Smart Local Energy Systems and Optimal Scheduling of Microgrids

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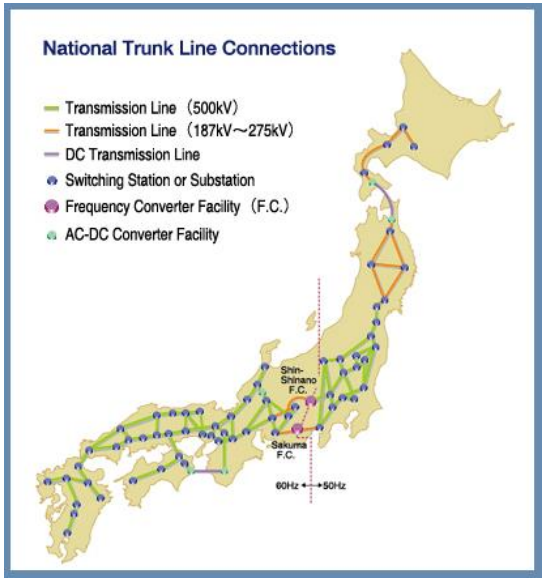
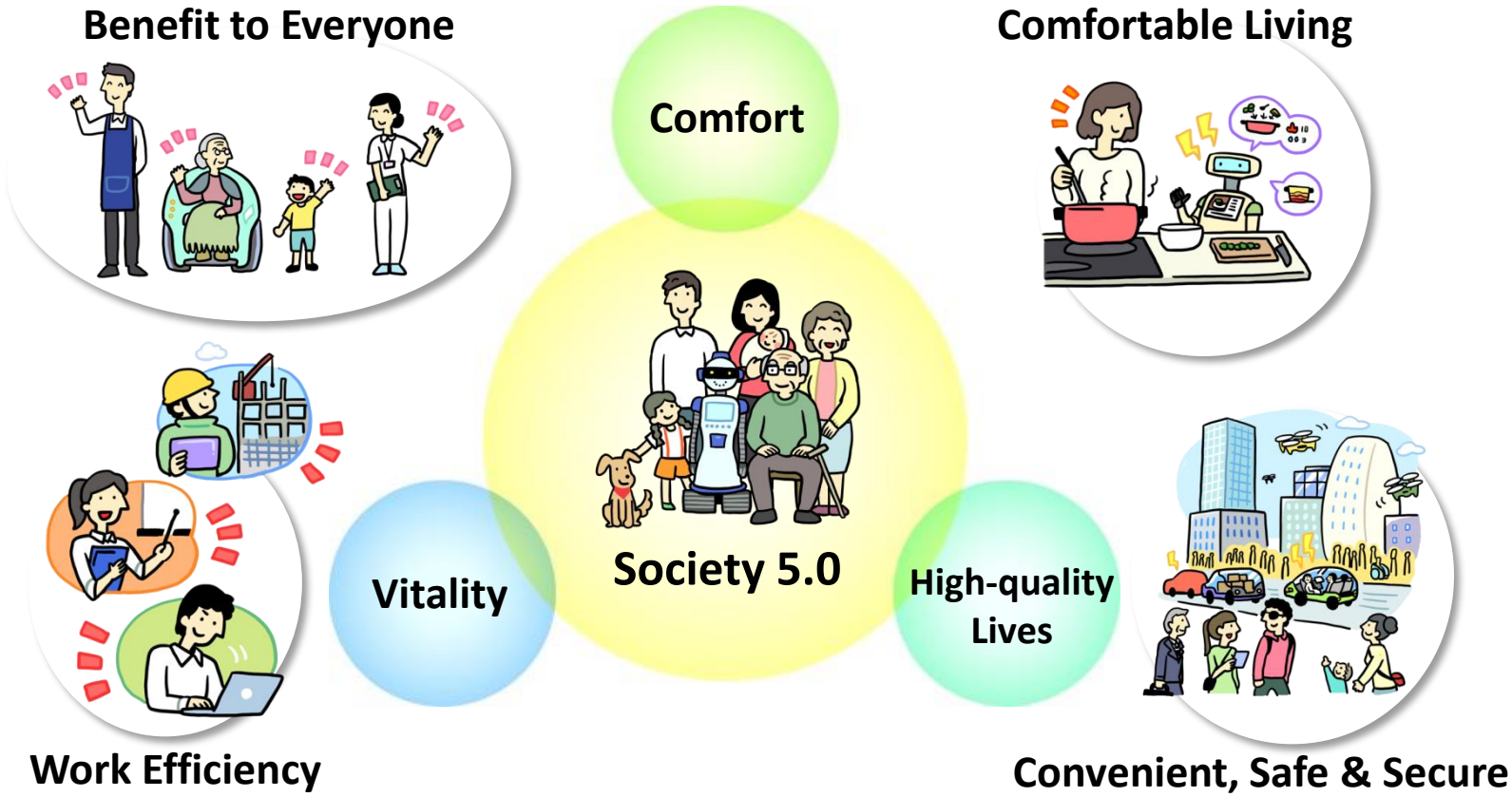


"Society 5.0" is a new society coming up after Information Society:

- Produced by sophisticated integration of cyberspace and physical space;
- Reconciles economic growth and resolution of social issues;
- Realizes a human-centered and inclusive society.



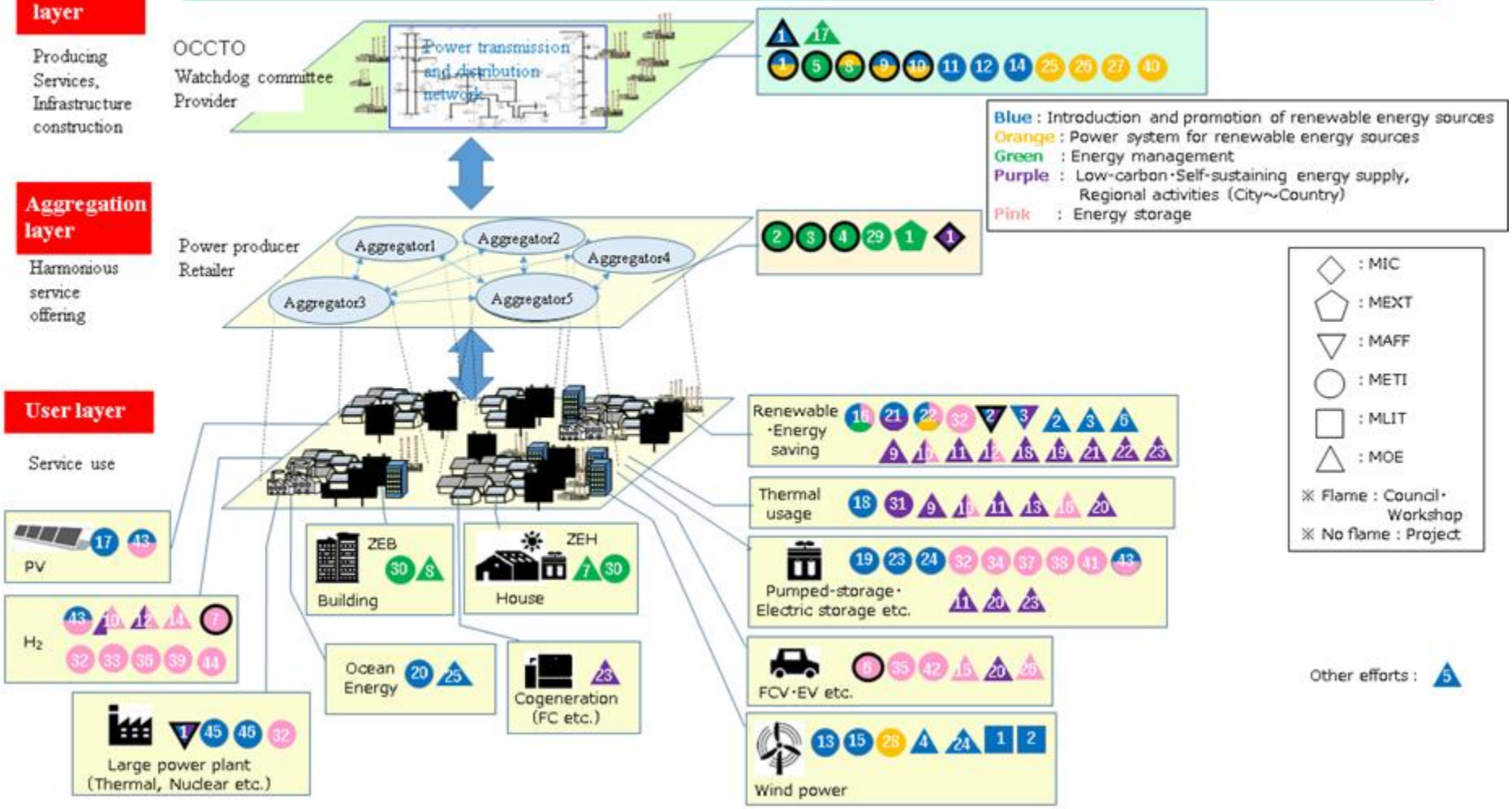
Cross-Ministerial Strategic Innovation Promotion, SIP accelerates the realization of Society 5.0:Super Smart Society

National Policies for Society 5.0 & Smarter Communities in Japan

- METI : Driving (local) economy revitalization, new business; VPP, DR aggregator, DER platform, P2P trading by block chain
- Ministry of the Environment: Towards decarbonized society in the long run, promoting ZEB(Zero Energy Bldgs.) & ZEH
- Ministry of Land, Infrastructure, Transport and Tourism: Resiliency of energy system
- Ministry of Internal Affairs and Communications: 5 G economy

- Drivers for smart local energy systems
  - Resiliency: after Hokkaido black out in Sep. 2018
  - Less power flow from renewable generation by T&D constraints
  - Post-FIT since 2019, more distributed battery storage
  - Progress of Hydrogen technology, RE-based H2

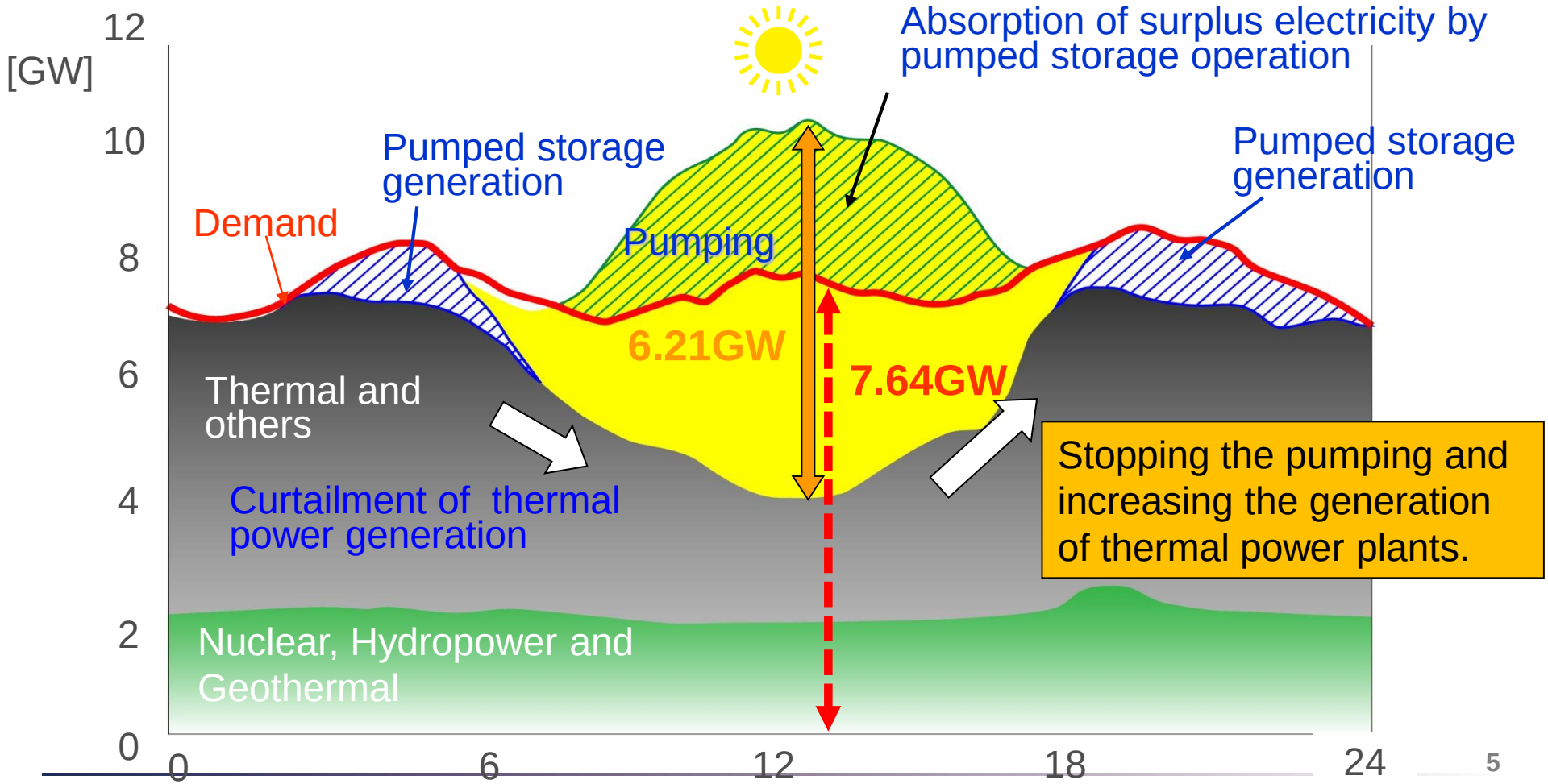
Ministries activity map (Efforts are plotted in next-generation energy system structure)



Surveyed by CAO, Energy management technical committee (March, 2019)

- More than 100 national pilots on advanced energy systems.
- Most of projects focus on element technology, say, battery storage.
- More efforts on data linkage for coupling between energy and transportation sectors
- necessary

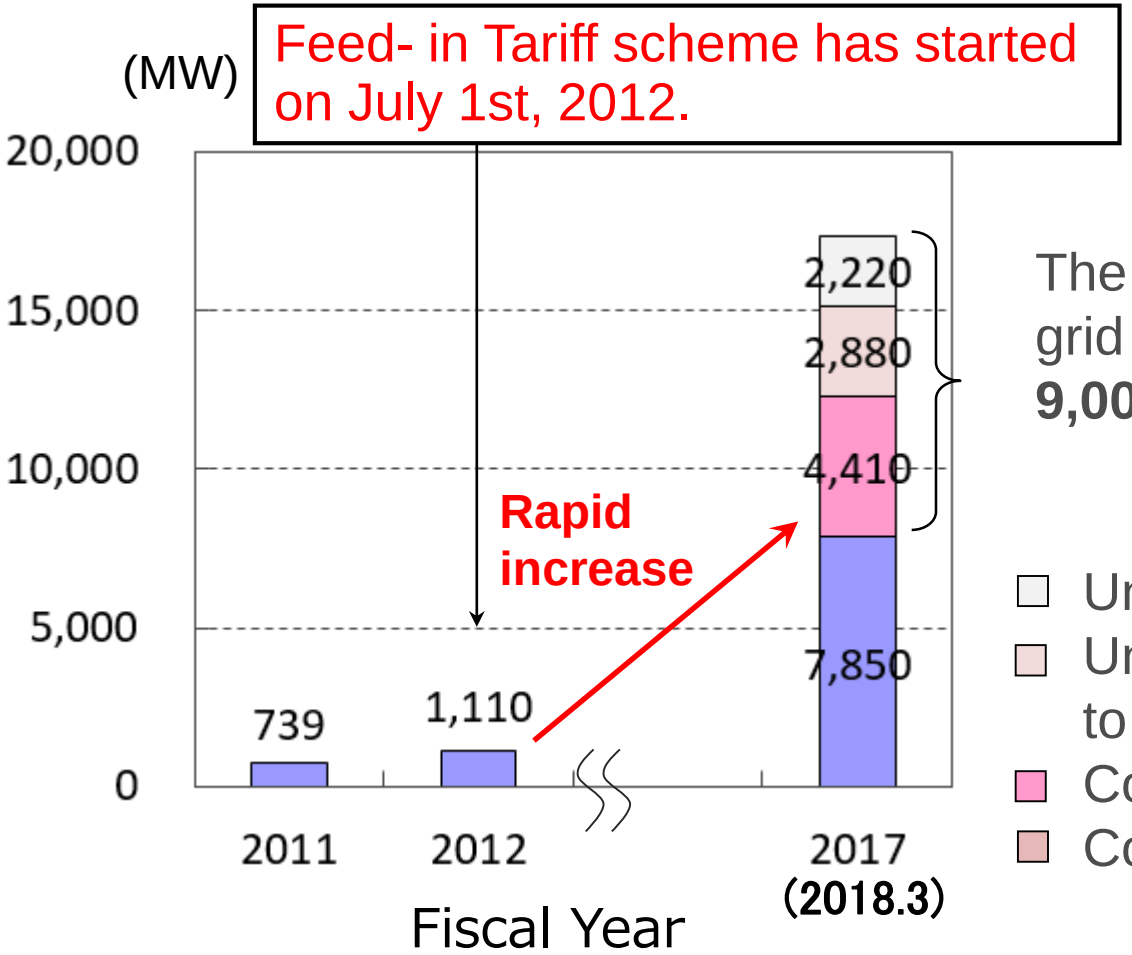
- Duck Curve in Kyushu on May 3, 2018
- The power supplied from PV has exceeded 80% of the demand in Kyushu area.
- 2 GW/hr ramp from 16:00
- Max forecast error of PV is 2 GW



Many Requests for PV Connection to Power Grid: Kyushu

- The capacity of connected PV was about **7.9GW*** in March 2018.

*** : 18% of Japan**



The total capacity waiting for grid connection exceeds **9,000MW.**

- Under consulting to connect
- Under technical investigation to connect
- Contracted to Connect
- Connected

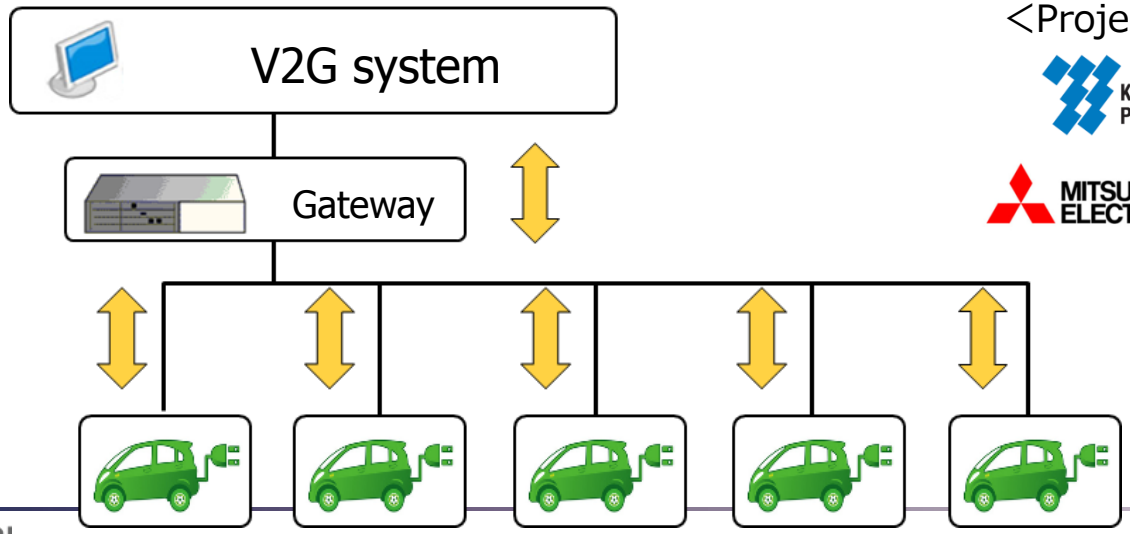
V2G Project in Kyushu

① Development of EV charging and discharging station, and verification of its V2G function

② Development and verification of V2G system operation, e.g. control and measurement of amount of charge and discharge

③ Evaluation of V2G potential of EVs in Kyushu area

Verification of V2G function of EV charging and discharging stations



<Project partners>

KYUSHU ELECTRIC POWER CO.,INC.

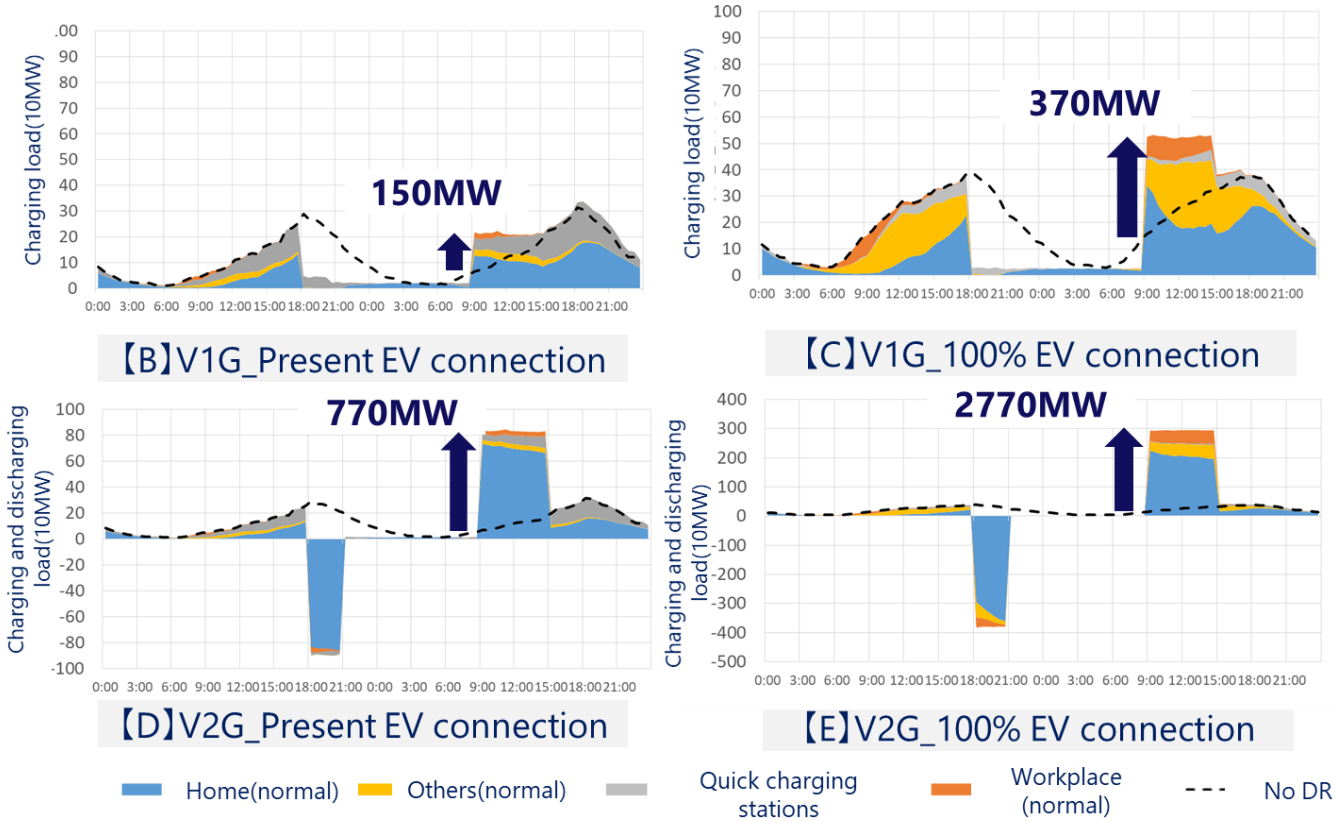
CRIEPI Central Research Institute of Electric Power Industry

MITSUBISHI ELECTRIC

MITSUBISHI MOTORS Drive your Ambition

NISSAN

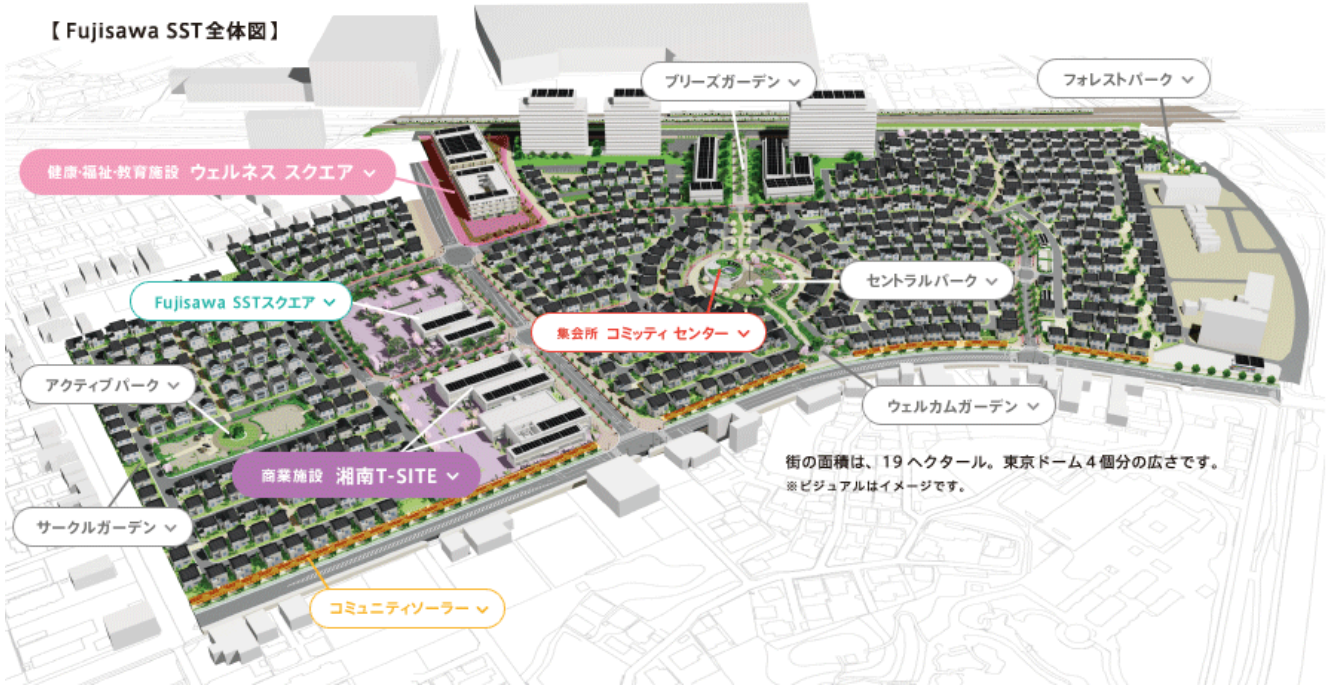
Area-wide V2G Load Potential Evaluation



- V1G : Shifting the EV charging load to the DR period 9:00-15:00 to create the daytime load demand
- V2G : In addition to V1G, discharging during the previous night 18:00-21:00 at homes to decrease the SOC level of EVs, and then charging during the DR period 9:00-15:00 to create the daytime load demand.

Grid-connected Microgrids in Japan

- Fujisawa Smart community: 1000 household, Residential Fuel Cell CHPs, Panasonic, Tokyo Gas
- F Grid: Toyota, Miyagi, corporation between industrial microgrid and local government, community continuity planning
- Higashi-matushima Smart Resilient Ecotown: presented by Prof.Aki last symposium in Bucharest



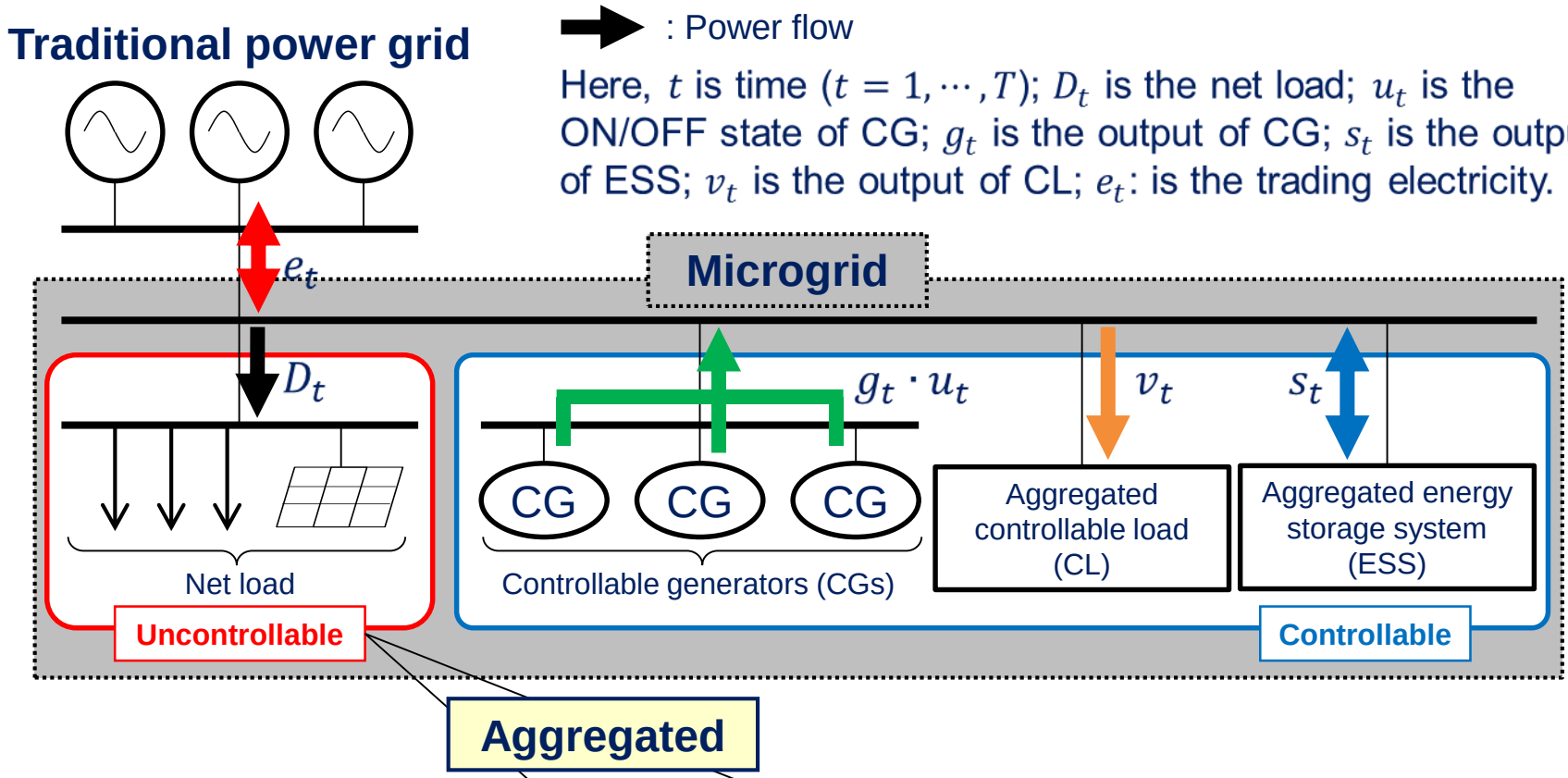
F-Grid (microgrid) in Miyagi since 2015

7.8 MW GE CHP, Automaker factory, Toyota group and municipal office, Ohira village, disaster management base

Coordinated Operation of Controllable Components in Microgrids

Hirotaka Takano, Ryota Goto, Hiroshi Asano
Gifu University

Microgrid Model



Microgrid components are classified into
1) CG, **2) ESS**, **3) CL**, **4) REG(PV)** and **5) electrical load**,
and **6) traditional main power grid**.

Objective Function and Constraints

➢ Objective function

- Sum of fuel cost and start-up cost of CGs,
  and profit from electricity trading,
  (ESSs and CLs shift electricity consumption,
  so that contribute indirectly to the above.)

  ⇒ $\min F(u, g, s, v, e)$

$$\begin{cases} F(u,g,s,v,e) = \sum_{t=1}^{T} \sum_{i=1}^{NG} \left[FC(g_t, u_t) + SC_i \cdot u_{i,t} \cdot (1 - u_{i,t-1}) + M_t \cdot e_t \right] \\ FC_t(g_t, u_t) = \sum_{i=1}^{NG} \left(A_i + B_i \cdot g_{i,t} + C_i \cdot {g_{i,t}}^2 \right) \cdot u_{i,t} \end{cases}$$

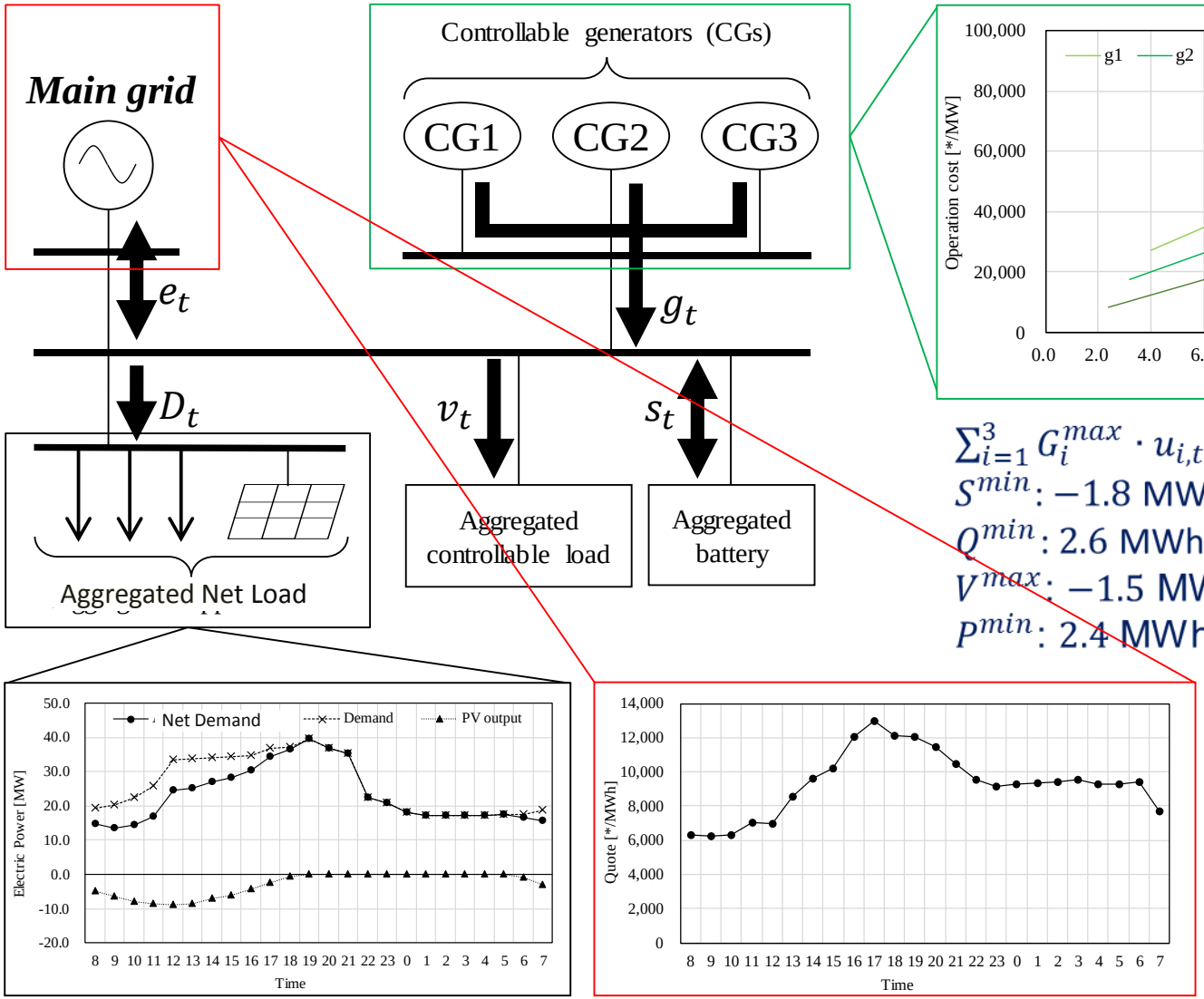
➢ Constraints:

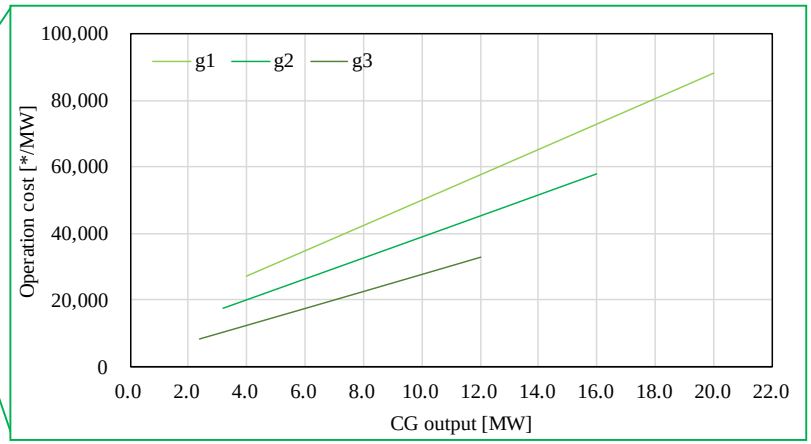
- Supply-demand balancing constraint
  ⇒ **Unnecessary** (equals to e_t)
- Operational constraints for CGs.
- Operational constraints for ESSs.
- Operational constraints for CLs.

Solution Method

- Binary particle swarm optimization(BPSO) creates UC candidates
- Quadratic programming calculates the output shares of DER for each UC candidates
- BPSO stops when it reaches the termination condition
- Less CPU time

Numerical Simulation Model





$\sum_{i=1}^{3} G_i^{max} \cdot u_{i,t}$: 48.0 MW,

S^{min}: −1.8 MW, S^{max}: 1.8 MW,

Q^{min}: 2.6 MWh, Q^{max}: 10.4 MWh,

V^{max}: −1.5 MW,

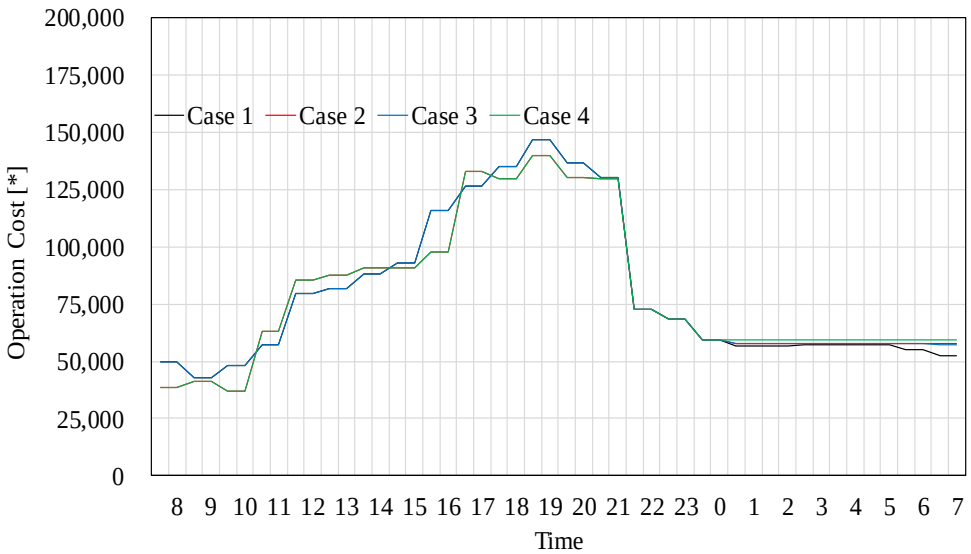
P^{min}: 2.4 MWh, P^{max}: 9.6 MWh

Numerical Simulation Cases

- **Traditional UC-ELD problem**
  - Case 1: CGs + Net load (sum of REGs and Loads)
- **Extended UC-ELD problems**
  - Case 2: CGs + aggregated ESS + Net load
  - Case 3: CGs + aggregated CL + Net load
  - Case 4: CGs + aggregated ESS + aggregated CL + Net load

Numerical Simulation Results

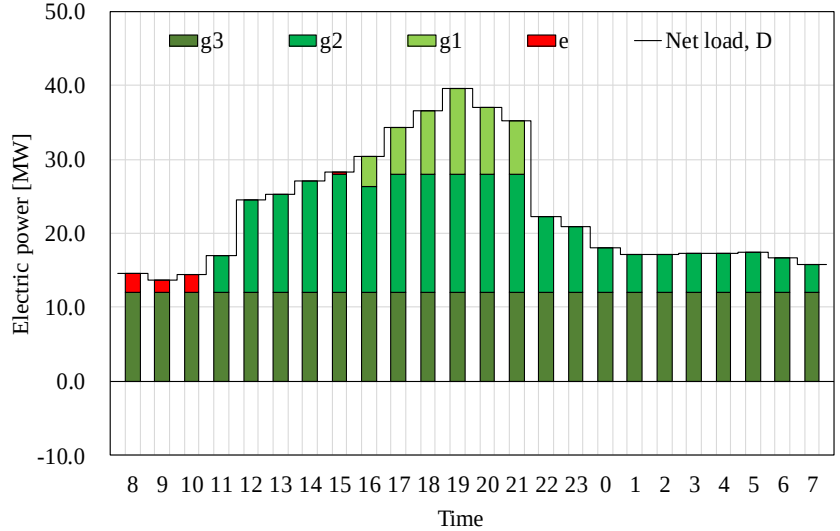
Case number	Fuel cost [*]	Percent reduction [%]
1	1,926,141	100
2	1,898,723	98.6 (-1.4)
3	1,936,365	100.6 (+0.6)
4	1,909,958	99.2 (-0.8)

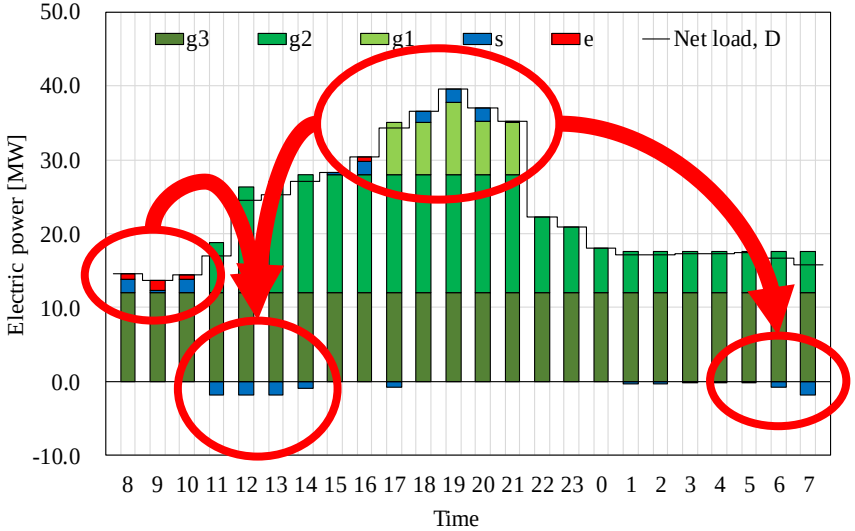


Cost: Case 2 < Case 4 < Case 1 < Case 3

- Aggregated ESS and aggregated CL works well for shifting electricity demand in Case 4.

Comparison of UC in Case 2 with Case 1





- Fuel cost is reduced by storage.
  ⇒ Reduction of purchased electricity from 8:00 to 10:00.
  Reduction of peak electricity from 18:00 to 20:00.
  Start-up delay of CG 1 at 10:00.

Summary

- Microgrids attract attention again in Japan
  - The 1st wave of microgids in early 2000. GE, DE-based
  - Now more carbon-free, H2-based, V2X, grid-connected, DER aggregation, communication with DSO/TSO for networked microgrids
  - More resilience; black-out, earthquake, typhoon, floods
  - shortage of interconnection capacity, massive requests of PV interconnection in local areas
  - More self-consumed customers with roof-top PV in the era of post-FIT <- distributed battery storage commercialized
- Could we efficiently make a stable and profitable schedule for controllable components of microgrids? Yes
- Applications of this simulation tool for smart local energy systems

Thank you!

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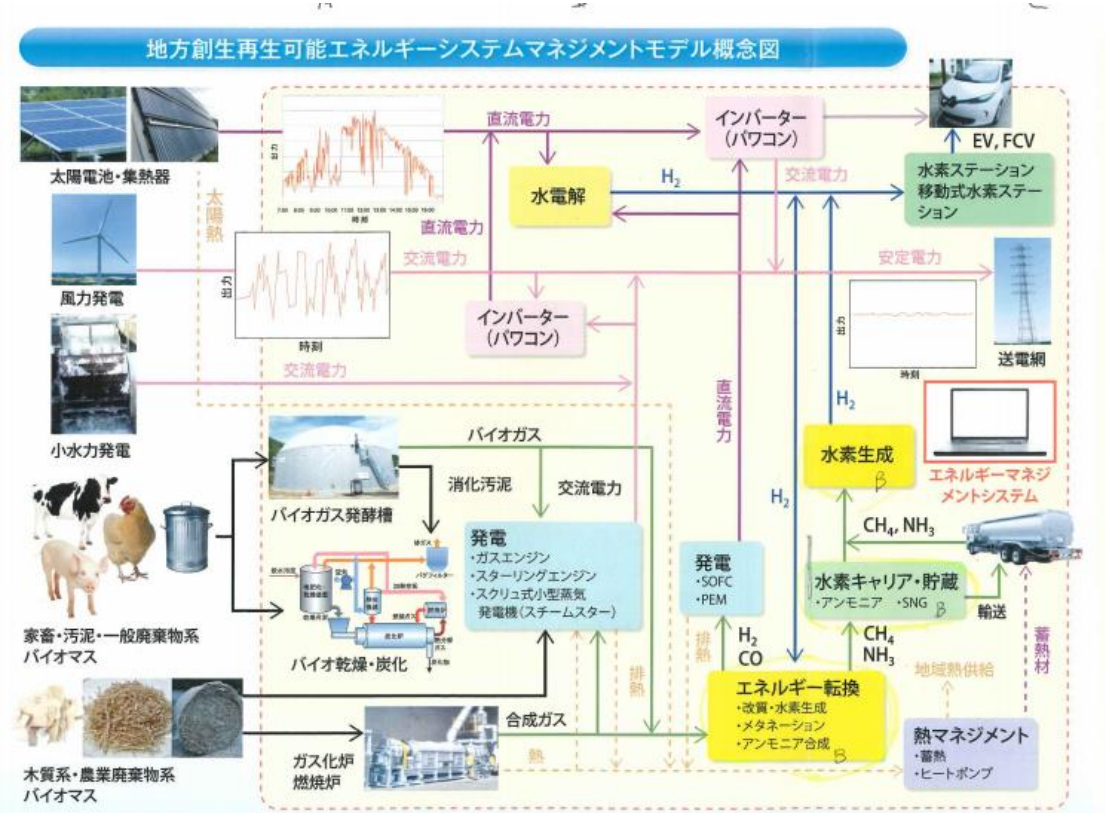
Regional revitalization through innovative energy technologies

Gifu Renewable Energy System Research Center (G-RESRC), Gifu University



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