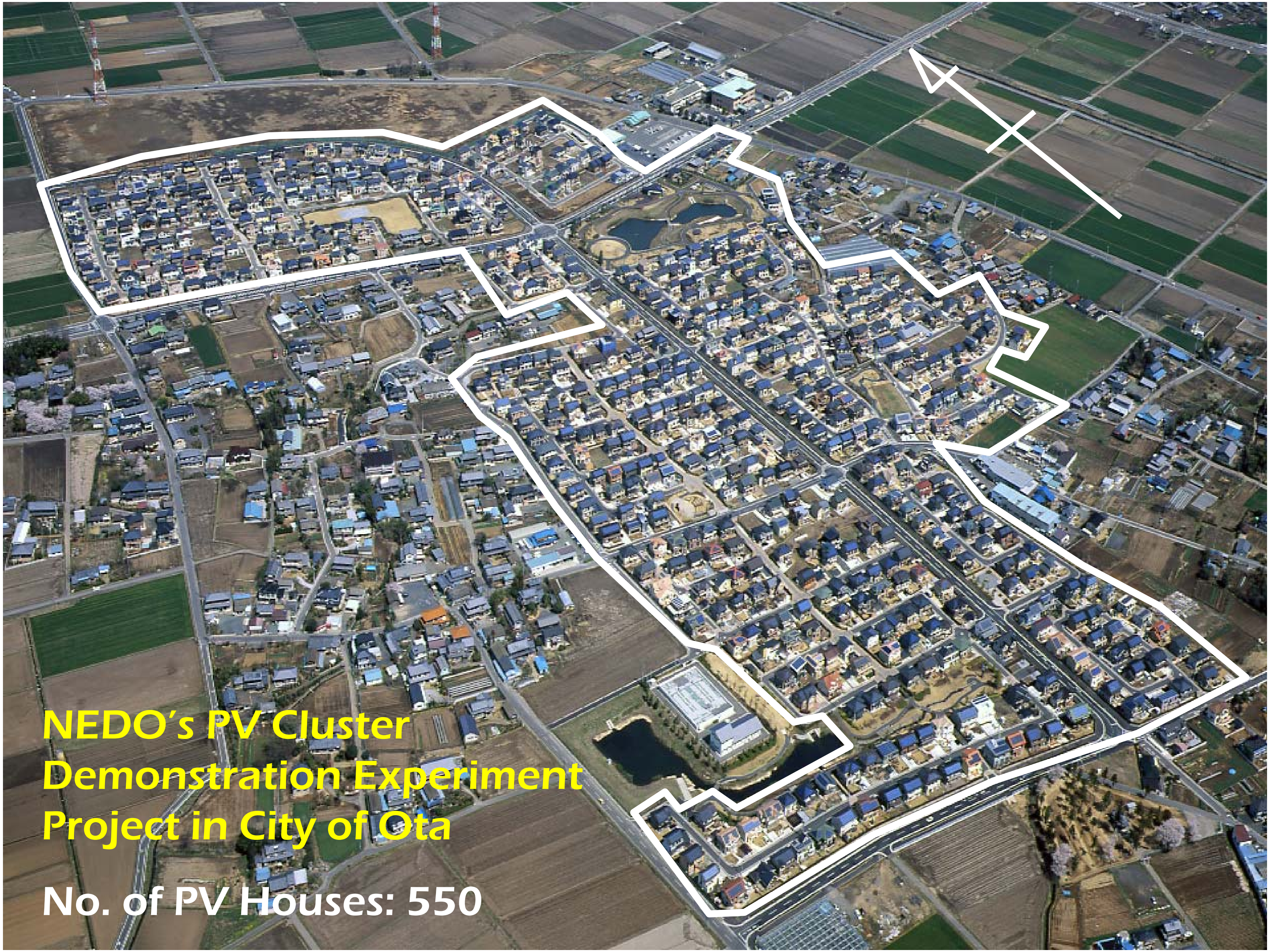


http://www.nedo.go.jp/english/archives/161027/pv2030roadmap.pdf

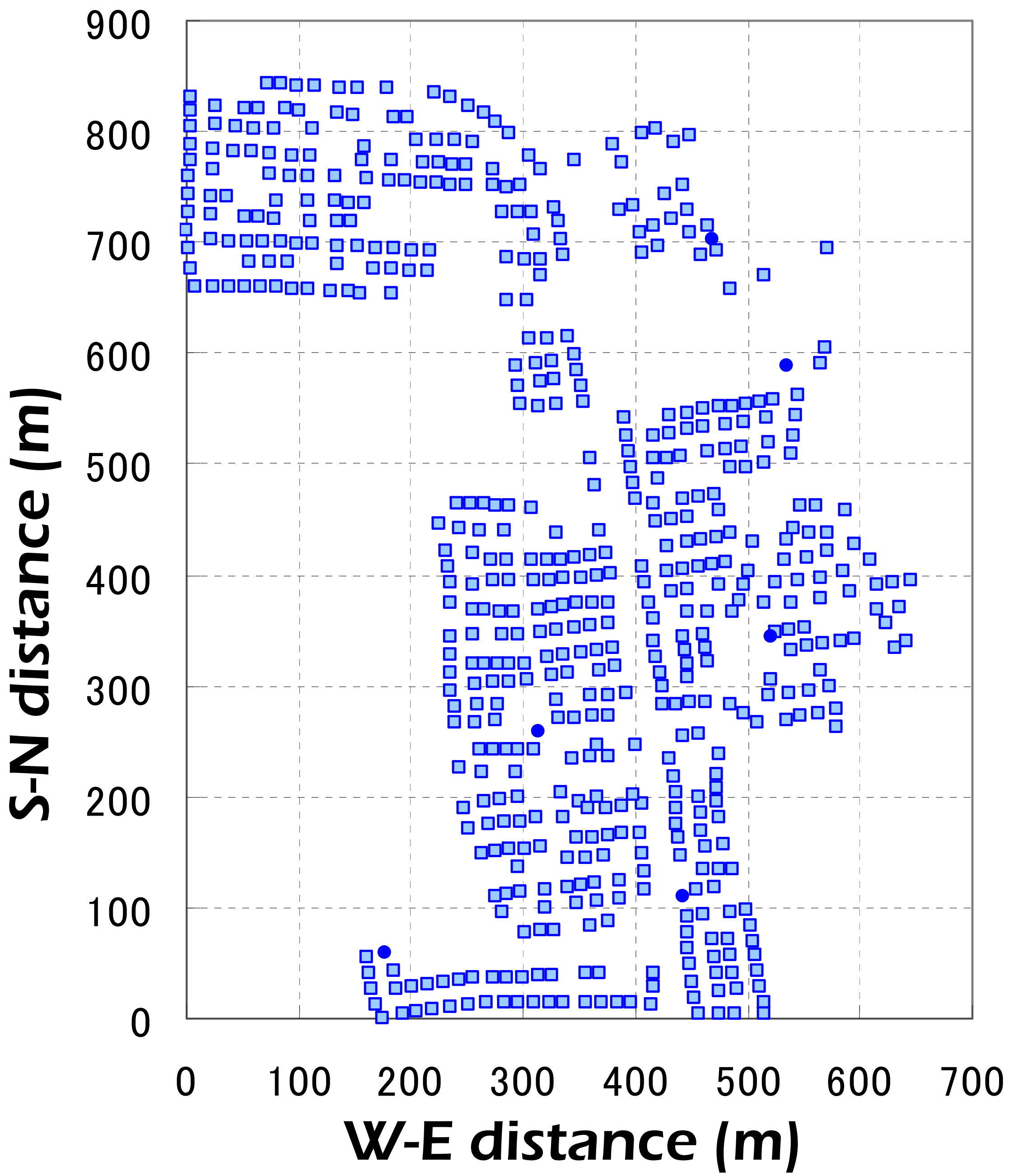
Installable PV (GW) up to 2030



Case 1: Business as usual
Case 2: R&D and Market Penetration according PV2030 Base Case
Case 3: Accelerated R&D and Market Penetration with large–scale industrial use
Potential: Physical Limit by residential, public, industrial, unused land, etc.

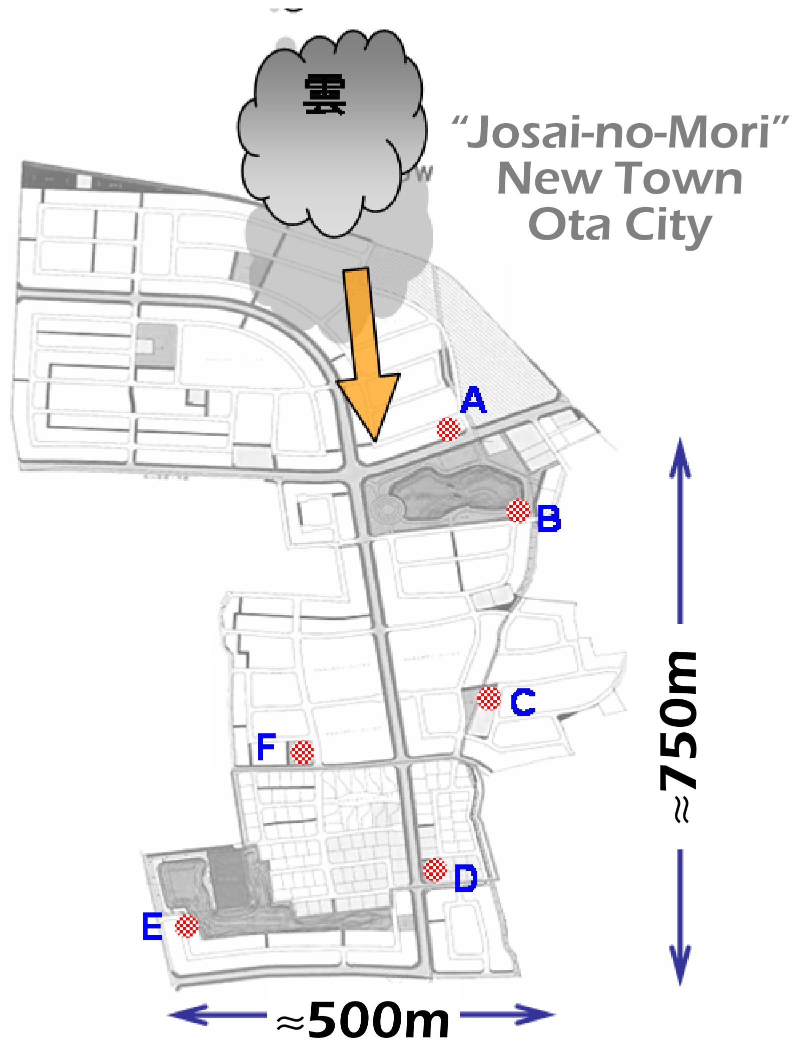

NEDO's PV Cluster
Demonstration Experiment
Project in City of Ota
No. of PV Houses: 550

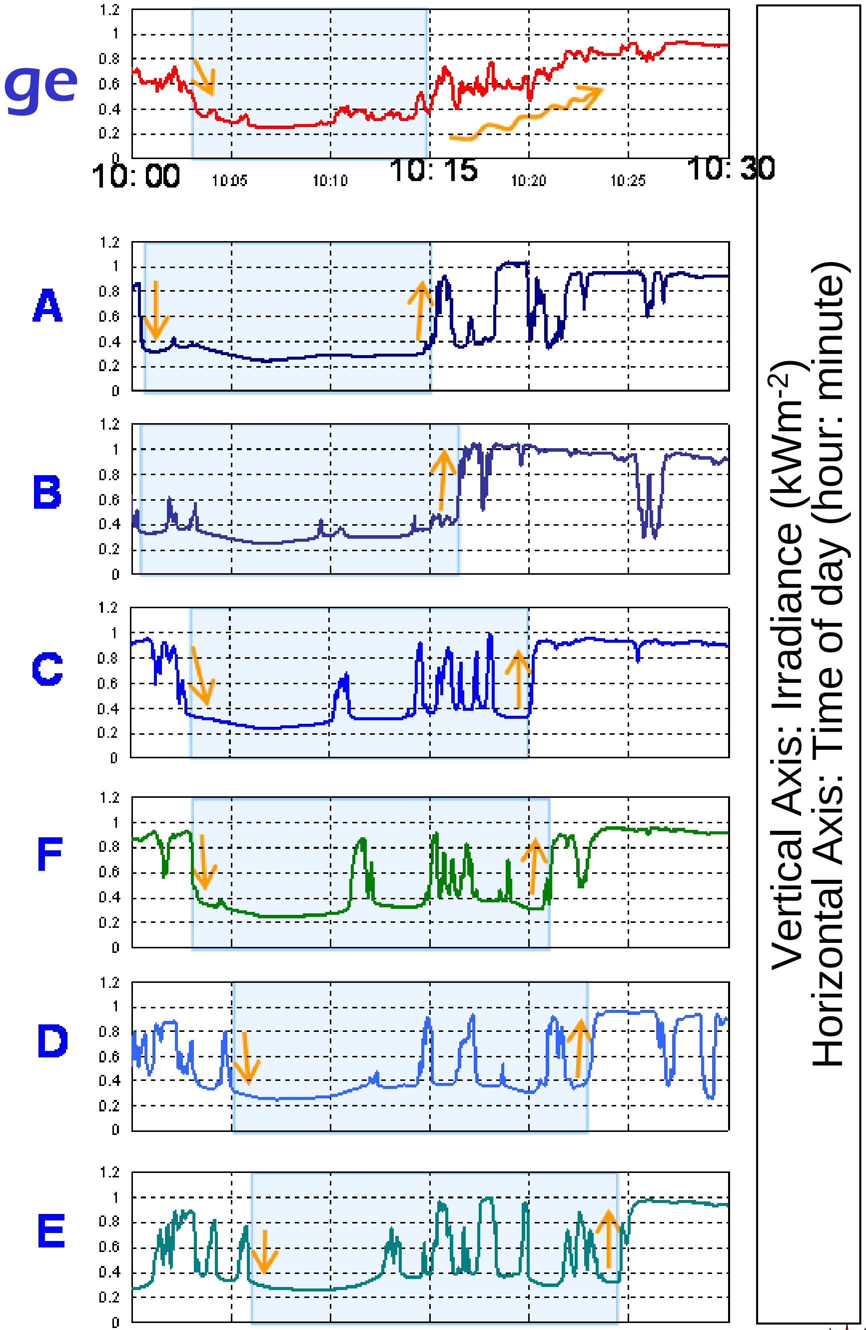
NEDO's PV Cluster Demonstration Experiment Project in City of Ota

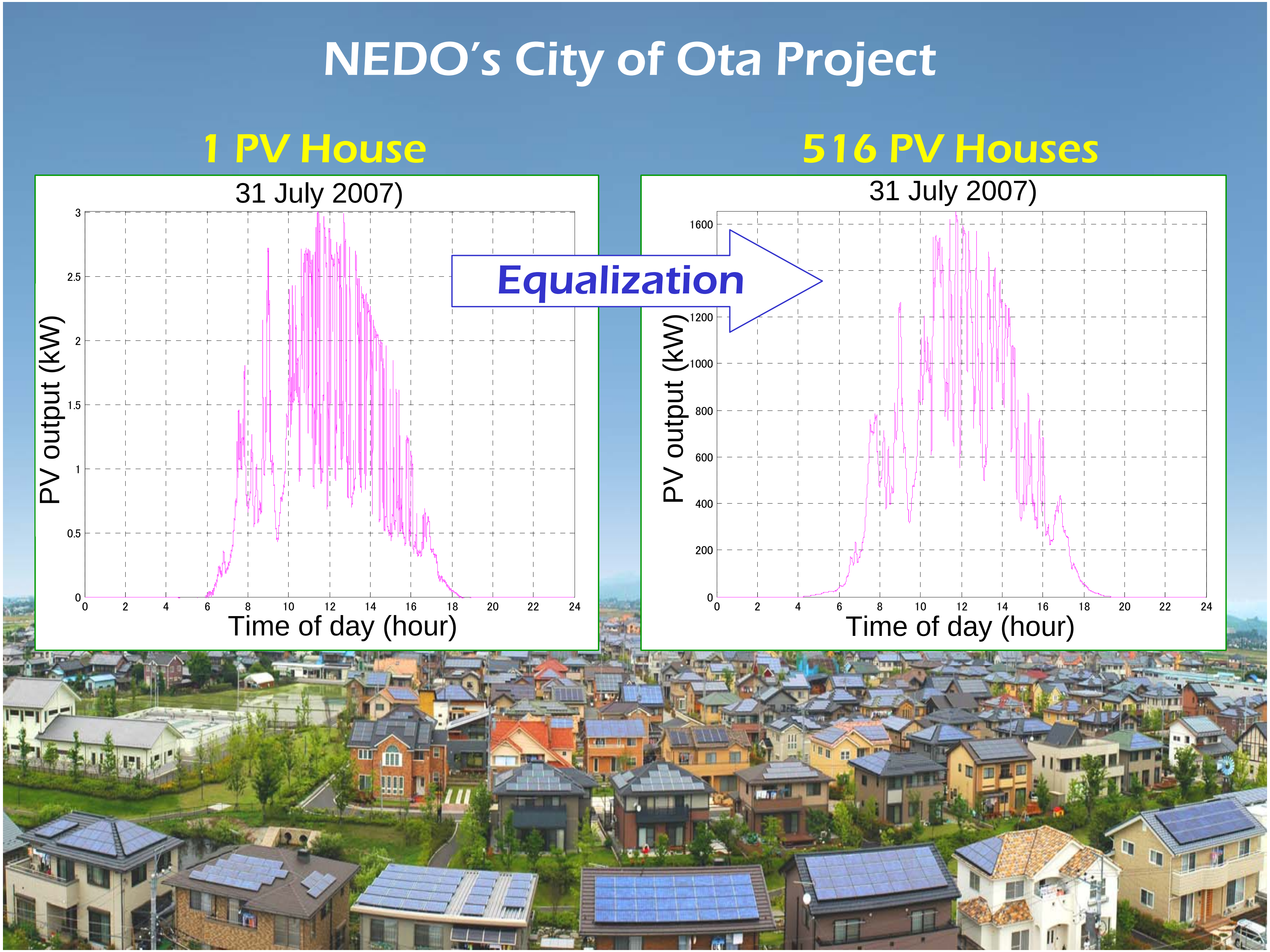


No. of PV Houses: 550

Example: Equalization over Area

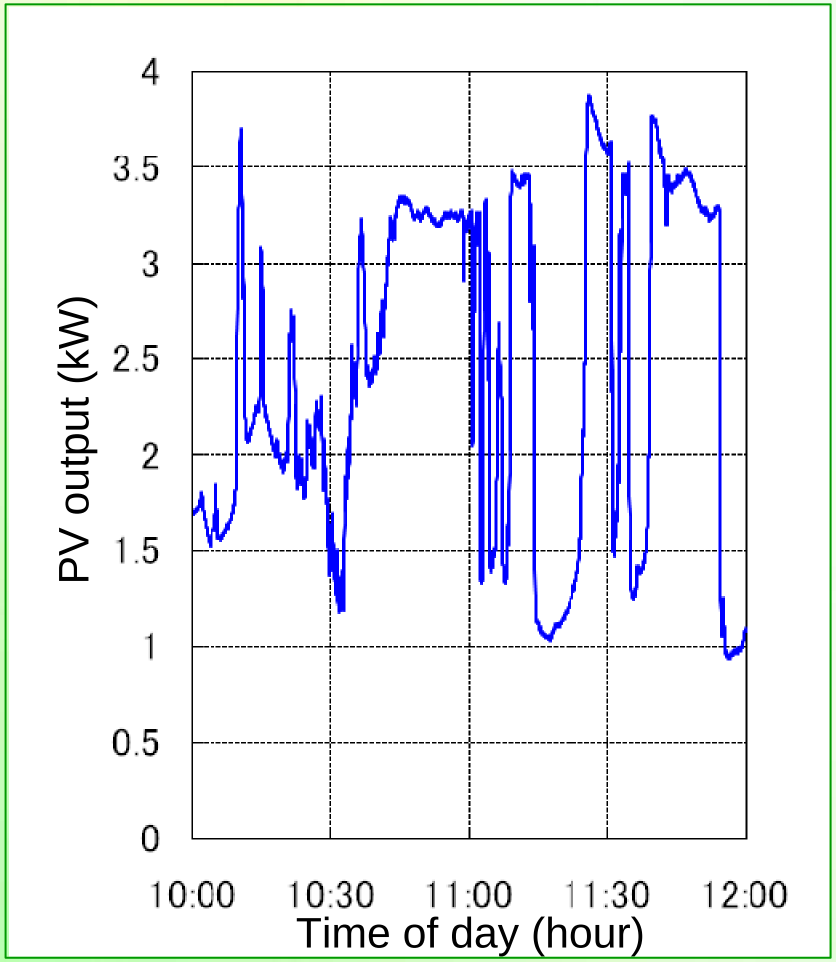




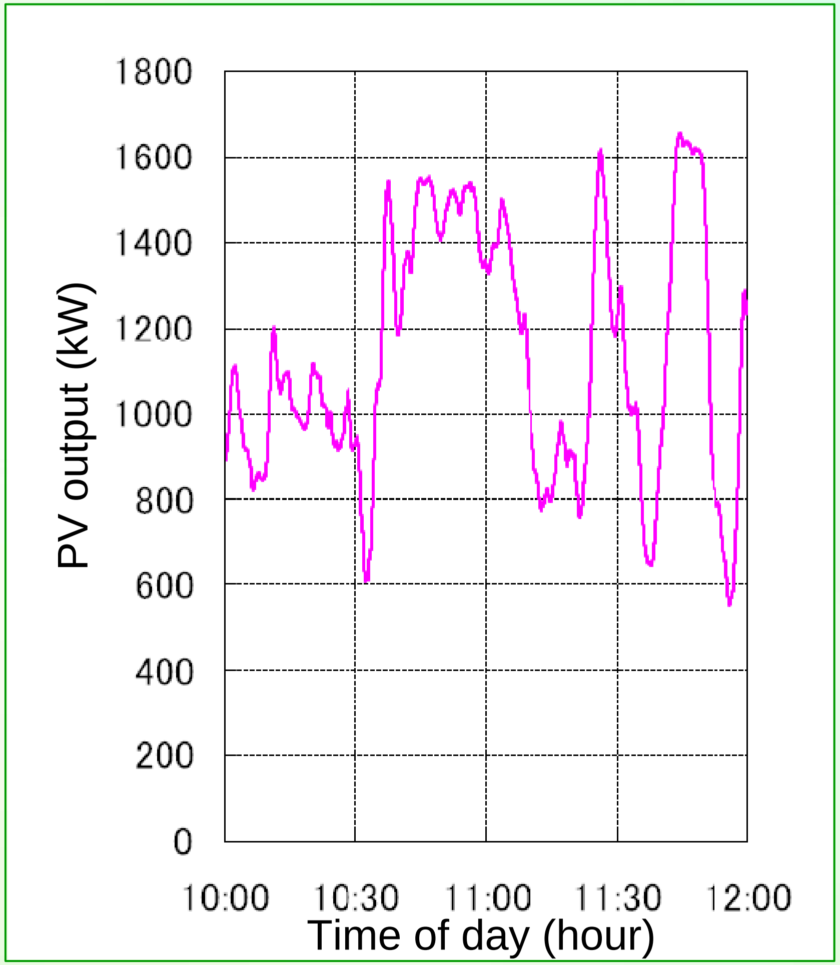

NEDO's City of Ota Project
1 PV House
516 PV Houses
31 July 2007)
PV output (kW)
Time of day (hour)
Equalization
31 July 2007)
PV output (kW)
Time of day (hour)

Equalization – An Example

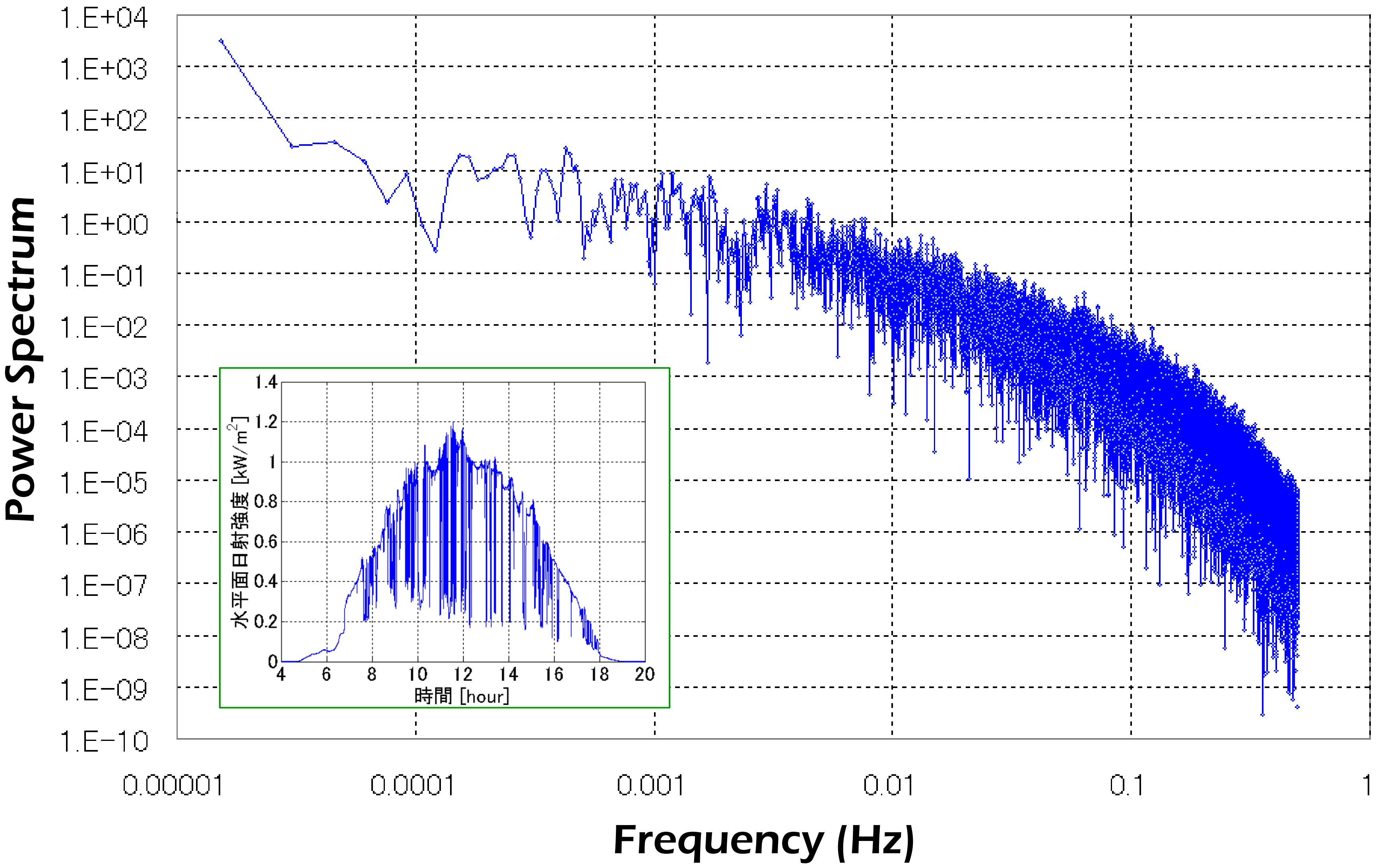
1 PV House



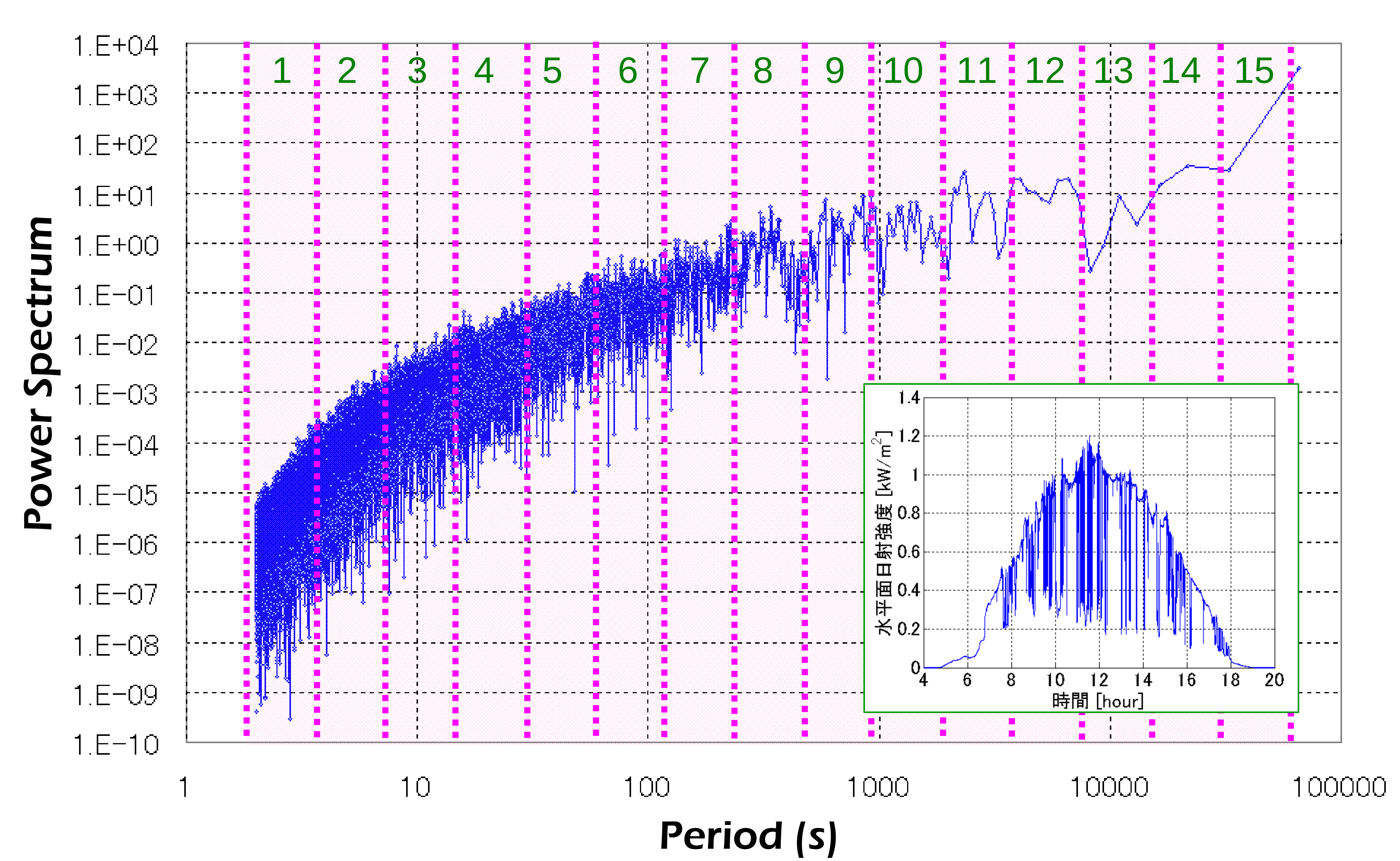
516 PV Houses



Fluctuation Energy by Frequency

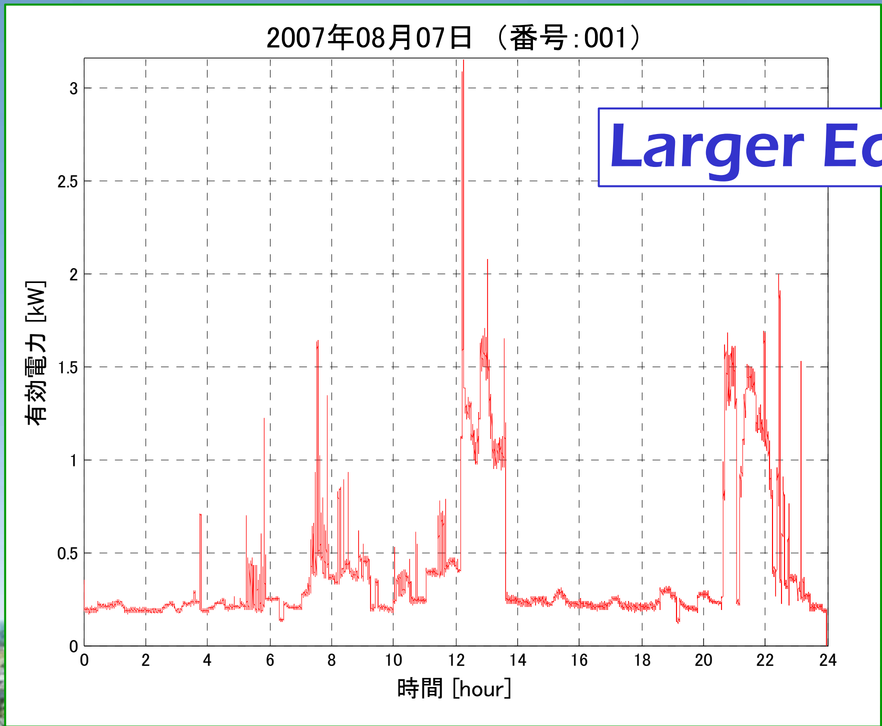


Fluctuation Energy by Time Period

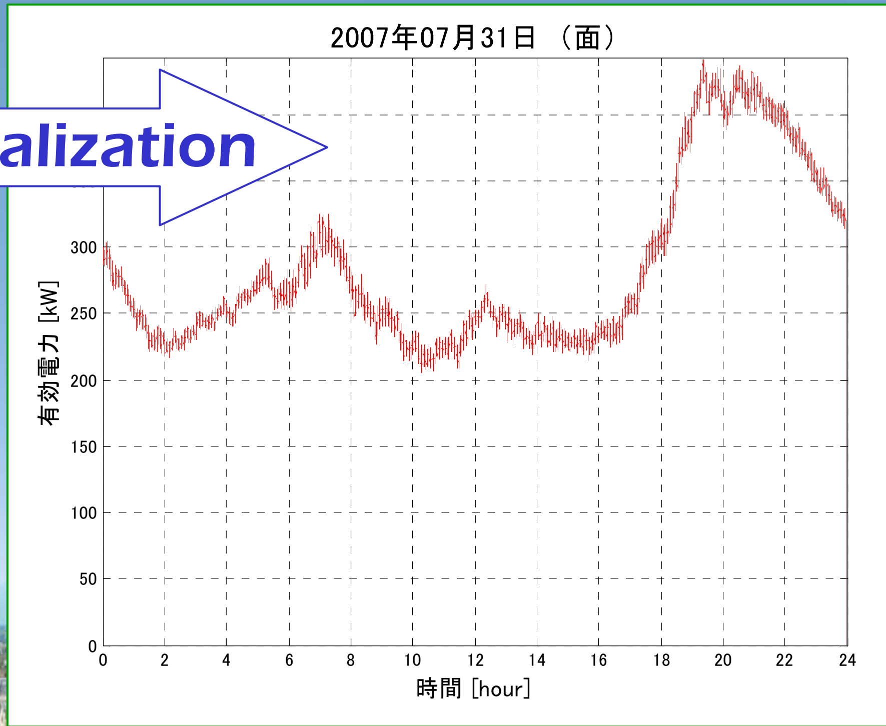


Residential Loads

1 PV House



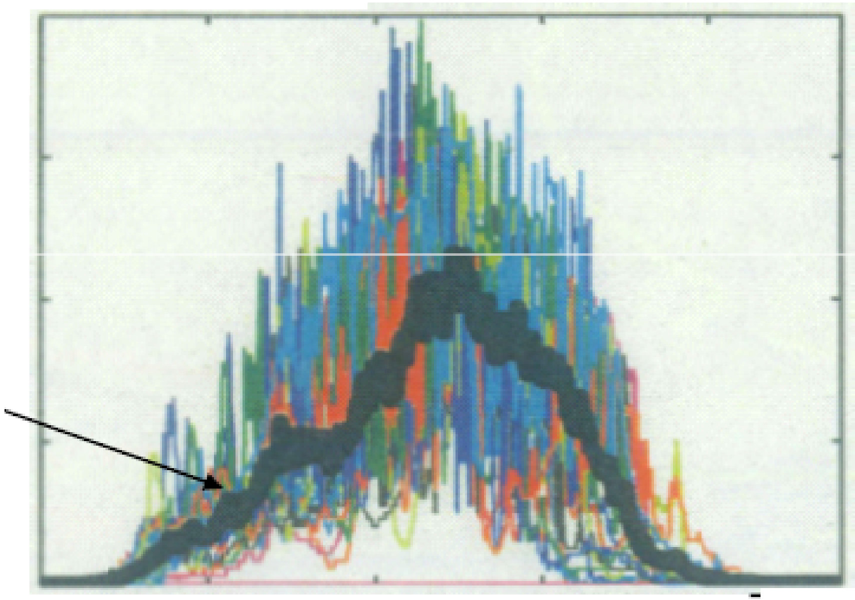
516 PV Houses



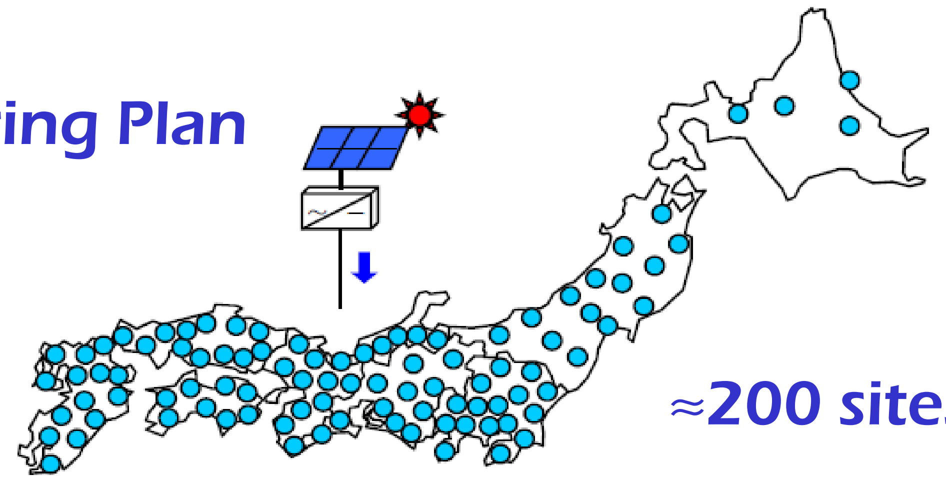
Larger Equalization

Expected Equaliztion for Broader Area

Expected Overall PV Output



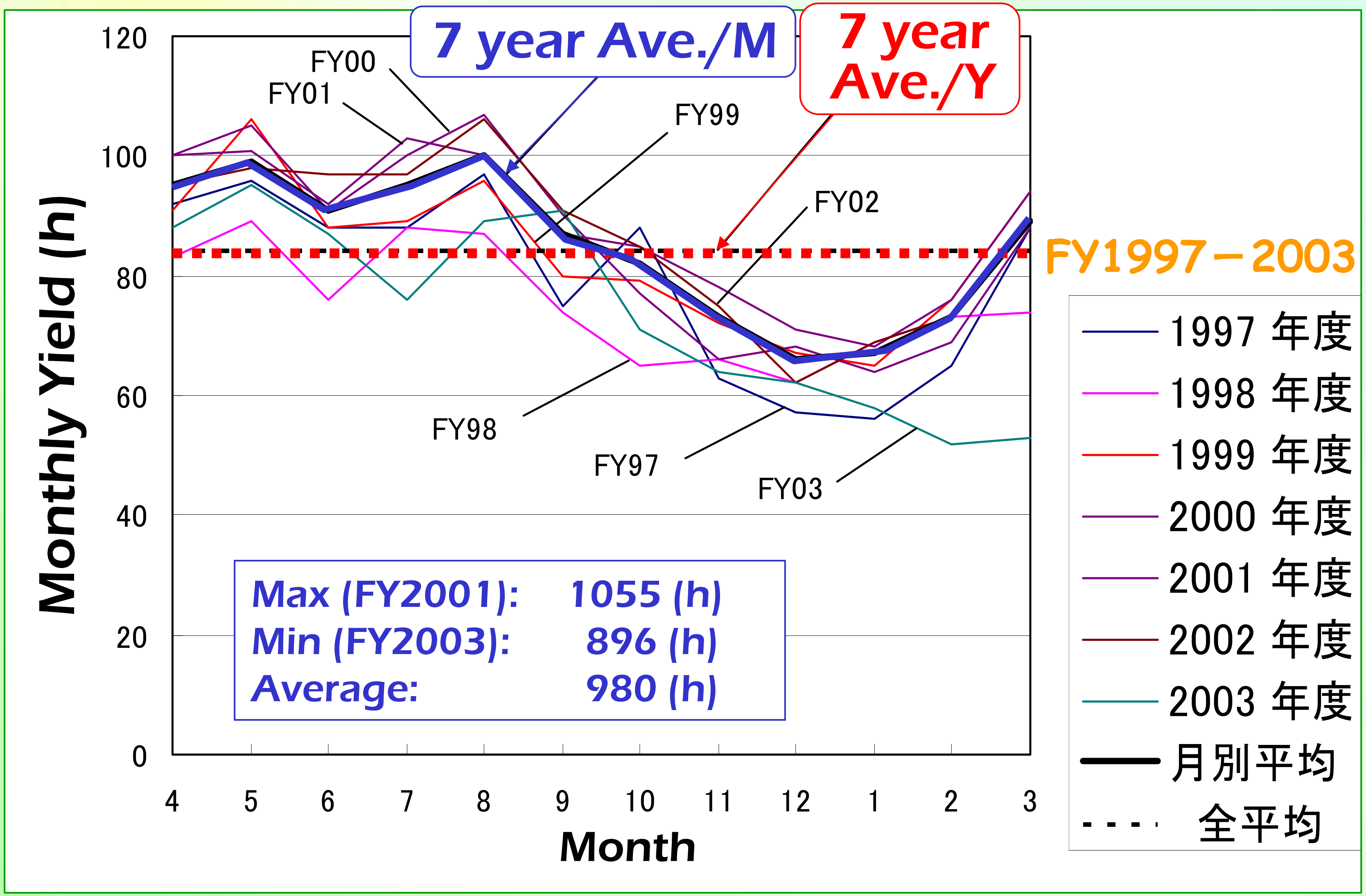
METI's Monitoring Plan



≈200 sites over Japan

Regularity - Residential PV Subsidy Program

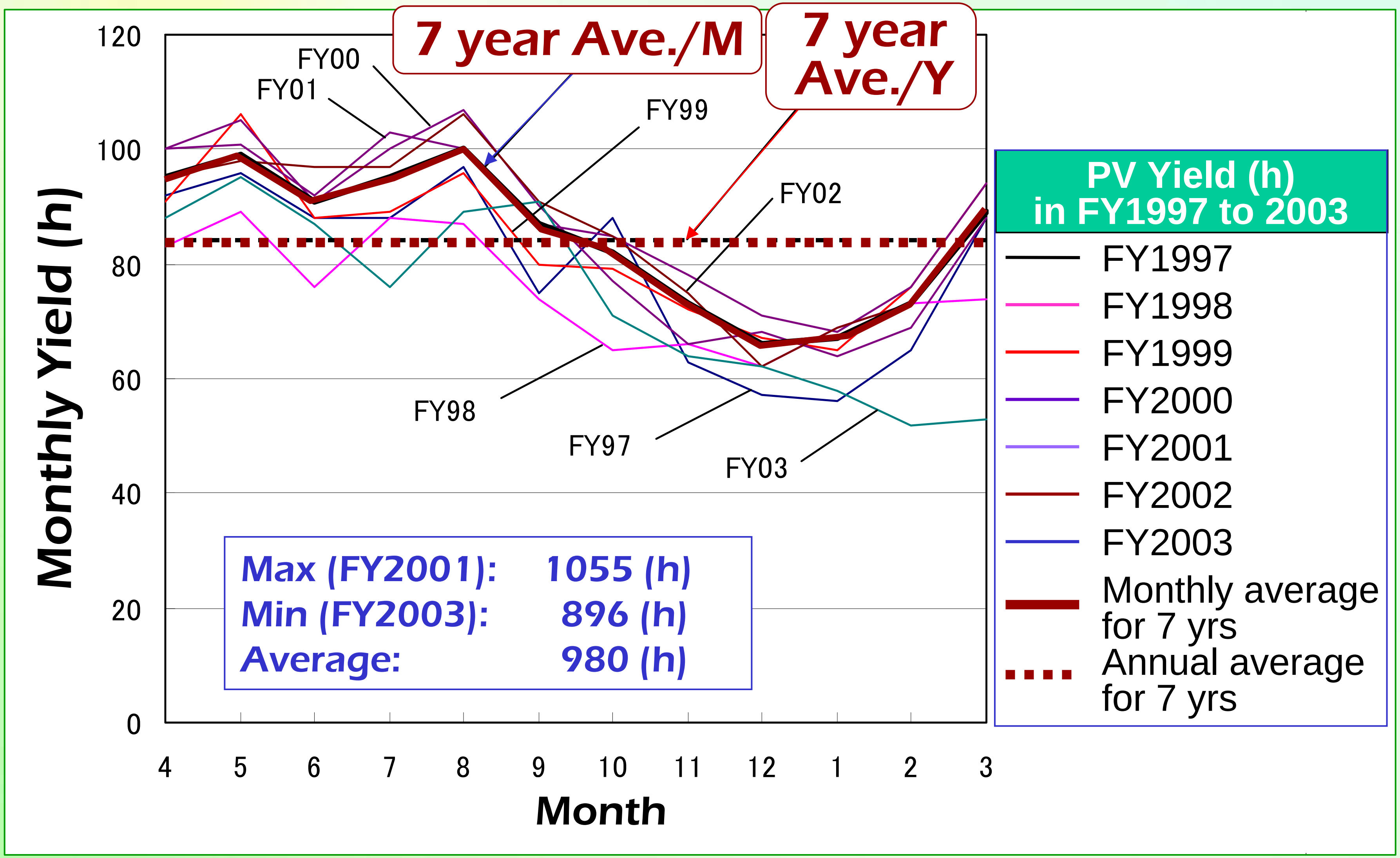
Average for All Reported Houses kWh/kW/Y



Source: New Energy Foundation

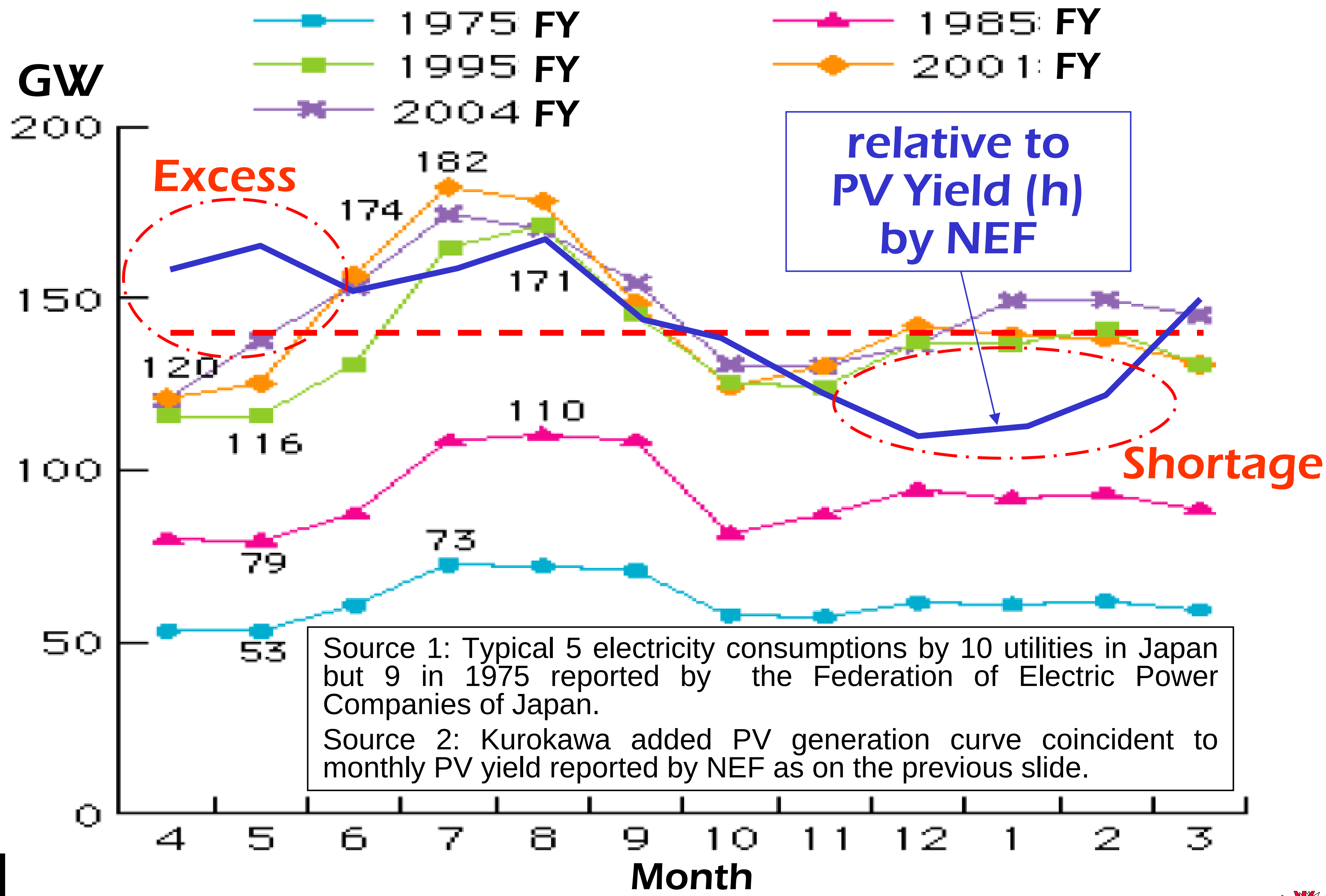
Seasonal Regularity - Residential PV Subsidy Program

Average Monthly Yield for All Reported Houses

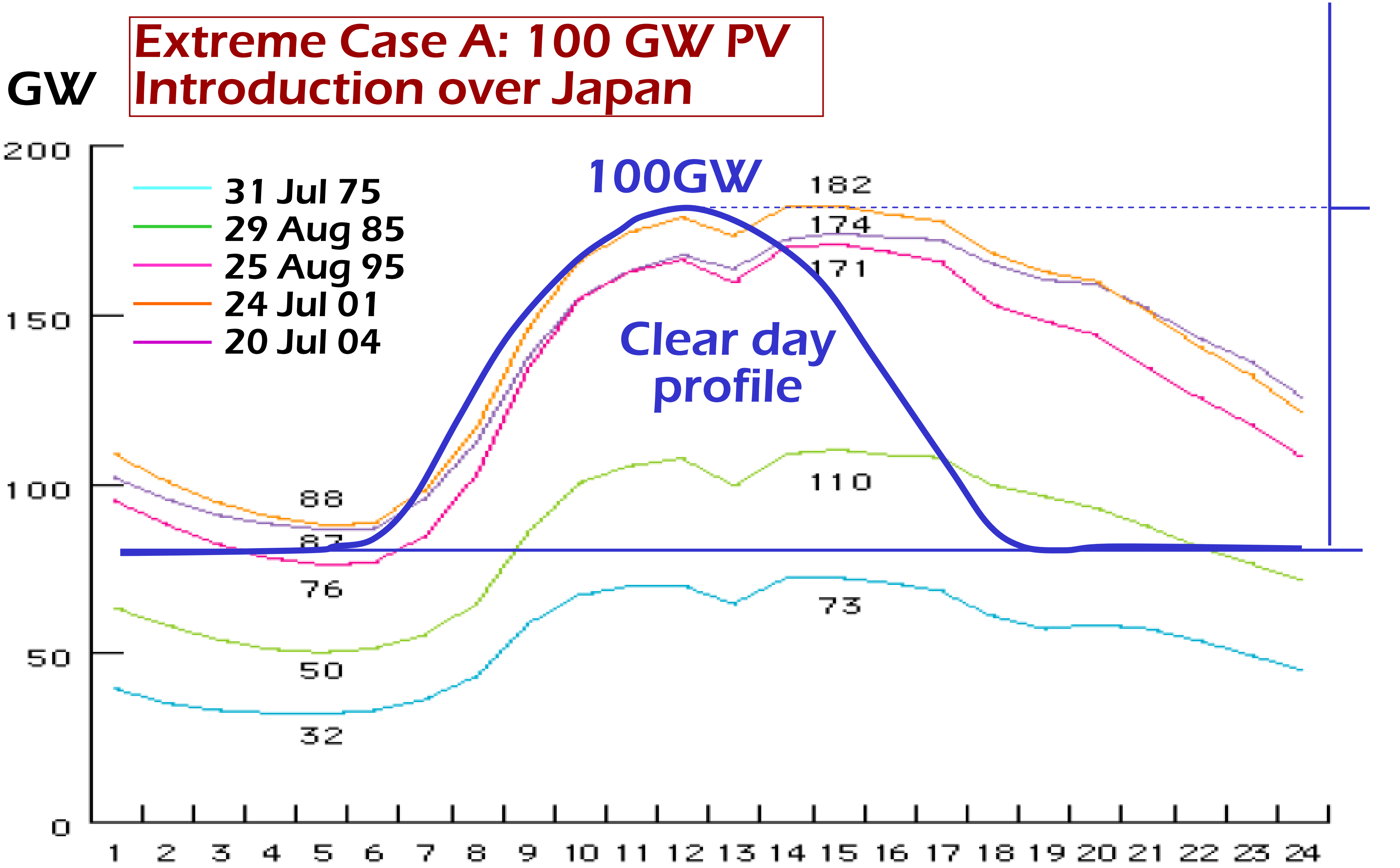


Source: New Energy Foundation

Seasonal Balance between PV and Electricity

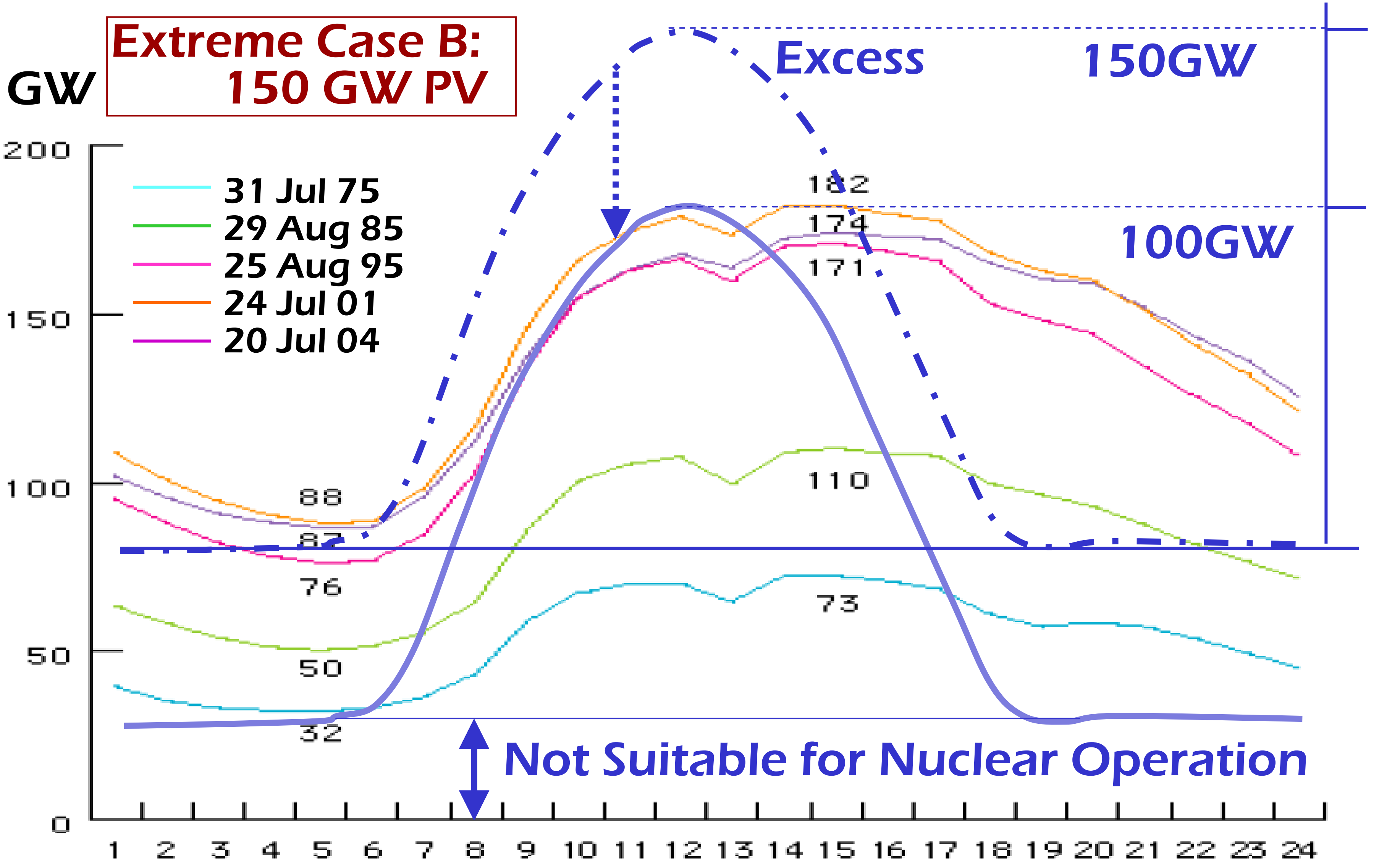


Daily Power Balance between PV and Electricity



10 Utilities in Japan but 9 in 1975
Source: The Federation of Electric Power Companies of Japan + Kurokawa

Daily Power Balance between PV and Electricity



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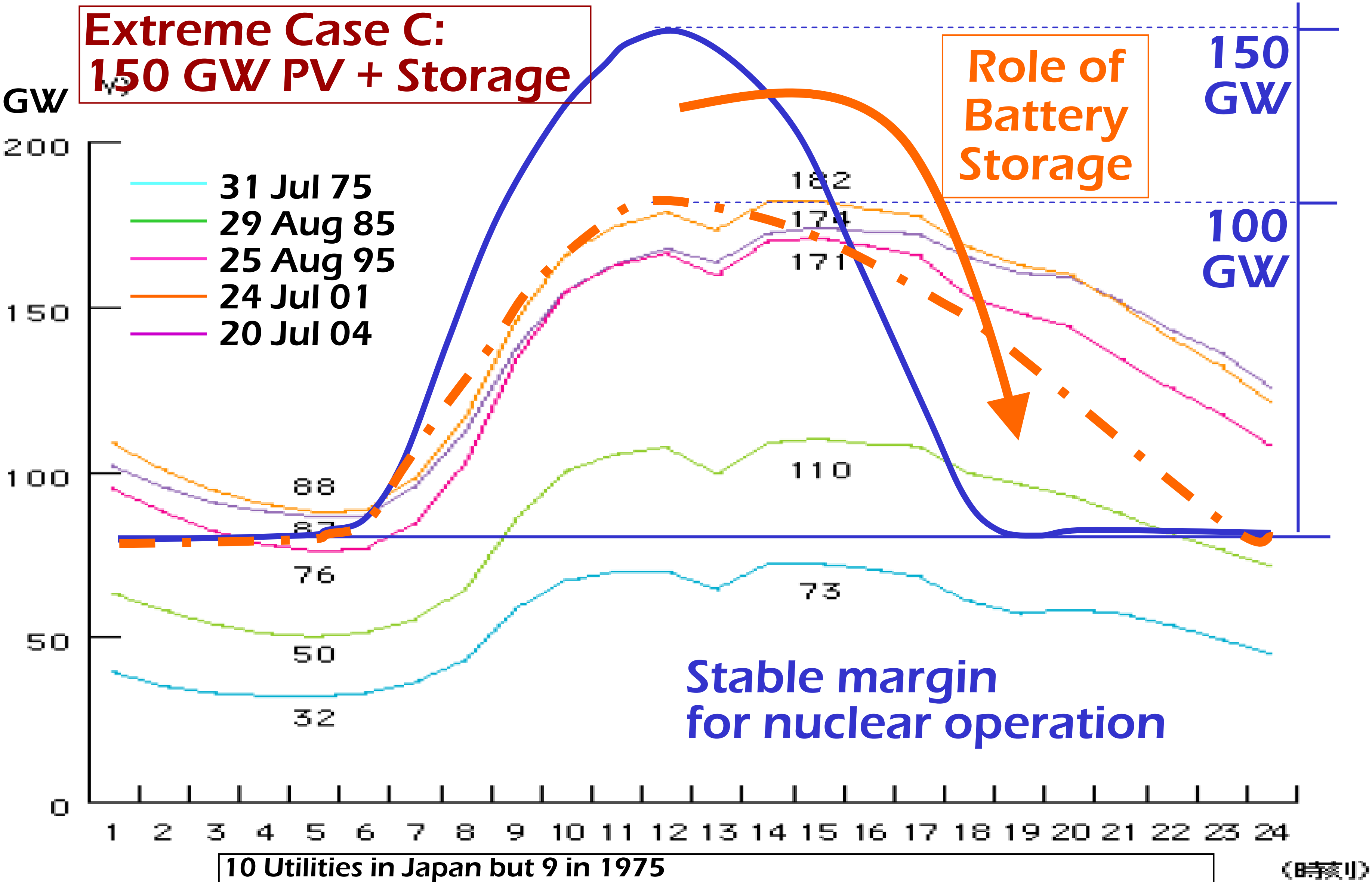
Daily Power Balance between PV and Electricity



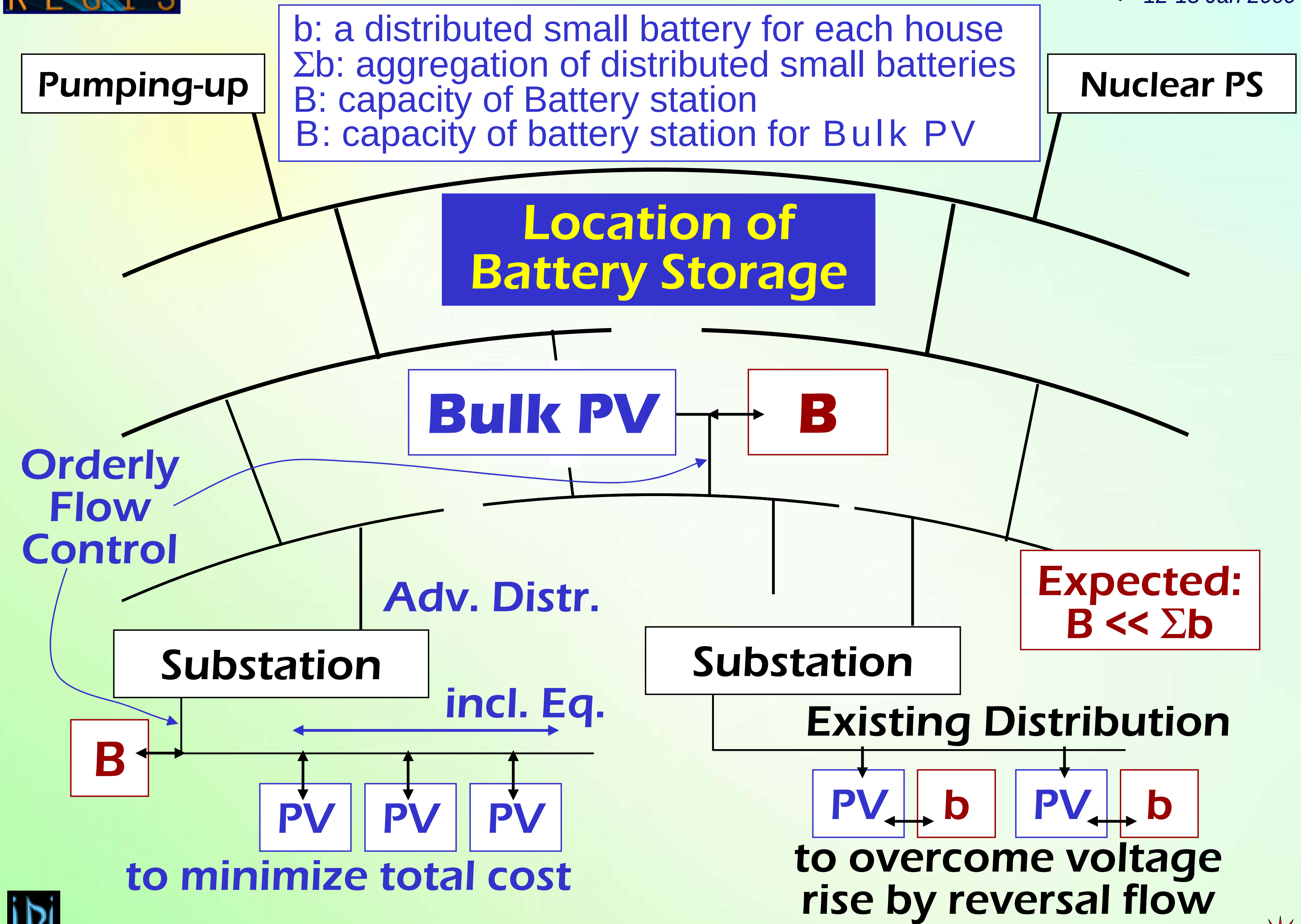
10 Utilities in Japan but 9 in 1975
Source: The Federation of Electric Power Companies of Japan + Kurokawa

Issues:

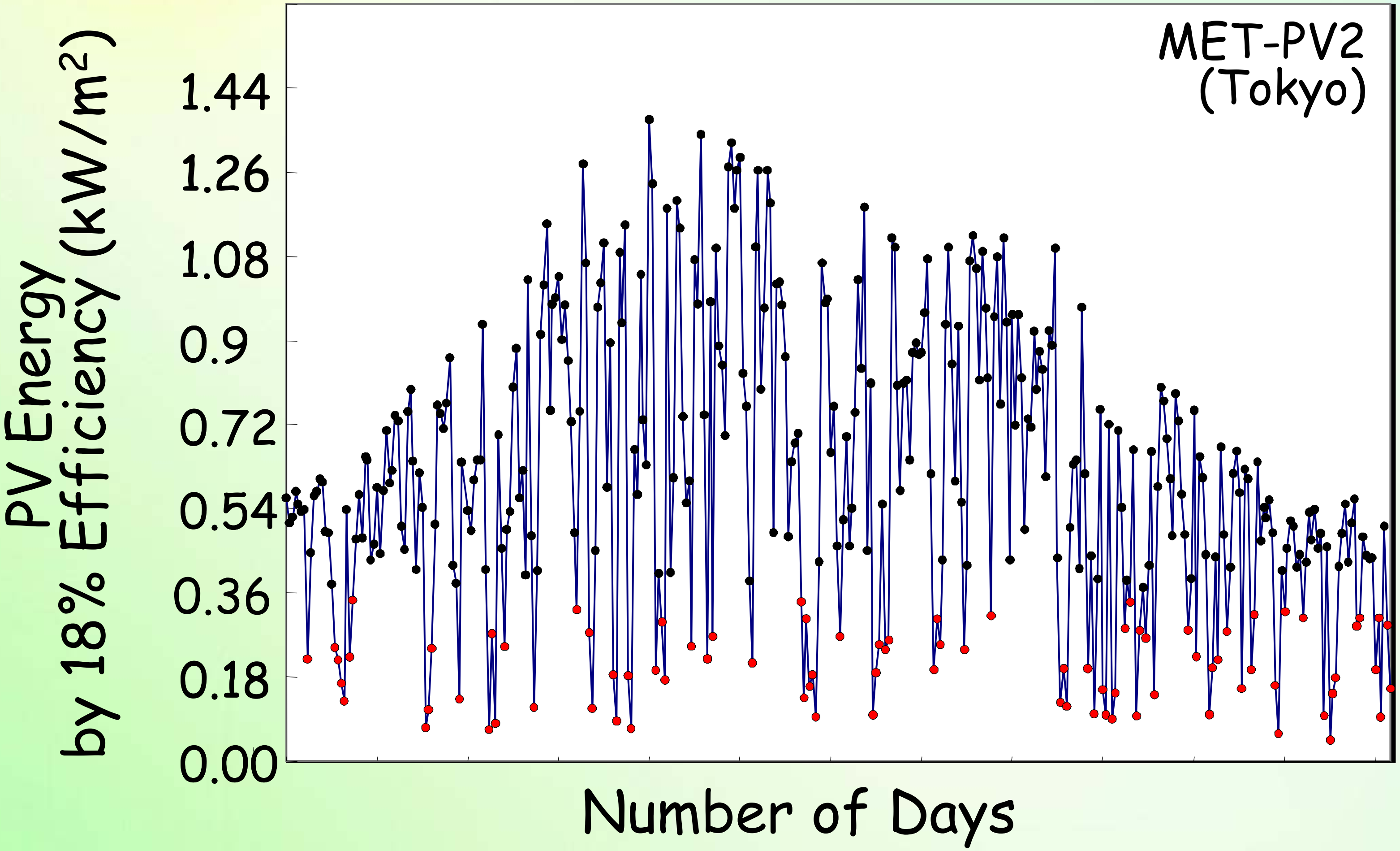
Massive, Bulky PV Penetration and its Integration to Power Systems

- In spite of large possibility for PVs in kWh, Solar Power Peak in kW tends to become much larger than gross electric power system peak .
- In case of Nuclear Power Station: utilizing Pumping-up Station for adjusting power balance.
- In case of the higher penetration of PV, some energy storage may be introduced. What Kind, Where and How Large?

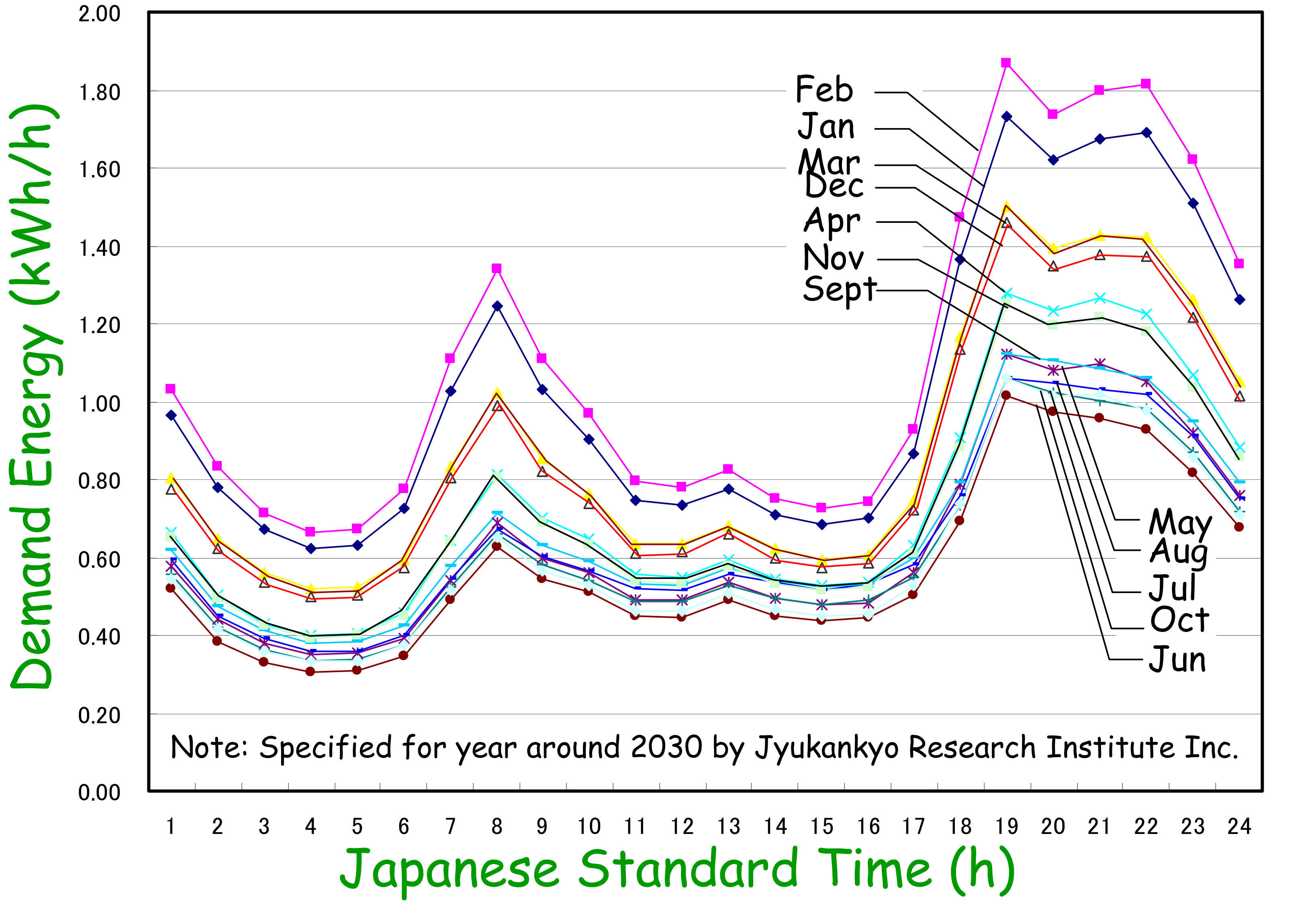
Location of Battery Storage



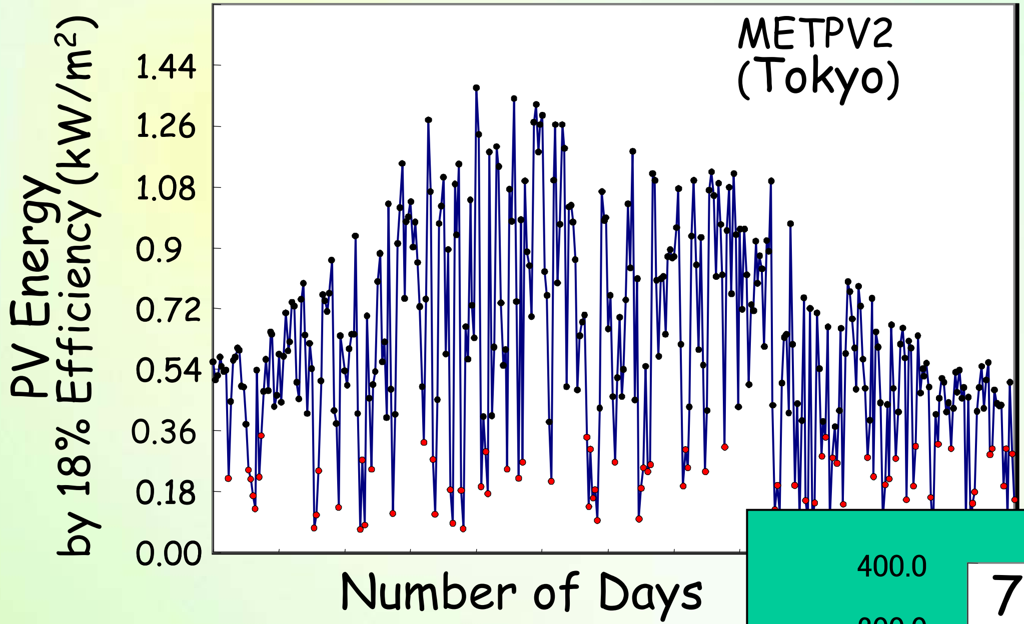
Hourly Irradiation for Average Year

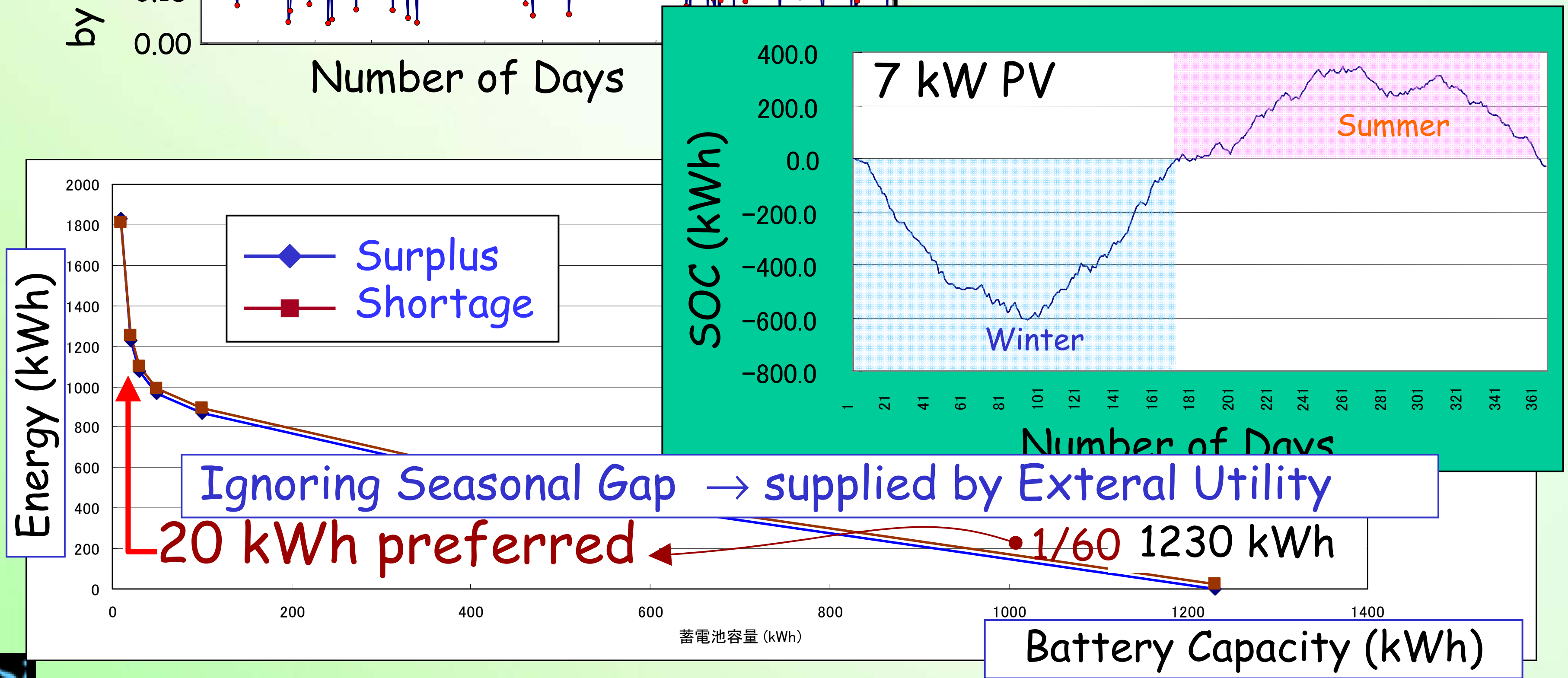


Monthly-Averaged Hourly Domestic Energy Consumption by A Fully Electrified Home

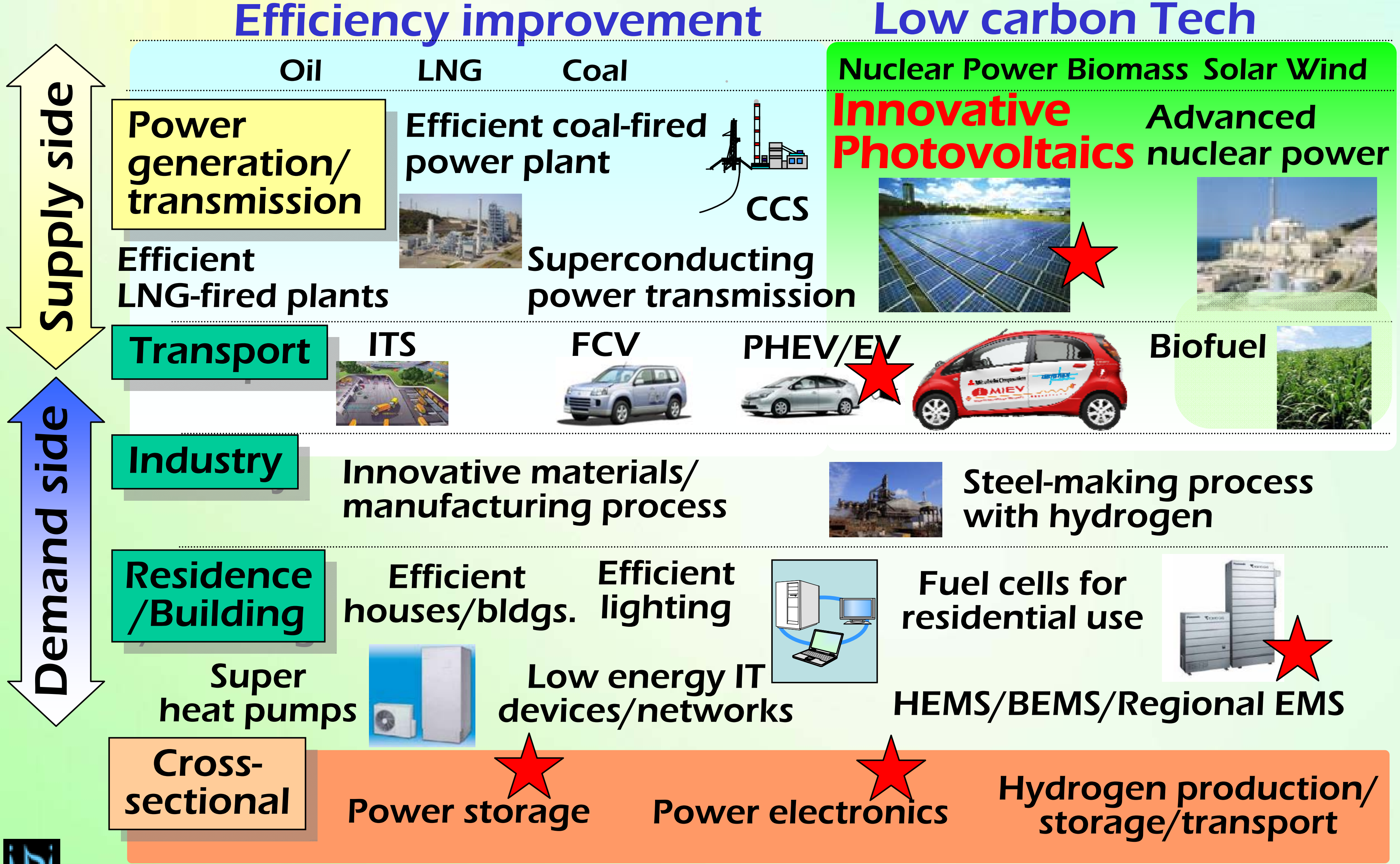


Optimized Storage Capacity

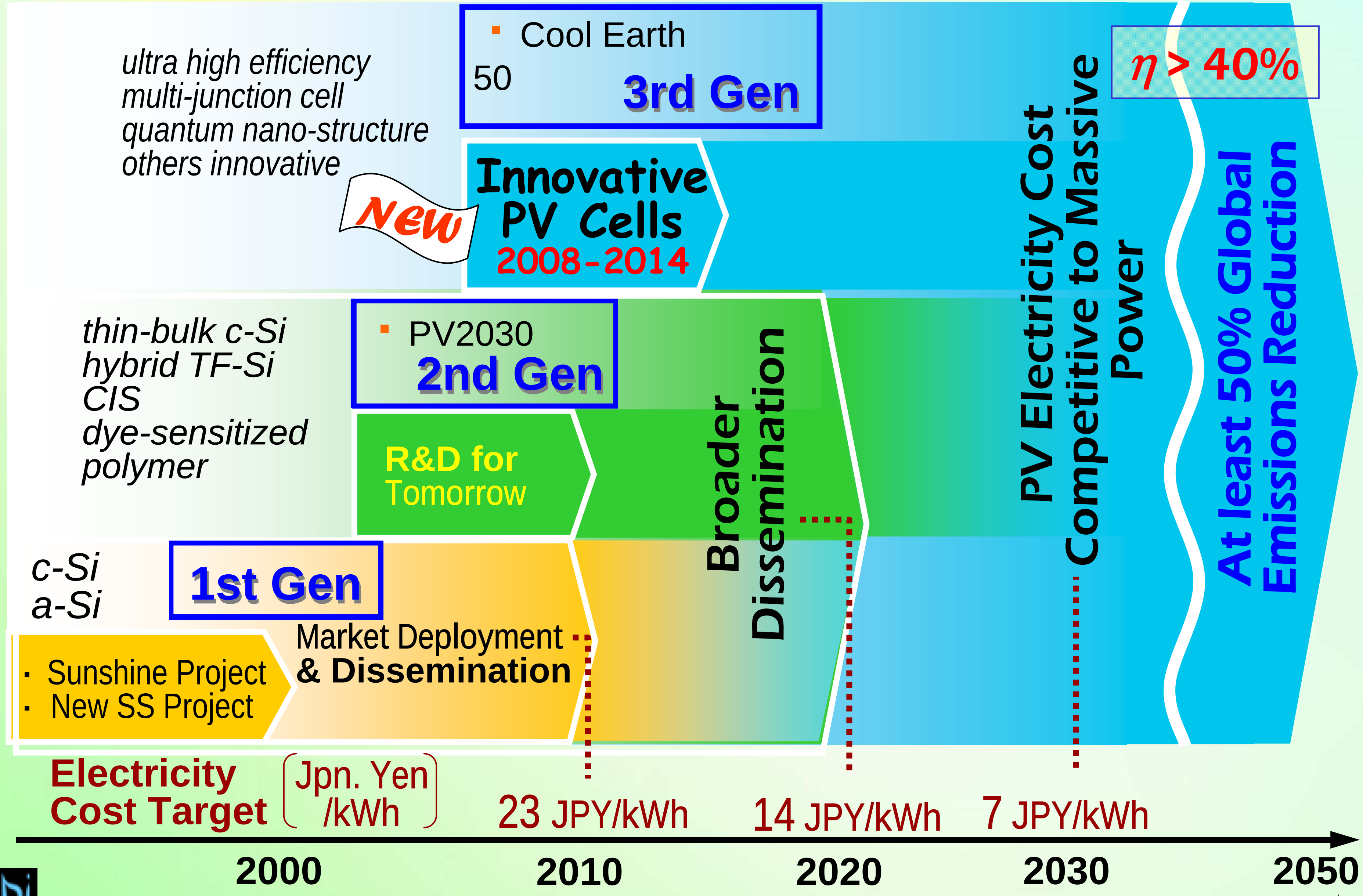




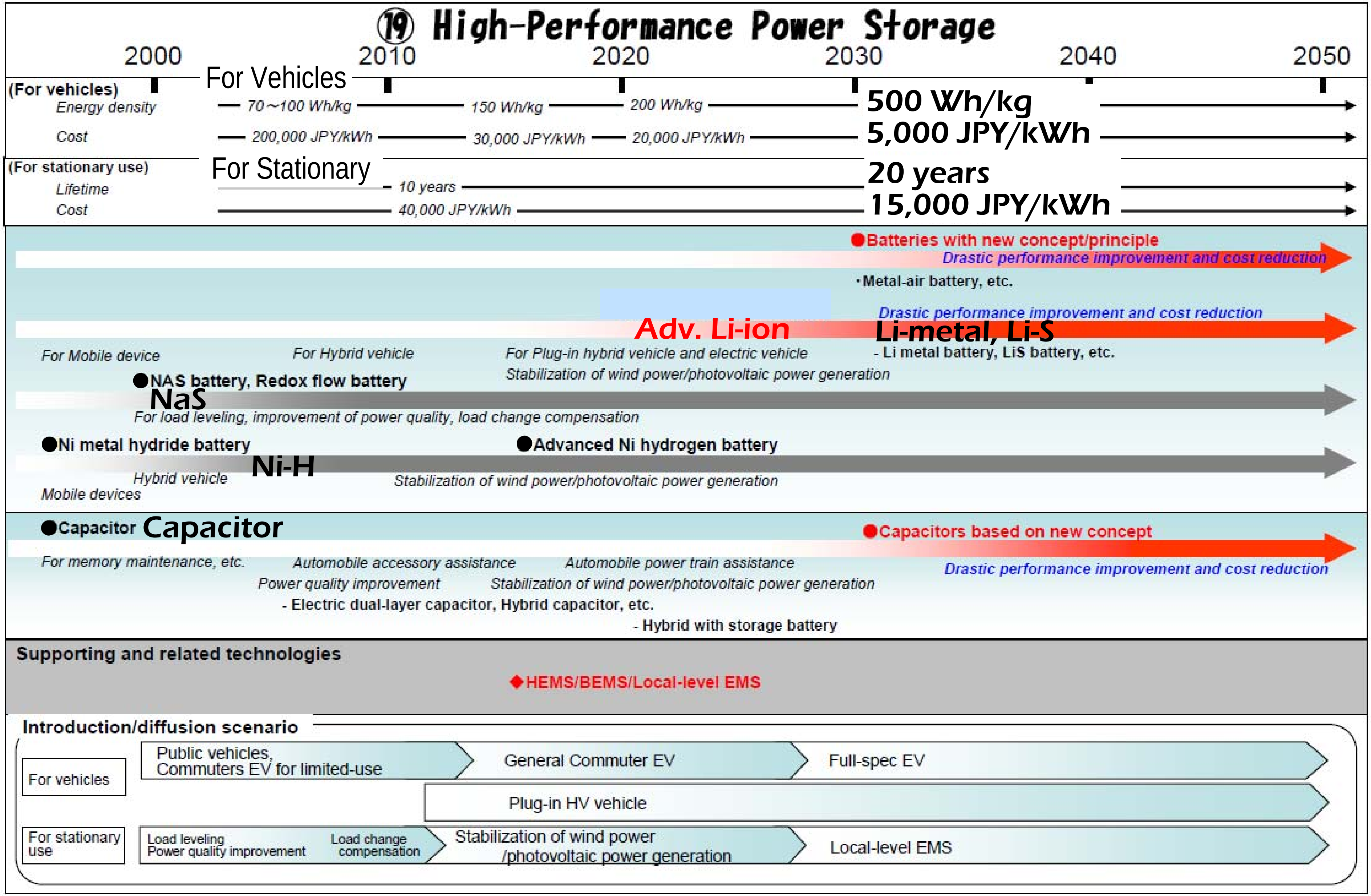
Key Innovative Energy Technologies toward "Cool Earth 50"



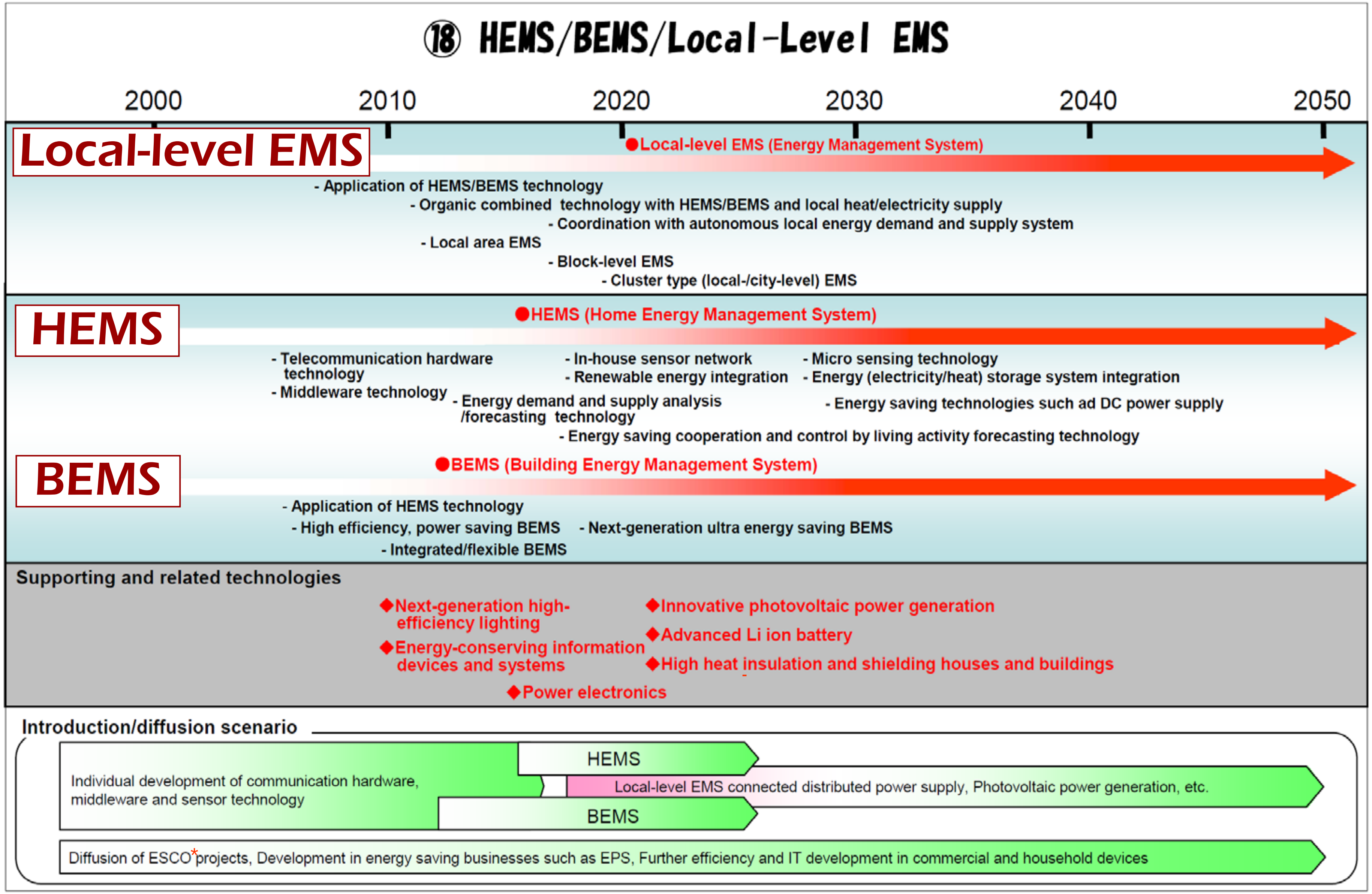
PV R&D Initiatives toward 'Cool Earth 50'



Considerations on storage in Cool Earth 50



Network Topic in Cool Earth 50



* ESCO: Energy Service Company proposing business for energy conservation

Considerations on storage battery for PV

- Possible Locations of Energy Storage in Grids with PV Systems (in summary)

In the case of bulk introduction of PV among national electric grids

- Bulk storage with PV Power Plant

In the case of distributed approach of PV aggregation in urban residential communities

- Battery Station beside distribution substation, as a social infrastructure (its cost met by the society), not for individual PV homes

Preferable Principle:
Social Cost Minimum to fulfill the balance of local energy supply and demand with local storage.

Battery controller gives an additional value – "Scheduled Orderly Power Flow"

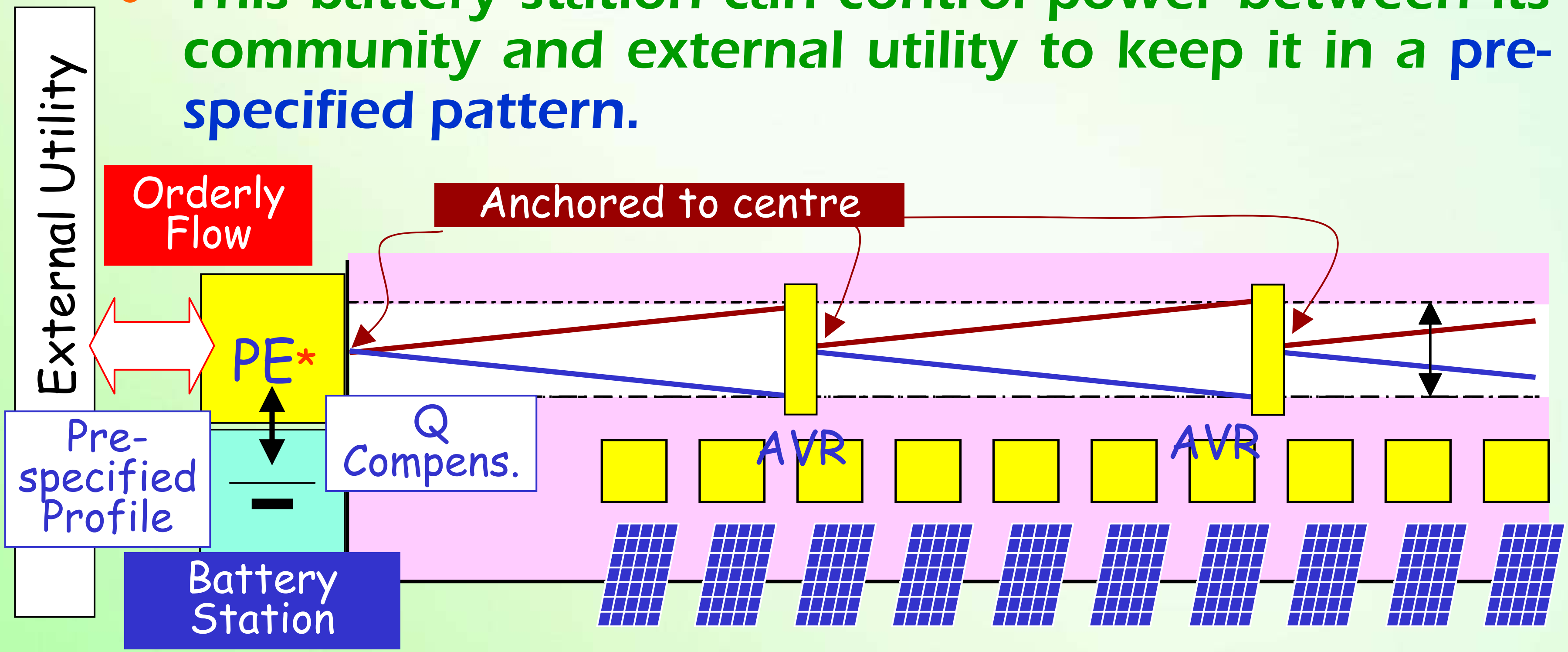
Proposal of Autonomy Enhanced PV Clusters

The Main Objectives:

- Maximize PV installation into a residential community.
- Allow grid power flow downward and upward equally.
- Stabilize the fluctuation of power flow specified by | PV ~ Load | to raise added value for purchase & sale.
- Minimize storage capacity by community-scale optimization.
- Extend to regional DES management in longer-term view.

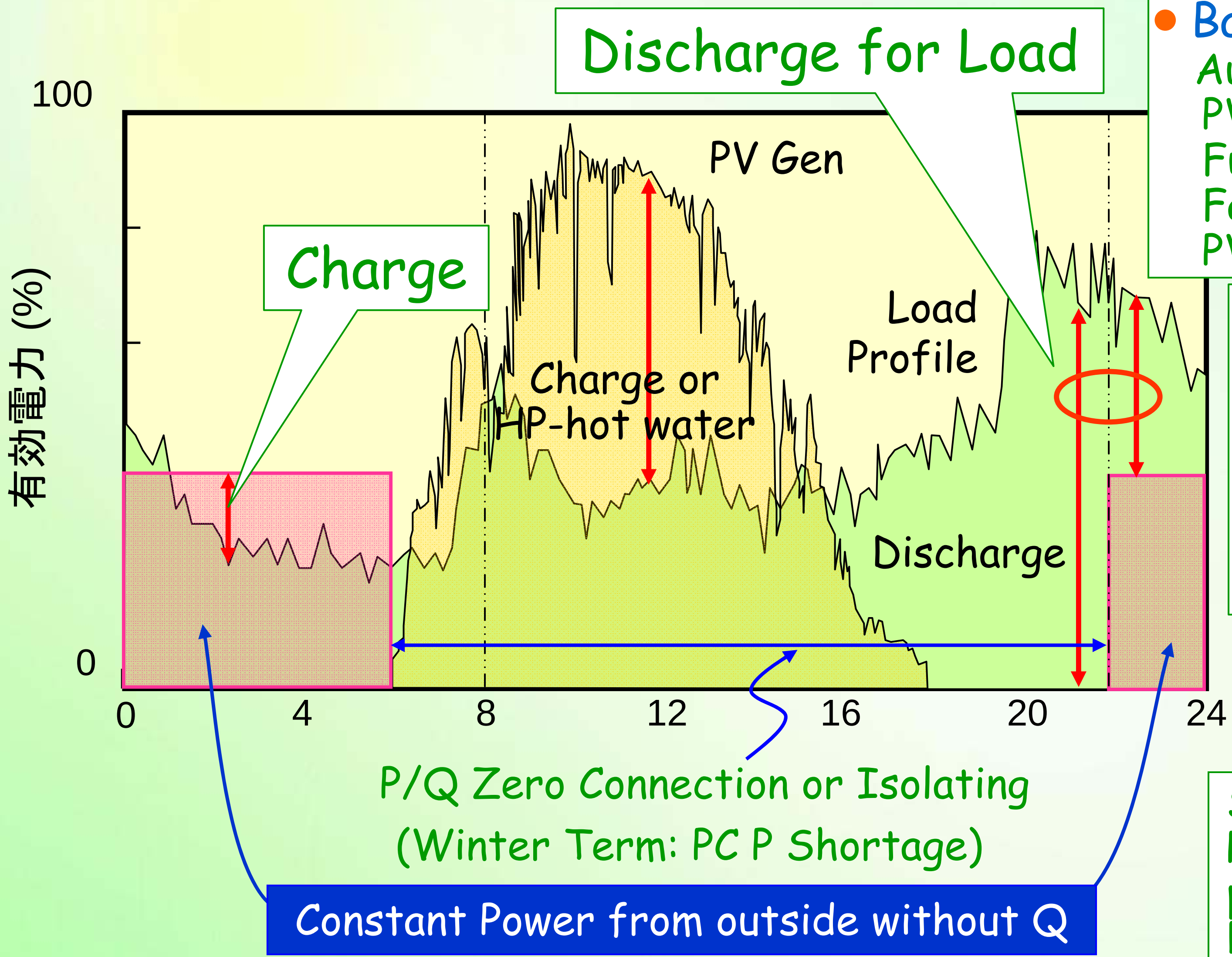
Possible Solution: Storage Battery + PE

- Local Battery station for the community can be provide for massive PV clusters in conjunction with voltage distribution compensation by power electronics (PE) to accept 100% reversal power flow.
- This battery station can control power between its community and external utility to keep it in a pre-specified pattern.



PE*: power electronic controller

Orderly Strategy for External Utility



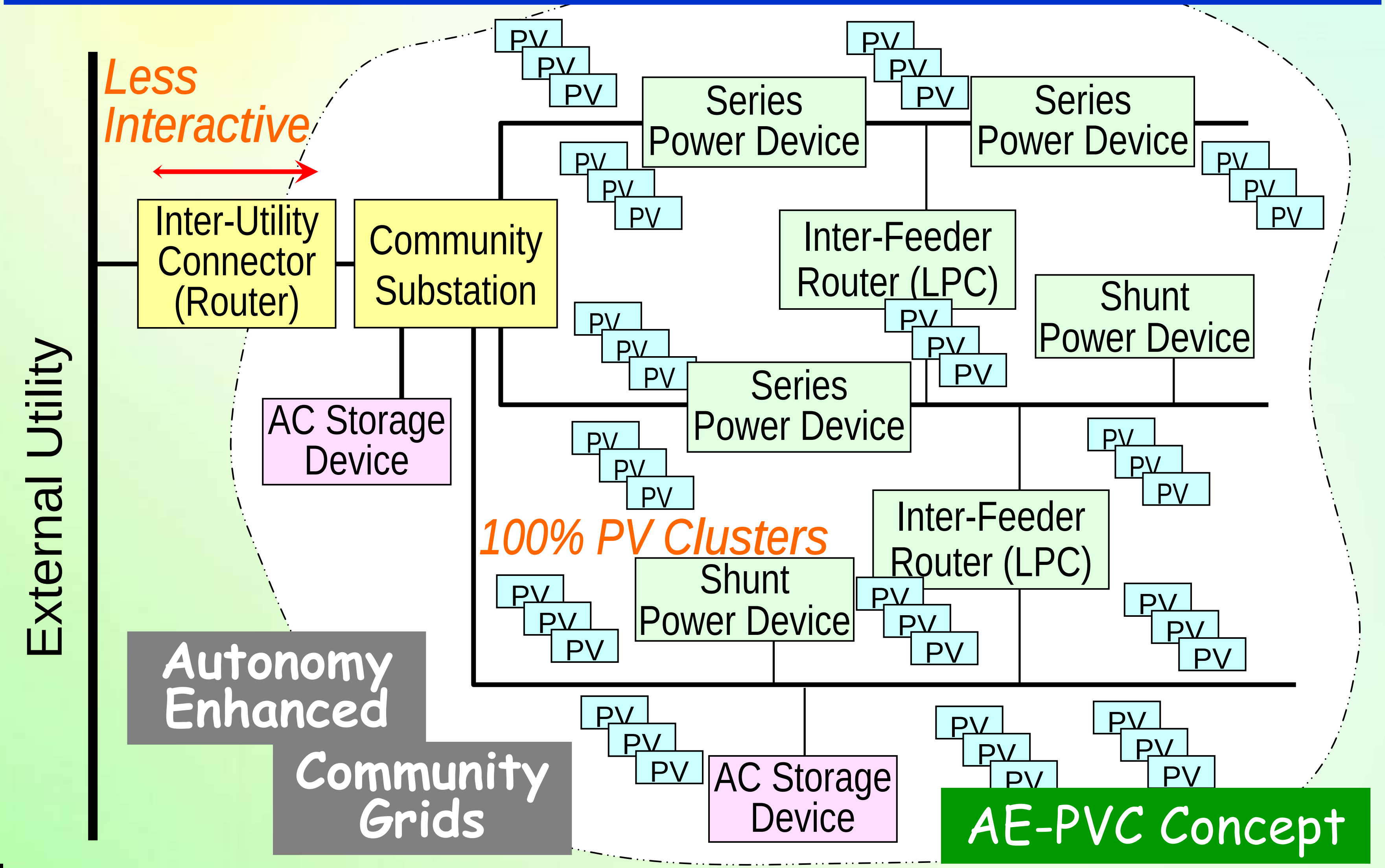
- Battery Storage
  - Autonomy-Enhanced PV Cluster (AE-PVC)
  - Function Following
  - Fast Load Orderly
  - PW Purchase

- Necessary Info
  - Next Day Load
  - Next day PV Gen
  - Battery SOC
  - Next Day Shortage
  - Power Pool Trends

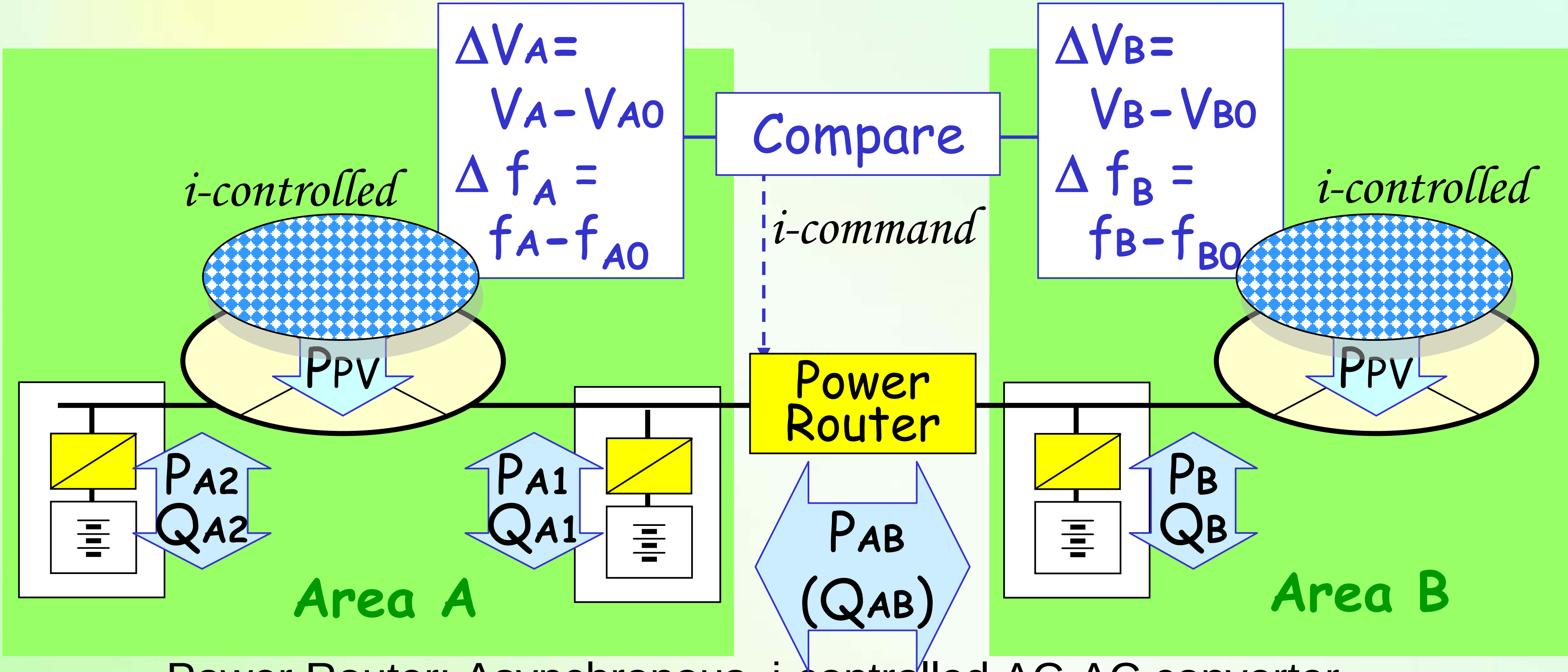
Submit Purchase Plan to power pool prior to 24 hours before

Orderly Purchase from outside

Autonomy-Enhanced, Community-base PV Cluster Concept by employing Active Control



Decentralized, Autonomous, Asynchronous Power Router - Basic Concept



Power Router: Asynchronous, i-controlled AC-AC converter
P_{PV}: Current controlled PV Inv.,
P_A, P_B: autonomously balanced by **freq.-droop** for each town.,)
Q_A, Q_B: autonomously balanced by **voltage-droop** for each town,
P_{AB}, (Q_{AB}): adjusted according to $\Delta f_A \sim \Delta f_B$ (and ・V_A~ ・V_B)

Source: K. Kurokawa: Further considerations on solar PV community concept consisting of massive roof-top PVs and domestic loads, 22nd EU-PVSEC, Milan, 3-7 Sept. 2007, PL2.

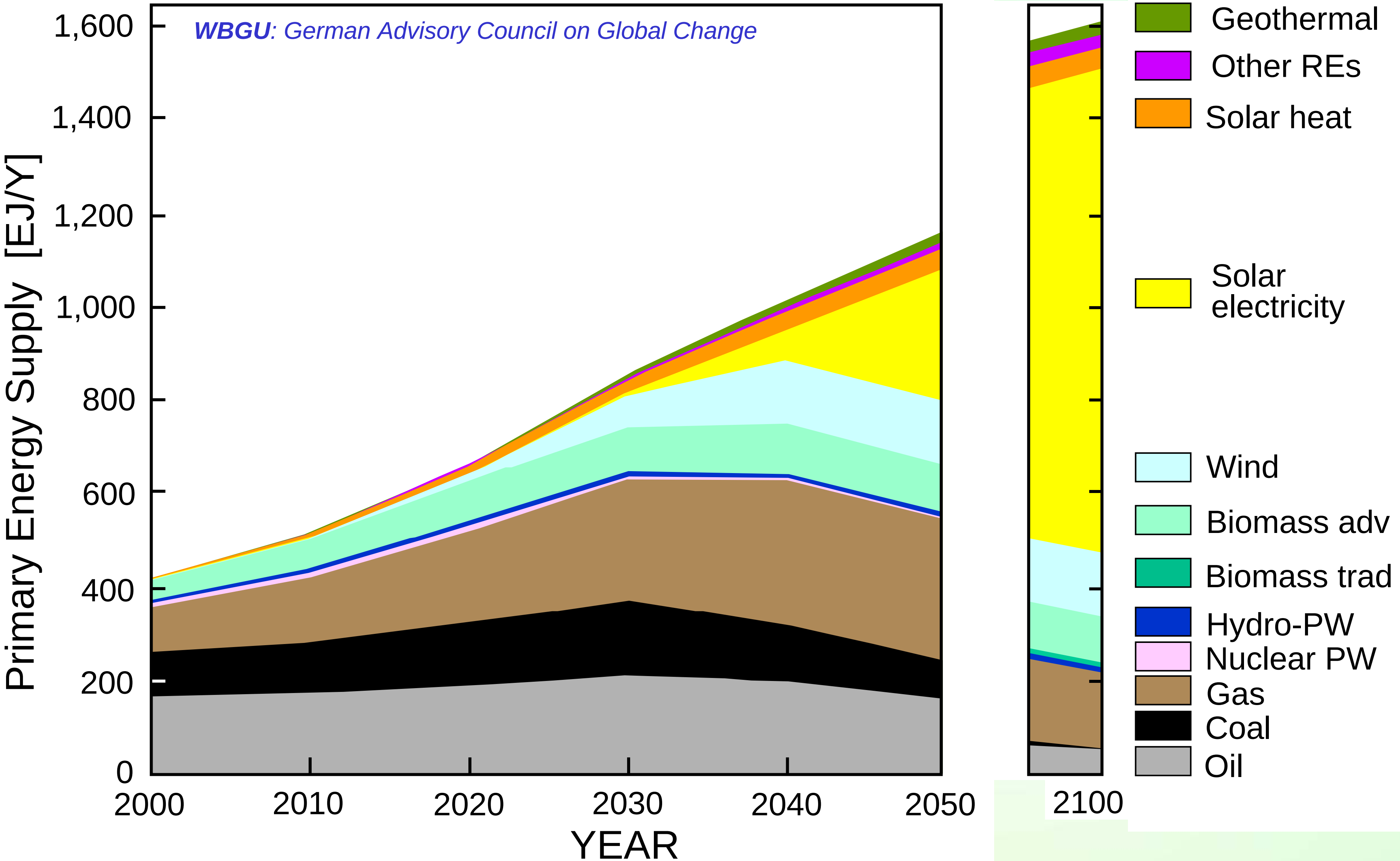
Decentralized, Autonomous Power Router
Expected Basic Control Functions

- Router Functions realized by **Asynchronous** Power Conditioners such as BTB, Matrix Converters, etc.
- Current control on individual PVs and droop V/F control on battery station(s).
- Power Flow Control by localized sensing on router terminals, including **zero P/Q** control.
- Local **Voltage** Control.
- Local **Frequency** Control independent from External Grids
- **Local Frequency** adjusted according to supply/demand balance.
- The possibility of Next Generation Power Electronics by **SiC** Technology for reducing size/cost. (BTB, Matrix C.)

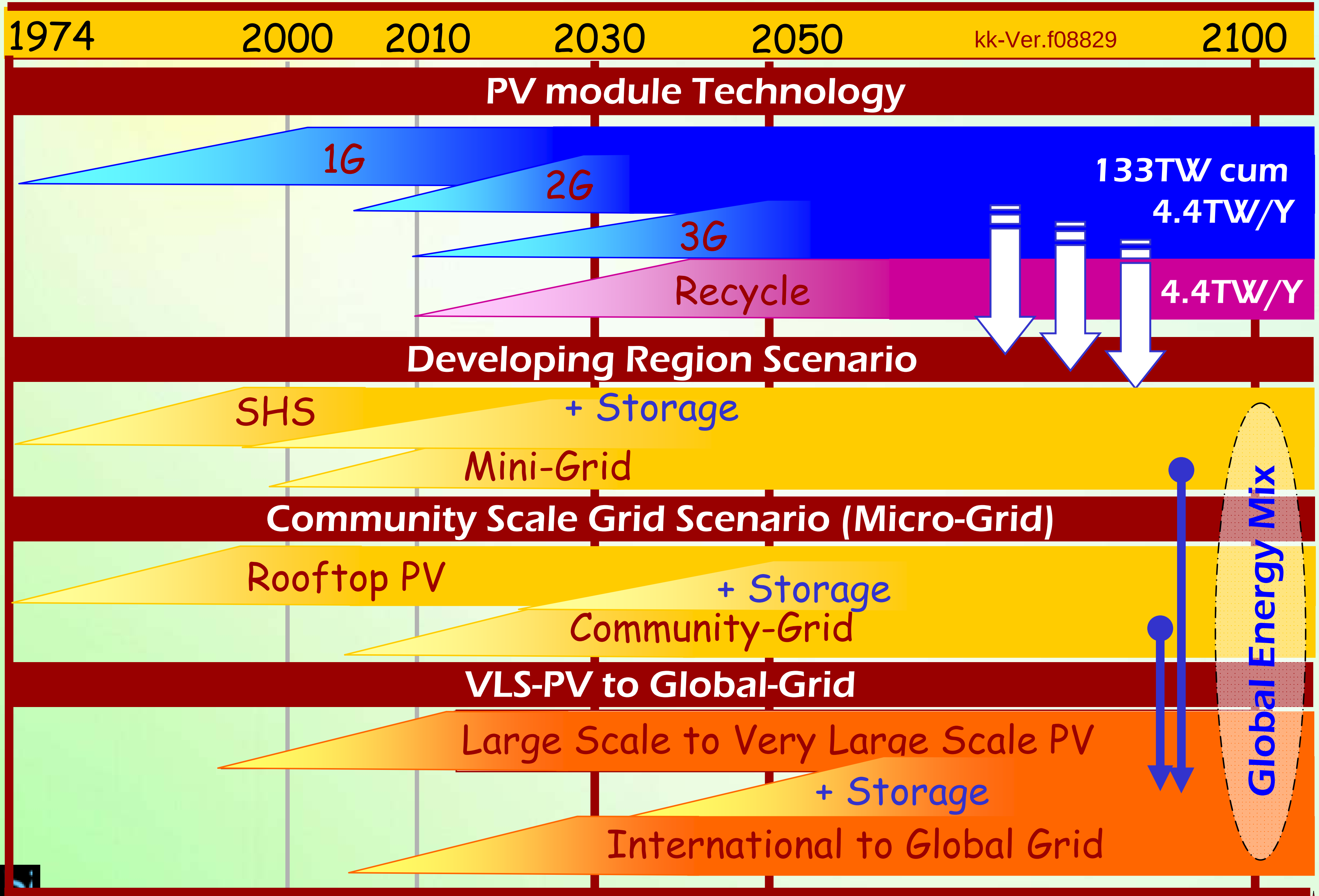
23MW La Hoya Plant - Cloud Movement !


60MW PV Plant: Olmedilla (Cuenca)
Presently World Largest PV Plant
08905

Our Future Directions toward 2100

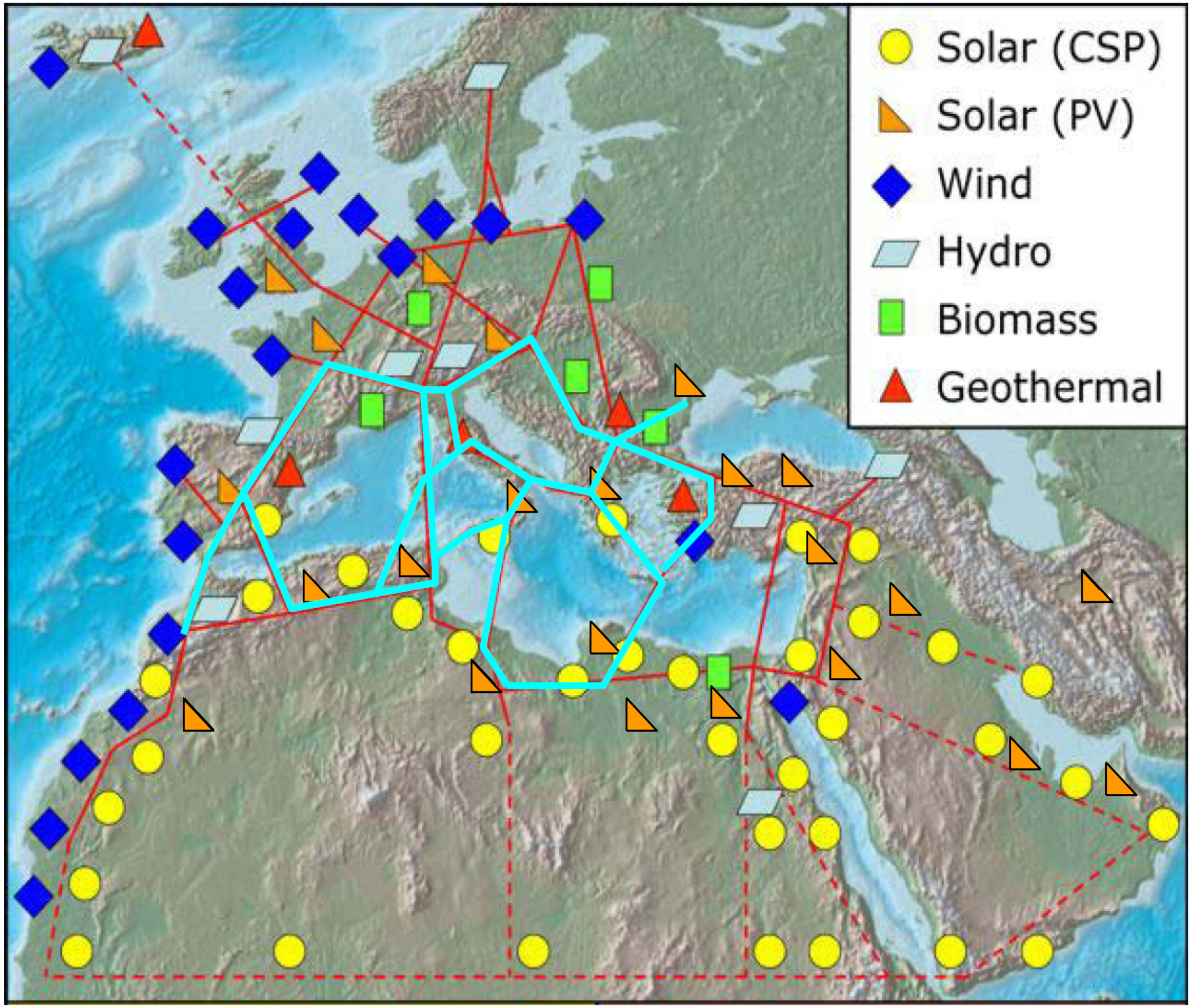


Proposed Scenarios toward 2030-2050 & beyond




Possible
MEDITERRANEAN NETWORK
TO GLOBAL NETWORK
IEA PVPS Task8

Necessary Steps to Realise the Vision



HDVC before 2020

HDVC after 2020

Picture source: TREC

Recommendations

- Solar PV is not a niche energy source: it is clearly a major contribution for the 21st century energy portfolio.
- Residential PV rooftops are the first option - meaningful for urban communities; they also play a part of the earlier investment in industrial applications for stations.
- Improvements in the distribution grids are required to integrate massive aggregation of residential PV and must be part of urban planning .
- Higher Penetration requires the modification of grid operation for balancing demand/supply and the deregulation of power systems.
- Bulk PV systems will require substantial social support to move forward in the 21st century.
- Power grid modification by the principle of Social Cost Minimum and its cost shared by the whole society with consensus.

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