Distributed Energy and Micro-energy Harvesting

Abderazek Ben Abdallah

School of Computer Science and Engineering, UoA
Neuroengineering Laboratory
https://www.u-aizu.ac.jp/misc/neuro-eng/aebis.html

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**Research in collaboration with Aizu Computer Science Laboratories, BJP バンプージャパン株式会社 A subsidiary of Banpu

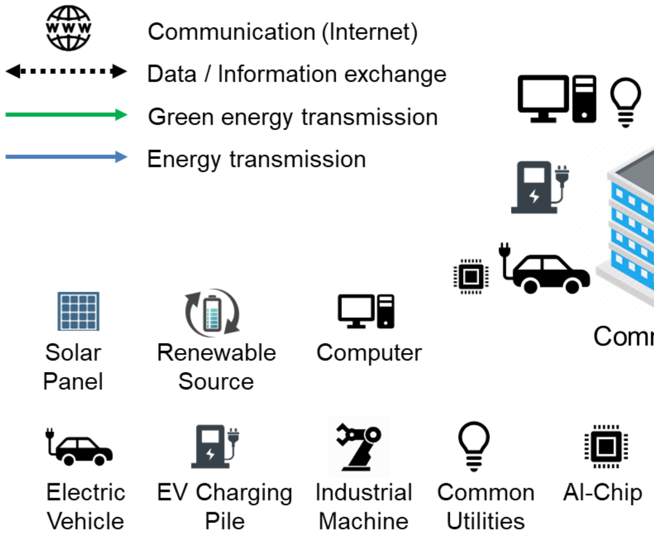
オフグリッドエネルギー貯蔵ソーラーカーポート
Off-Grid Energy Storage Solar Carport (1/5)

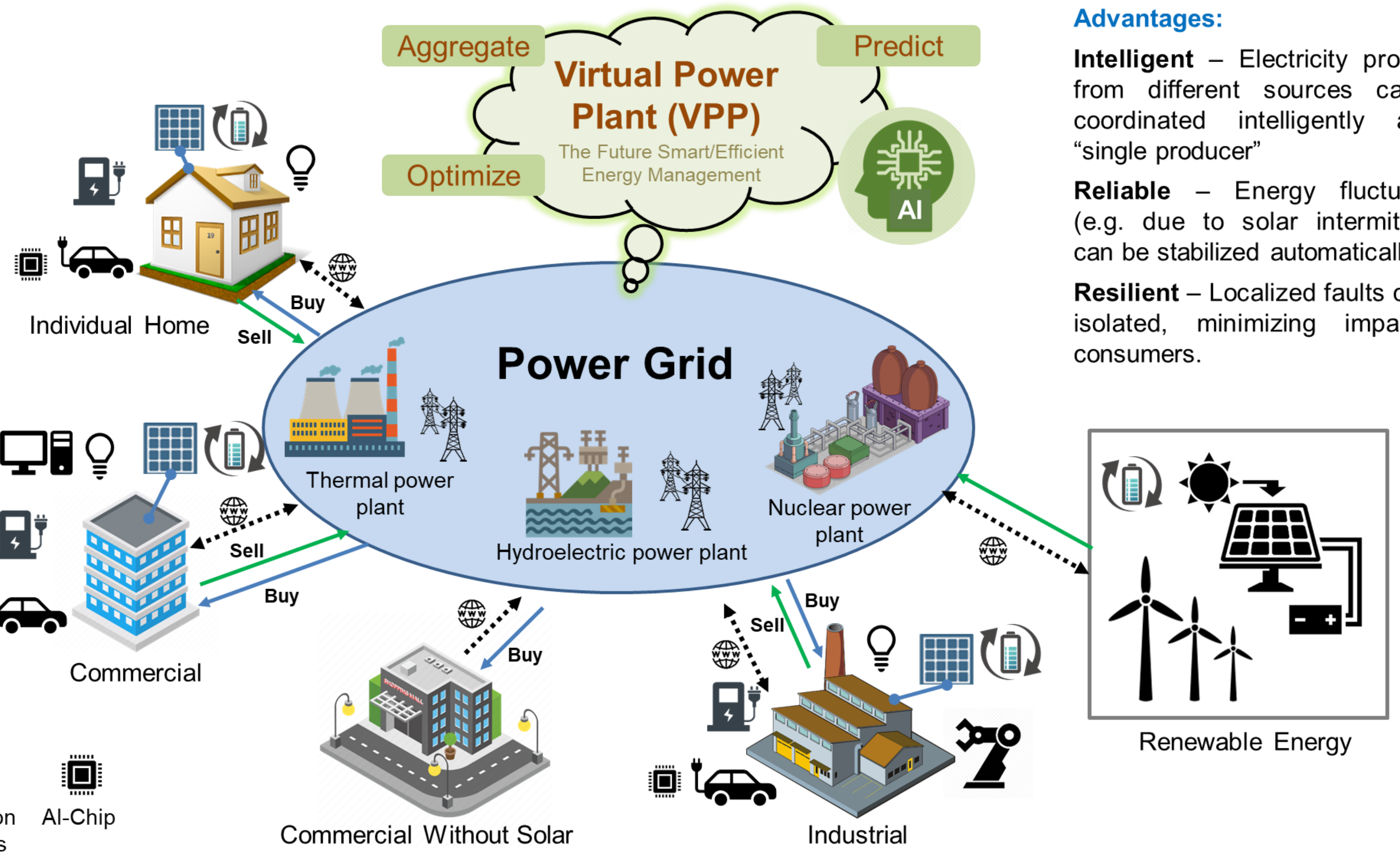
- To achieve efficient demand response, particularly during peak hours.
  特にピーク時の効率的なデマンドレスポンスを実現するため
- Deploy electric vehicles (EVs) to serve as both energy consumers and energy suppliers.
  電気自動車 (EV) を配備して、エネルギーの消費者とエネルギーの供給者の両方として機能させます。
- Utilize solar energy to provide electricity to vehicles.
  太陽エネルギーを利用して、車両に電力を供給します。
- A control method for EV charge/discharge.
  EVの充放電の制御方法。

オフグリッドエネルギー貯蔵ソーラーカーポート
Off-Grid Energy Storage Solar Carport (2/5)

Optimized Energy Distribution for a Cleaner, Greener Energy Future

VPP is a digital platform that links decentralized energy resources across different locations in Japan and optimizes energy usage.





Advantages:

Intelligent – Electricity produced from different sources can be coordinated intelligently as a "single producer"

Reliable – Energy fluctuations (e.g. due to solar intermittency) can be stabilized automatically.

Resilient – Localized faults can be isolated, minimizing impact to consumers.

Virtual power plant (VPP) for power management.

Z. Wang, M. Ogbodo, H. Huang, C. Qiu, M. Hisada, A. Ben Abdallah, "AEBIS: AI-Enabled Blockchain-based Electric Vehicle Integration System for Power Management in Smart Grid Platform," IEEE Access, vol. 8, pp. 226409-226421, 2020, doi:10.1109/ACCESS.2020.3044612.

オフグリッドエネルギー貯蔵ソーラーカーポート
Off-Grid Energy Storage Solar Carport (3/5)

- We developed an off-grid energy storage solar carport that integrates solar panels and electric vehicles (EVs).
  ソーラー パネルと電気自動車 (EV) を統合したオフグリッド エネルギー貯蔵ソーラー カーポートを開発しました。
  - A control method for EV charge/discharge based on neural network models realized in both software and hardware platforms.
    ソフトウェアとハードウェアの両方のプラットフォームで実現されるニューラル ネットワーク モデルに基づくEV 充放電の制御方法
  - We developed a software tool that displays the status of vehicles (state of charge (SoC), charge/discharge activities, etc.)
    車両の状態（充電状態（SoC）、充放電状況など）を表示するソフトウェアツールを開発しました。

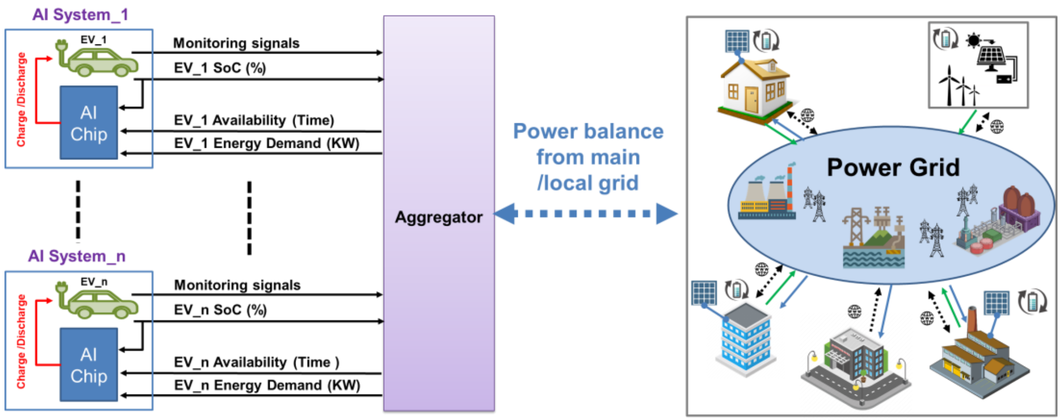
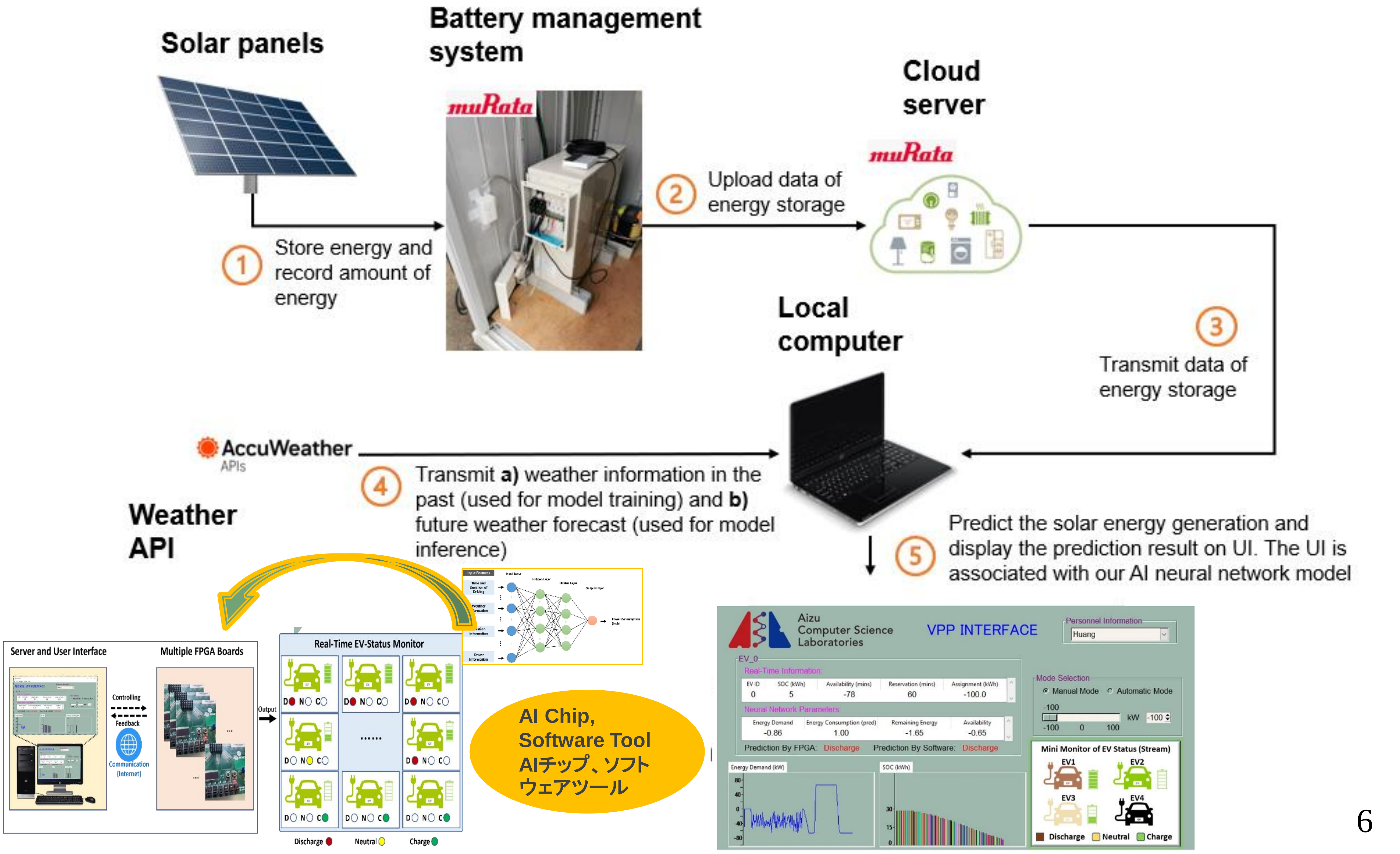


Illustration of data exchange between the power grid and EV-AI systems via an aggregator. The EV-AI systems are used to control the charge/discharge tasks of EVs.

オフグリッドエネルギー貯蔵ソーラーカーポート
Off-Grid Energy Storage Solar Carport (4/5)



オフグリッドエネルギー貯蔵ソーラーカーポート
Off-Grid Energy Storage Solar Carport (5/5)

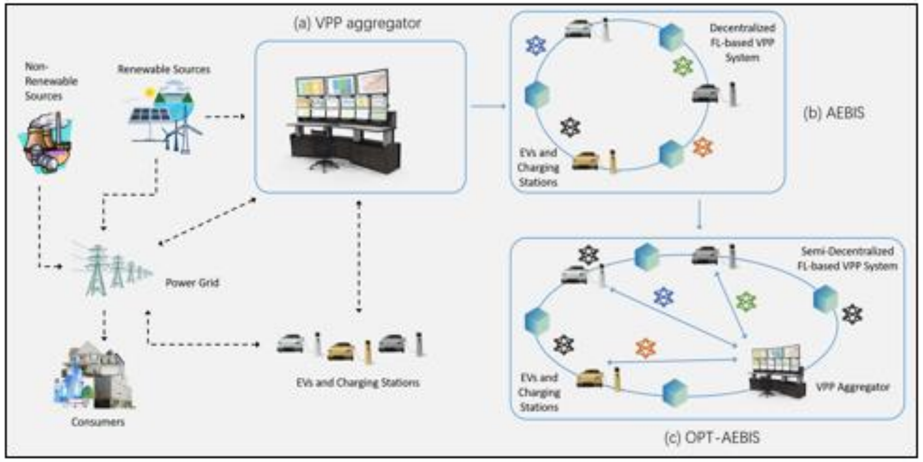


Fig. 1. Virtual Power Plant (VPP): (a) conventional VPP aggregator, (b) AEBIS, (c) optimized AEBIS (O-AEBIS).

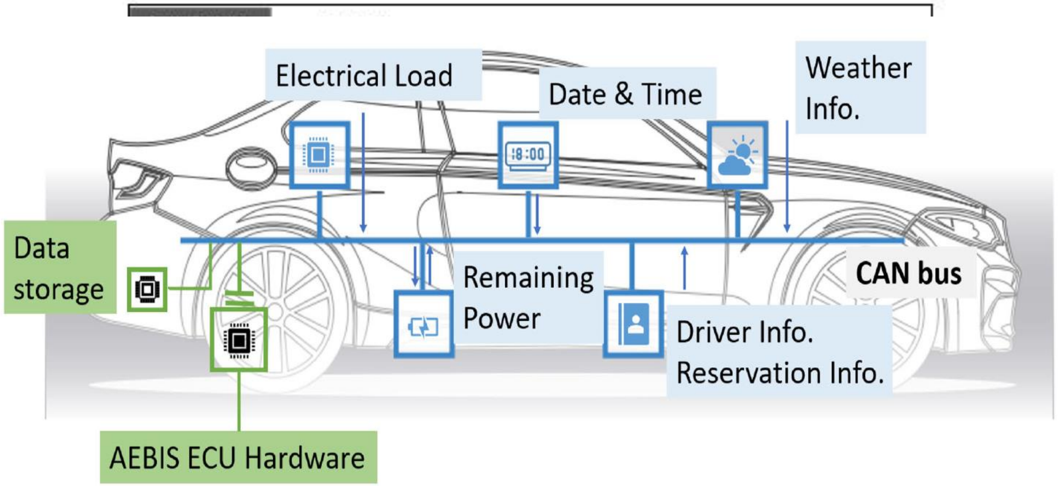
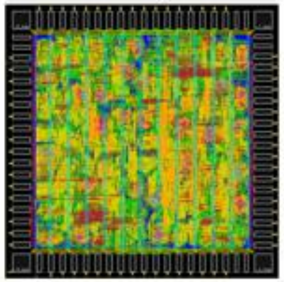


Fig. 2. Neural Network for Power Consumption Prediction of Electric Vehicle (EV).

Field Experience, UoA, 2021 年 5 月 25 日

ASIC Layout



Area	0.265 mm²
Voltage	1.1 V
Power	318.224 mw
Temperature	25°C

Fig. 5. A demonstration of the energy management system based on our system named AEBIS and its optimized version O-AEBIS.

Name	BRAM_18K	DSP48E	FF	LUT
Expression	-	-	0	493
Instance	-	5	414	950
Memory	2	-	320	20
Multiplexer	-	-	-	627
Register	-	-	454	-
Total	2	5	1188	2090
Available	120	80	35200	17600
Utilization (%)	1	6	3	11

Weights	Memory required
Weights	568 Bytes
Biases	60 Bytes
Inputs	44 Bytes
Total	672 Bytes

Fig. 6. Hardware complexity of power consumption prediction system on the Zynq-7010 FPGA. The system utilized 3% of the FF, 11% of the LUT, 6% of the DSP48, and approximately 1% 18k BRAM.

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ネルギーの取引方法とシステム
Energy Trading Method and System

- To utilize the battery of an electric vehicle as an energy storage system for the smart grid that can address peak demand issue.
電気自動車のバッテリーをスマートグリッドの蓄電システムとして活用し、ピーク需要に対応したい
- The renewable energy fluctuates greatly depending on the situation and is not stable. However, the electric power stored in the EV can become stable electric power.
再生可能エネルギーは状況によって大きく変動し、安定していません。しかし、EVに蓄えた電力は安定した電力になることができます。
- If EV owners can make money by selling electricity, it will make electric cars more cost-effective for owners.
EV所有者が電気を売ってお金を稼ぐことができれば、所有者にとって電気自動車の費用対効果が高くなります。

A campus control system (CS) is deployed to serve as a mediator, by communicating with other participants, including electric company, end consumers, and EV fleet.

ネルギーの取引方法とシステム

Energy Trading Method and System

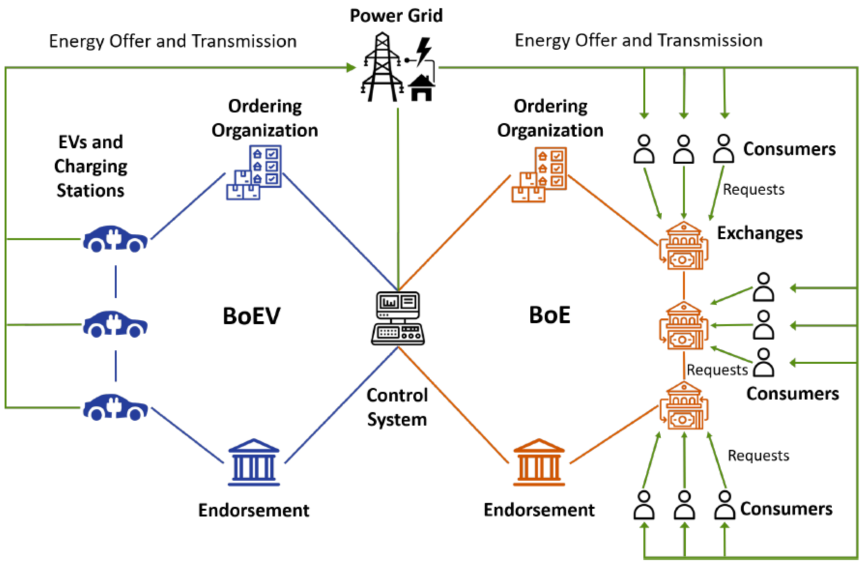
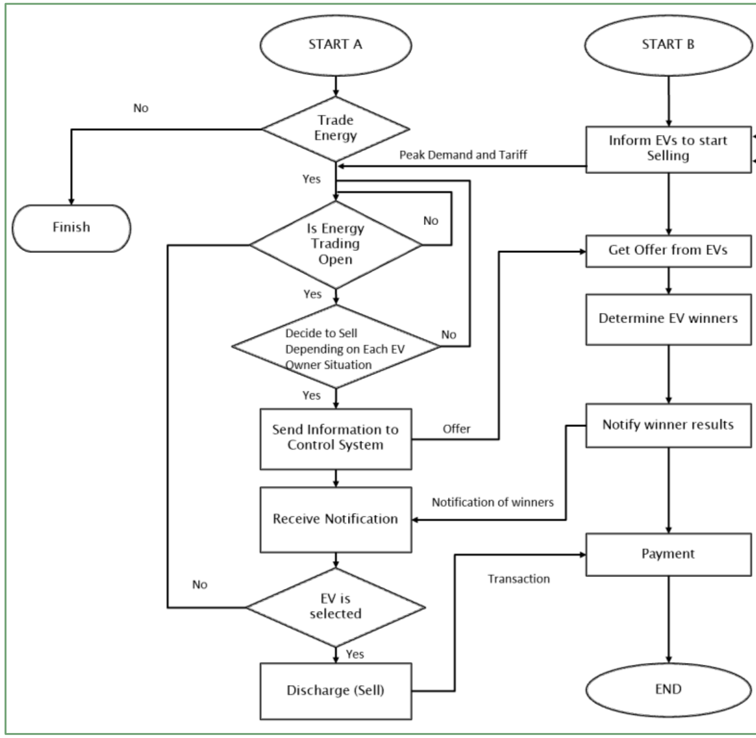
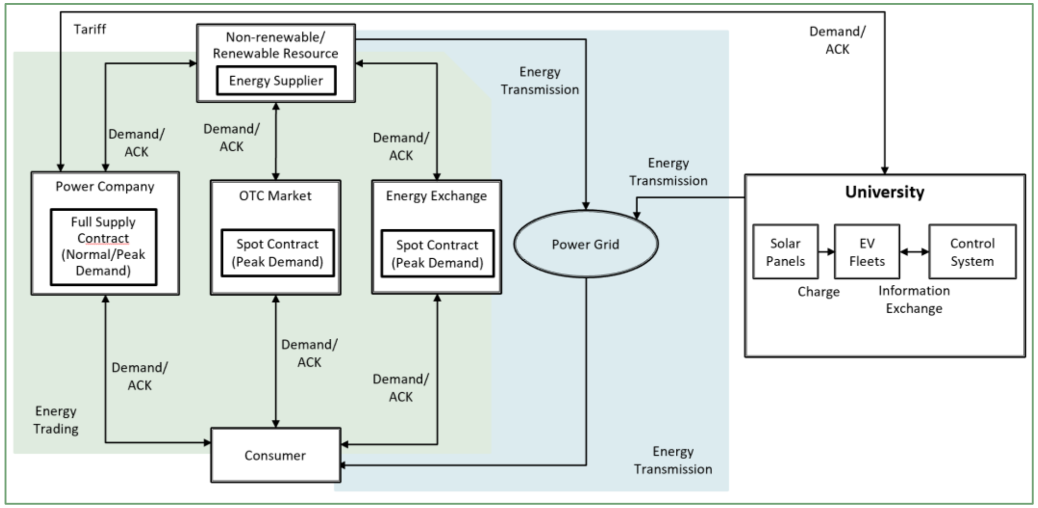


Fig. 2. Overview of the proposed V2GNet. Each campus' control system (CS) works as a mediator between energy consumers and suppliers (EVs). Each



Algorithm Flowchart of the Energy Trading Algorithm.



Our Energy Trading System

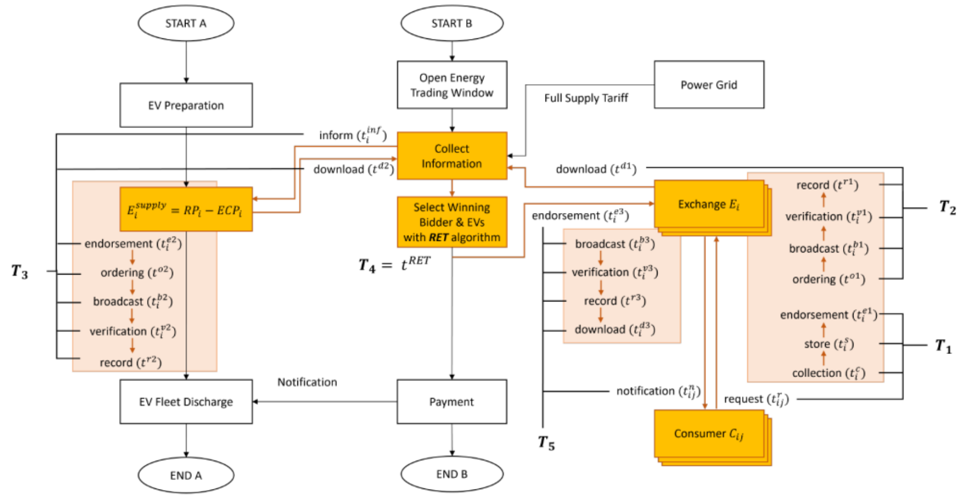


Fig. 6. Analysis of Response Time in V2GNet. The whole workflow can be divided into five stages. T_1: From the request submission until the endorsement of transactions (containing request lists) is finished. T_2: From the ordering of transactions until the CS collects the request lists. T_3: From the CS informs EVs until it receives offers from EVs. T_4: Select winning consumers and offers with *RET* algorithm. T_5: From the endorsement of the result about winning consumers until the consumers receive the notification.

ネルギーの取引方法とシステム
Energy Trading Method and System

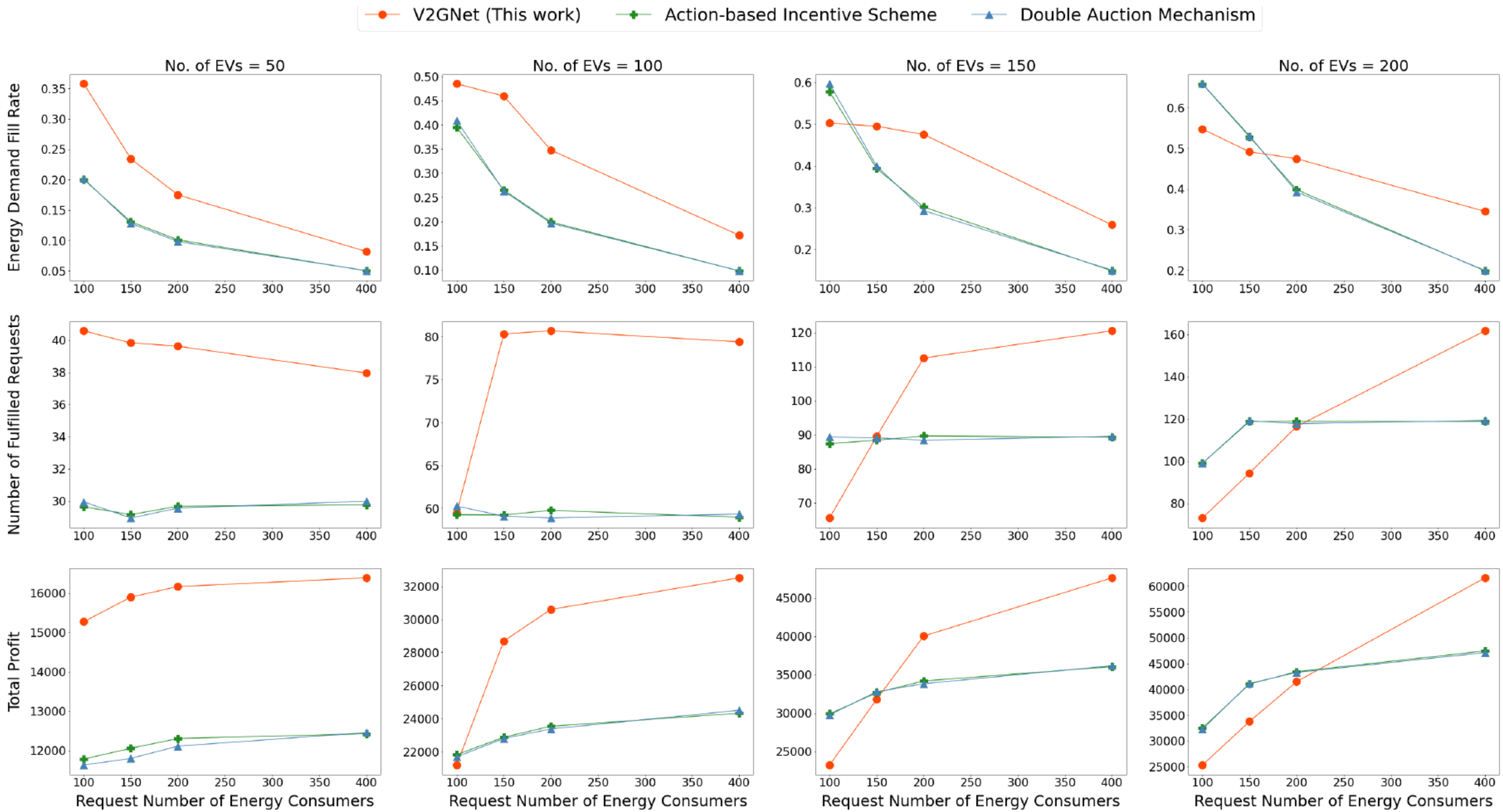


Fig. 9. Comparison between V2GNet (this work), the action-based incentive scheme [17] and the double auction mechanism [15]. We used a different combination of EV and request amount, as shown in Table 1. We considered three evaluation indicators: 1) Energy Demand Fill Rate; 2) Number of Fulfilled Requests; 3) Total Profit.

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EV Power Consumption Prediction Method and System for Power Management in Smart Grid/ スマートグリッドにおける電力管理のためのEV消 費電力予測 方法とシステム

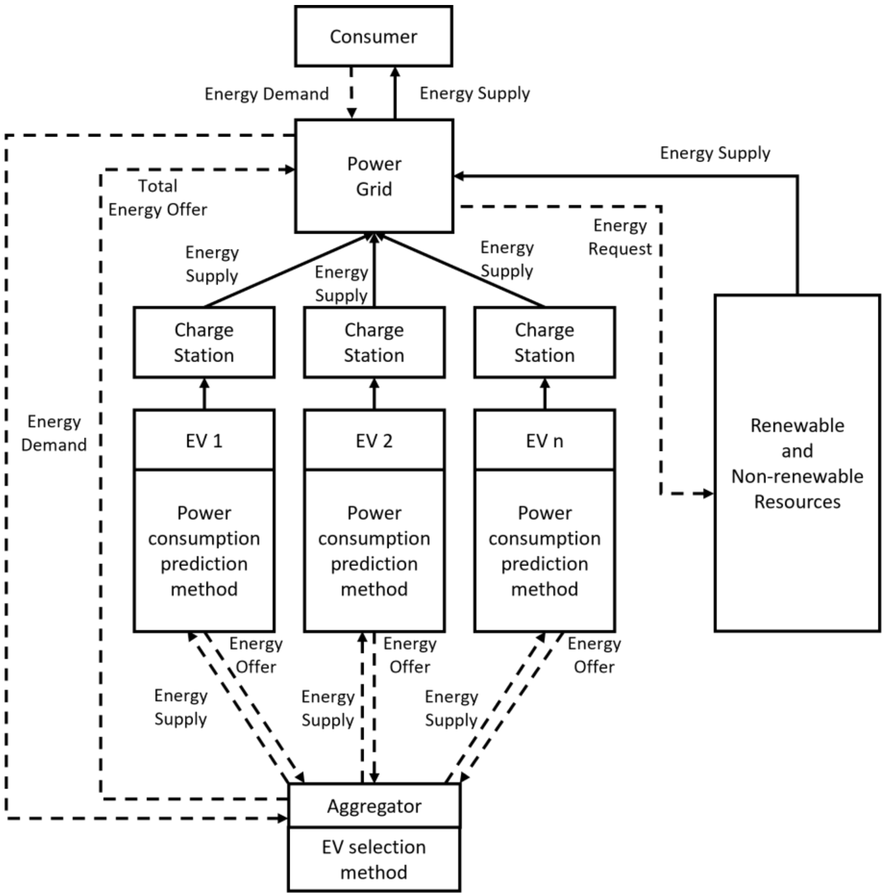
- Balancing energy supply and demand with integration of a virtual power plant (VPP) and vehicular networks.
  仮想発電所 (VPP) と車両ネットワークの統合により、エネルギーの需給バランスを調整します。

- Achieving accurate prediction of battery power consumption of EVs.
  EVのバッテリー消費量を正確に予測。

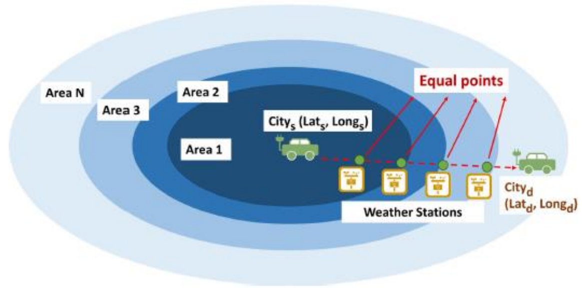
- A smart control mechanism to guide the charge/discharge behaviors of EVs. This will help improve the efficiency of the energy transaction between EVs and the power grid.
  EVの充放電挙動を誘導するスマート制御機構。 これにより、EV と電力網の間のエネルギー取引の効率が向上します。

- Making decisions based on the status of the vehicle, weather information, user information, and future trips.
  車両の状態、気象情報、ユーザー情報、および今後の旅行に基づいて意思決定を行います。

EV Power Consumption Prediction Method and System for Power Management in Smart Grid/ スマートグリッドにおける電力管理のためのEV消 費電力予測 方法とシステム



Proposed Method and System



(a) **Illustration of Power Consumption Prediction for A Single Trip. The green dots indicate positions that the car will pass through. Icons in yellow denote the nearest weather stations with respect to the green dots.**

(b) **An Example of Power Consumption Prediction for A Single Trip from Sendai to Tokyo in Japan. Each yellow star denotes a city associated with an explicit weather record. Created from Google Map [52].**

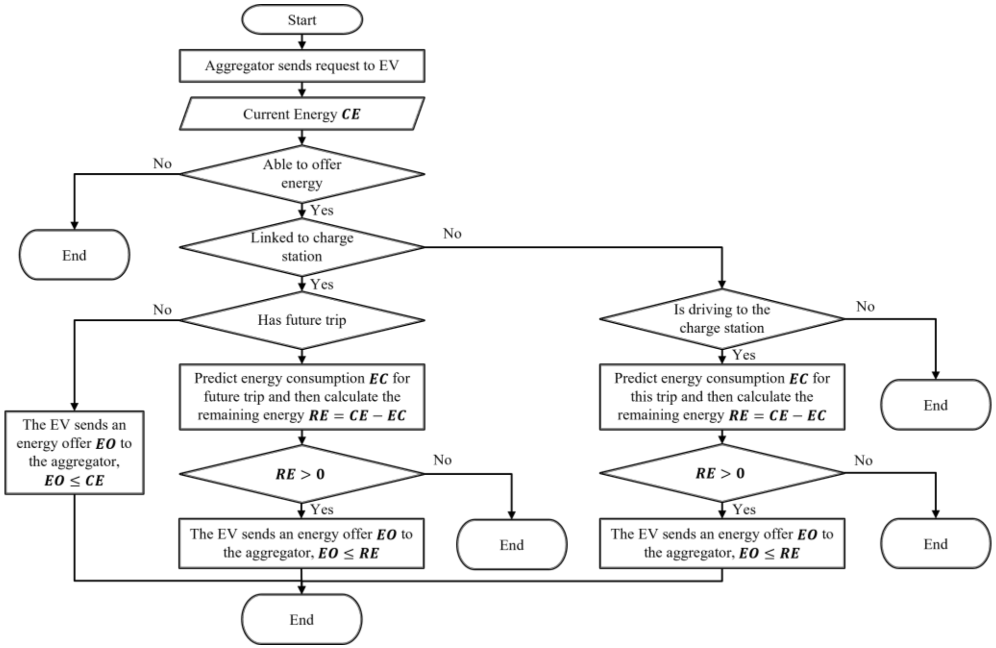
Algorithm 1 Multi-Stage Power Consumption Prediction

Require: Lat_s, Lat_d, $Long_s$, $Long_d$, DoD, t_s, $\{Lat_k\}_{k\in K}$, $\{Long_k\}_{k\in K}$, $\{Weather_{k,t}\}_{k\in K, t\in T}$, $User\_Info$, N_{total}, M
Ensure: Predicted Power Consumption PC_{pred}

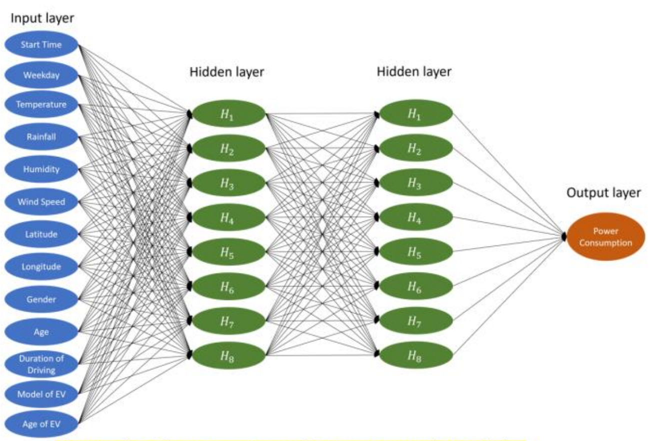
Initialize empty arrays Lat_c, $Long_c$, Lat_p and $Long_p$
Initialize $City\_ID$
Initialize temporary variables ED and ED_{min}
Initialize sample S of size 11, which will be fed into model M
for each $i \in [0, DoD)$ **do**
  $Lat_c[i] = Lat_s + \frac{Lat_d - Lat_s}{DoD} i$
  $Long_c[i] = Long_s + \frac{Long_d - Long_s}{DoD} i$
end for
for each $i \in [0, DoD)$ **do**
  $ED_{min} = \sqrt{(Lat_c[i] - Lat_0)^2 + (Long_c[i] - Long_0)^2}$
  $Lat_p[i] = Lat_0$
  $Long_p[i] = Long_0$
  $City\_ID[i] = 0$
  for each $j \in [1, N_{total})$ **do**
    $ED = \sqrt{(Lat_c[i] - Lat_j)^2 + (Long_c[i] - Long_j)^2}$
    if $ED < ED_{min}$ **then**
      $ED_{min} = ED$
      $Lat_p[i] = Lat_j$
      $Long_p[i] = Long_j$
      $City\_ID[i] = j$
    end if
  end for
end for
$PC_{pred} = 0$
for each $i \in [0, DoD)$ **do**
  $S[0], S[1] \leftarrow$ hour, weekday from $t_s + i - 1$
  $S[2], S[3], S[4], S[5] \leftarrow$ temperature, rainfall, humidity, and wind speed from $Weather_{City\_ID[i], t_s+i-1}$
  $S[6] = Lat_p[i]$, $S[7] = Long_p[i]$
  $S[8], S[9] \leftarrow$ gender, age from User_Info
  $S[10] = DoD$
  $PC_{pred} = PC_{pred} + M(S)$
end for
return PC_{pred}

Illustration of the optimized power consumption prediction.

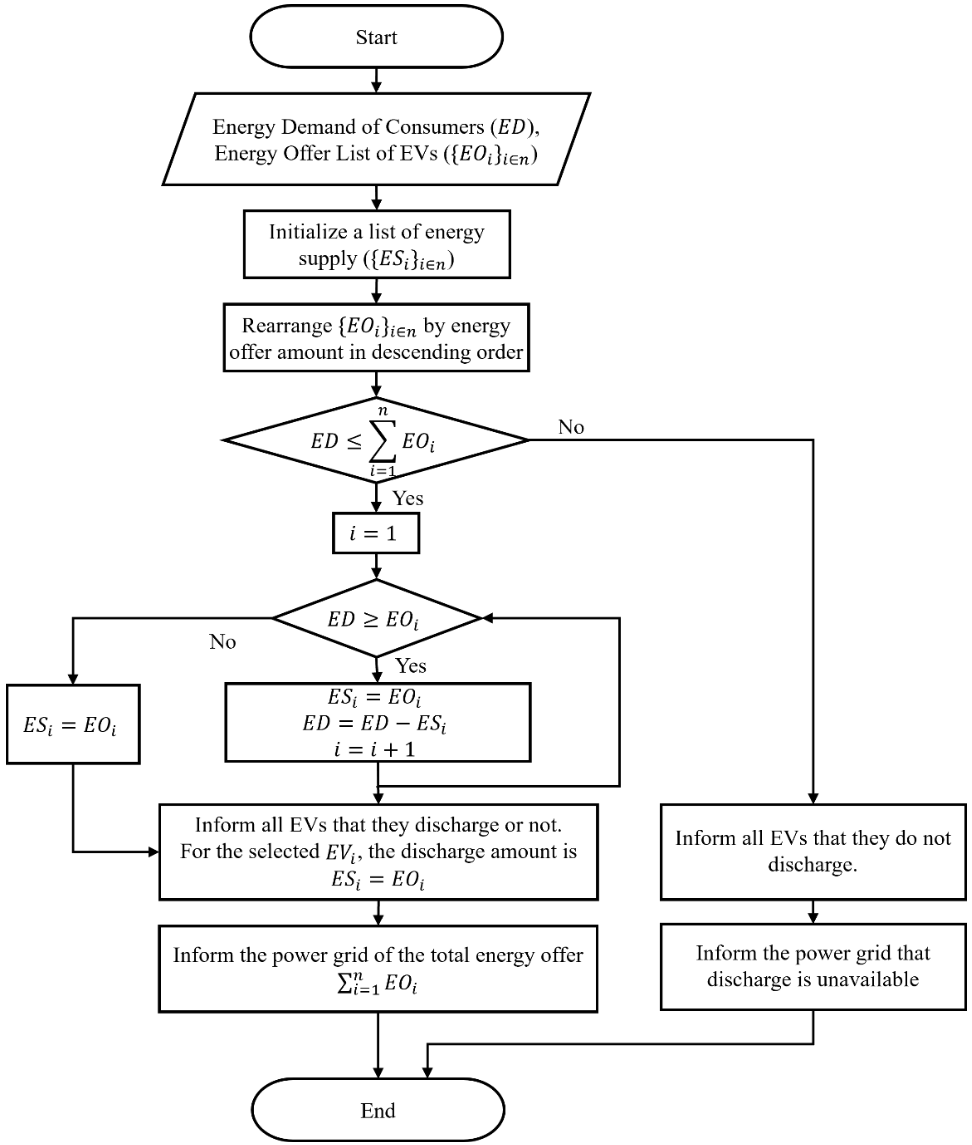
EV Power Consumption Prediction Method and System for Power Management in Smart Grid/ スマートグリッドにおける電力管理のためのEV消 費電力予測 方法とシステム



Flowchart of decision process of energy offer from an EV to the aggregator.

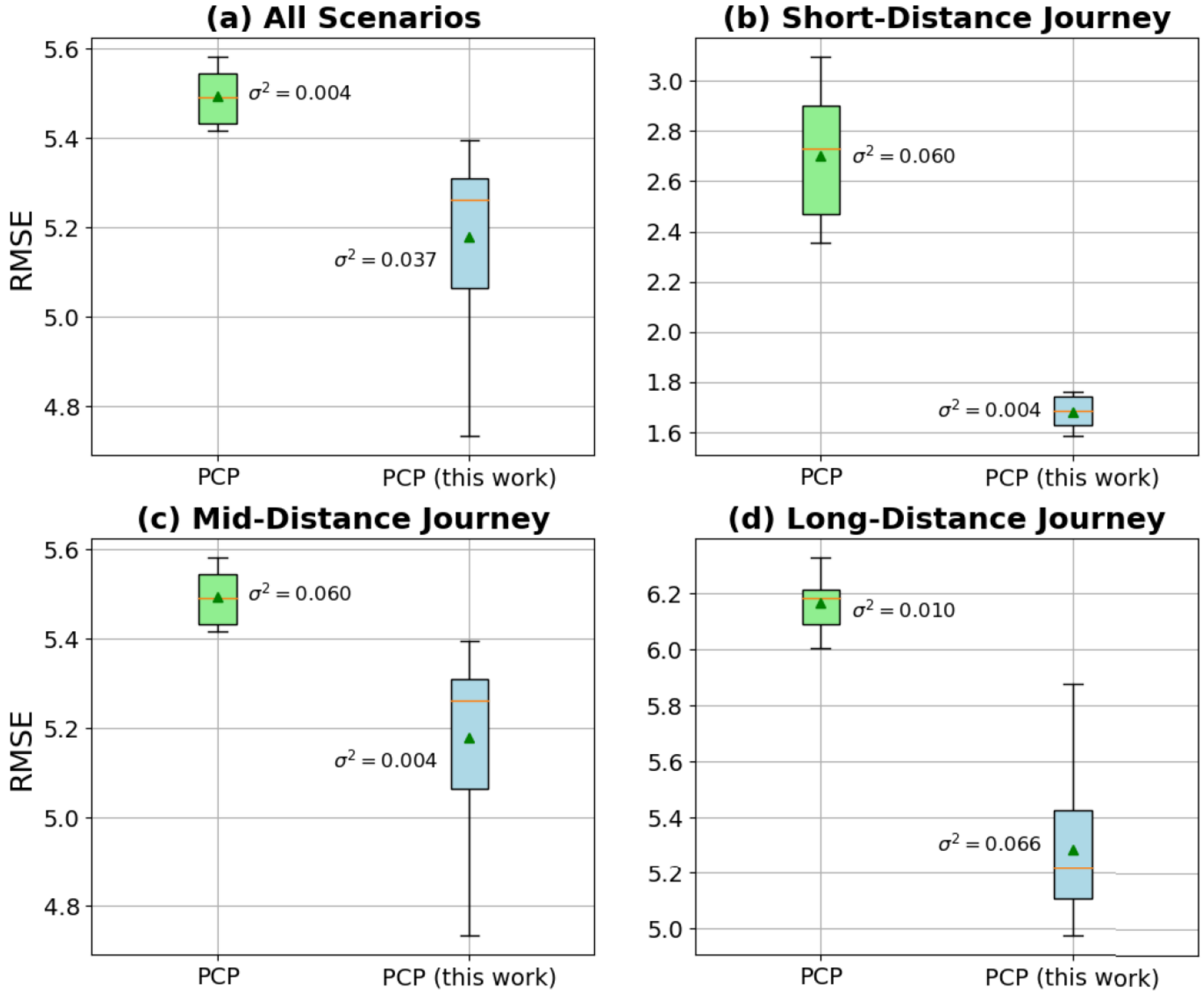


The output layer has one output neuron, i.e., power consumption prediction.



Flowchart of EV selection method.

EV Power Consumption Prediction Method and System for Power Management in Smart Grid/ スマートグリッドにおける電力管理のためのEV消 費電力予測 方法とシステム



Comparison between PCP and the multi-stage PCP (this work) in different scenarios.

Z. Wang and A. Ben Abdallah, "A Robust Multi-Stage Power Consumption Prediction Method in a Semi-Decentralized Network of Electric Vehicles," in IEEE Access, vol. 10, pp. 37082-37096, 2022, doi: 10.1109/ACCESS.2022.3163455.

Summary/概要

1. オフグリッドエネルギー貯蔵ソーラーカーポート/ Off-Grid Energy Storage Solar Carport
   [特許第6804072号] (2020.12.04) ベンアブダラ アブデラゼク(Abderazek Ben Abdallah), 久田雅之, "Virtual Power Platform Control System [仮想発電所制御システム]", 特願2020-033678号 (2020.02.28)

2. ネルギーの取引方法とシステム/Energy Trading Method and System
   Abderazek Ben Abdallah, Wang Zhishang, Masayuki Hisada, "An electricity trading system and an electricity trading method [電力取引システム及び電力取引方法に関する], 特願2022-022472

3. EV Power Consumption Prediction Method and System for Power Management in Smart Grid/ スマートグリッドにおける電力管理のためのEV消 費電力予測 方法とシステム
   Abderazek Ben Abdallah, Wang Zhishang, Khanh N. Dang, Masayuki Hisada, "EV Power Consumption Prediction Method and System for Power Management in Smart Grid [スマートグリッドにおける電力管理のためのEV消費電力予測方法とシステム]", 特願2022 –U