Evaluation of Economic and Environmental Superiority of EV Battery in Power Systems: Development of Multi-objective Optimized Model for V2H

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Japan’s target for the spread of EV

➢ **Based on 2°C scenario, Japan set the target for car sales**

Year	Conventional	Next-Generation					
			HEV	BEV	PHEV	FCEV	Clean Diesel
2017 (actual)	63.6%	36.4%	31.6%	0.4%	0.8%	0.02%	3.5%
2030 (target)	30~50%	50~70%	30~40%	**20~30%**		~3%	5~10%

Ref: METI, Strategy Meeting for the New Era of Automobiles

35%/year UP

… Need for explosive spread !

For the spread..

Modified from Ref. : METI, Strategy Meeting for the New Era of Automobiles

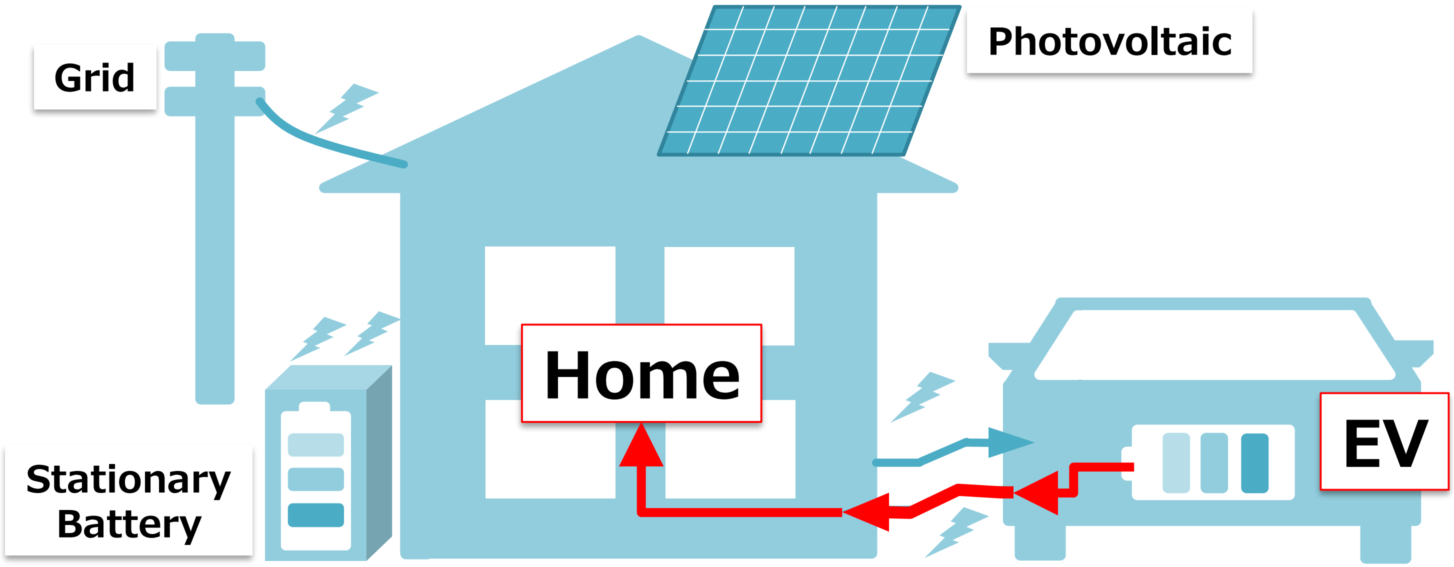
- **There are various measures to spread the use of EV ··· Among them is "V2X"**

However···

- **<u>The advantages of V2X are unclear</u>**
- **<u>Need to evaluate quantitatively</u>**

In this study, we focus on V2H

Vehicle to home (V2H)



Discharge = "V2H"

Motivation

Issues

- V2H competes with the Stationary Battery (SB) as power storage
- Consumer tastes are becoming environmentally-oriented (not only economic)

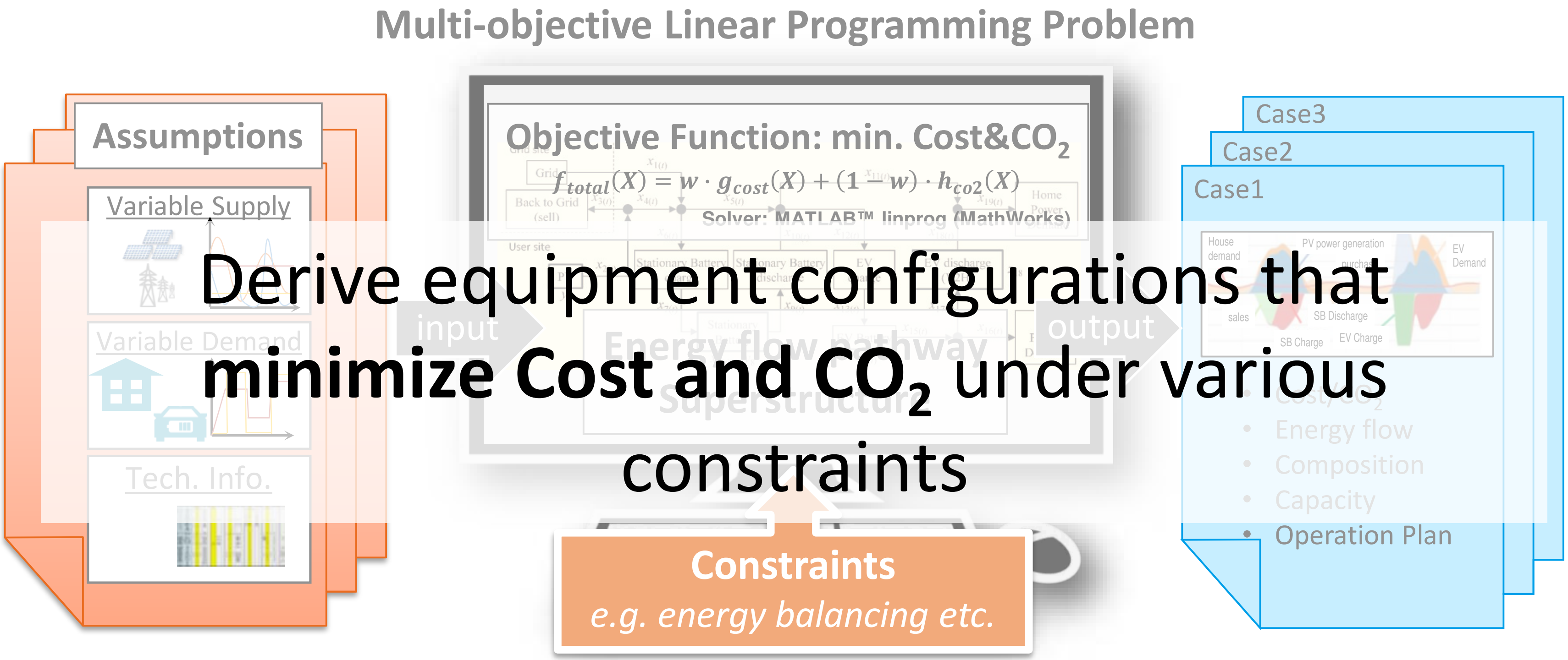
Is V2H a reasonable option?

Objective

- Evaluating the **economic and environmental** performance of V2H

Approach| Energy Flow Optimization Model

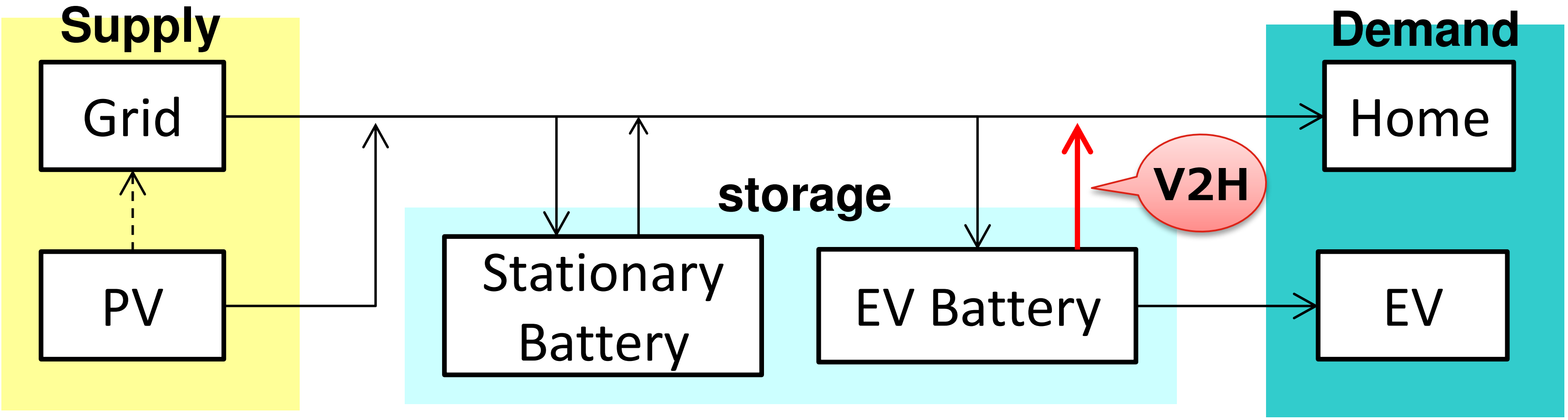
Energy systems model to optimize the energy flow while minimizing Cost/CO_2



$$f_{total}(X) = w \cdot g_{cost}(X) + (1 - w) \cdot h_{co2}(X)$$

Derive equipment configurations that **minimize Cost and CO_2** under various constraints

Energy Flow Superstructure



Overview of the energy flow in the EV owner's home

Multi-objective optimization problem

Objective function

$$f_{total}(x,y,z) = w \cdot \frac{f_{cost}(x,y,z)}{\min\{f_{cost}(x,y,z)\}} + (1-w) \cdot \frac{f_{co2}(x)}{\min\{f_{co2}(x)\}}$$

Cost function

- initial cost of the equipment (PV, SB, V2H)
- cost of electricity from the grid
- profits from the sale of PV power to grid

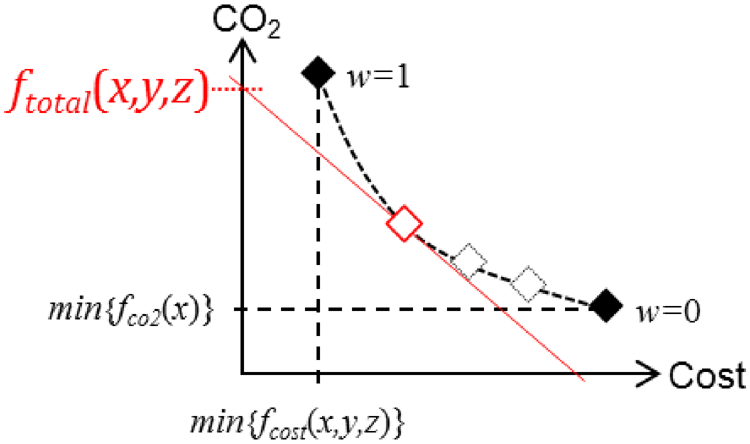
CO_2 function

- quantity from grid power

Optimize

- Capacity of PV and SB
- Operation schedule

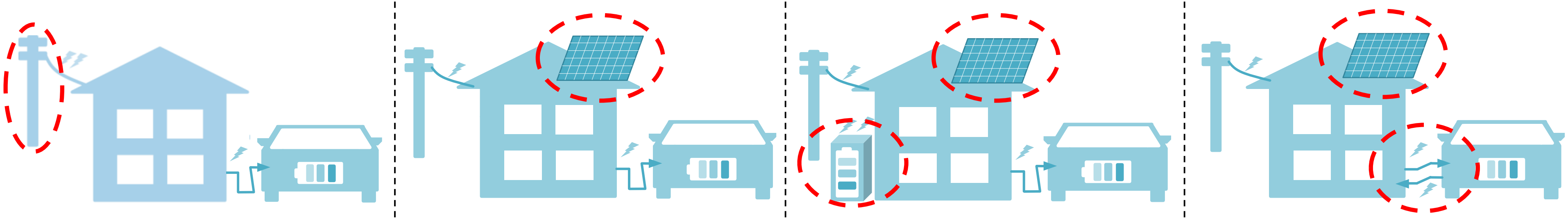
Pareto solution



Case study in Japan

Installable equipment

1. Grid only | 2. PV | 3. PV&SB | 4. PV&V2H



Scenarios

- Commuting or non-commuting EV
- Various initial V2H costs were assumed
- In each case, the EV owner lives in the average detached house

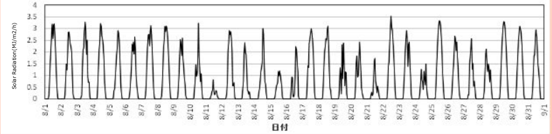
...evaluate whether V2H is a reasonable option

Assumption| Input Parameters

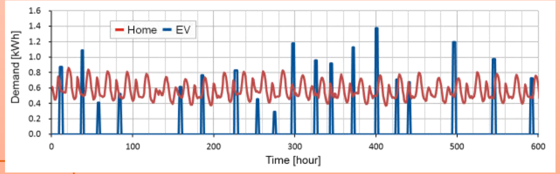
Set input parameters based on public information, literatures, database, interview, actual value, estimation, etc.

Time Series Info.

- PV power generation



- Power Demand



Equipment Info.

- Cost(initial, maintenance)
- Lifetime
- Efficiency
- Installable capacity

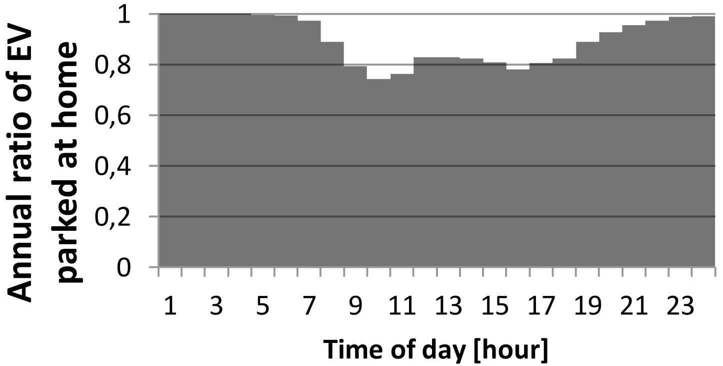
Grid Info.

- Cost
- CO_2 coefficient

EV Constraints

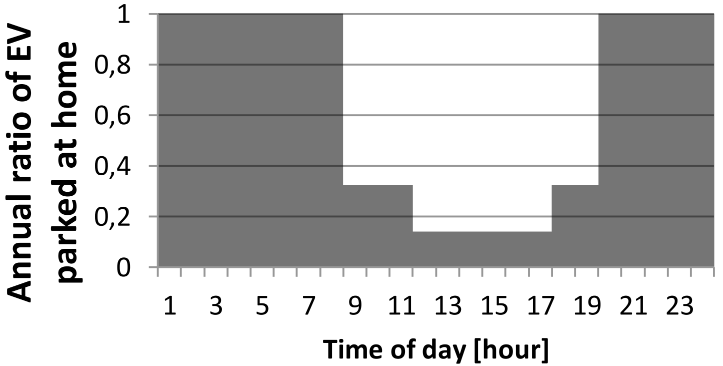
Non-Commuting EV

Annual power demand:
697 [kWh/year] (4881[km/year])



Commuting EV

Annual power demand:
1354 [kWh/year](9470[km/year])



EV can charge or discharge only at home at normal speed (3.3kW)

System parameters

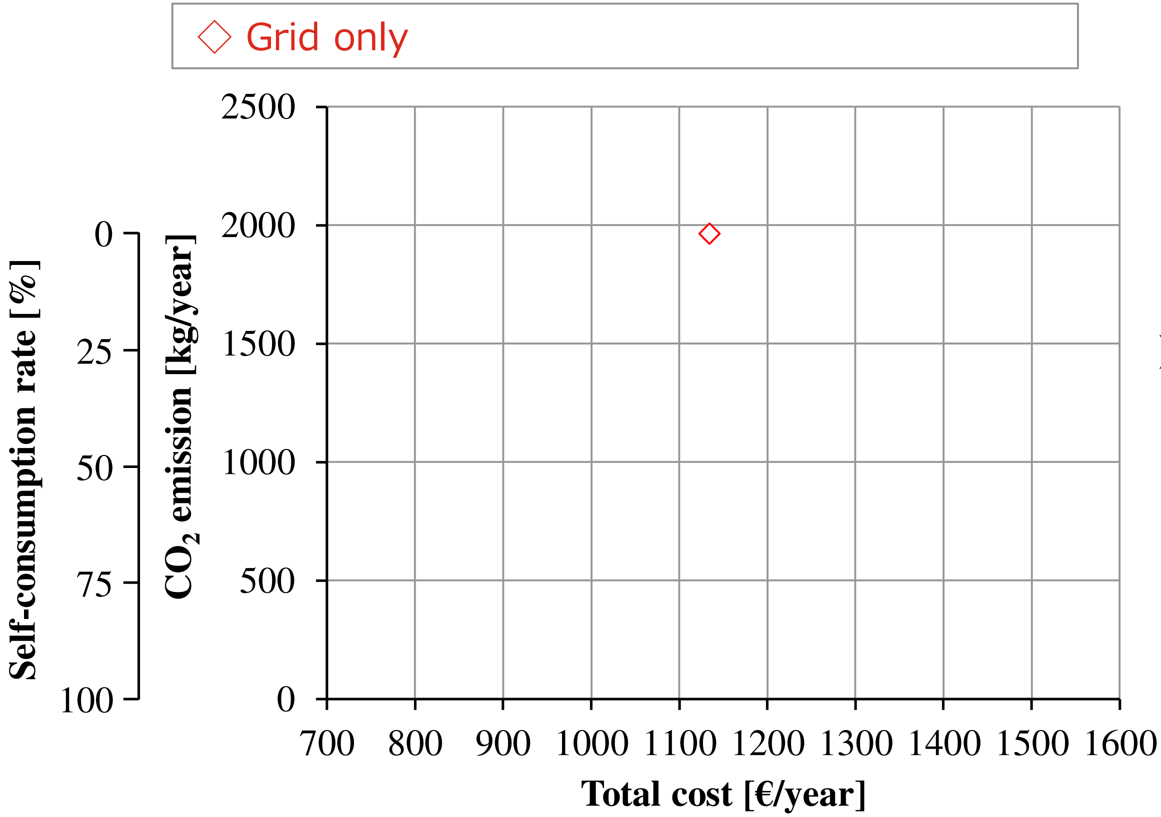
- The cost of V2H is assumed in **various scenarios**
- The cost of other equipment (PV & SB) and the CO_2 efficiency of grid power are assumed for 2030 (from Japanese targets etc.)

	Cost parameter of the equipment				installable maximum cap.
	initial	maintenance	life	Total annual cost	
V2H | current	3600[€/unit]	2[%]	10[year]	432[€/unit/year]	3.3[kW/unit]
V2H | 2/3	2400[€/unit]	2[%]	10[year]	288[€/unit/year]	3.3[kW/unit]
V2H | 1/3	1200[€/unit]	2[%]	10[year]	144[€/unit/year]	3.3[kW/unit]
PV	2064[€/kW]	1[%]	30[year]	89.44[€/kW/year]	10[kW]
SB	240[€/kWh]	2[%]	10[year]	28.8[€/kWh/year]	15[kWh]

	CO_2 efficiency	Purchase price	Sales price
Grid	0.37[kg-CO_2/kWh]	18.5[¢/kWh]	4[¢/kWh]

(constant values)

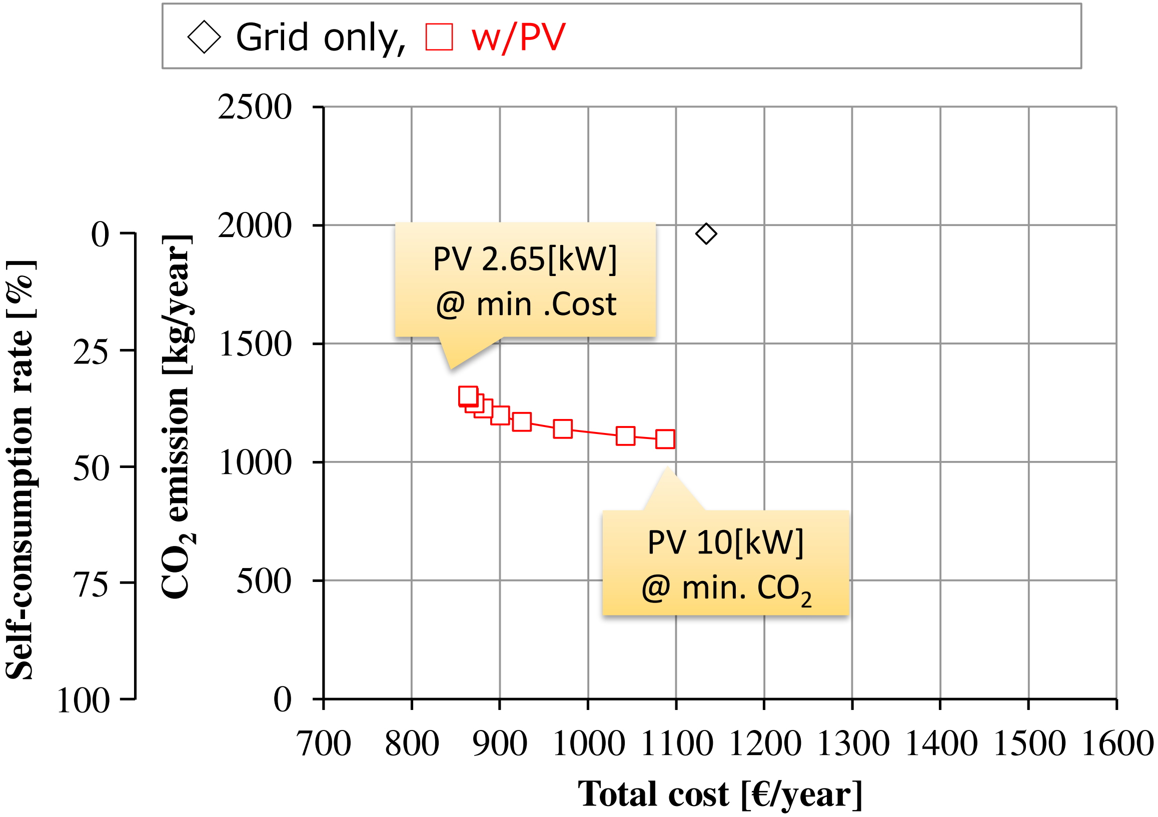
Result | Non-commuting EV owner’s house



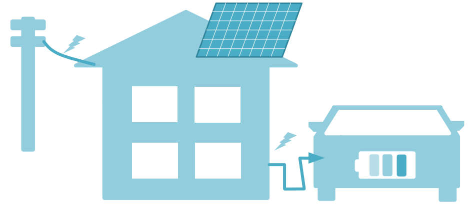
<Grid only>

- baseline for other conditions

Result | Non-commuting EV owner’s house

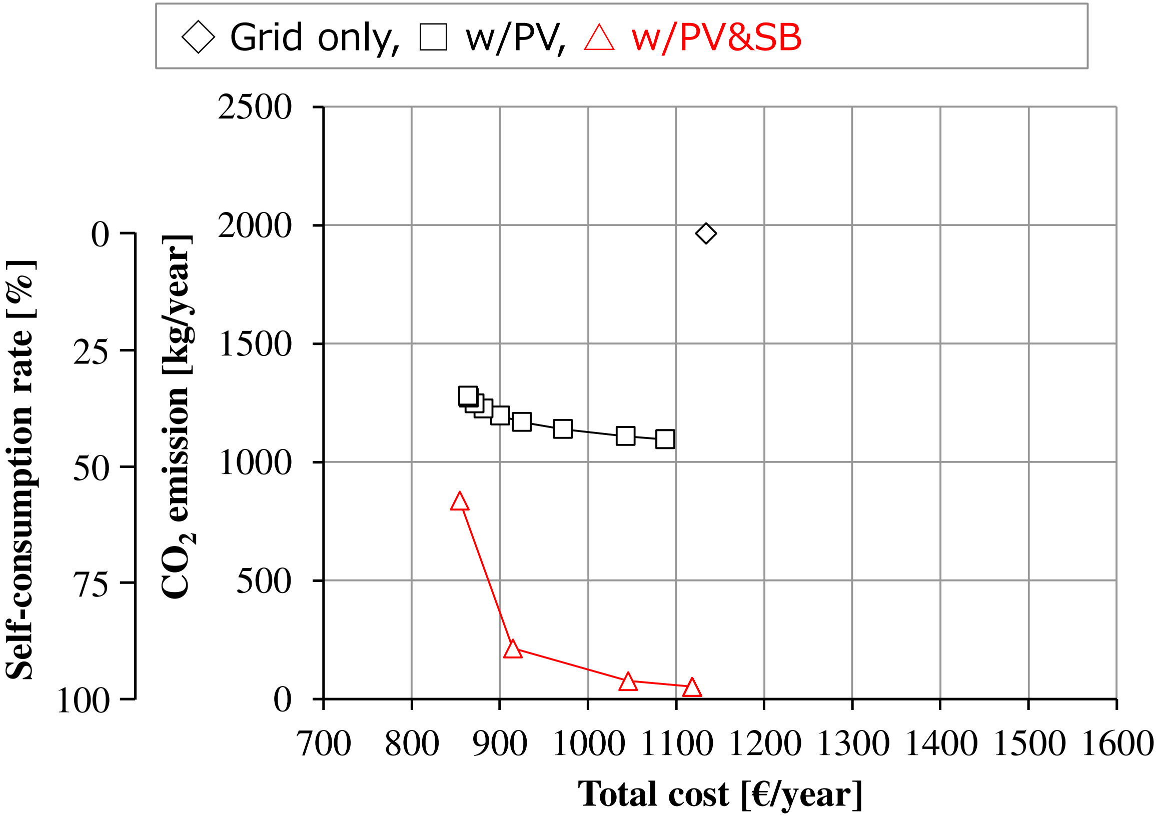


<w/ PV>

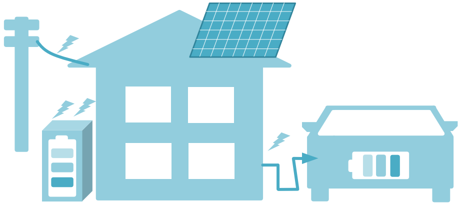


- PV power generation cost is 7.3 [¢/kWh] (if no excess); more economical than the purchase price from the grid.
- self-consumption rate is about 40%; PV and demand can be balanced in the daytime.

Result | Non-commuting EV owner's house



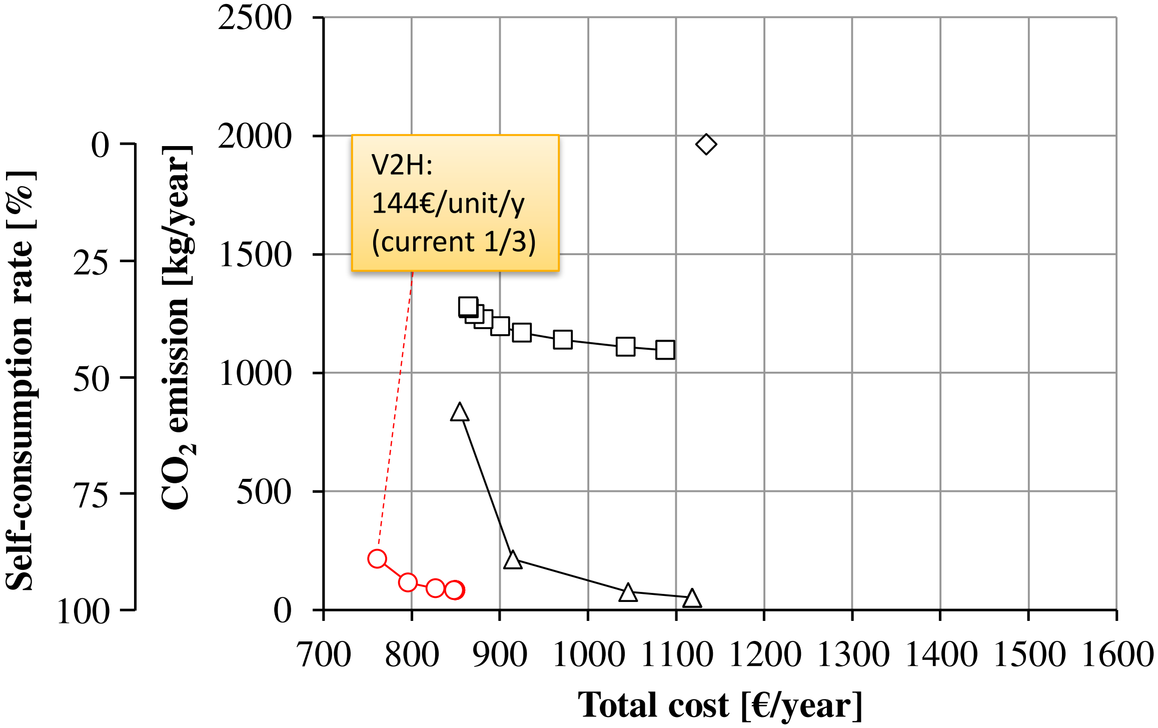
<w/ PV and SB>



- This system can produce environmental benefits at the same cost as <w/PV>
- SB and demand are balanced at night; the self-consumption rate increases—ranging from 60% to about 97%

Result | Non-commuting EV owner's house

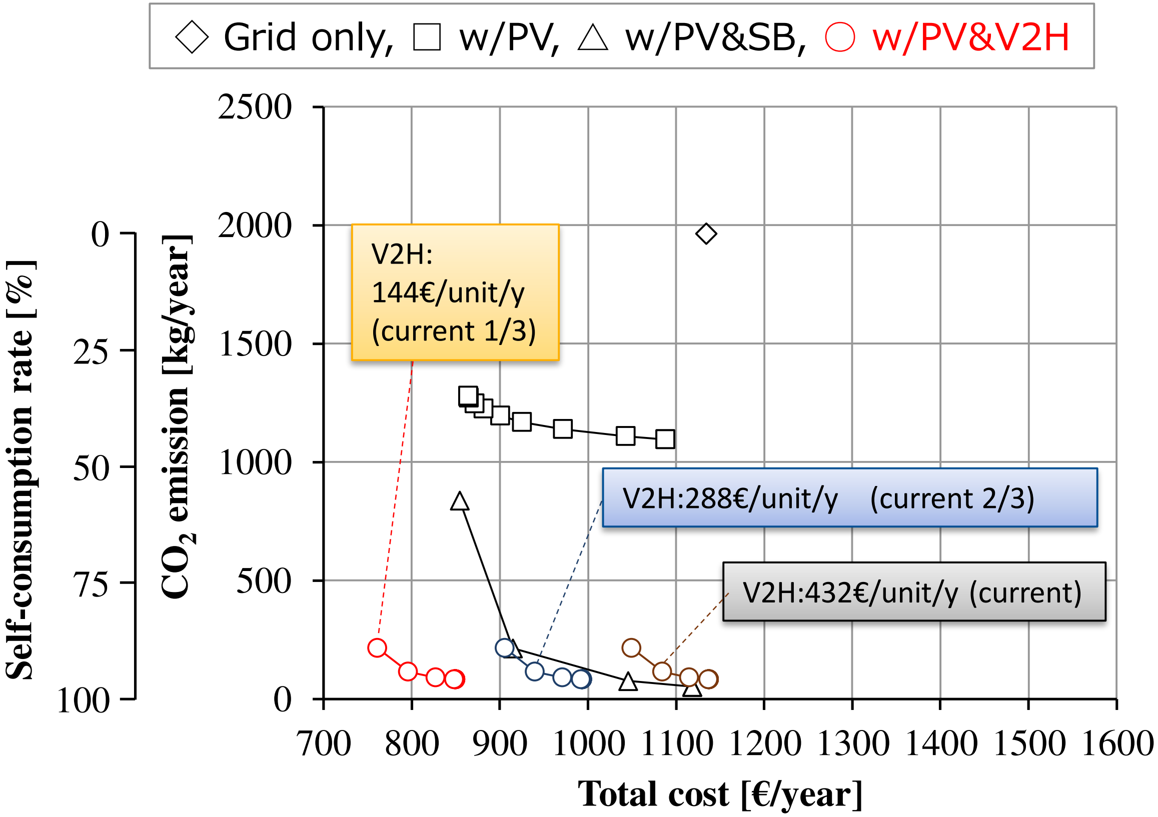
◇ Grid only, □ w/PV, △ w/PV&SB, ○ w/PV&V2H



<w/ PV and V2H>

- This system is environmentally and economically superior to <w/PV&SB> (if V2H cost is set to 1/3 current)
- The maximum self-consumption rate is slightly lower than SB but reached 90% or more.

Result | Non-commuting EV owner's house



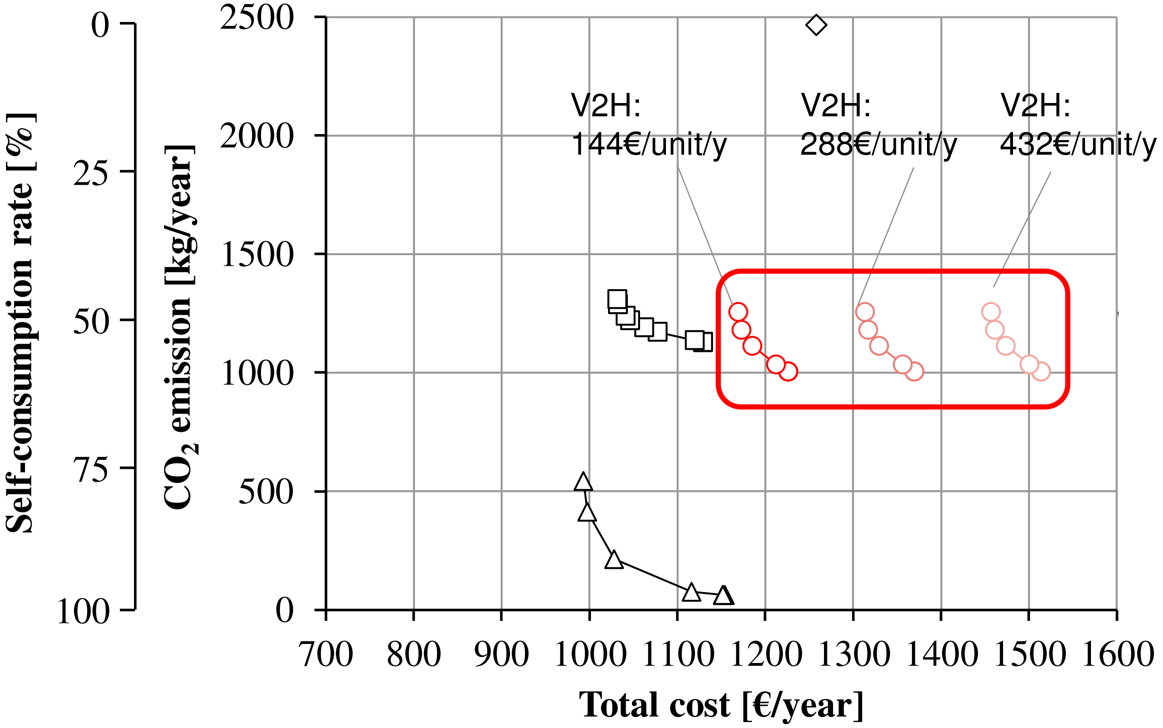
<w/ PV and V2H>

However...

- There is no advantage over SB at the current price (same level as SB at 2/3 price)

Result | Commuting EV owner's house

◇Grid only, □w/PV, △w/PV&SB, ○w/PV&V2H



- There are the same tendencies as in the non-commuting EV case for <w/PV> and <w/PV&SB>
- <w/ PV& V2H> has no advantage even if V2H cost is set to 1/3 of current
- Influence of absence during the daytime

Conclusion

- A multi-objective optimization method was developed to evaluate the economic and environmental performance of V2H
- Japan-based case studies were conducted:
- V2H system could be superior to SB in combination with non-commuting EV if its cost is 1/3 of the current cost
- In the case of a commuting EV, V2H does not work at all because the EV is absent during the daytime

Future work

- The scope of this study is limited; we will examine various other scenarios in the future.
- Considerations: the fluctuation of grid power's CO_2 rate and price, well-to-wheel, the cost of other equipment, the size of the EV battery, the charge / discharge power, etc.

Thank you for your attention !