

# Cooperative Social Service design utilizing distributed resources with IoT devices

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# Kenji Tanaka

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## Academic Background

1998 the Univ. of Tokyo  
2000 the Univ. of Tokyo  
2009 the Univ. of Tokyo

B.E. in Naval Architecture  
M.E. in Information Engineering  
Ph.D in Systems Innovation

## Business Background

2000 McKinsey & Co., Management Consultant  
2003 Japan Industrial Partners, Private Equity Fund, Vice president  
2006 the Univ. of Tokyo, Research Associate  
2008 , Assistant Professor  
2013- , Project Associate Professor  
2019- , Associate Professor

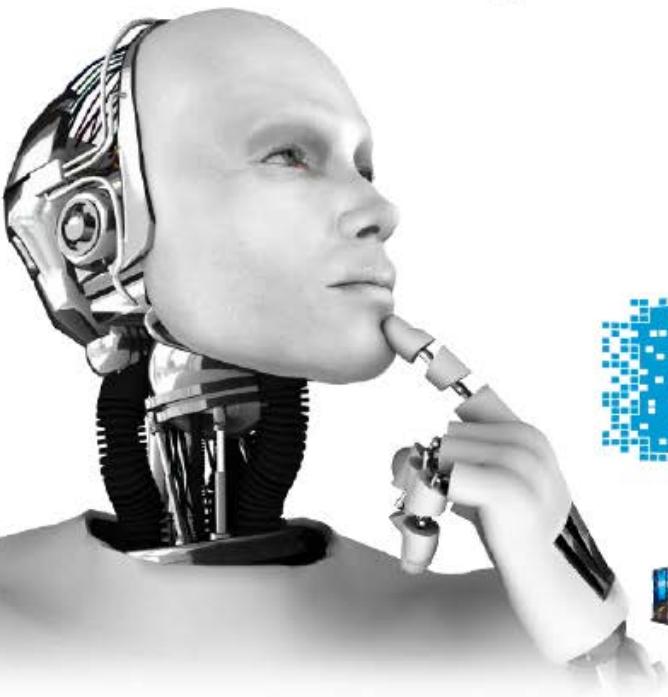
Research field; Logistics and Energy,

Policy advisor for Minister of MLIT (2011-12)

Advisory committee member for METI on Future Energy Network Design (2015-)  
IPCC LA

# Applying New Enabling Technologies to the Society

## DigitalGrid

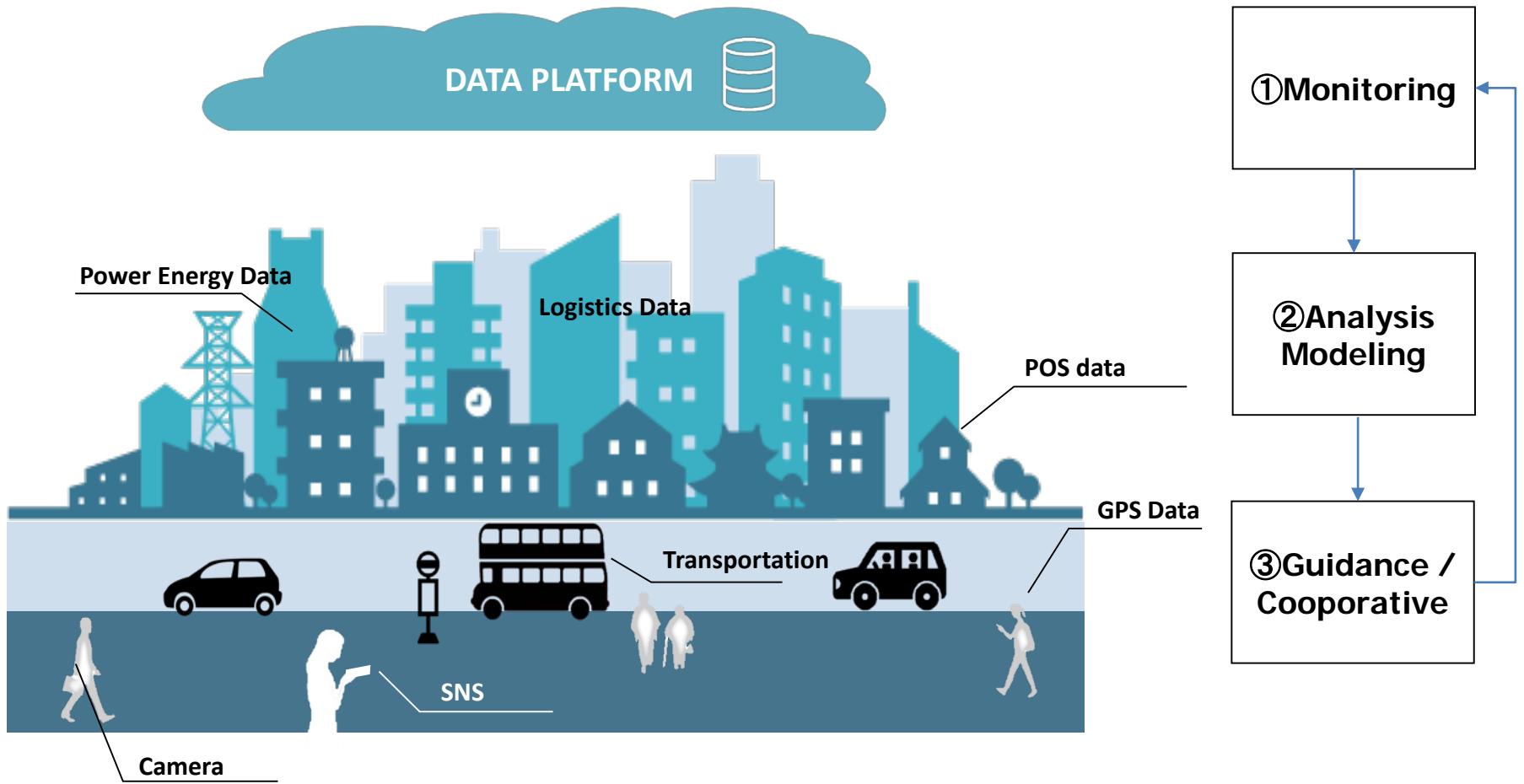


BLOCKCHAIN



# Applying New Enabling Technologies to the Society

Optimization of social systems starting with IoT sensor networks



# What is happening in Social Infrastructure?

A case of Energy industry

# Distributed Resources is emerging

Centralised Generation



Distributed Generation



Source: Risø

30 years ago

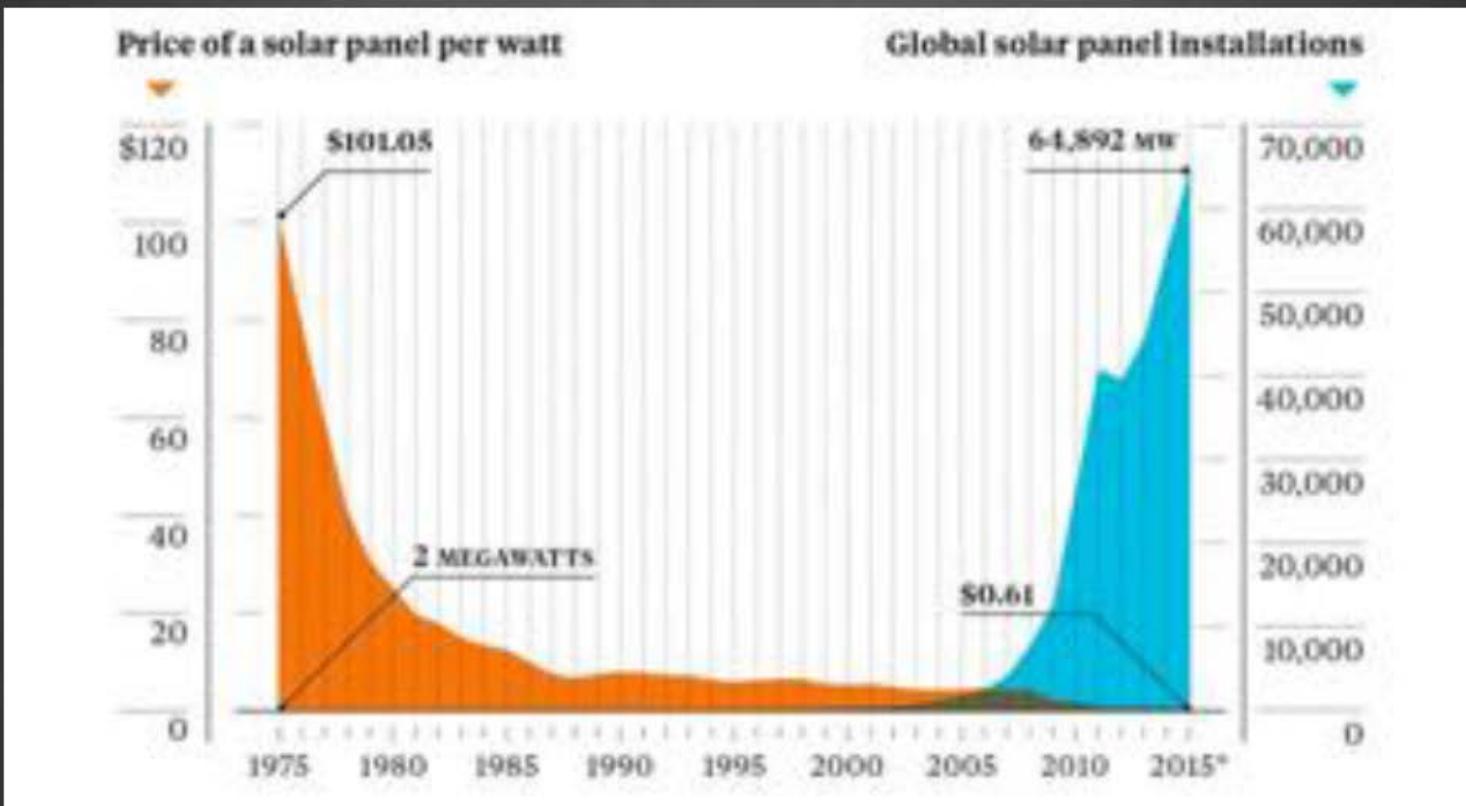
Present

Wind 2010: x4 times larger than forecast in 2002

Solar 2010: x5 times larger than forecast in 2002

# Destructive Power of Marginal Cost ZERO

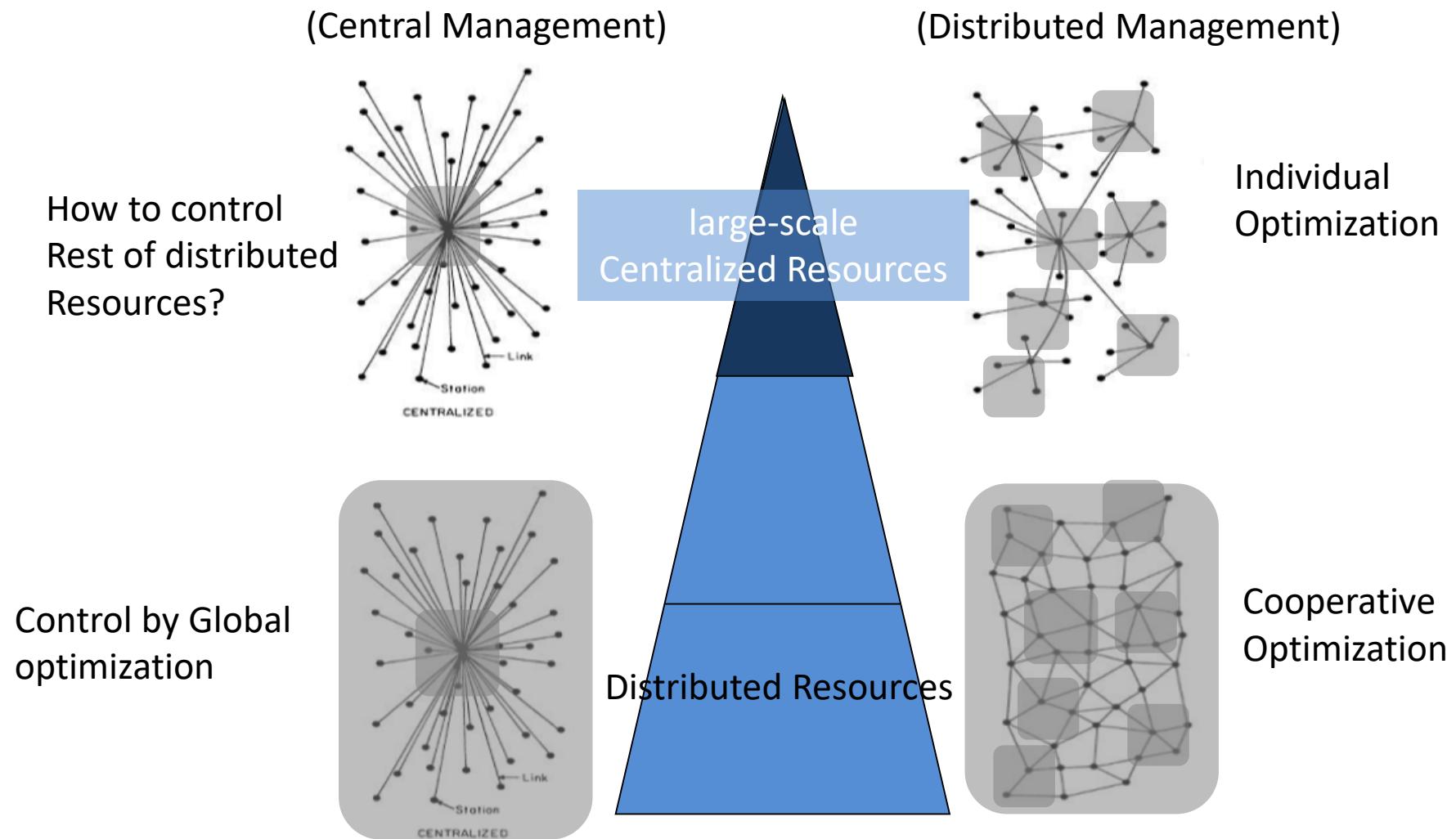
Consumer and Economic Power Driven Shift



Source: Bloomberg New Energy Finance

Increasing uncertainties for balancing

# Distributed Cooperative System Design



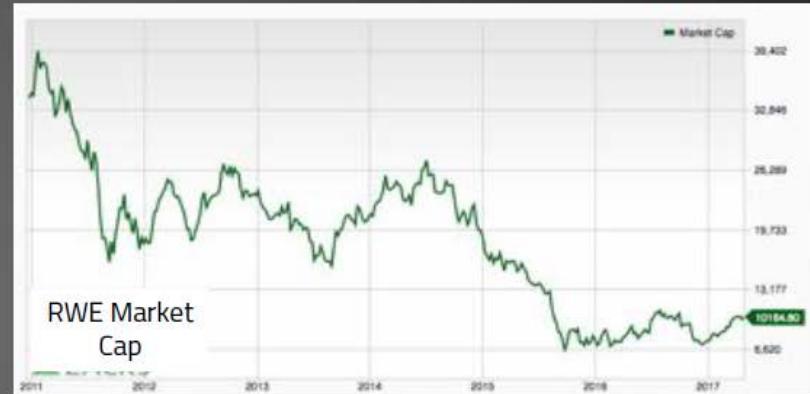
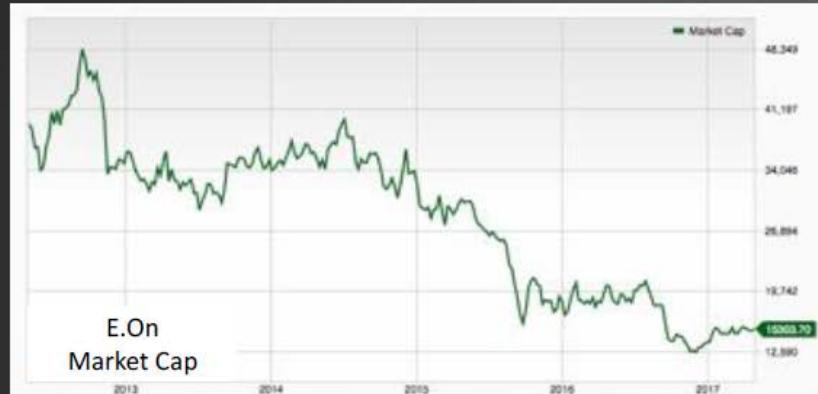
What is a good strategy against changing?

Accelerate it?

Prevent it?

# Clear Messages from Capital Markets

Utility business model must change



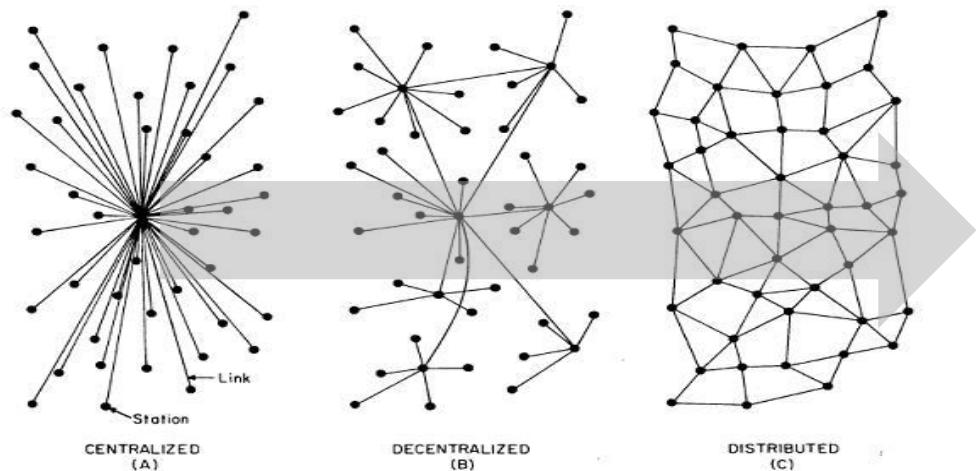
Losses exceed **\$135B**

Market cap decrease of over **80%**

Source: Zacks Investment Research

# Internet of Energy at UTokyo : IoE

- The future grid will have millions of consumers and prosumers interacting each other bi-directionally.



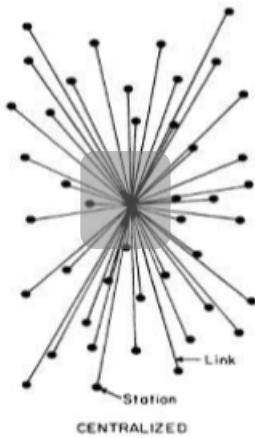
“the Internet of Energy”



- It is not feasible for centralized system to manage the balance of millions of users and generators.

# Challenges of centralized systems and utilization of distributed resources

centralized management  
global optimization



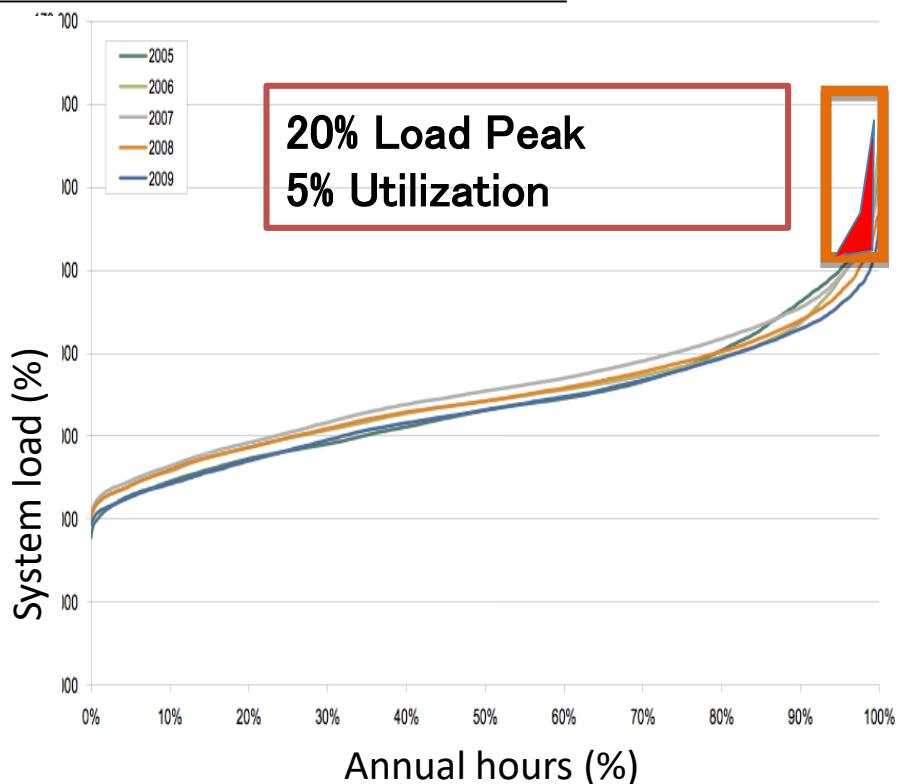
Centralized  
Cooperative

reliability	efficiency	Available resources	supply cost	
◎	◎	▲	▲	limit
▲	▲	**◎	◎	◎

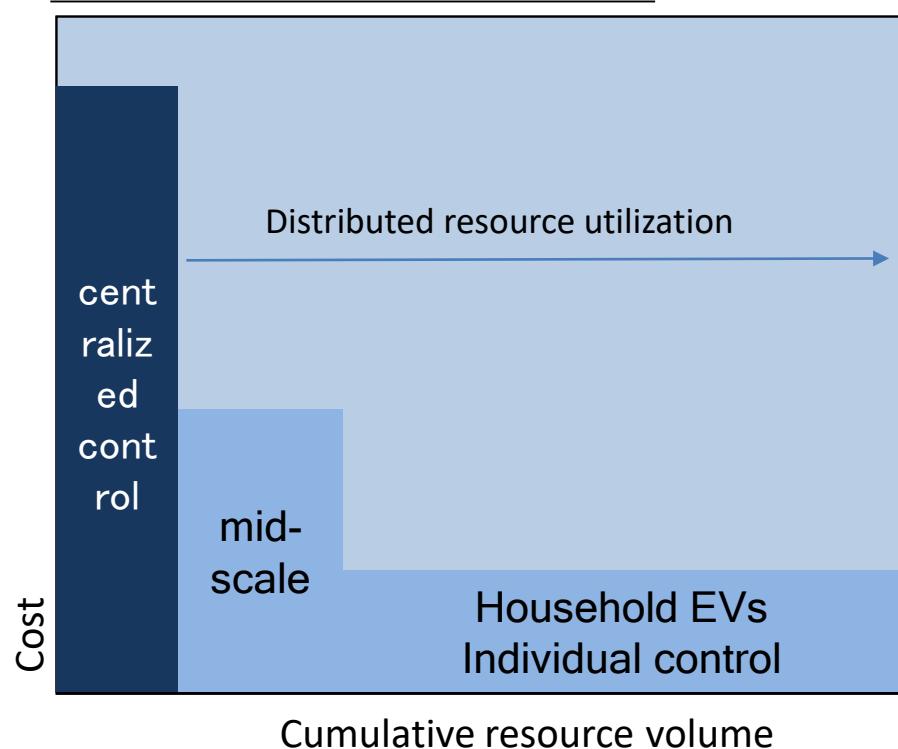
\*Utilization of distributed resources for overall optimization requires coordination with individual control

# Potential for Distributed Resource Utilization

## System Load Peak Distribution



## Expansion of available resources



# Harmonizing distributed energy facilities is inevitable



Orchestra



Modern Jazz



Hard Rock

## Government driven approach

Strict policy control all participants  
based on the long-term planning

## Market mechanisms approach

harmonized power-grids  
Allow energy access for all

→Approach of this study

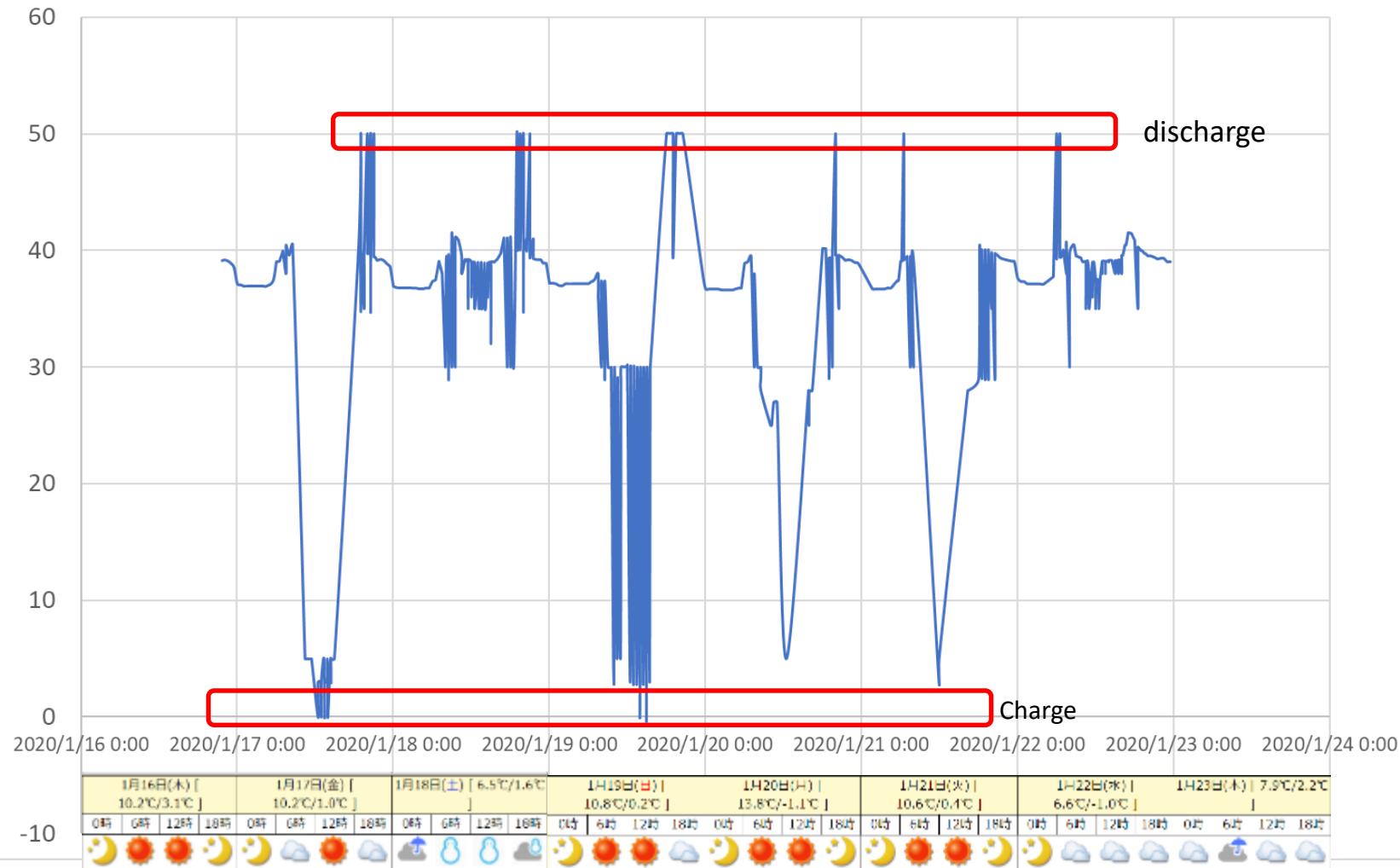
## Fragmented local approach

independent policies  
Best-fit local solutions

# Market Mechanism

Price Trend of Energy[¥/kWh]

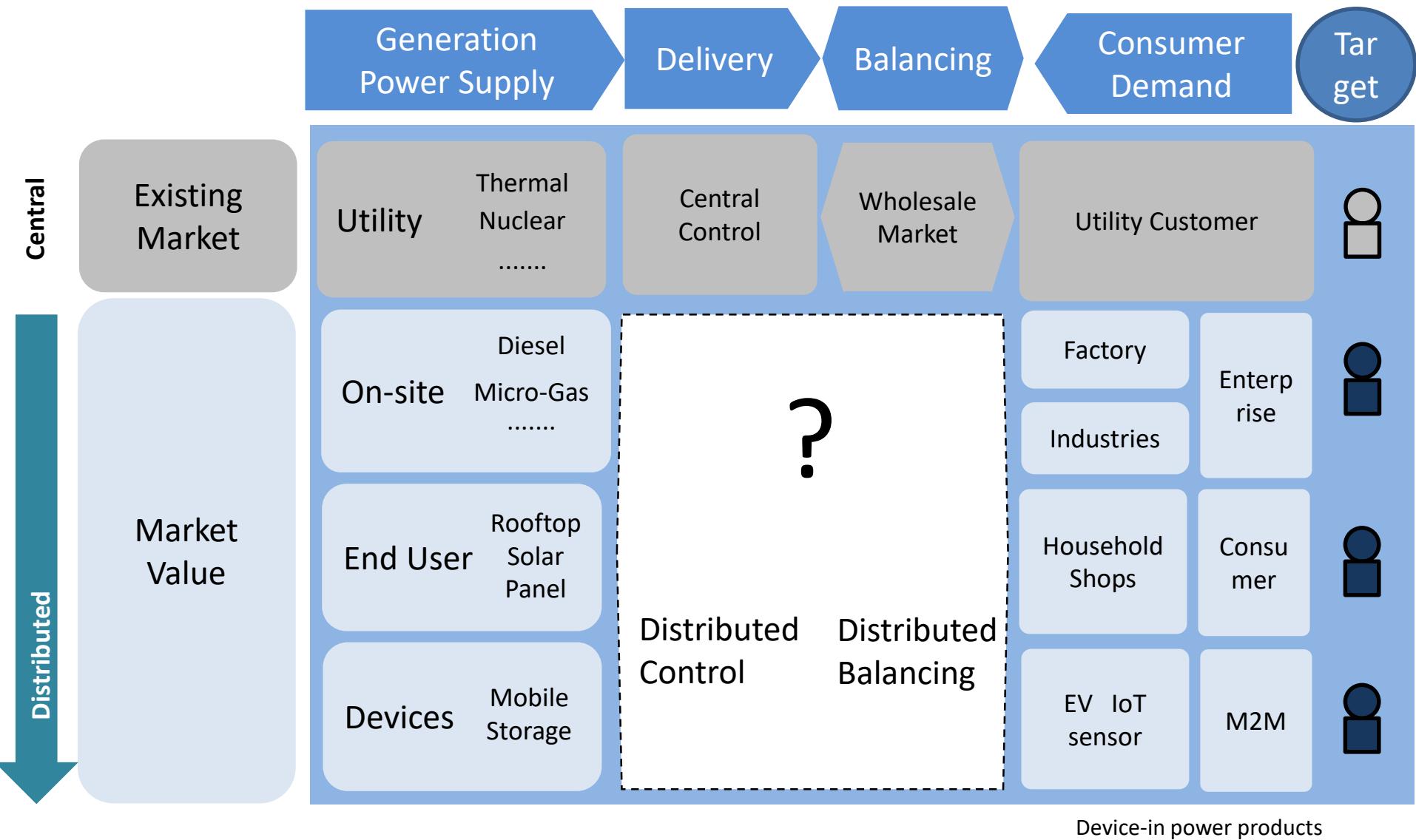
約定単価



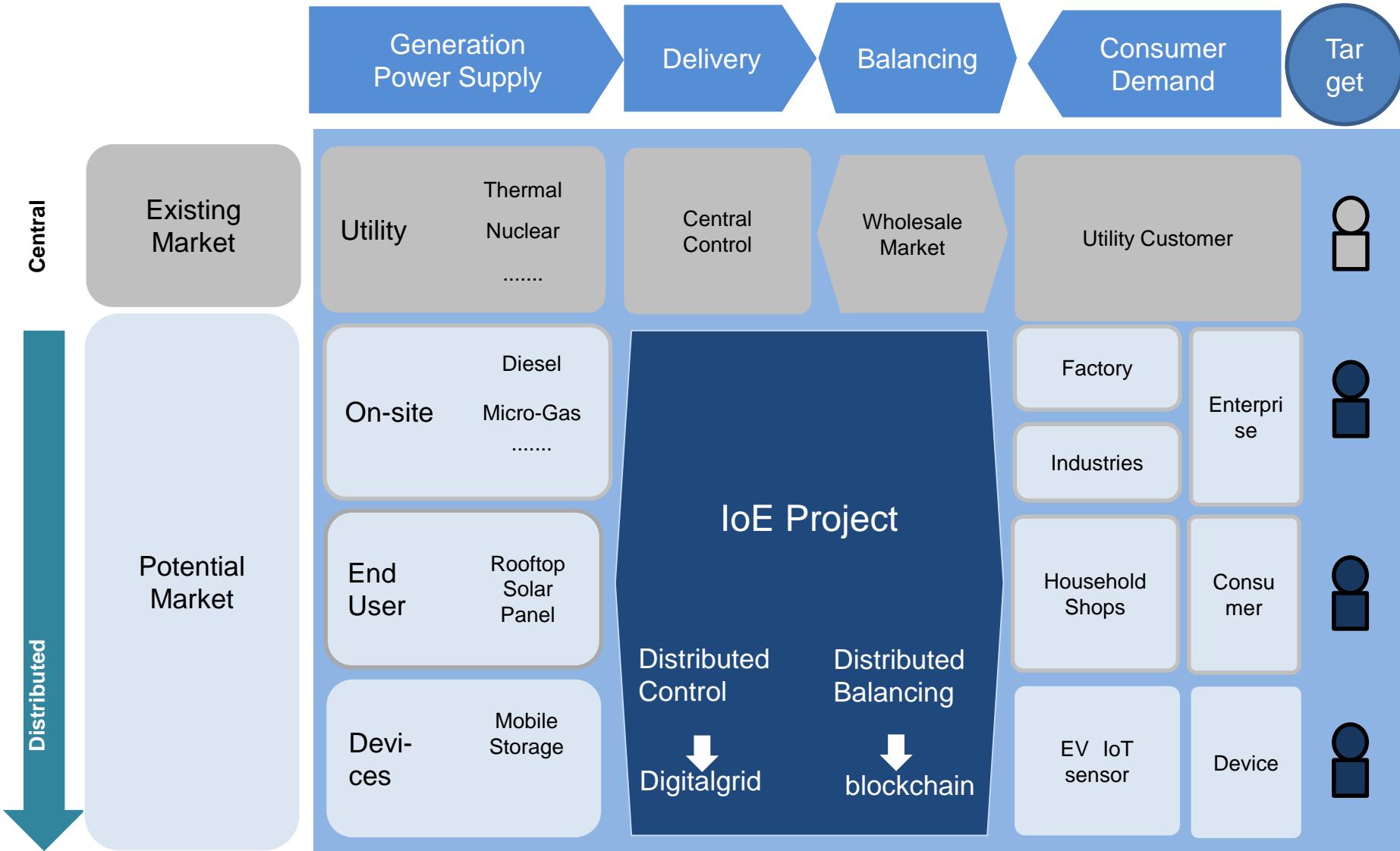
# How to obtain potential market?

Achieving decentralized resources is very important

## Power Service Delivery System



# What is lacking for Harmonizing mechanism ?



# Distributed Cooperative System Design Studies



Advances in  
Sensing technologies  
Communication technologies  
Data analysis technologies

have enabled us to design  
distributed cooperative system  
in the 2010s

# Objectives and Approach

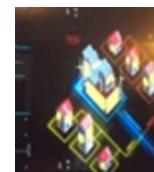
## Objectives

The development of market-based decentralized electricity trading system to realize the internet of energy grid system.

## Approach

- Let each user choose and purchase electricity by their strategy
- Blockchain-based electricity trading system as an underlying platform
- Auto-power delivery is done with digital-inverter  
DGR ( Digitalgrid router) and DGC (Digitalgrid controller)

# Blockchain projects in the world and IoE UTokyo

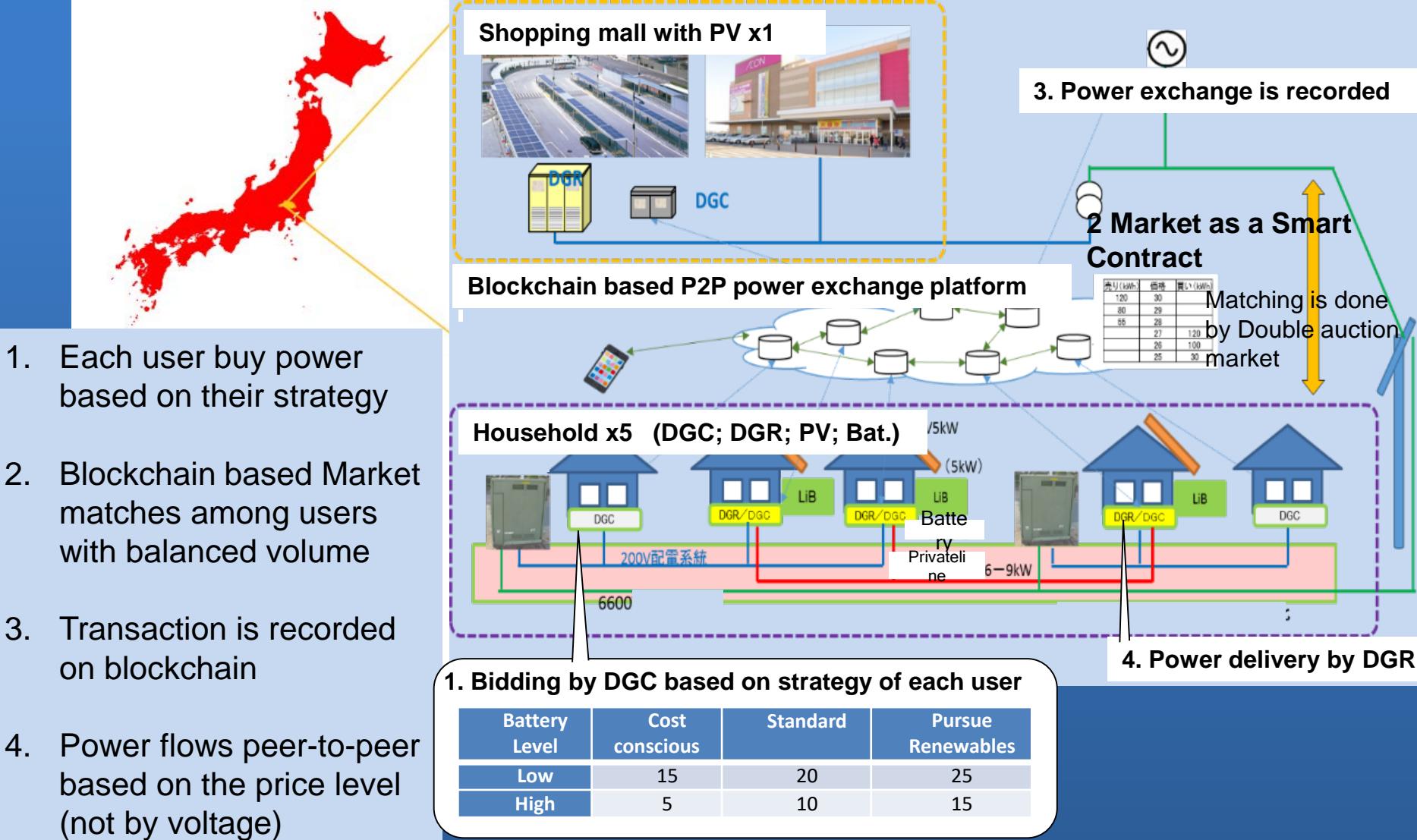
		P2P Matching	Power Control	
Scott (2017,USA)	Brooklyn Microgrids LO3 energy	n/a w/Block Chain n/a	n/a BEMS	
PowerLedger (2017,AUS)	Power Ledger	Record w/BC	n/a	
Faizan (2018,Ger)	D3A Energy Web foundation	w/Block Chain	n/a	
Varga (2018,GB,SIN)	Cranfield University, LBS	Double Auction	n/a	
Werth (2018) Abe(2009)	Open Energy System Digitalgrid (Japan, UTokyo)	n/a	P2P exchange by DC Power Flow	
IoE Project	UTokyo	Market w/Block Chain	P2P exchange with Digitalgrid	

Few projects deal with both P2P matching and Power control.

# 1<sup>st</sup> Project Misono project P2P power exchange

P2P Autonomous Power Control is enabled with IoT devices and Blockchain System

## Urawa-Misono Project (2017-2019)



# User preferences and bidding Algorithm

## A Prosumer



Cheaper energy!

Renewables!

Local produced energy!

Obtain profit from energy trading!

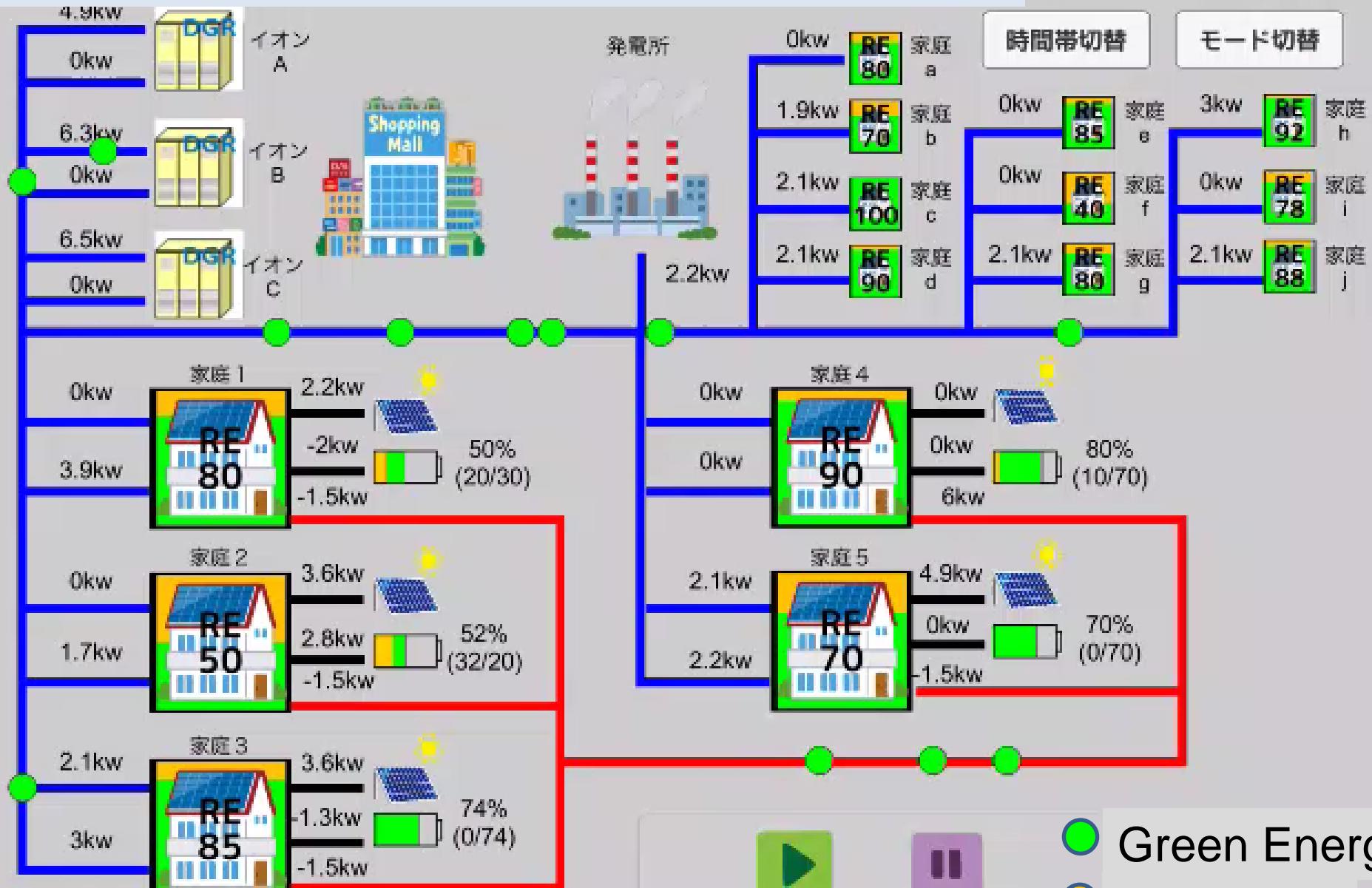
## B EV User



Utilize car batteries when it is parked

Charge when price is lower than 10cents

# 1 Misono Project Overview of Energy transaction 17/09/28 14:26

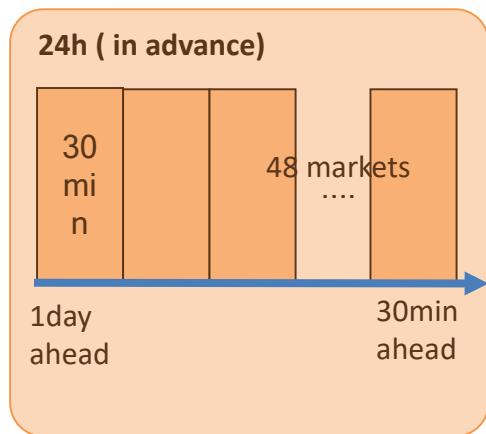


Household Consumers w/  
Solar Panel Buttons

Green Energy  
Grid Energy

# Market Algorithm: Double auction matching

## Power Markets



## Double Auction Matching

2017/09/28 14:30~15:00 market

最終更新時刻 18:26:05

SELL	PRICE	BUY
16	OVER	
3	21	
30	20.8	
15	20.7	
12	20.6	
10	20.5	
20	20.4	
10	20.2	
20	20.1	
	19.9	40
	19.8	5
	19.7	10
	19.6	50
	19.5	20
	19.4	9
	19.3	4
	19.1	12
	UNDER	18

## Balanced Units

Each unit of matching result has a set of seller and buyer with a same amount.

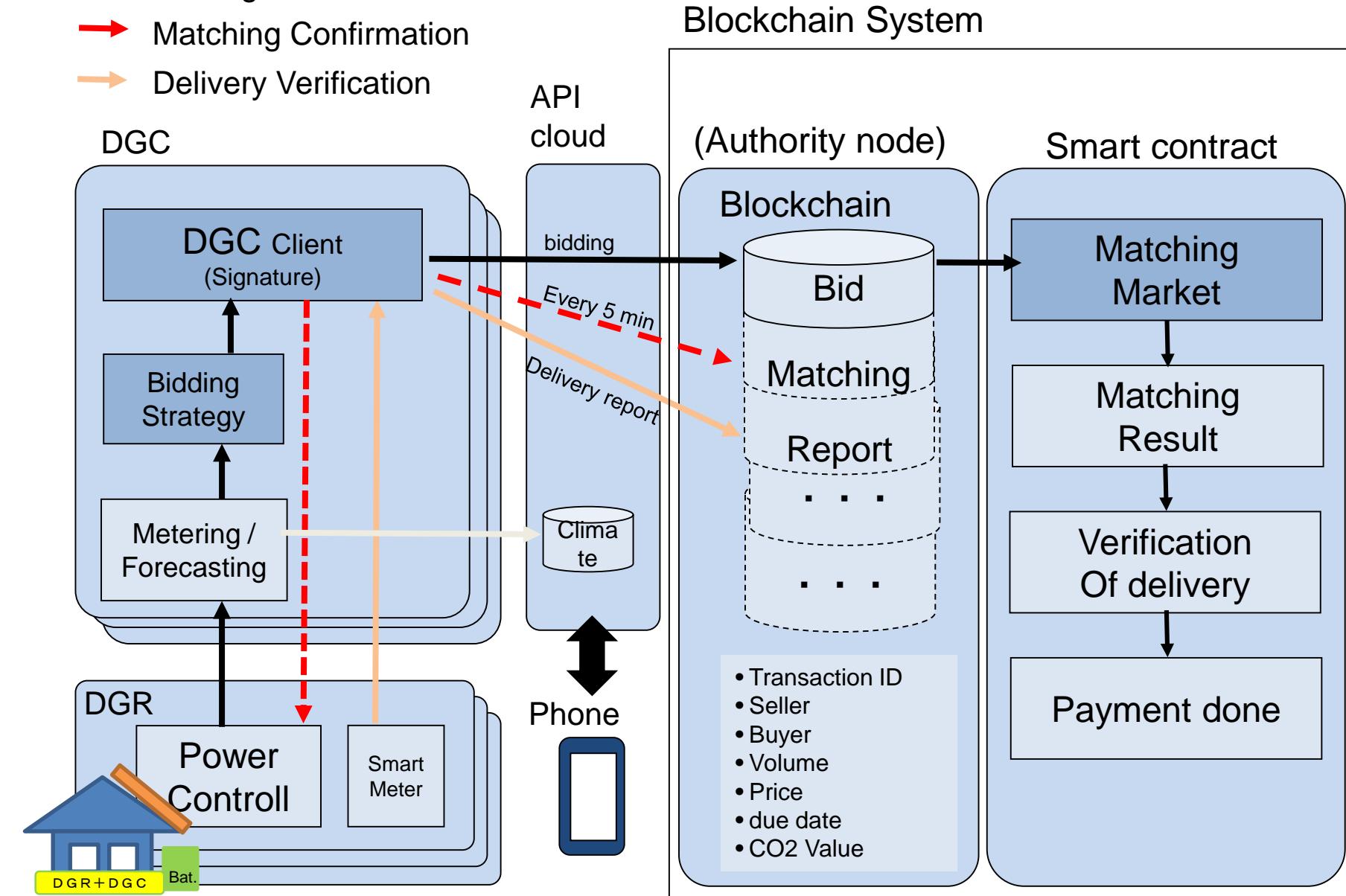
Seller	Buyer	Amount
User 1	User 5	1.0 kWh
User 11	User 2	1.2 kWh

Accumulated flow of balanced units is balanced between supply and demand.

1円/weiで計算しています

# System Overview

- Bidding Process
- Matching Confirmation
- Delivery Verification



# MISONO Project: Real Scale Demonstration



# MISONO Project: Real Scale Demonstration



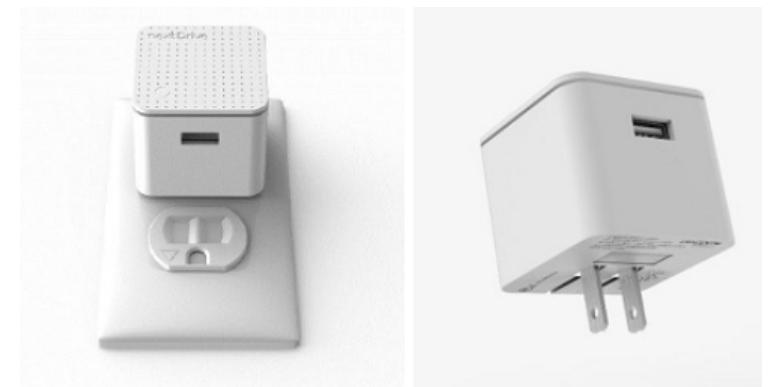
# MISONO Project: Real Scale Demonstration



# IoT devices: Digitalgrid Controller and CUBE



Source:Tessera



「Cube J1」 Source:Next Drive

# ① Measurement and bidding

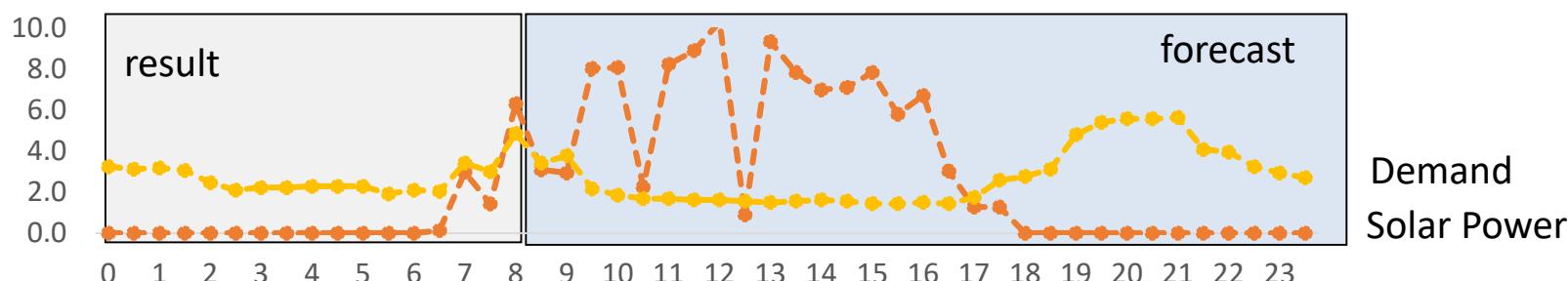
## ①-1 Smart-metering and forecasting

forecast	13:30	14:00	14:30	.....	...
PV[kWh]	-	+1.5	+1.0		0.5
Demand[kWh]	+0.5	+0.5	+1.5		0%
SOC [%]	50%	30%	40%		0%

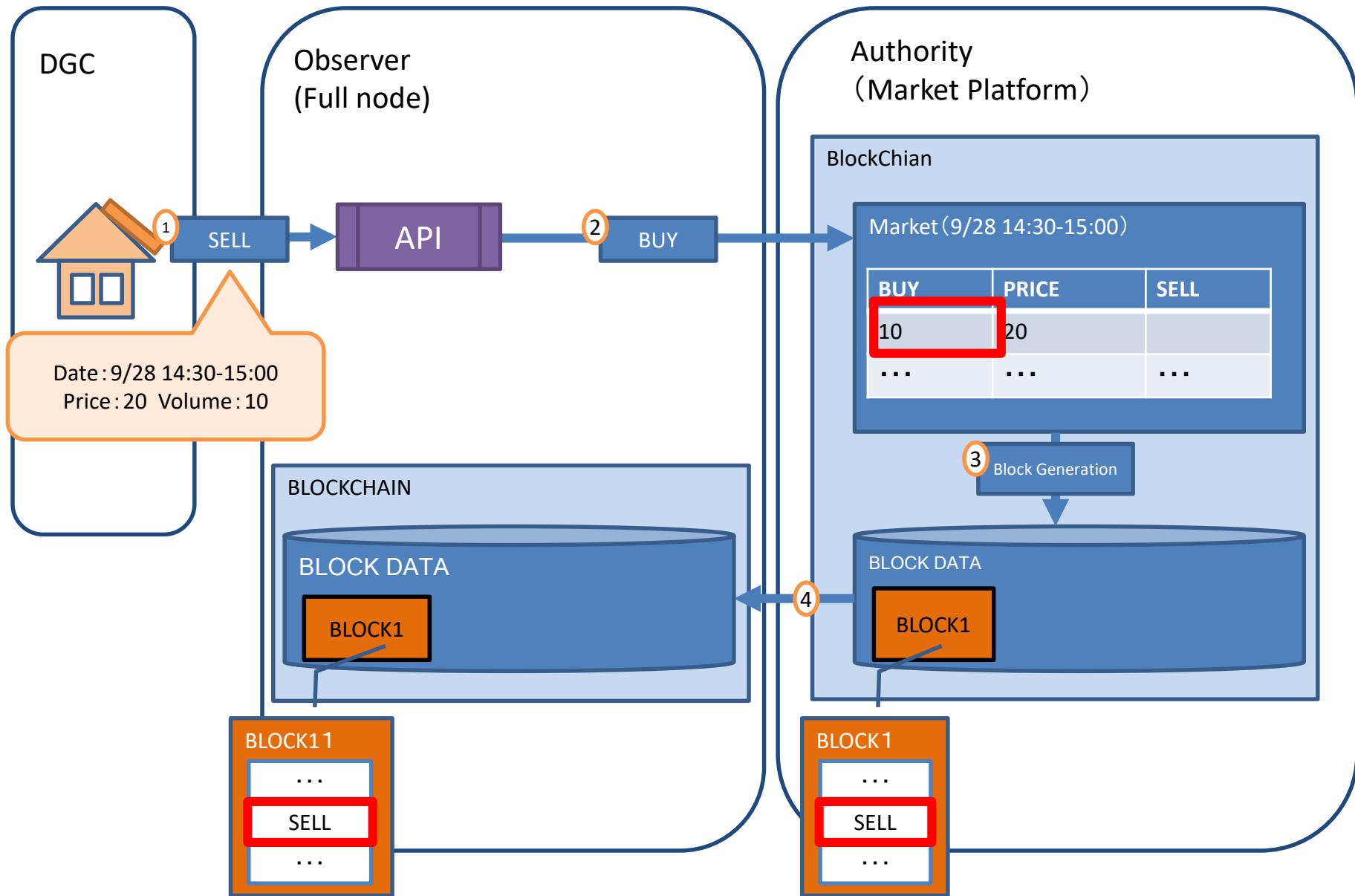
## ①-2 bidding is done

SOC(%)	SELL	BUY	Amount
30%	-	25	1.0
40%	30	20	1.0
50%	20	10	1.0
60%	15	5	1.0
70%	10	-	-

## (Forecasting)

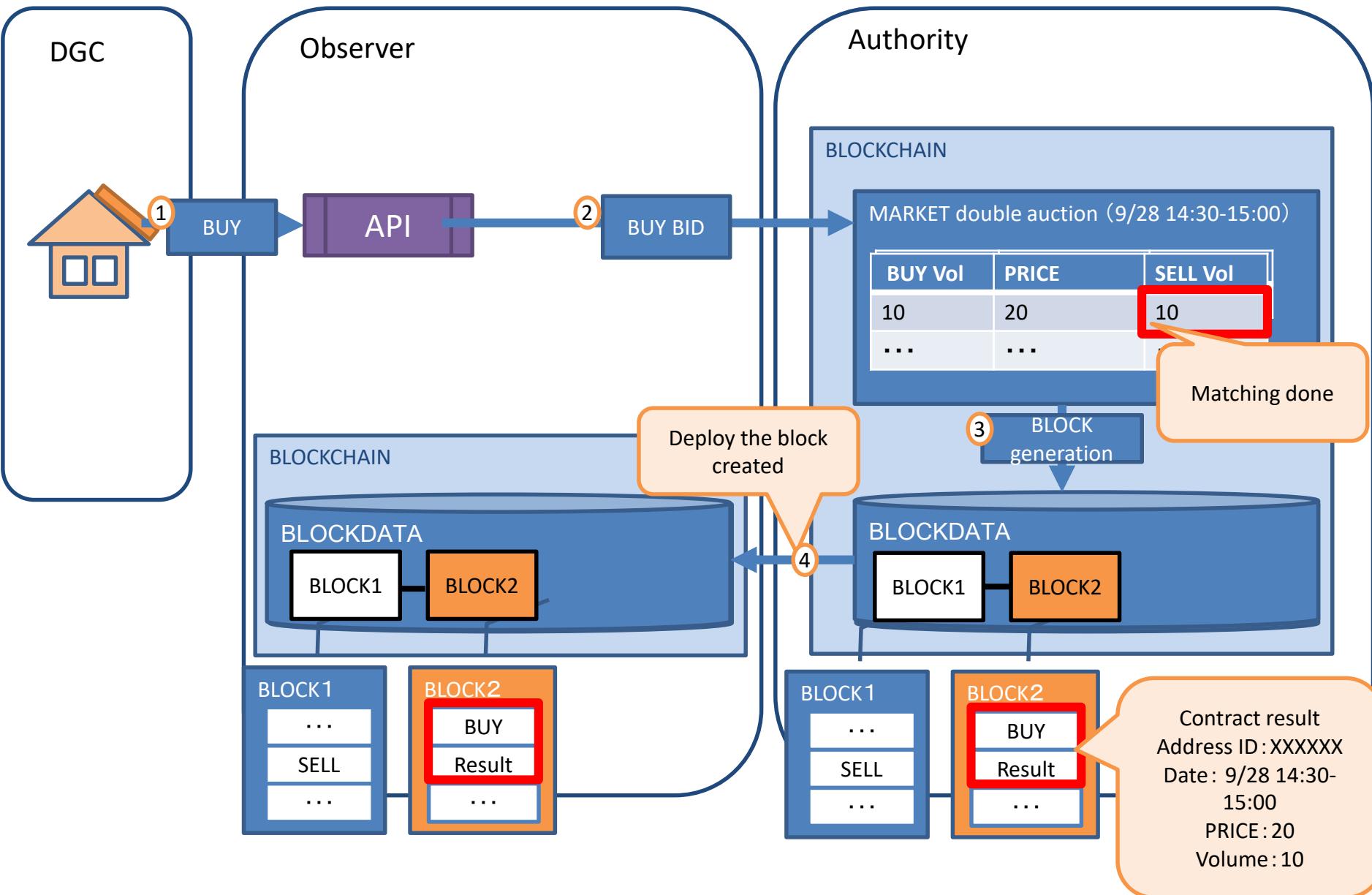


# ① Bidding for Blockchain

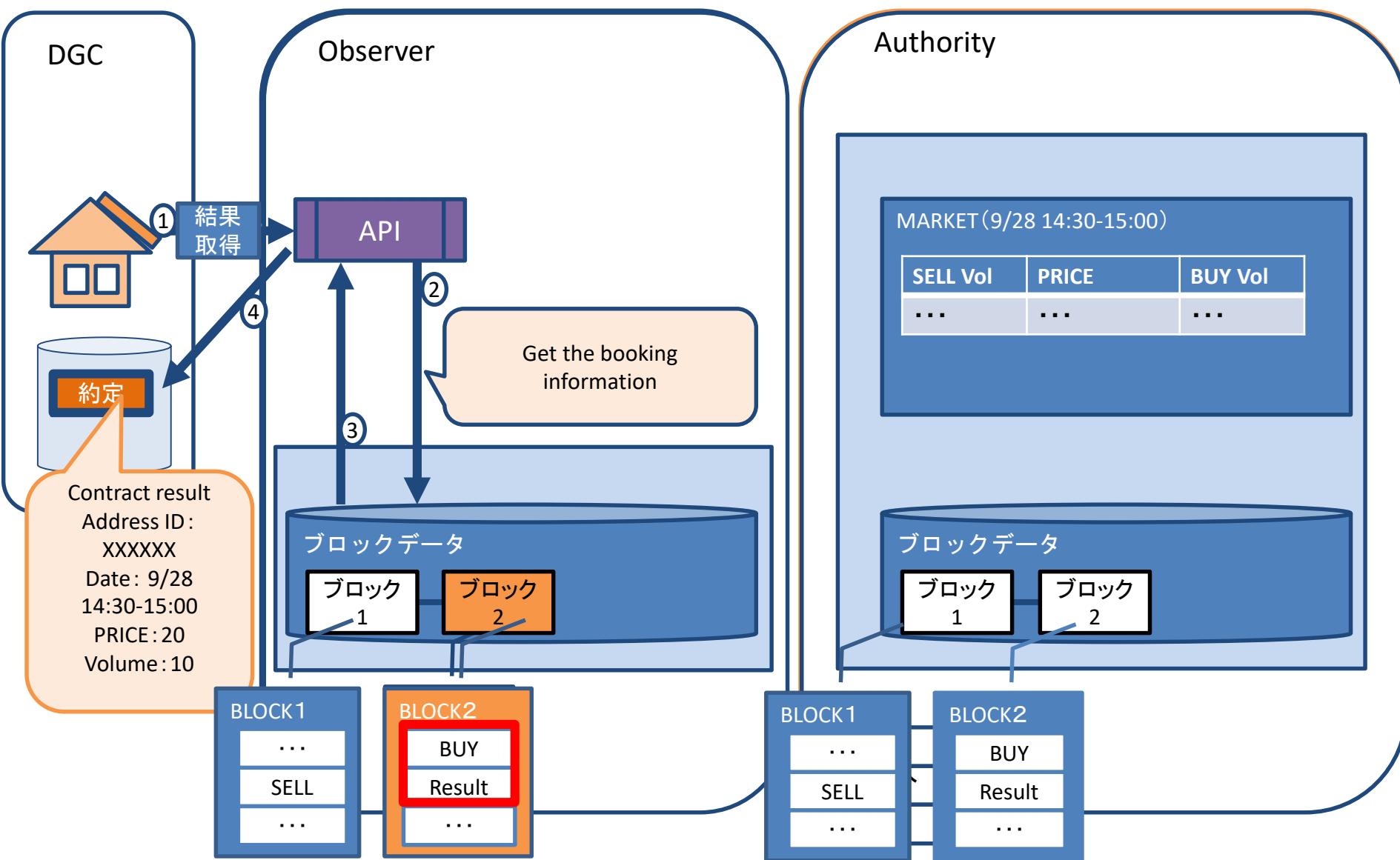


## ② Matching and Recording Results :

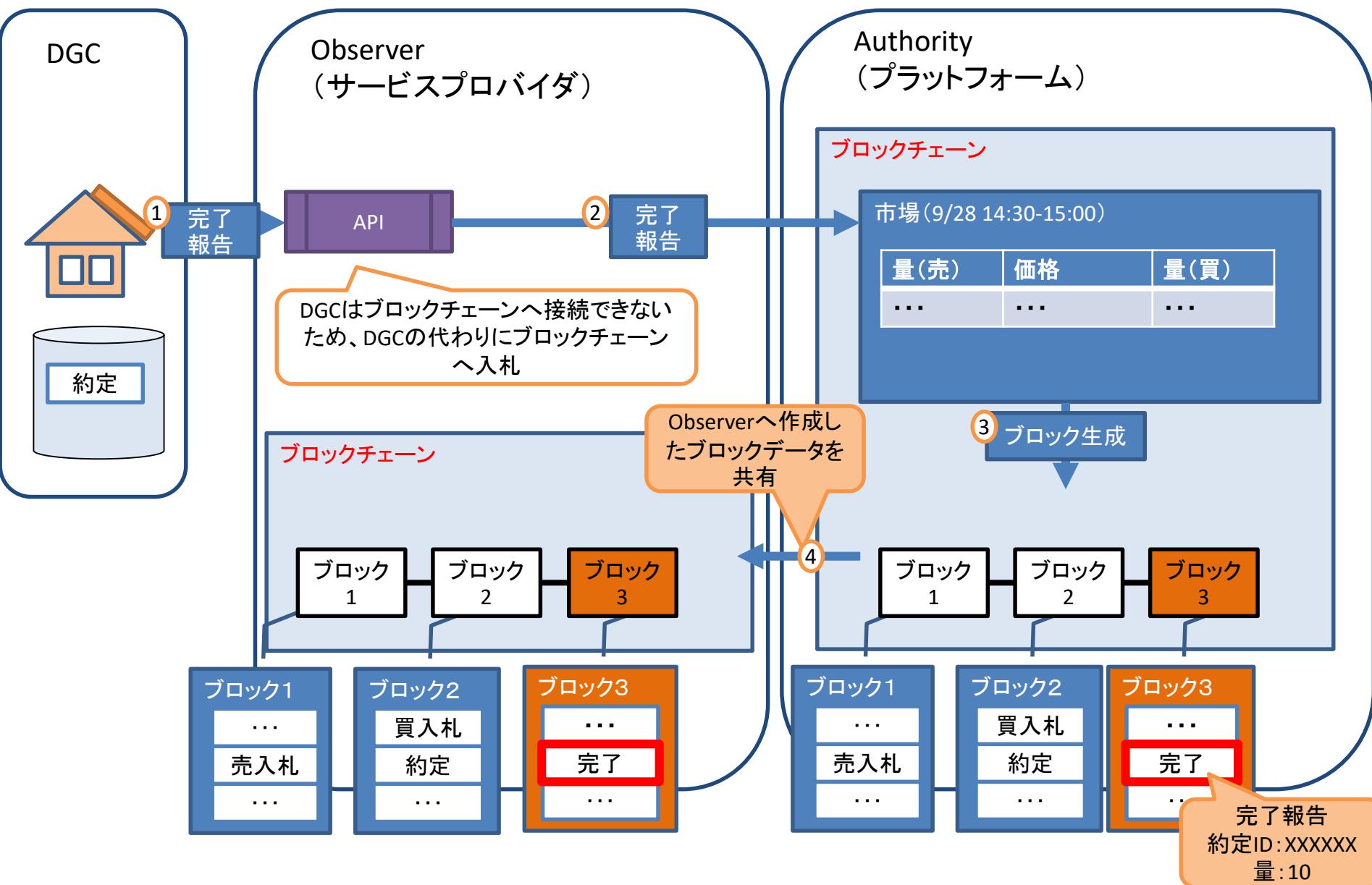
Executed on the blockchain market and booked on the block



### ③ Preparation for Power Exchange at Local IoT Devices



## ⑤Verification by SmartMeter Log

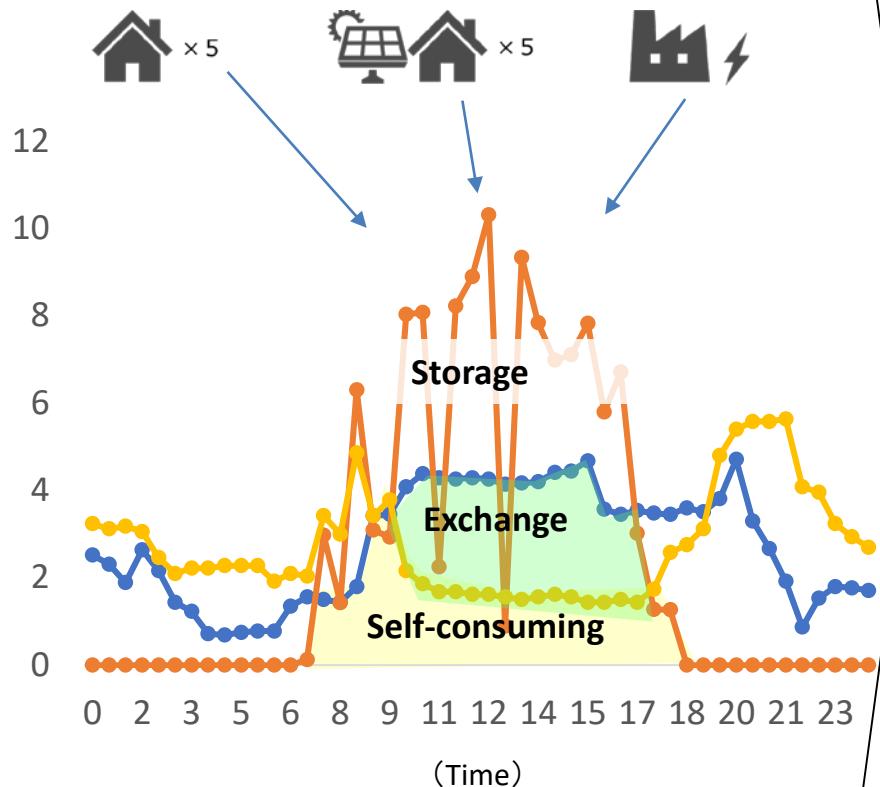


# Case Study: Misono case

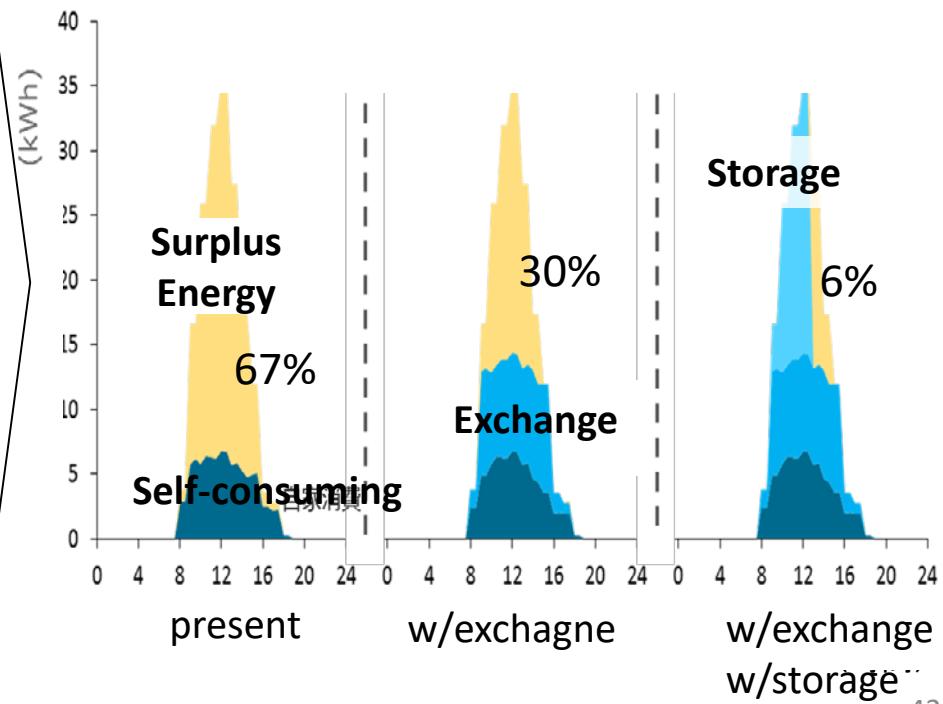
## A simulation result of Urawa-Misono case

### Power trend of demand and supply in a day

(household ; shop ; Solar) (kWh/30min)



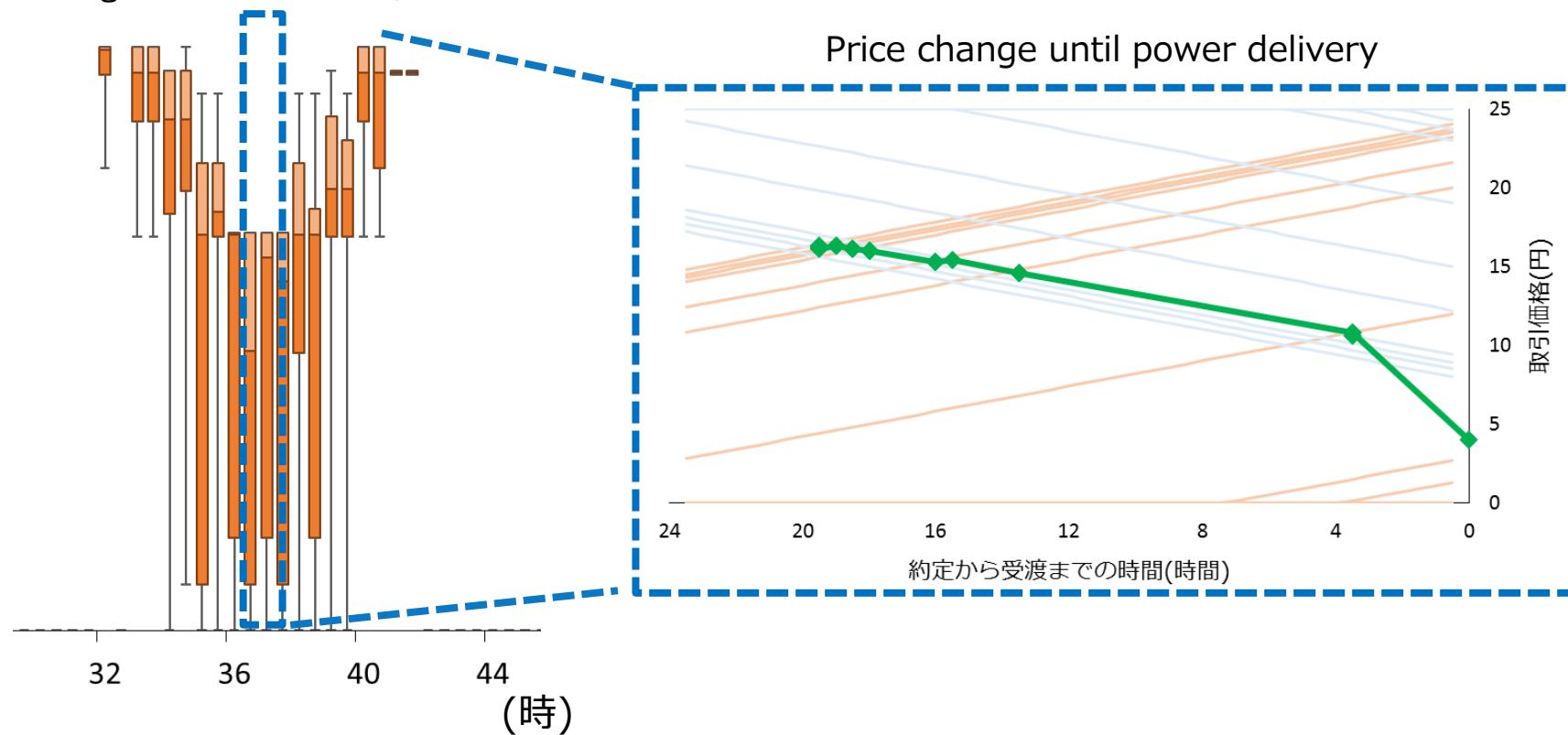
### Simulation result of Surplus Energy in a day



# Price trend (Sufficient supply case)

## Power Price trend of a day

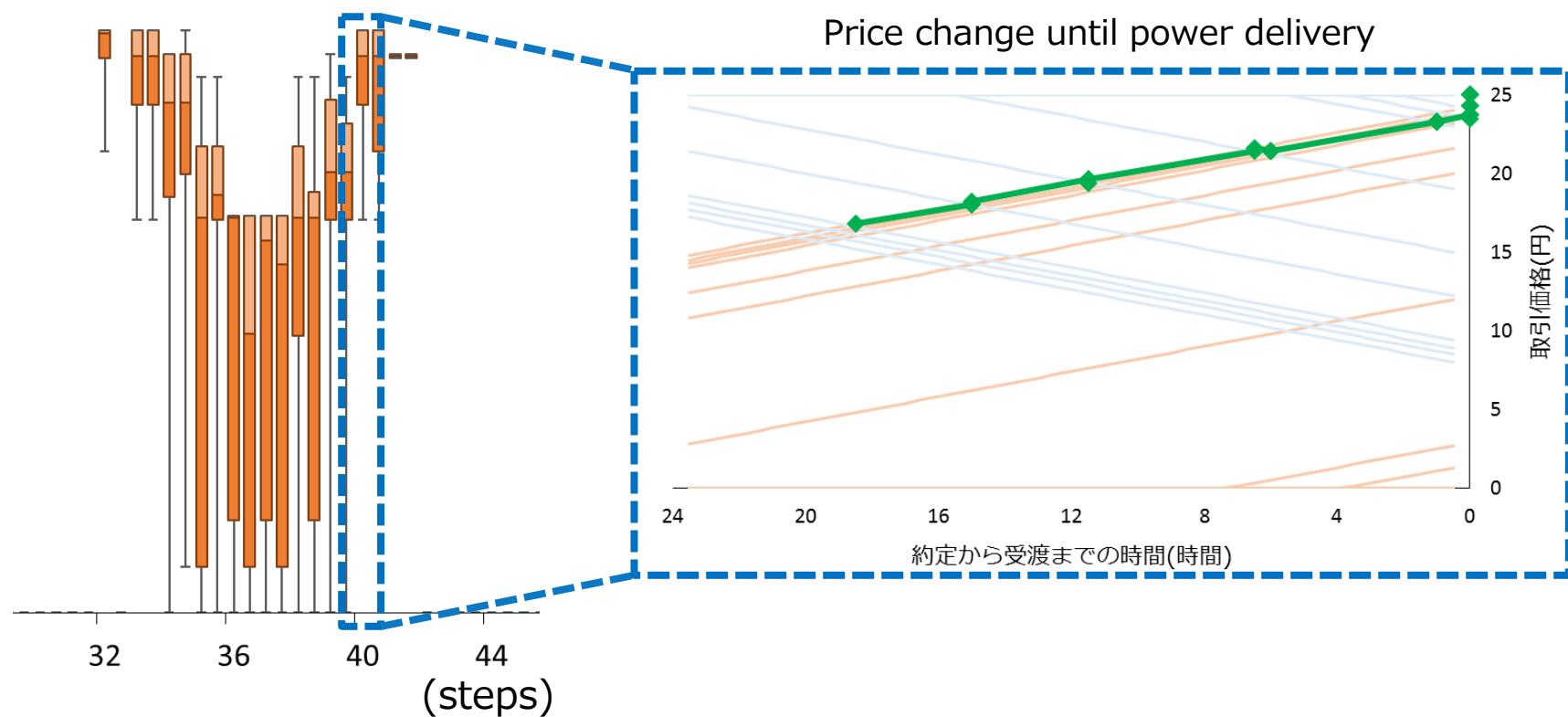
(with exchange : ¥: 12:00-12:30)



# Price trend ( Not sufficient supply case)

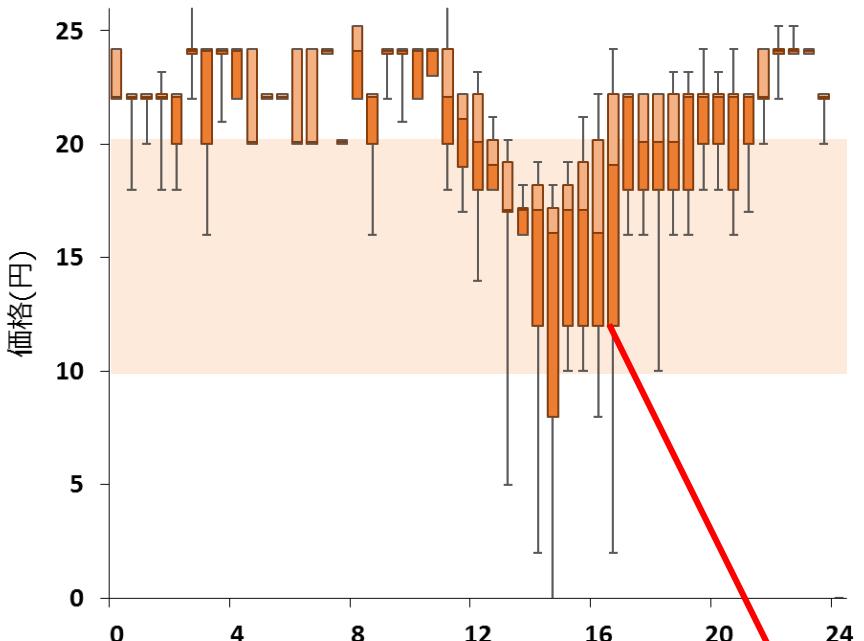
## Power Price trend of a day

(with exchange : ¥: 15:00 - 15:30)

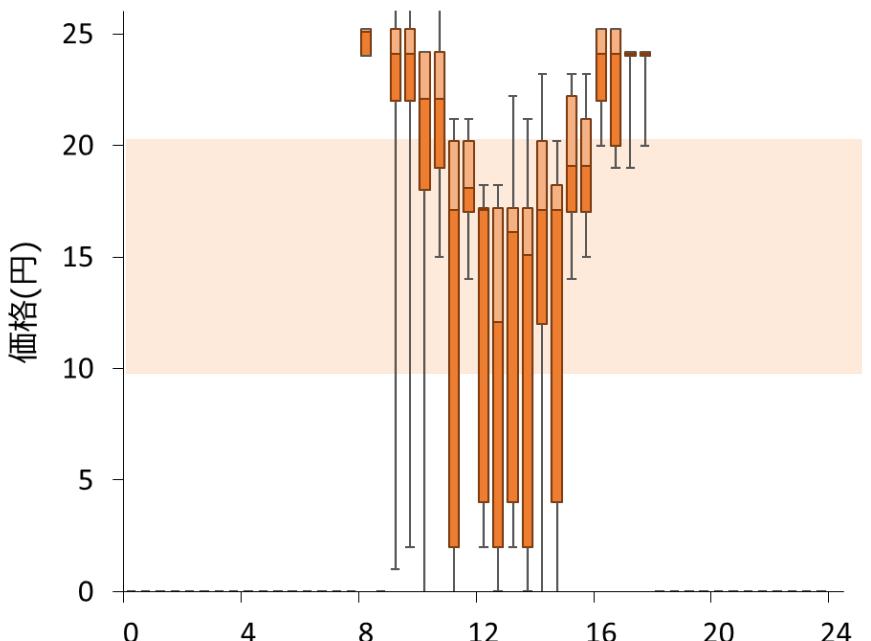


# Price Trend with Battery

Price Trend of a day: w Battery



Price trend of a day: w/o Battery



Prices are stabled when batteries are installed

# Distributed Power balancing

## ALL UNITS ARE BALANCED BY MATCHING

Continuous Double Auction

Sell	Price	Buy
30	26	
80	25	
100	24	
400	23	
	22	300
	21	200
	20	150
	19	100

Units of Matching Result

Seller	Buyer	Amount
User 1	User 5	1.0 kWh
User 11	User 2	1.2 kWh

All units are balanced

Power Markets



Thus accumulated flow of balanced units is balanced between supply and demand. Producer control outflow to grids based on the matched results.



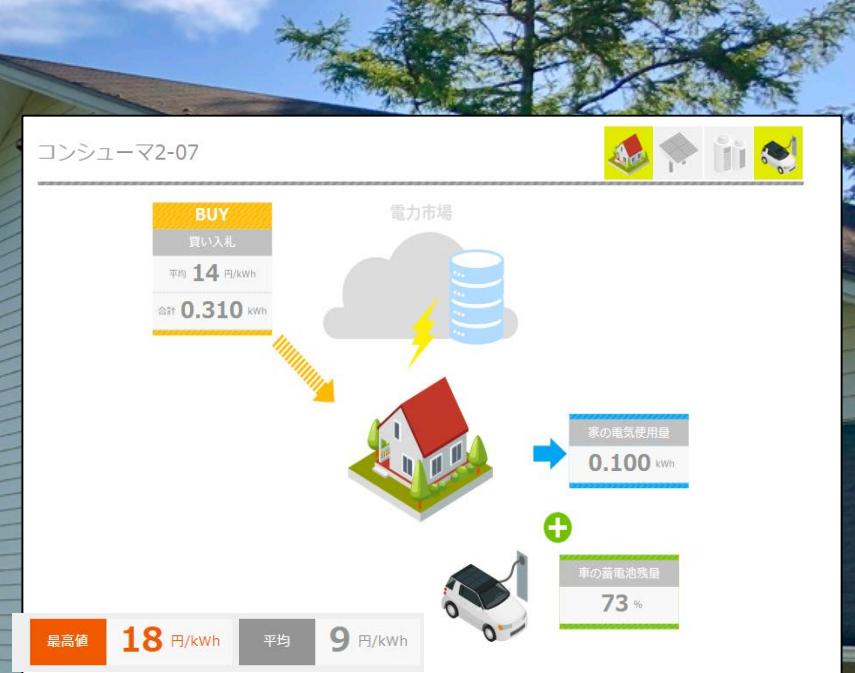
Expand to EV

## 2 TOYOTA-UTokyo Project

PHEV automatically start charging when energy price is low

Energy Storage in EV has a great potential for energy storage .

Incentives for joining sharing battery capacity EV drivers is needed



Auto charging according to drivers pattern

2 TOYOTA-UTokyo Project

V2G starts in Jun 2019 (Jun17)

## Toyota to launch ‘world first’ P2P trading pilot with V2G capability

Aiming for the efficient usage of electricity, Toyota, UTokyo and TRENDE Inc., will test a system for trading electricity between individuals by utilizing distributed power supplies such as solar panels, secondary batteries, and electrified vehicles.

### LATEST NEWS



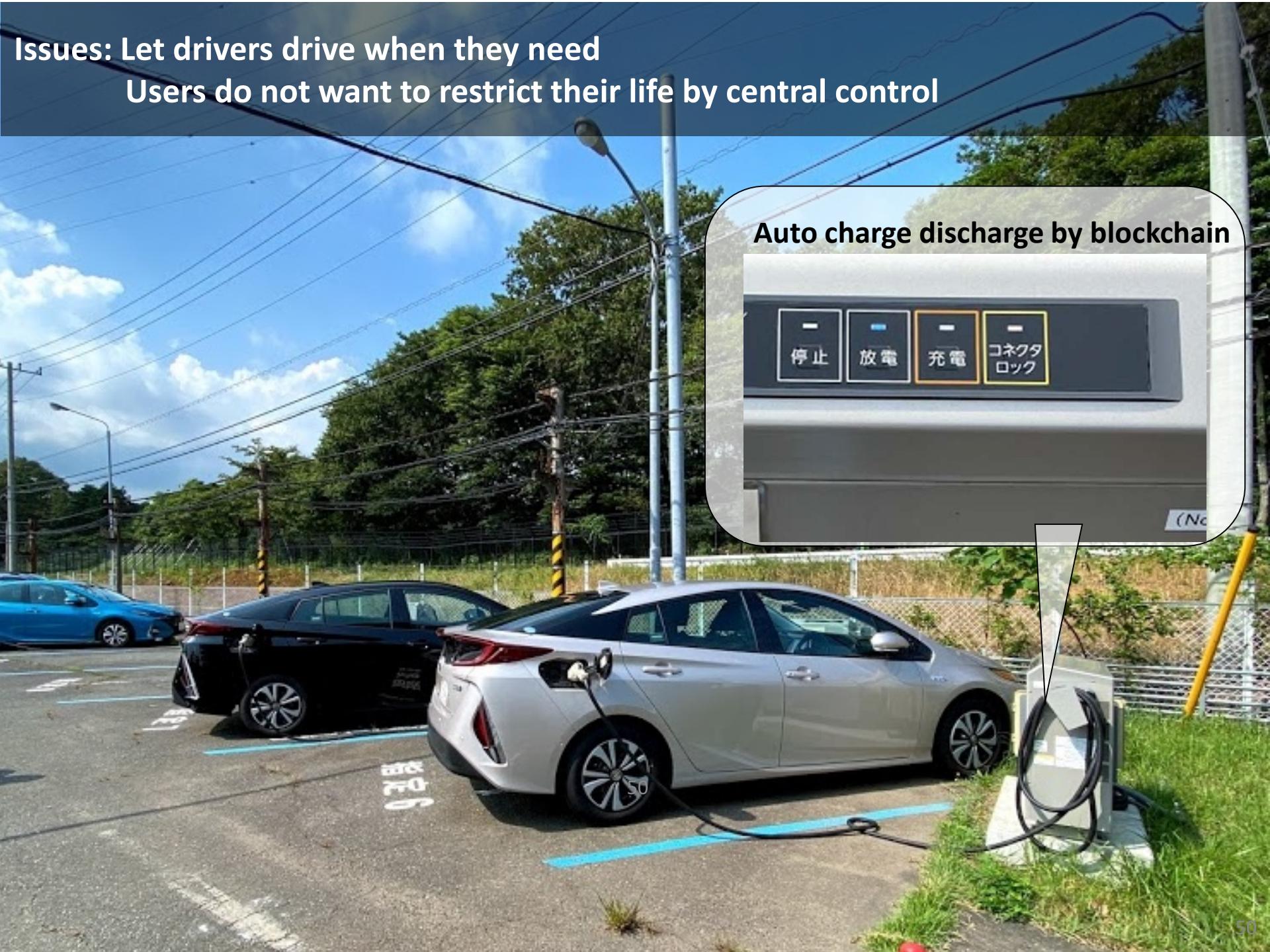
May 23, 2019

**The University of Tokyo, Toyota, and TRENDE to Begin Testing of Next-generation Electricity System**

News Release, Management, Innovation, Environmental Technology



**Issues: Let drivers drive when they need  
Users do not want to restrict their life by central control**



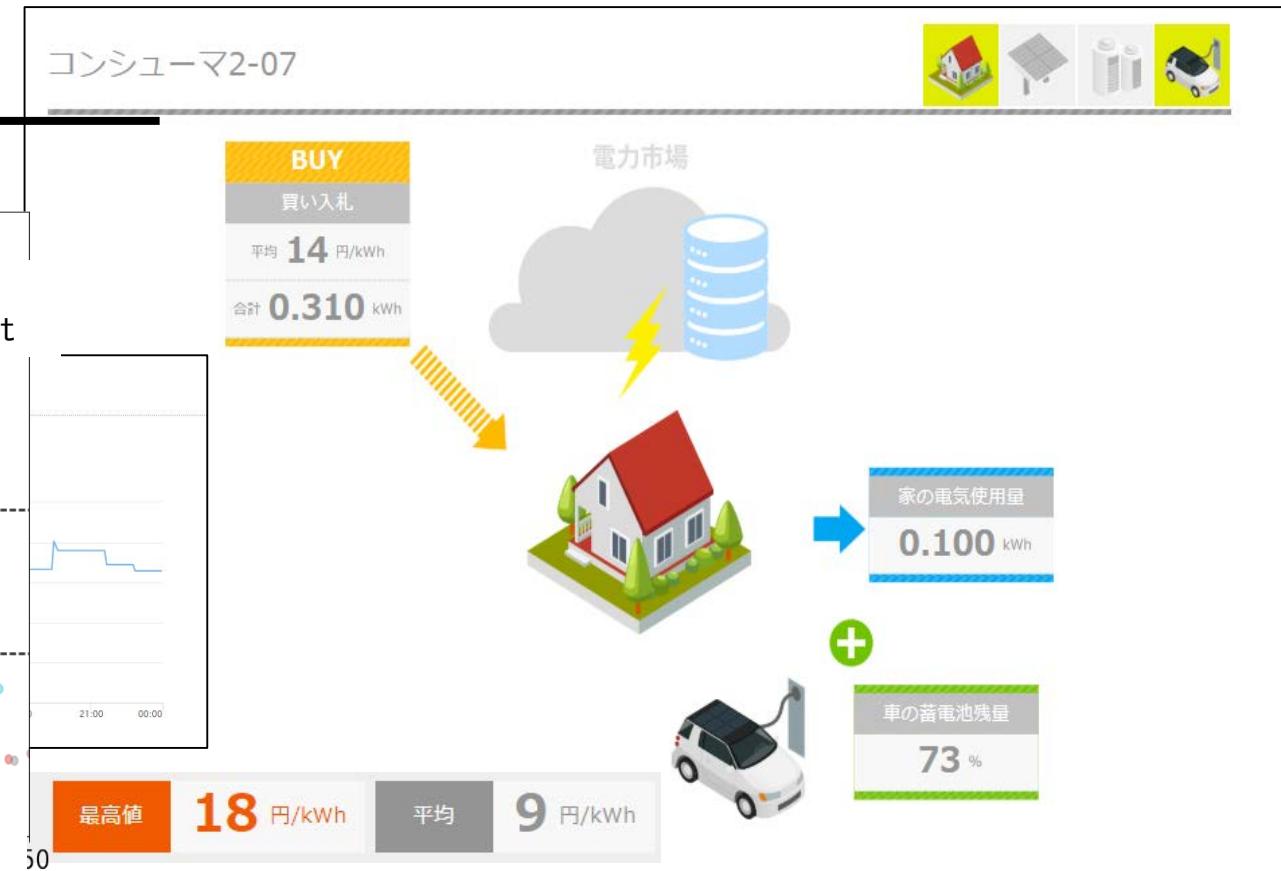
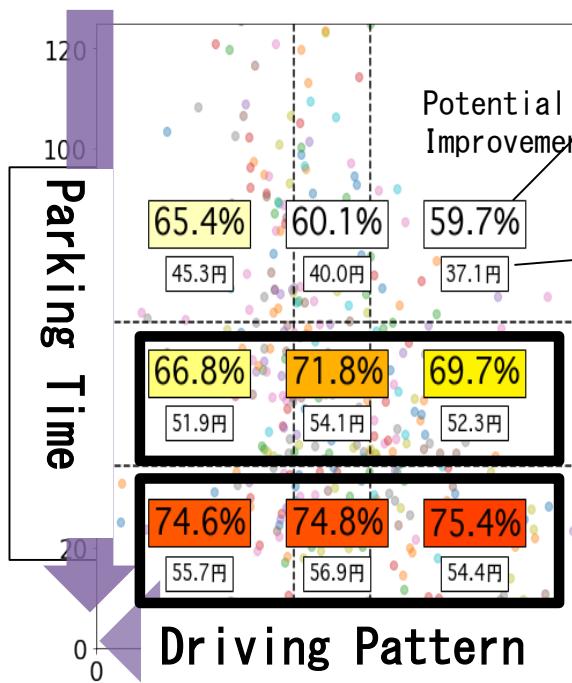
**Auto charge discharge by blockchain**

停止 放電 充電 コネクタ  
ロック

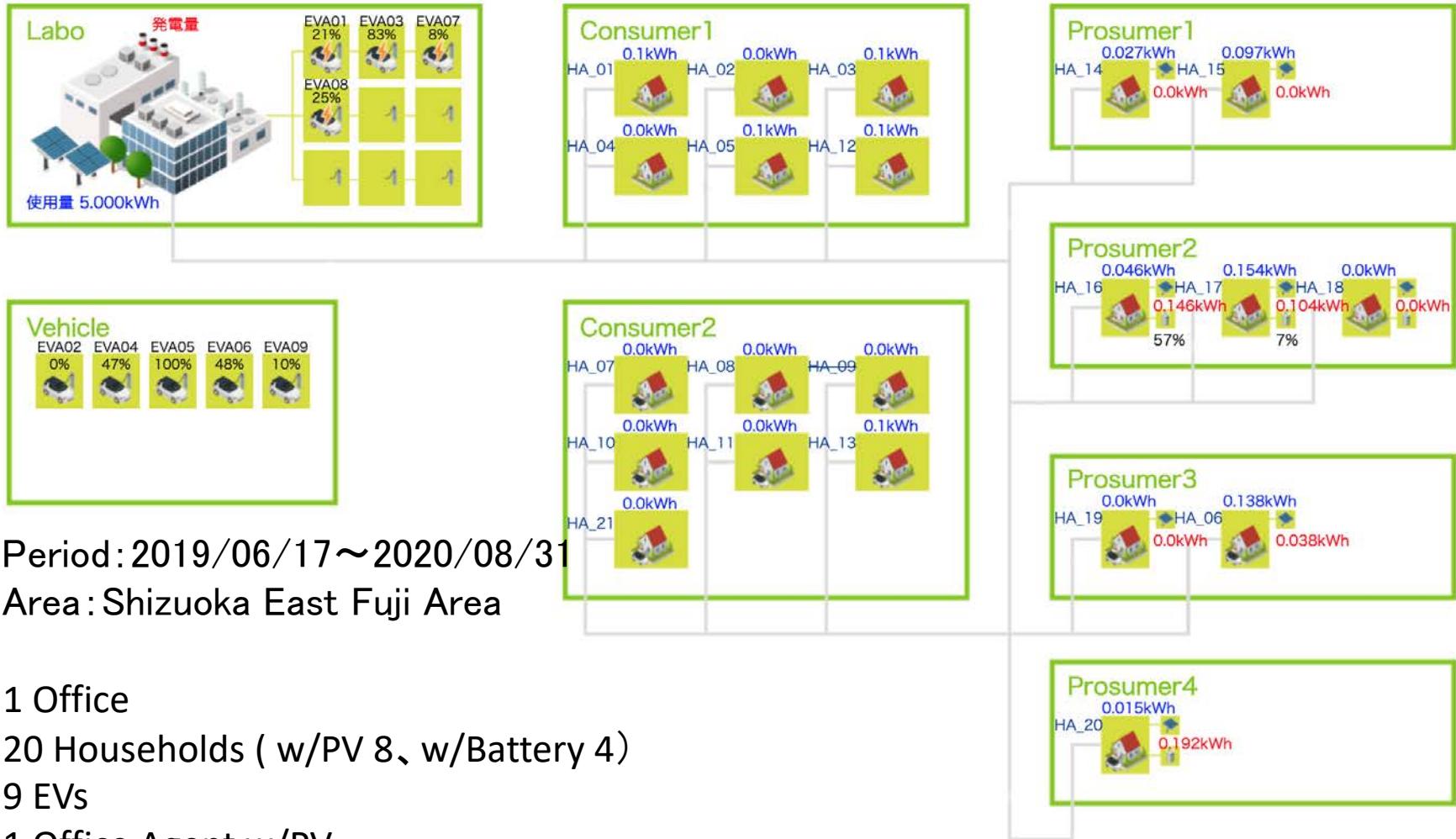
# Auto charging according to drivers pattern

## Example of A day

### Driving Pattern

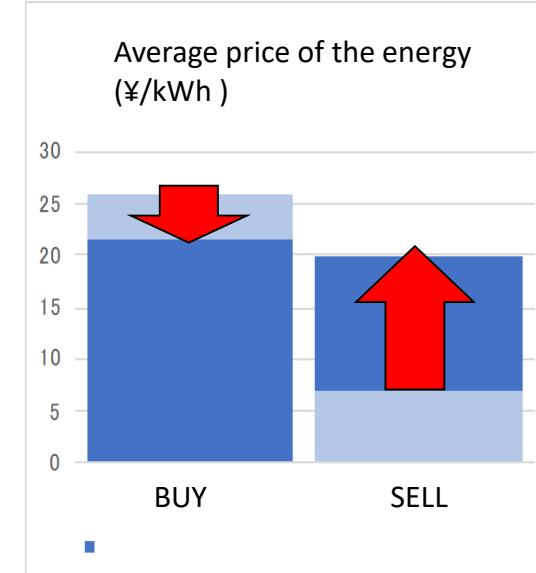
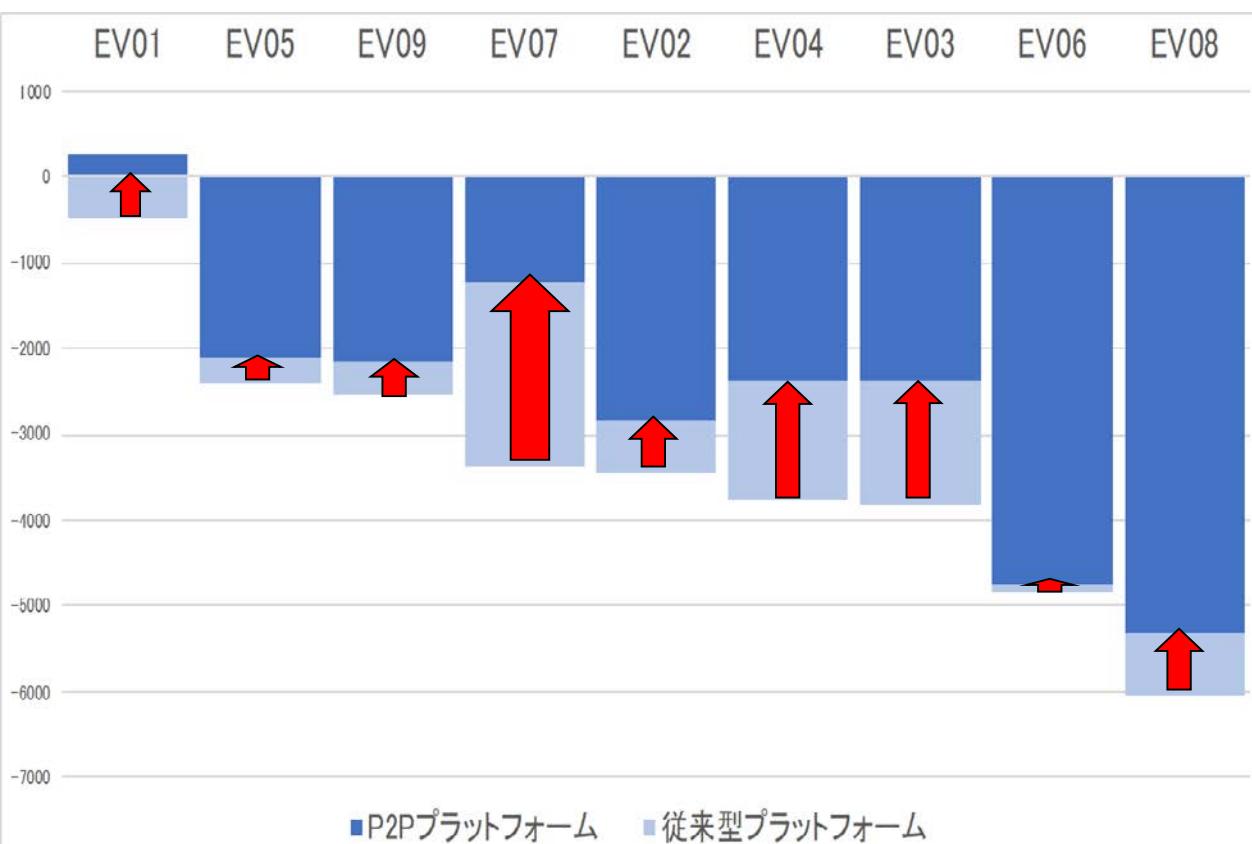


# Overview of the demonstration experiment



# Result①: All EV drivers reduced Energy cost by 25.4%

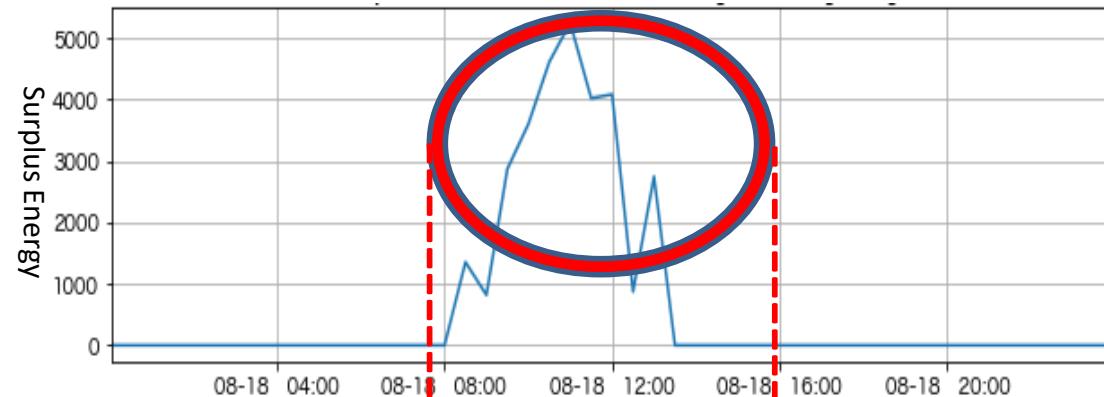
## Energy Cost reduction of household (2020 Aug)



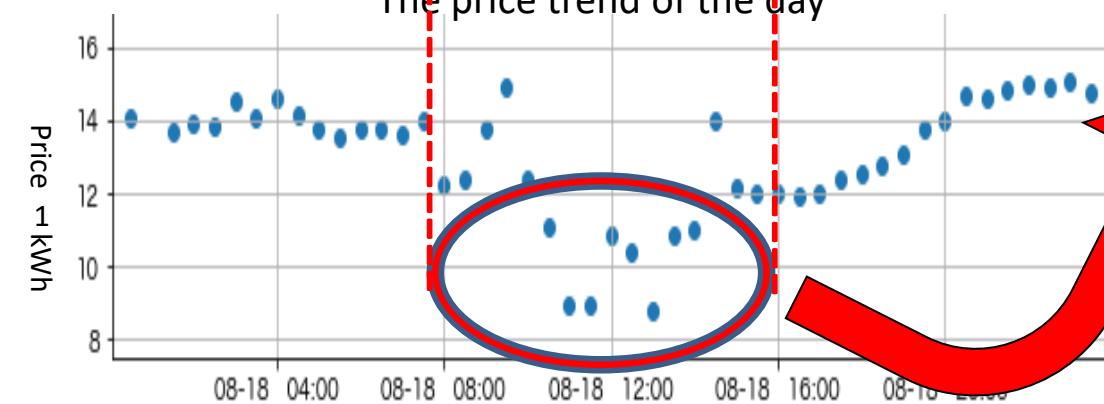
※result of 2020 Aug

## Result②: EVs absorbed surplus energy from PVs in daytime with low price

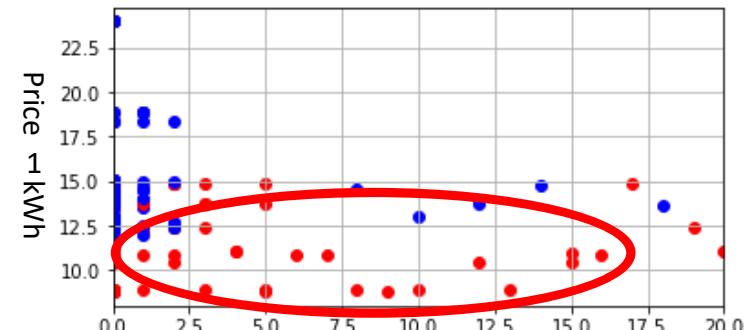
Surplus Energy from PV of the day



The price trend of the day



Charging log of EVs

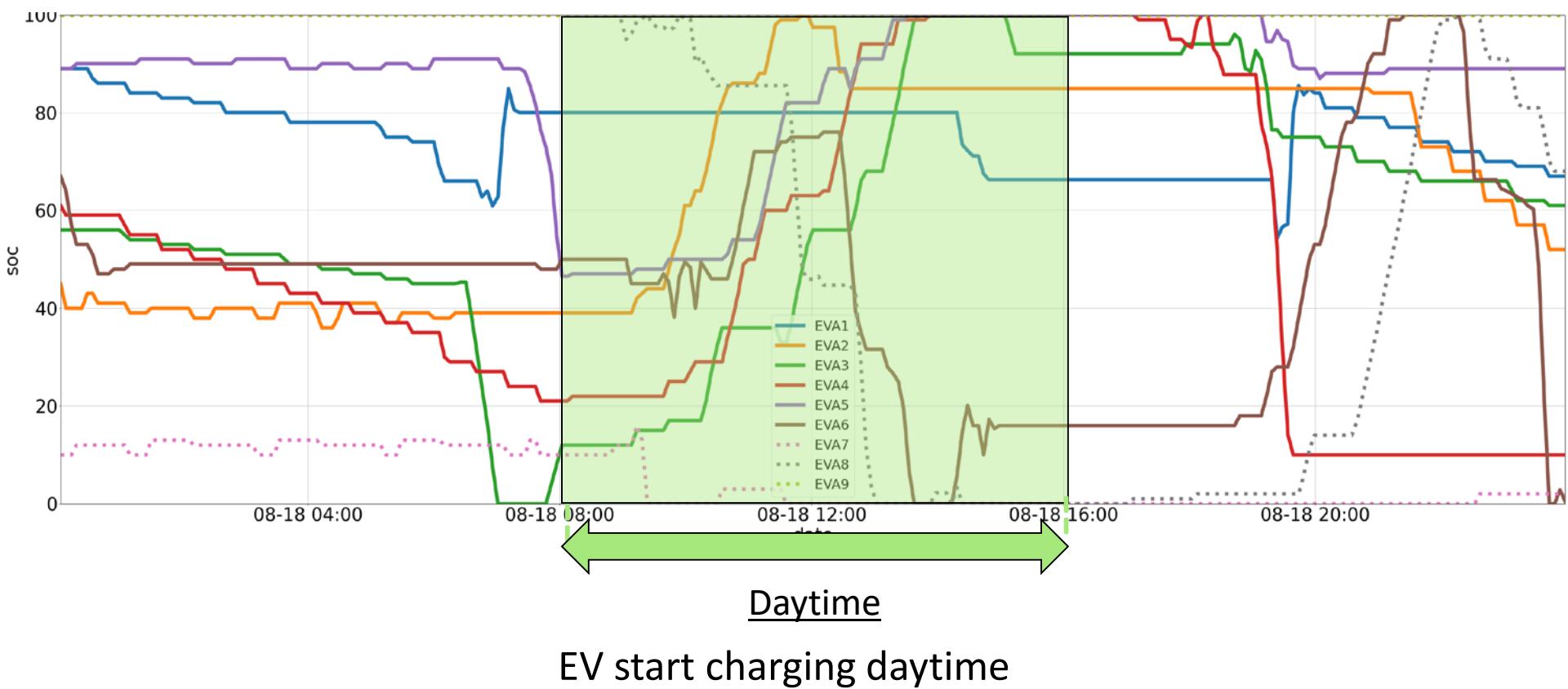


Charging result of EVs[%]

## Result② EV succeed to absorb the surplus energy

EV SOC trend of a day (8/18)

EV Battery charging level trend



### Result③Machine-to-machine auto charging is done



Auto charge discharge by blockchain

# Car agents are getting smarter and more automated trading that is useful to society

自動車エージェントが自律的に余剰再生可能エネルギーを吸収します。自動車はどんどん賢く行動するようになることでしょう。



TOYOTA / トヨタ自動車株式会社

11月17日 10:00 ·

電動車（PHV）と家と事業所で、「再生可能エネルギー」を賢く使うための実証実験を #TRENDE と #東京大学 と共同で行いました。

結果はこちら

[https://www.toyota.co.jp/.../partne.../news/20201113\\_01.html](https://www.toyota.co.jp/.../partne.../news/20201113_01.html)

#P2P電力取引 #ブロック... もっと見る

## TOYOTA:

- By utilizing electric vehicles for P2P power trading, we would like to disseminate new vehicle applications to millennials and Gen Z, who have a keen interest in the sharing economy and environmental issues.

## TRENDE:

- we would like to promote collaboration with different industry areas such as payment and healthcare, aiming to develop into a cross-industry data utilization platform.

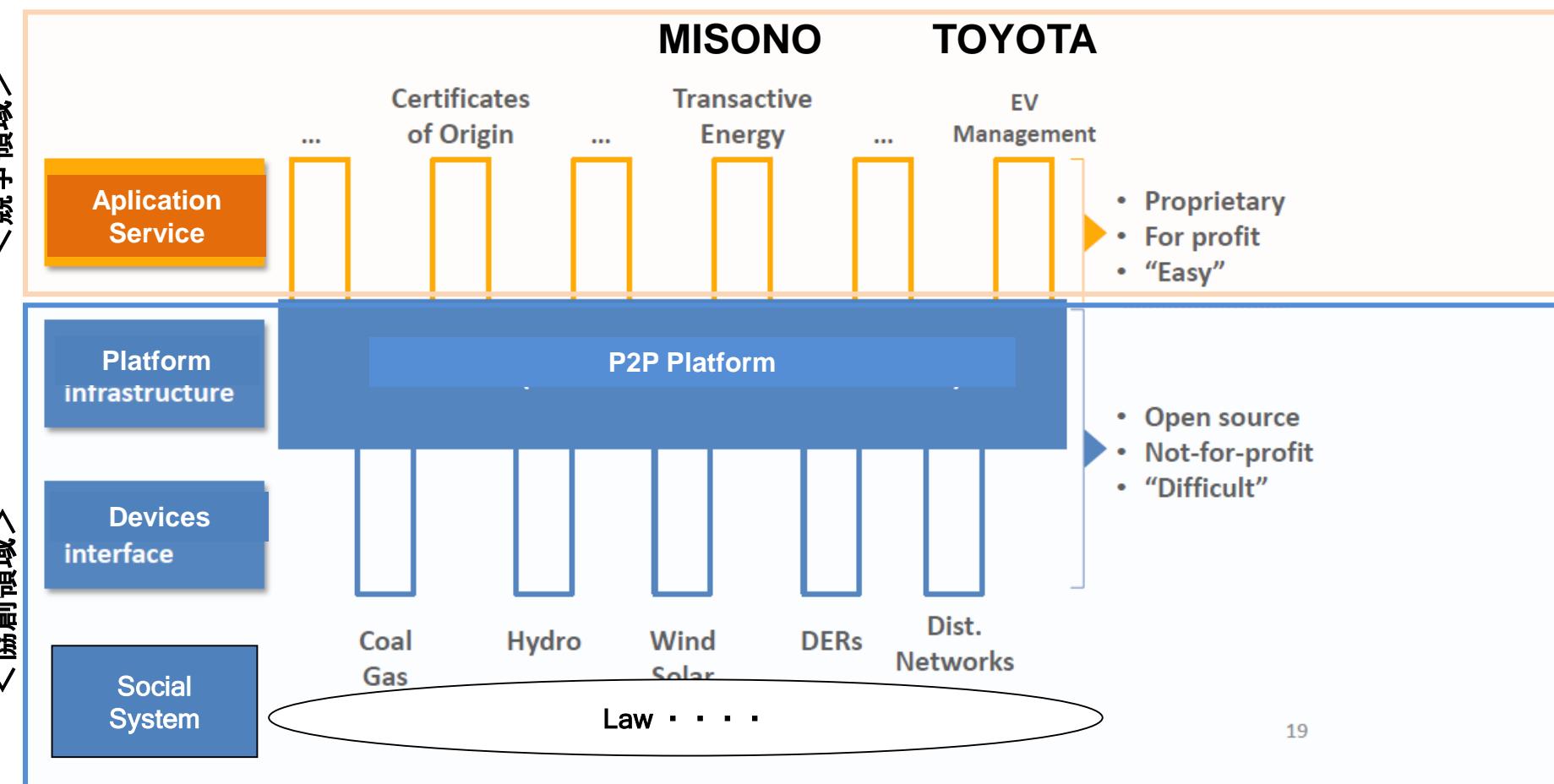
## Tanaka Lab (UTokyo):

- Now that we have a technical prospect for a business platform that automatically trades with IoT devices in cooperation, we would like to proceed with research toward the realization of services that make us feel the future, such as energy and mobility.

# Develop a Service Platform with Digital Technologies



## IoE UTokyo Research

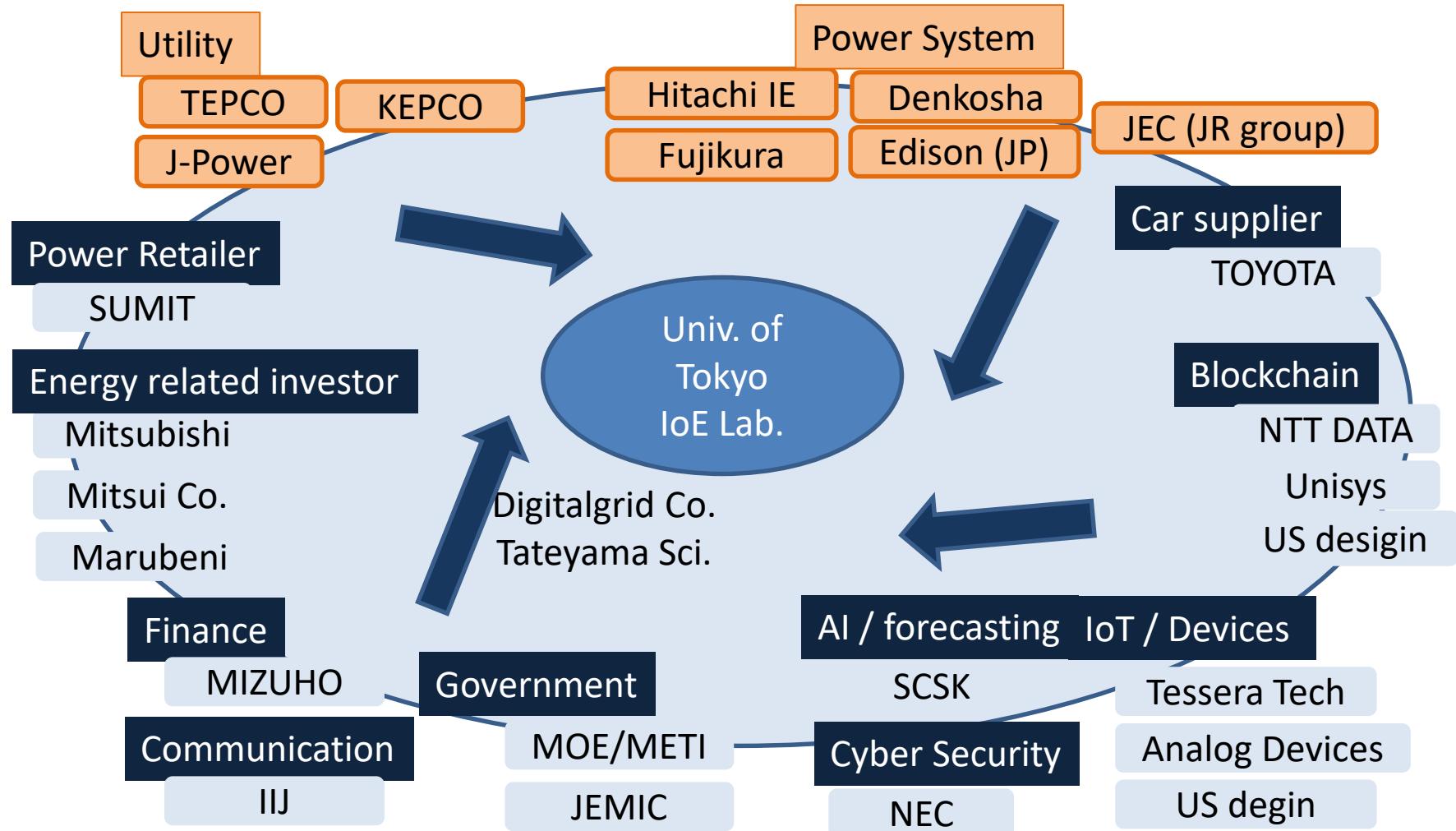


## Conclusion and further issues

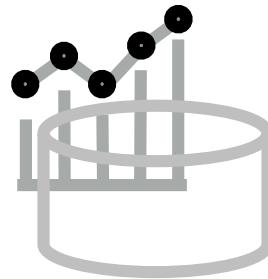
- We propose a platform to procure electric power exchange based on the policies of individual users using the market mechanism.
- Auto-power exchange and delivery with this system has been demonstrated. Using Digital Inverter and blockchain platform, power exchanges according to the result of peer-to-peer matching through double auction market mechanism.
- This system shows the potential feasibility of distributed power balancing by providing economic incentives through market mechanisms.

# Further Research of Digital Service development Transdisciplinary Approach is inevitable

Around 30 related companies joined this project from 9 industries



# THANK YOU



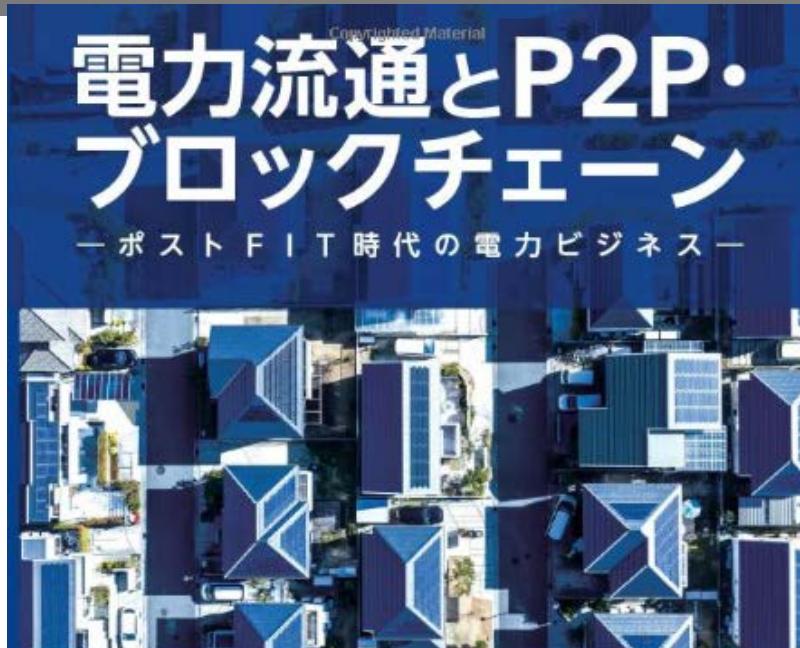
— Impossible



Kenji Tanaka  
[kenji\\_tanaka@sys.t.u-tokyo.ac.jp](mailto:kenji_tanaka@sys.t.u-tokyo.ac.jp)

Book

# 電力流通とP2P・ブロックチェーン: ポストFIT時代の電力ビジネス



田中 謙司 監修 武田 泰弘 著

2009年に開始された太陽光発電電力の固定価格買取制度は、温室効果ガス削減、エネルギー自給率の向上に一定の成果をもたらした。そして現在、FIT切れの設備の活用方法に注目が集まっている。本書は、再生可能エネルギー設備の新しい活用方法および、さらなる普及の鍵の一つであるP2P技術による電力ネットワークについて、次世代エネルギーインターネット網IoE(Internet of Energy)を視野に解説した。



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