Toward Sustainable Power: Intelligent Energy Harvesting with ICT and Electric Vehicles

持続可能な電力に向けて：ICT とEVによるインテリジェントなエネルギー収集

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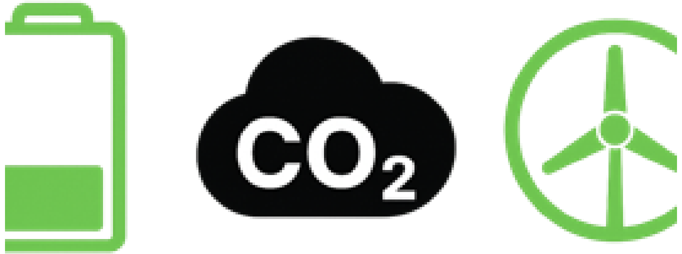
Energy Consumption, CO_2 Emissions & Renewable Opportunities

Current Energy Consumption

- Global demand continues to rise, driven by industry, transport, and digital infrastructure.
- Heavy reliance on fossil fuels (oil, coal, natural gas) still dominates the energy mix.

CO_2 Emissions Impact

- The energy sector accounts for ~73% of global greenhouse gas emissions.
- Rising emissions linked to climate change, air pollution, and health risks.
- Urgent need for decarbonization to meet **2050 net-zero targets.**



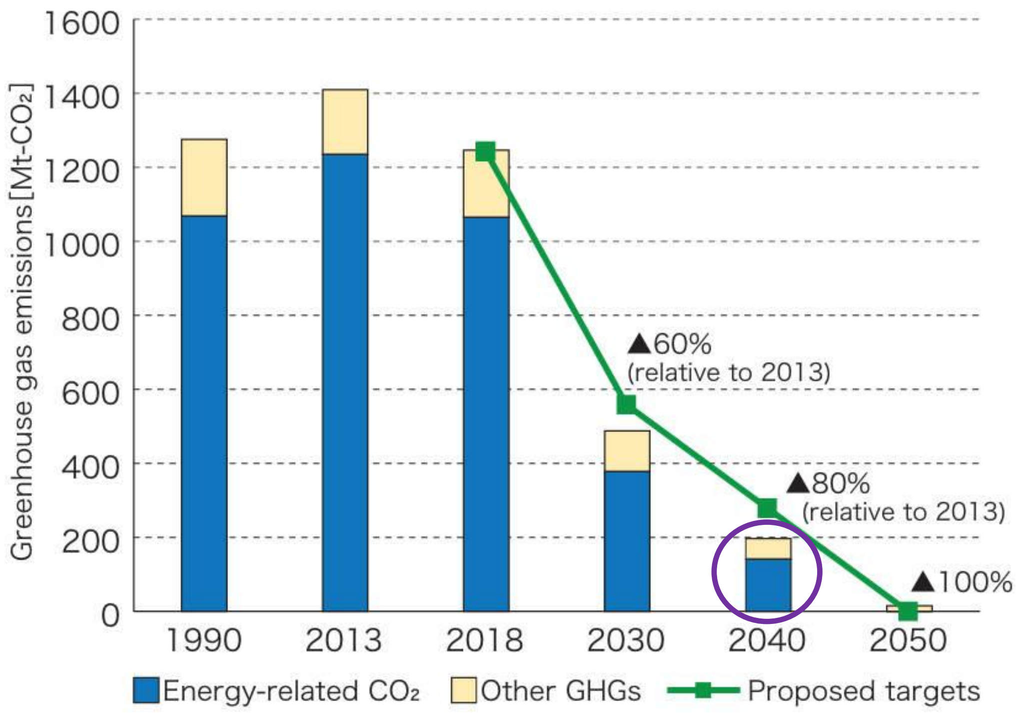
Renewable Energy Opportunities

- Solar and wind now cost-competitive with fossil fuels.
- Battery Energy Storage Systems (BESS) enable stable integration of renewables.
- Policy tools (FIT/FIP schemes, carbon pricing) accelerate adoption.
- Potential to reduce CO_2 emissions **by 40–70% by 2050 with renewable deployment.**

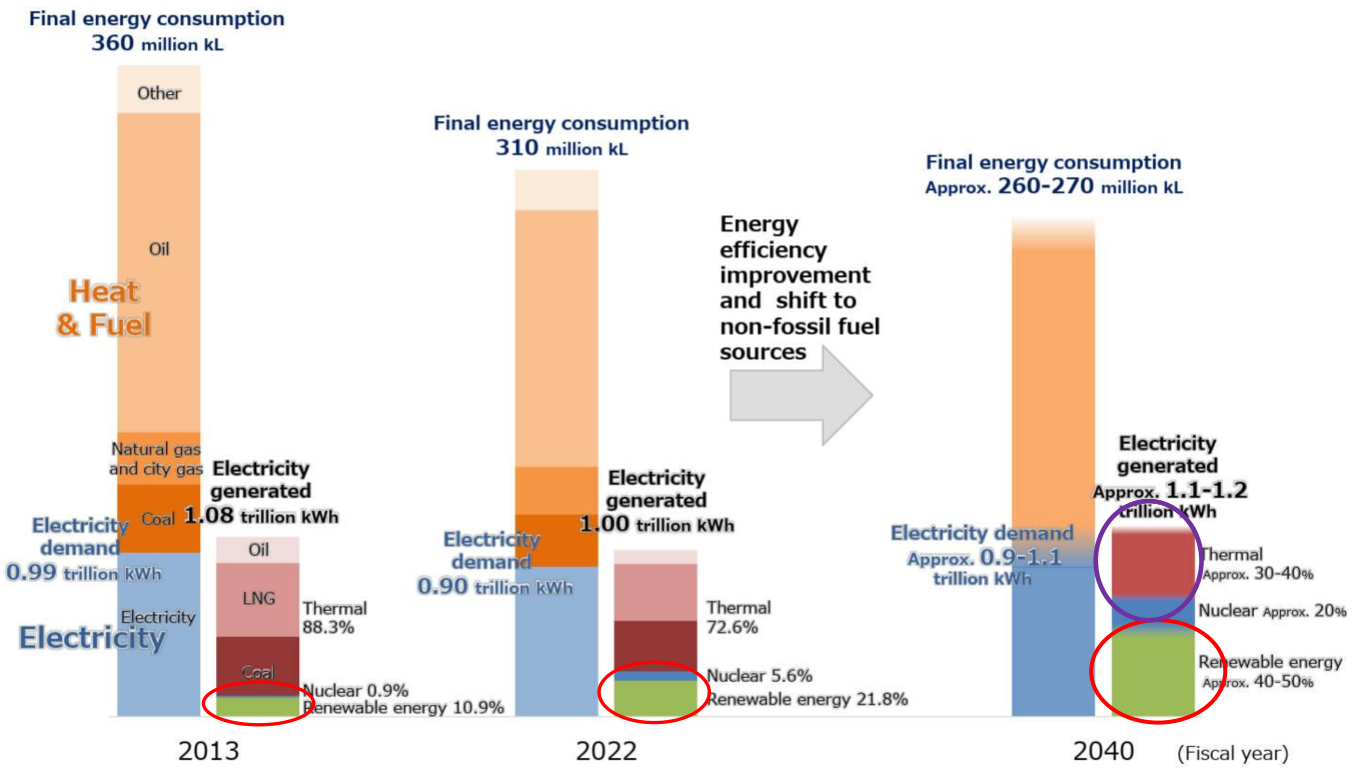
Japan's CO_2 Emissions and Long-Term Decarbonization Strategy

日本のCO_2排出量と長期脱炭素戦略

Japan's Path to Net Zero by 2050



Japan — FY2040 Power-Mix Targets (Seventh Strategic Energy Plan, Outline)



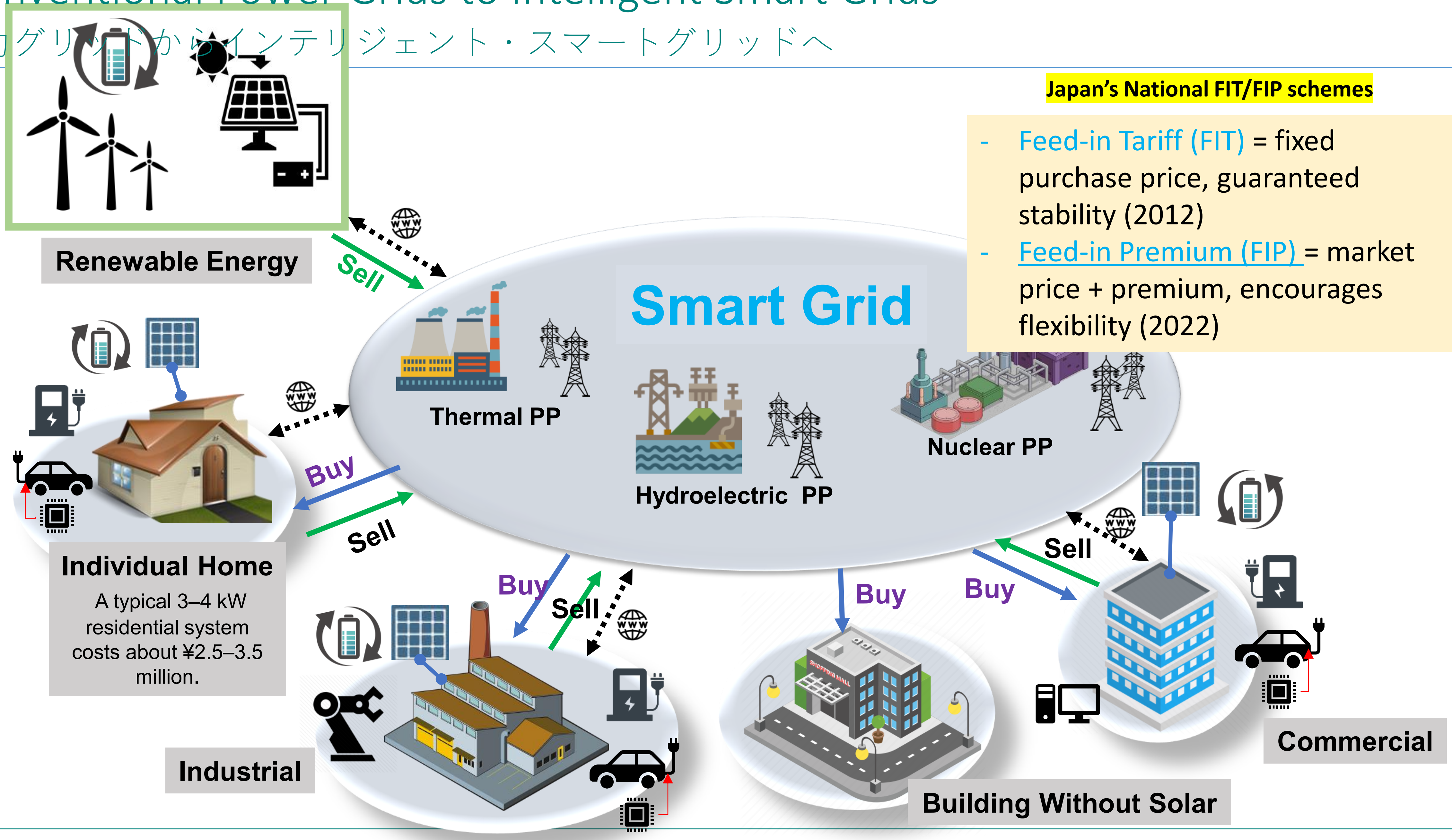
[Kiko Network, "Japan's Path to Net Zero by 2050," accessed Oct 20, 2025, https://kikonet.org/en/content/31180
[METI, "The 7th Strategic Energy Plan — Outline," accessed Oct 20, 2025, www.enecho.meti.go.jp/en/category/others/basic_plan/

From Conventional Power Grids to Intelligent Smart Grids

従来型電力グリッドからインテリジェント・スマートグリッドへ

Japan's National FIT/FIP schemes

- Feed-in Tariff (FIT) = fixed purchase price, guaranteed stability (2012)
- Feed-in Premium (FIP) = market price + premium, encourages flexibility (2022)



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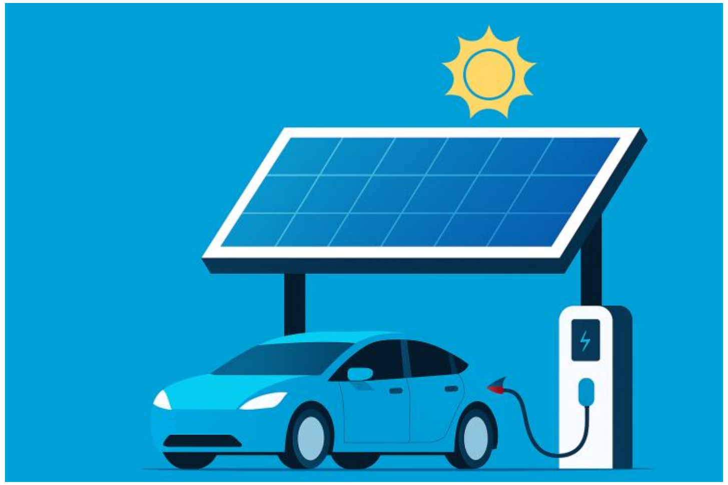
Vision and Motivation/ビジョンと動機

- **Sustainable Power**: Harness solar energy for EV charging, reducing grid dependency and carbon footprint
  - **In Japan (2025), installing solar panels typically costs between ¥840K and ¥1400K per kW**
  - Panels in Japan generally achieve 20–23% efficiency, similar to global averages.
  - A 4 kW system can generate 4,000–4,500 kWh annually, depending on location and sunlight.
  - **Fukushima and Tohoku regions have slightly lower annual solar radiation compared to Tokyo, but still viable for residential systems.**



- **AI Optimization**: Predictive control of solar input, battery usage, and EV charging schedules
- **Urban Innovation**: Transform parking into intelligent, energy-generating infrastructure
- **Resilience**: Ideal for remote, disaster-prone, or underserved regions

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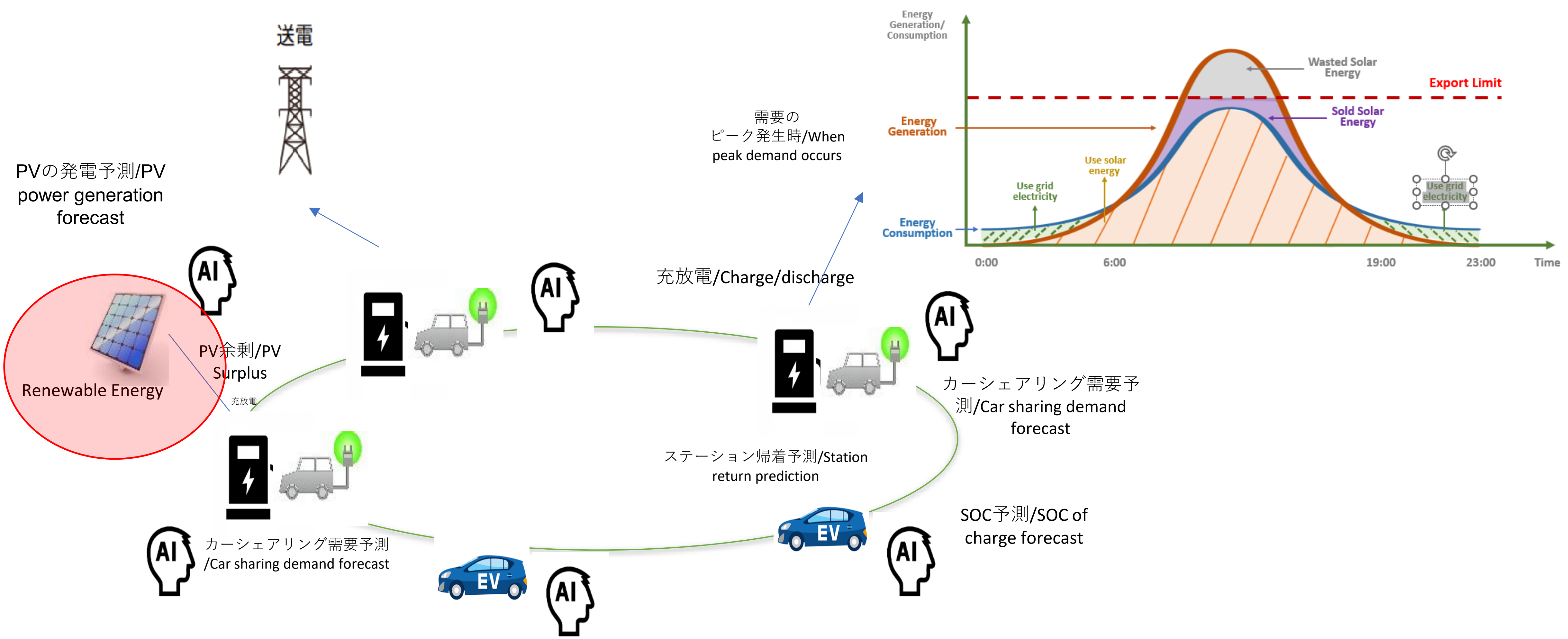

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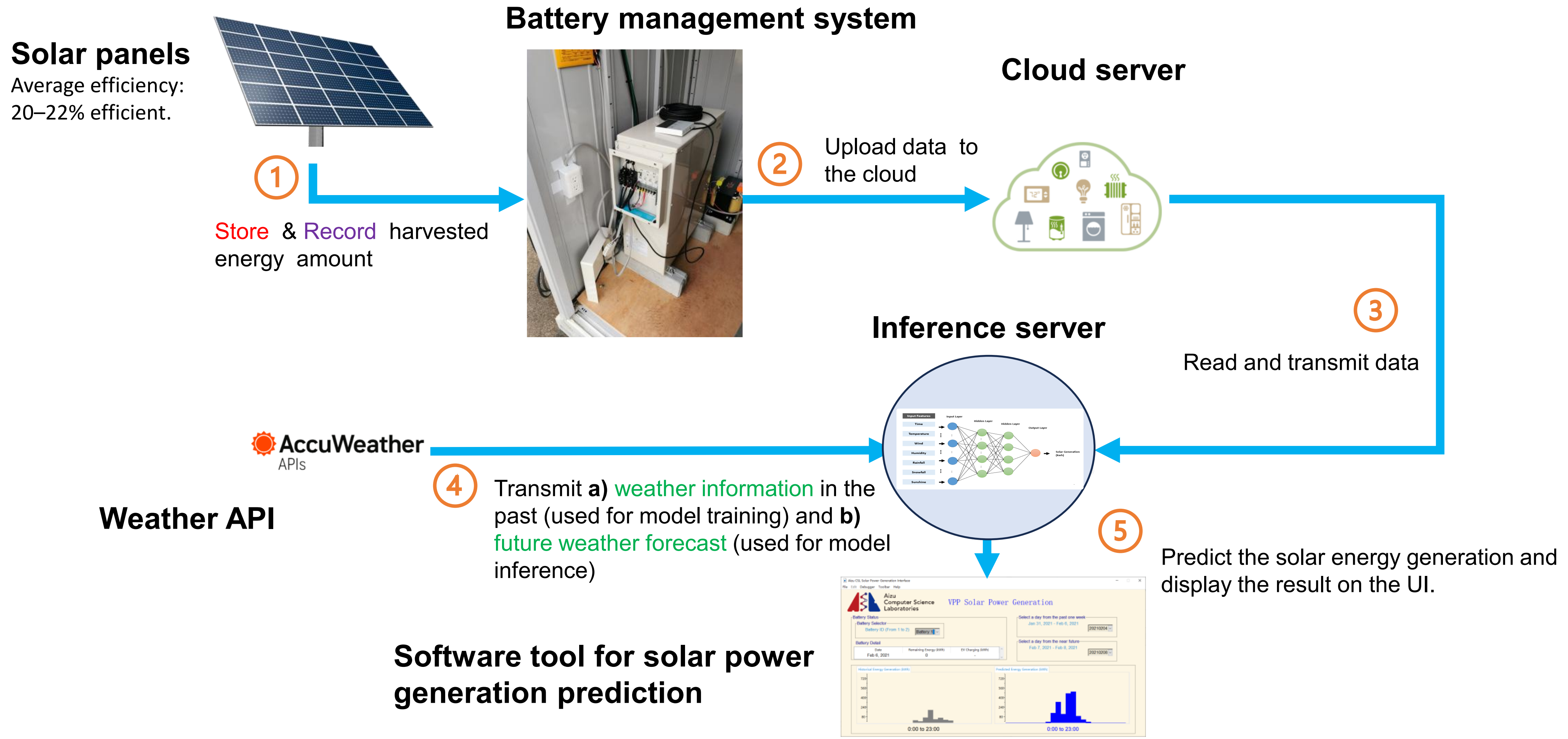
System Overview



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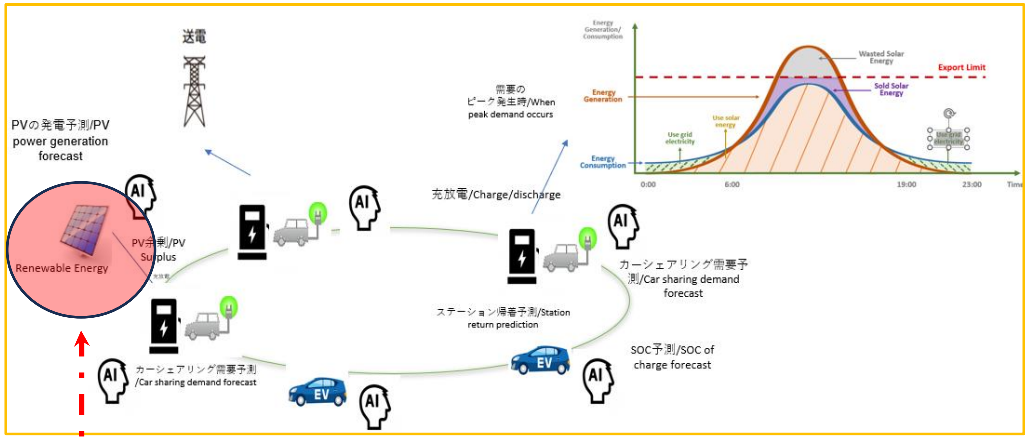
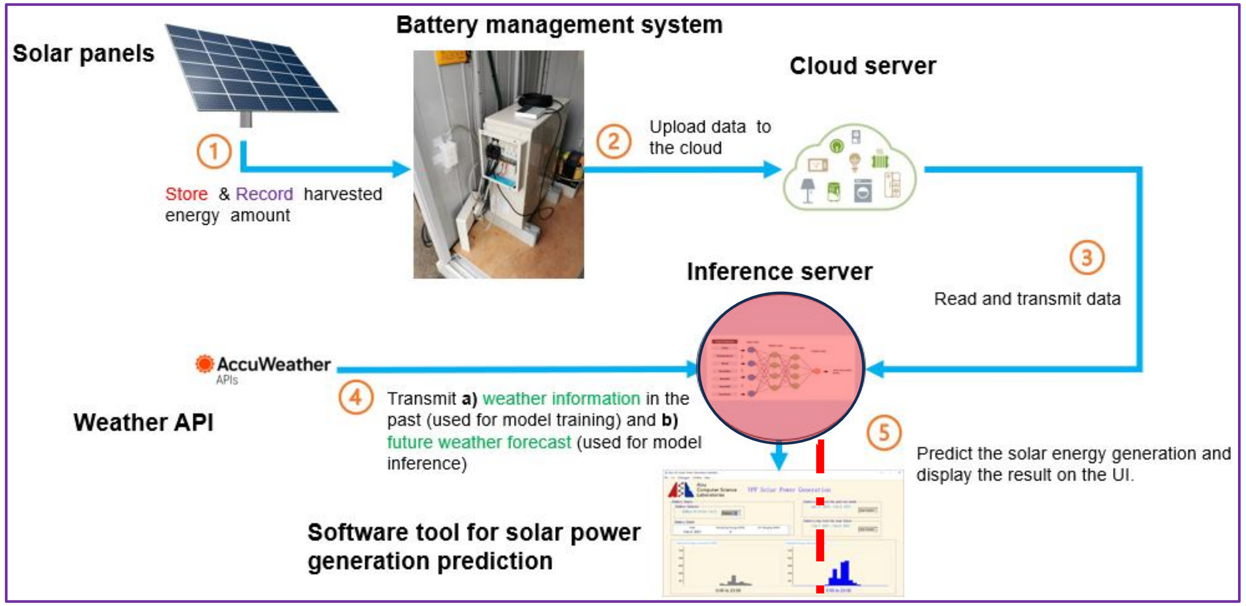
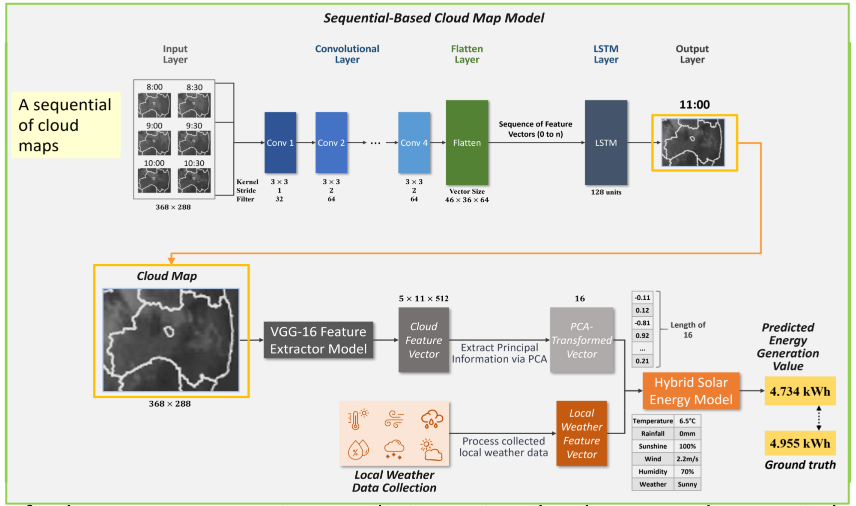


1. PVの発電予測/PV power generation forecast





Workflow of solar energy generation prediction using cloud maps and numerical weather data.

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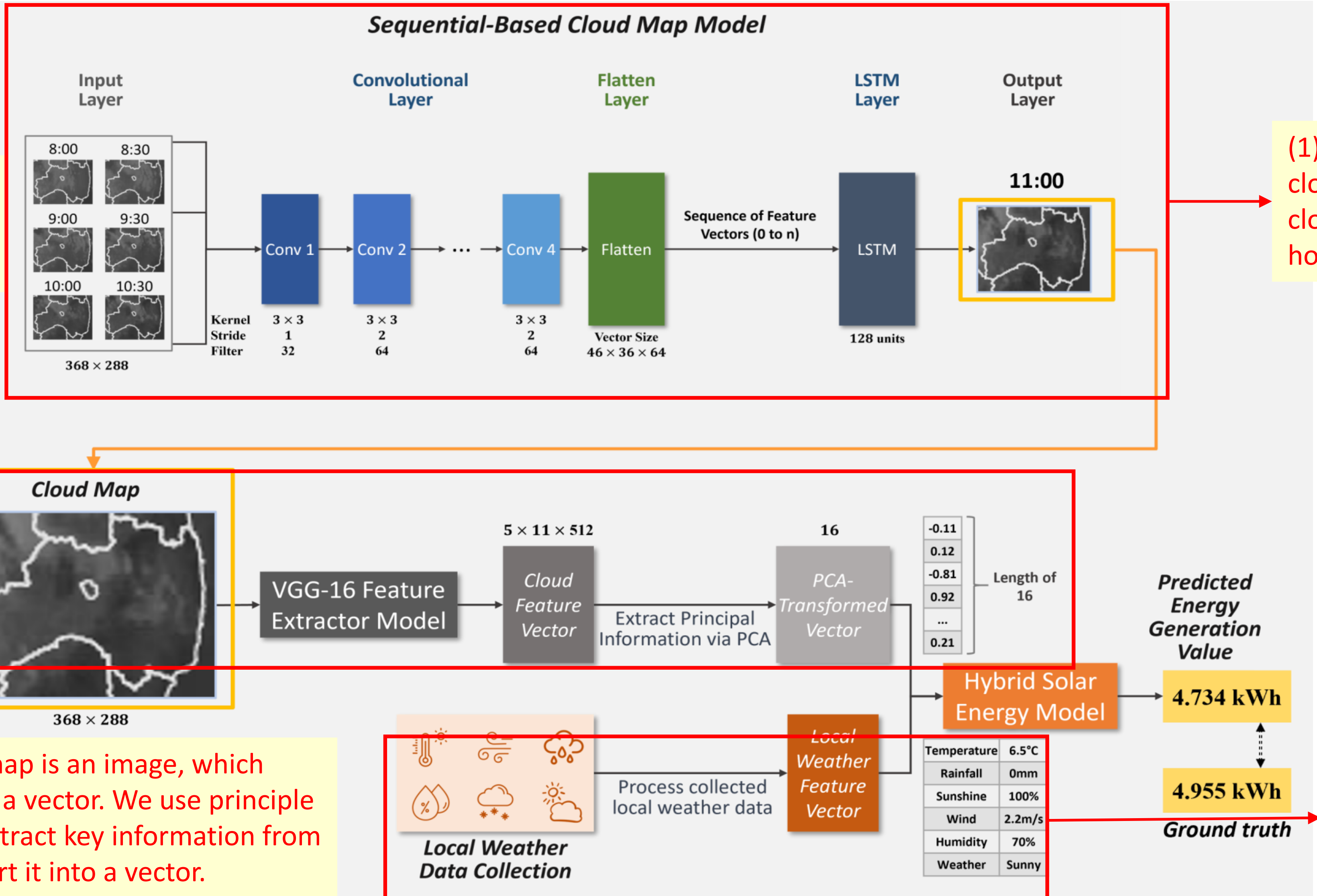
A sequence of cloud maps



(1) Using past sequence of cloud maps to forecast future cloud maps (30 min, up to 2 hours)

(2) The predicted cloud map is an image, which needs to be converted to a vector. We use principle component analysis to extract key information from the cloud map and convert it into a vector.

(3) We collect weather data in numerical format, to be integrated with cloud map (already converted into vectors rather than image)

Workflow of solar energy generation prediction using cloud maps and numerical weather data.

For cloud map: Japan Meteorological Agency, "Weather Satellite Himawari," accessed Nov. 25, 2025, https://www.jma.go.jp/bosai/map.html
For weather data: Japan Meteorological Agency, "Historical weather data," accessed Nov. 25, 2025, https://www.data.jma.go.jp/risk/obsdl/index.php

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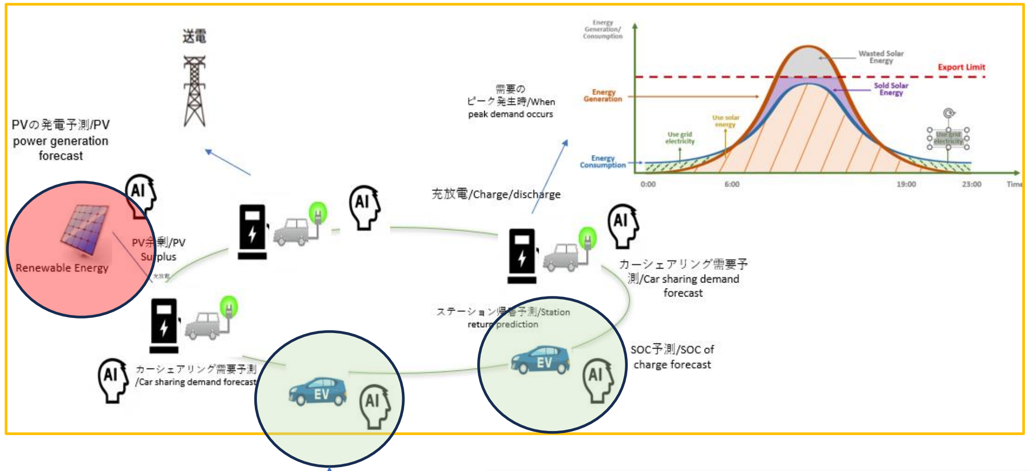
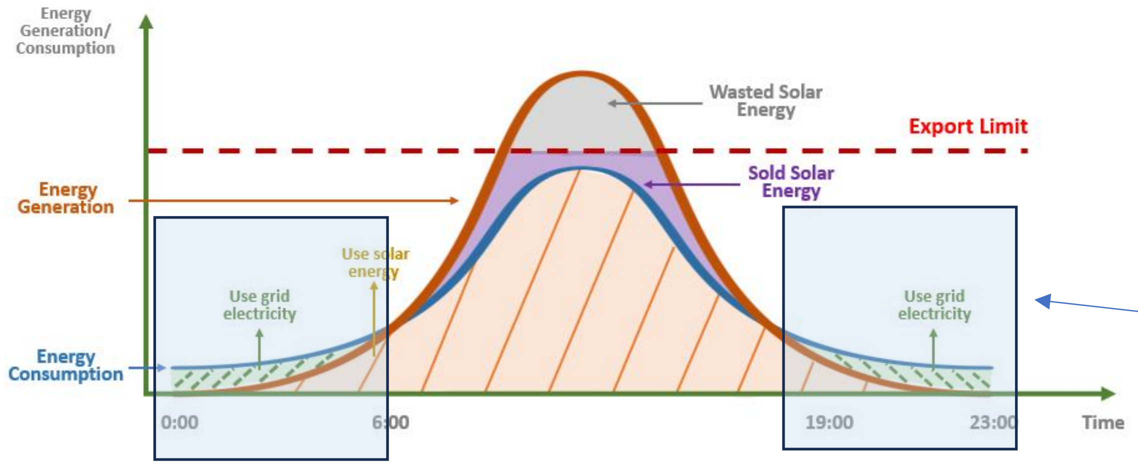
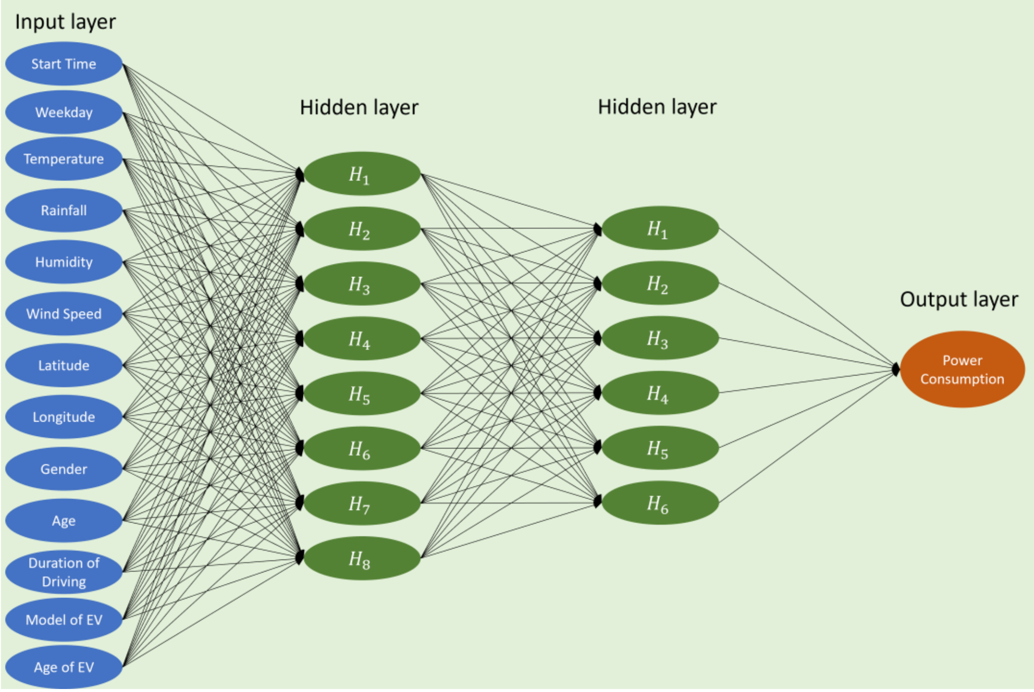


EV Power Consumption Prediction



EV discharge period

2. EV Power Consumption Prediction



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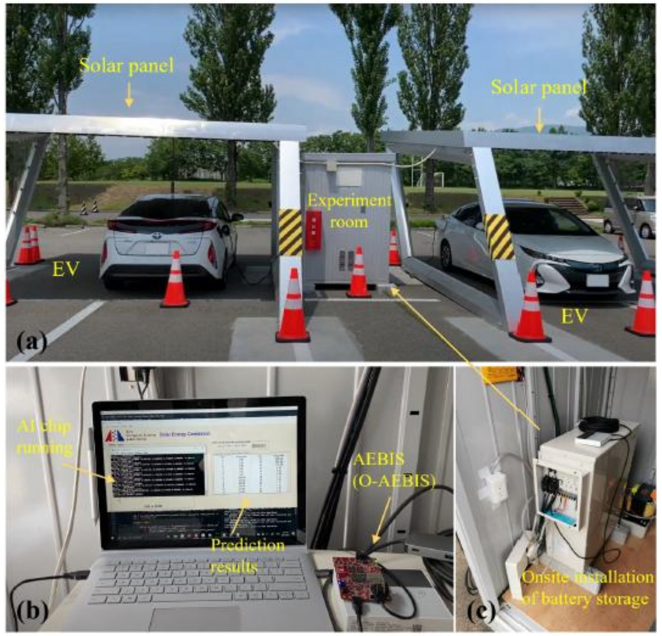
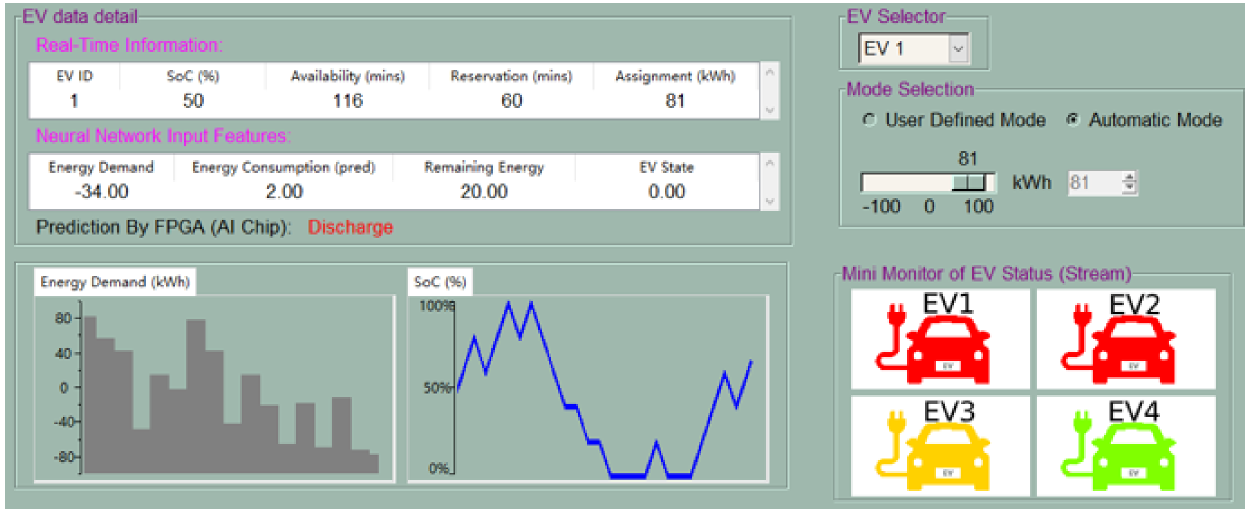
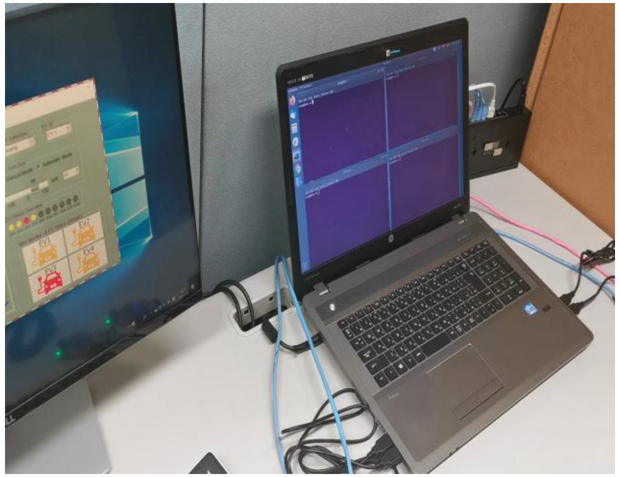
On-site Field Experiment, UoA, 2021

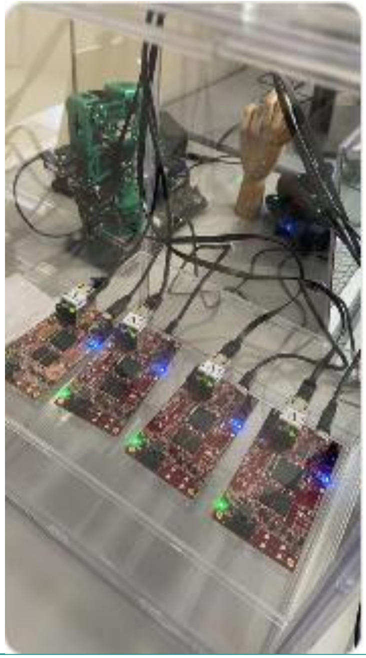


Software Tool – EV Charge/Discharge Status Display





Hardware Experiments



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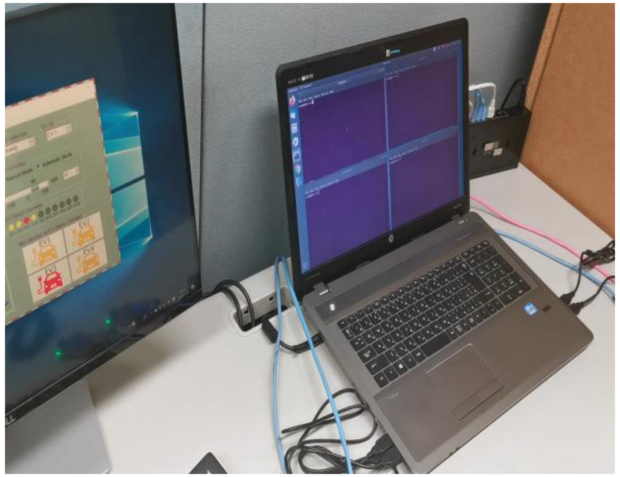
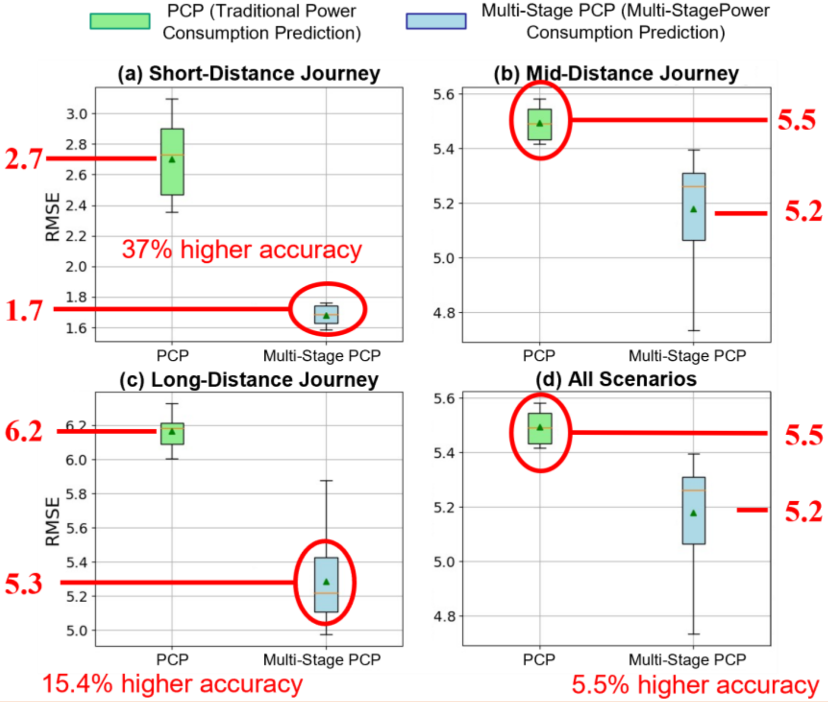




The multi-stage prediction method achieves better performance, increasing EV power consumption prediction accuracy by 5.5% across all scenarios compared to the baseline method.

Cloud Map Prediction

Table 2. Evaluation of the cloud prediction method using Fukushima cloud maps (comparative image pairs) [1].

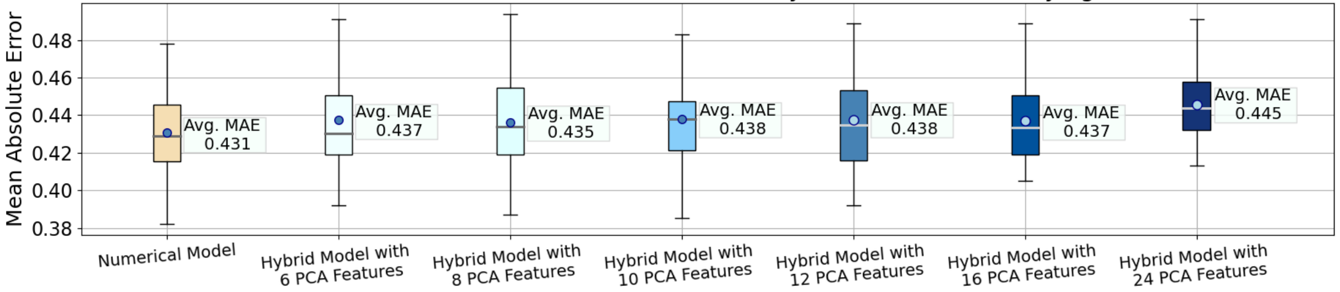
Forecast Interval	Avg. MSE	Avg. PSNR	Avg. SSIM
30 minutes	277.30	23.75	0.893
1 hour	297.35	23.57	0.891
1.5 hours	309.49	23.53	0.892
2 hours	452.64	21.88	0.884

Table 3. Evaluation of the super-resolution-based cloud prediction method using Fukushima cloud maps (comparative image pairs) [1].

Forecast Interval	Avg. MSE	Avg. PSNR	Avg. SSIM
30 minutes	2056.39	16.52	0.909
1 hour	1906.75	16.87	0.914
1.5 hours	1863.41	16.68	0.916
2 hours	1578.94	17.89	0.926

Robust performance of the cloud map prediction with high accuracy and structural similarity. The cloud map prediction benefits from super-resolution. Combining the cloud map with numerical meteorological data maintains the accuracy

Evaluation on MAE across the numerical model and hybrid models with varying PCA features



Solar Energy Generation Prediction

[Japan Meteorological Agency, “Weather Satellite Himawari,” accessed Nov. 25, 2025, https://www.jma.go.jp/bosai/map.html

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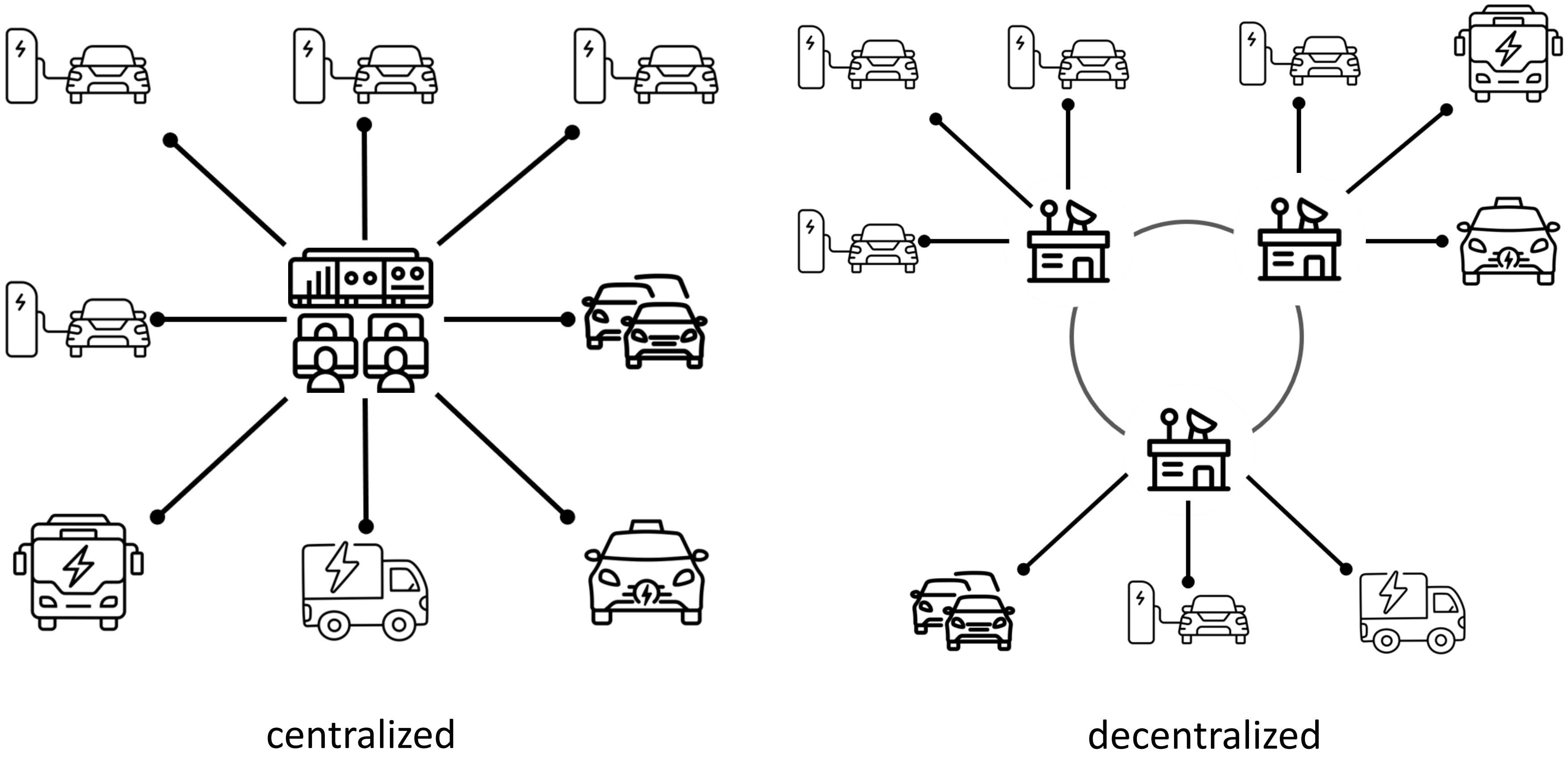
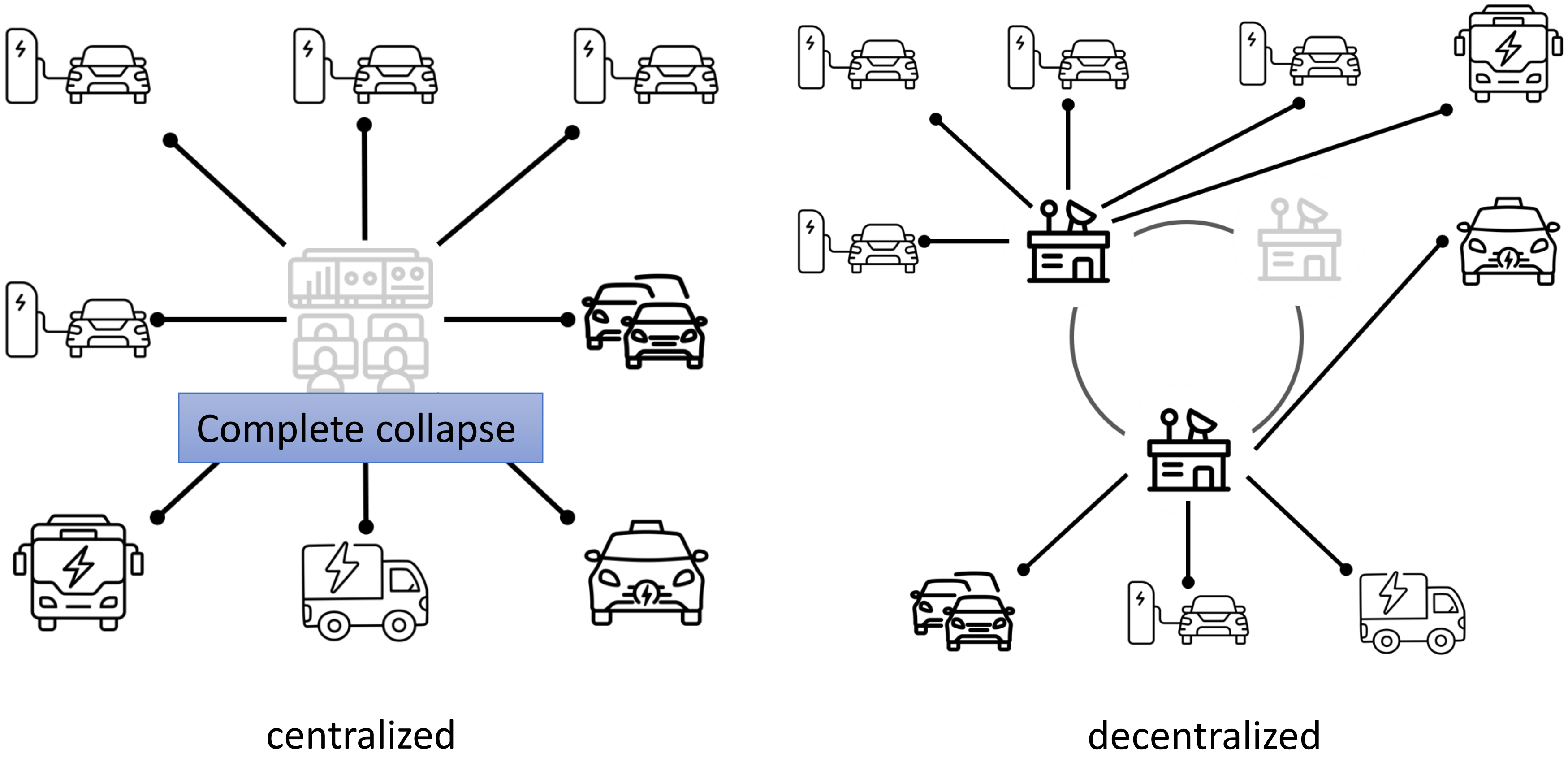


Centralized and decentralized energy trading system networks.
Its objective is to optimize efficiency, security, privacy, and scalability.

V2G Energy Trading: Building Trust in the Grid
V2Gエネルギー取引：グリッドにおける信頼構築



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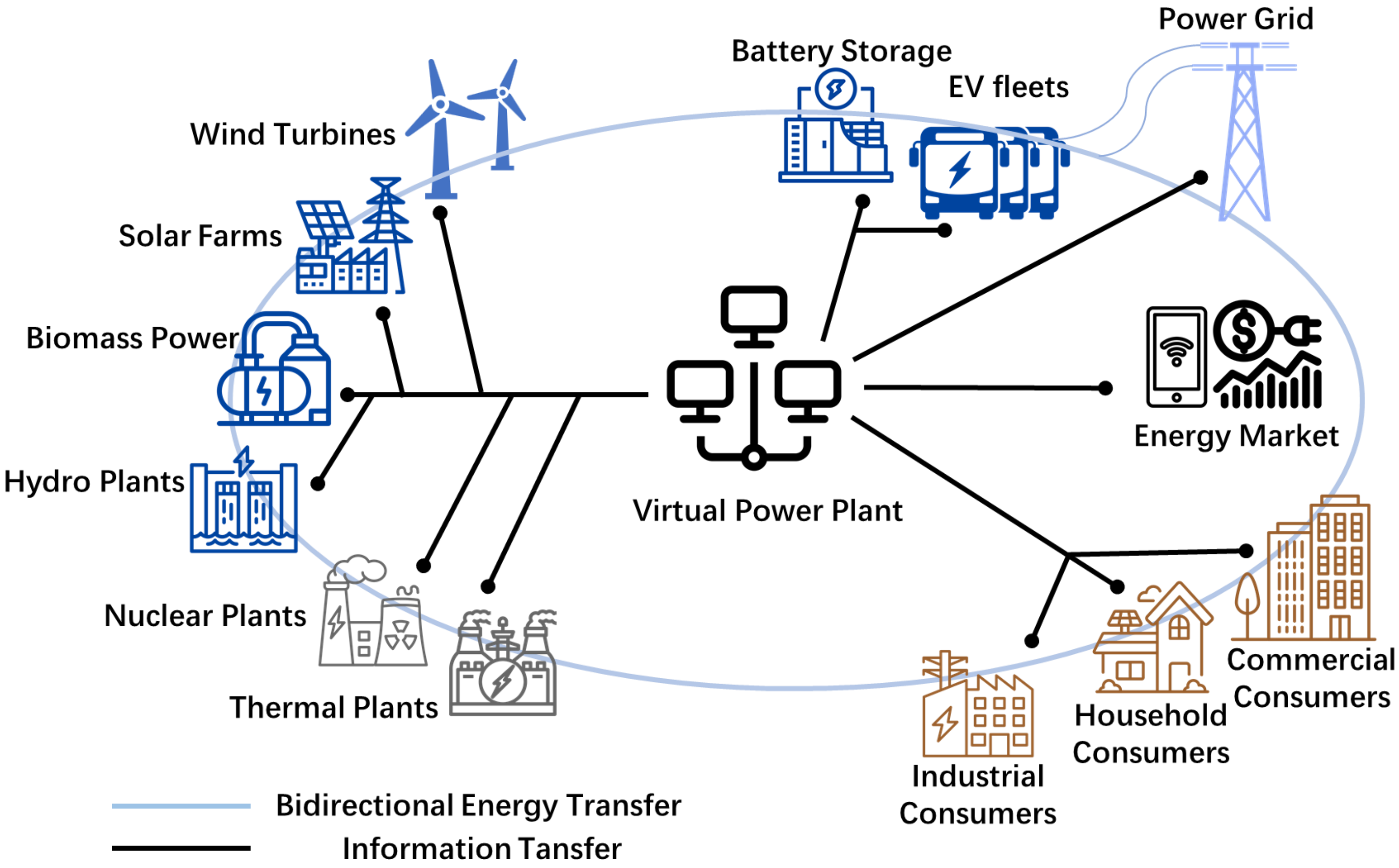


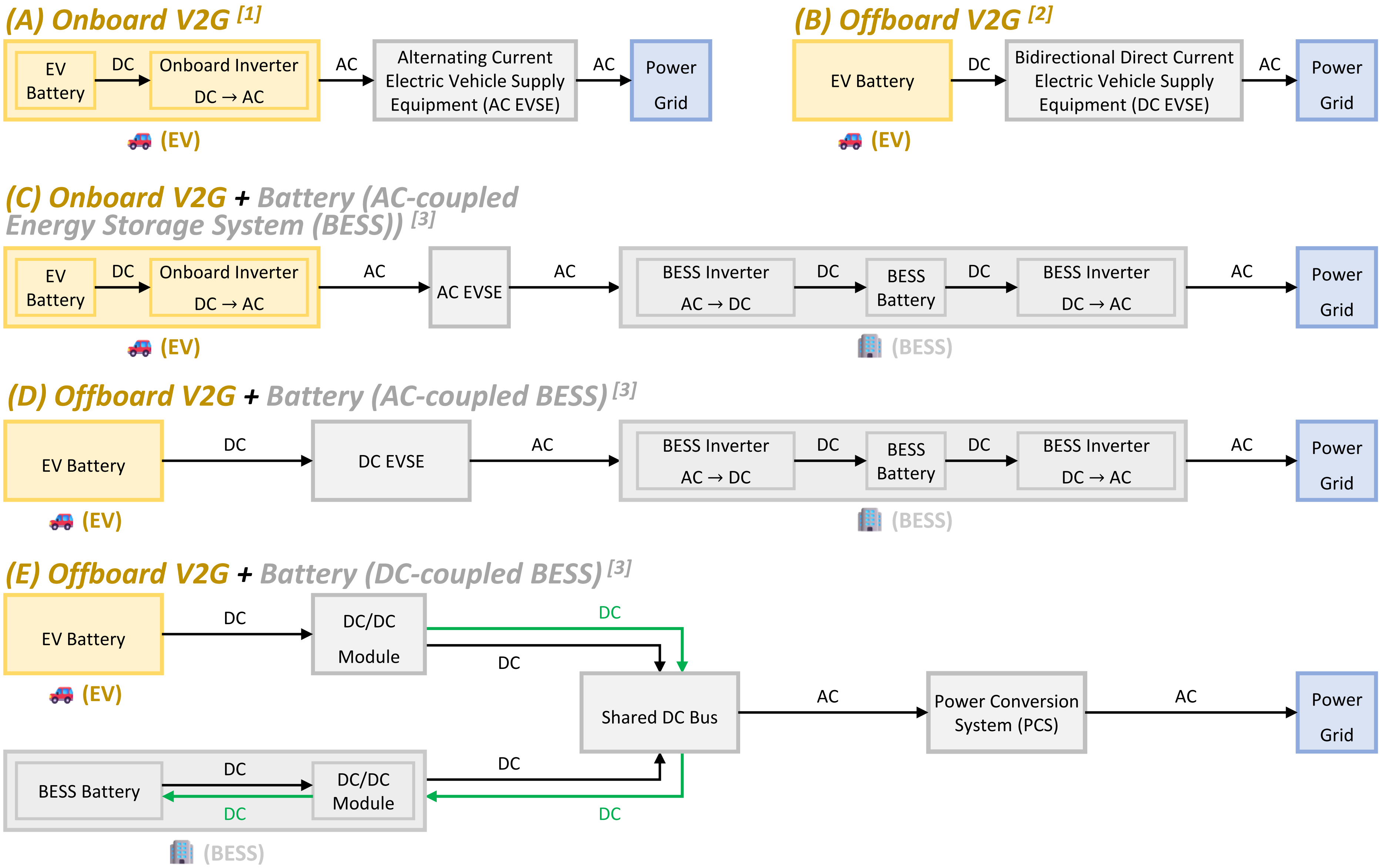
Illustration of a distributed power system updated with a VPP and energy storage departments.

The grid turns from the center of the system to a necessary ancillary part.

The VPP now serves as an information processing center, integrating the power grid, energy market, renewable and non-renewable resources, energy storage systems, and energy consumers.

V2G Energy Trading: Building Trust in the Grid
V2Gエネルギー取引：グリッドにおける信頼構築

V2G Solution and Topologies



[1] Nissan, "Nissan to launch affordable vehicle-to-grid technology in 2026," accessed Nov. 25, 2025, https://global.nissannews.com/en/releases/nissan-to-launch-affordable-vehicle-to-grid-technology-in-2026
[2] Kia, "Kia EV9 Bidirectional Charging (V2H and V2G) Successfully Trialled," accessed Nov. 25, 2025, https://zecar.com/resources/kia-ev9-bidirectional-charging-v2h-and-v2g
[3] Volvo, "Battery Energy Storage System – Powering the Future," accessed Nov. 25, 2025, https://www.volvoenergy.com/en/energy-storage/energy-storage.html

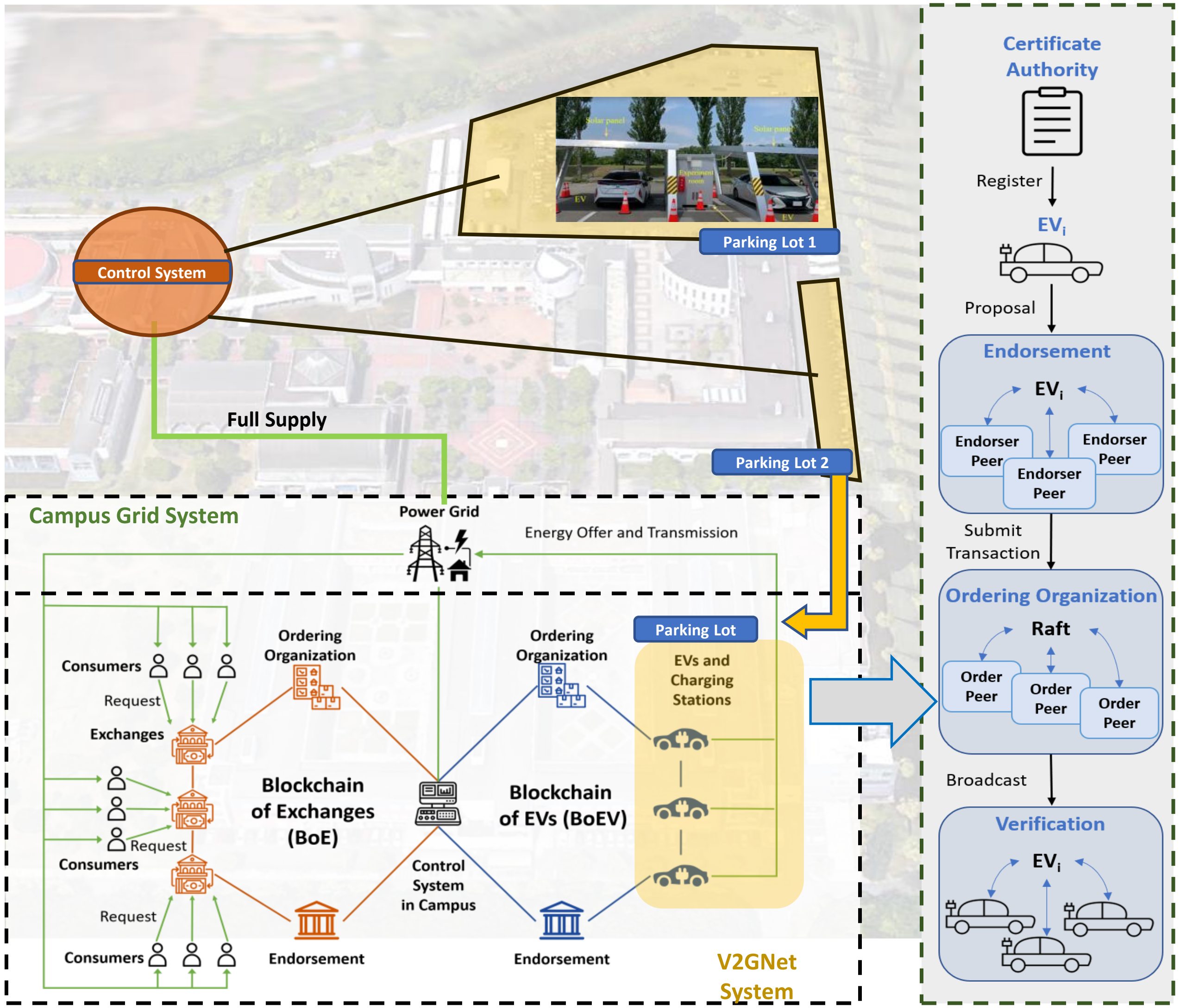
V2G Energy Trading: Building Trust in the Grid
V2Gエネルギー取引：グリッドにおける信頼構築

- Each campus' V2G control system (CS) works as an information mediator between energy consumers and EV suppliers.
  各キャンパスの V2G 制御システム（CS）は、エネルギー消費者と EV 供給者の間で情報の仲介役として機能します。

- Each consumer connects and submits the energy request to the energy exchange.
  各消費者はエネルギー取引所に接続し、エネルギー要求を提出します。

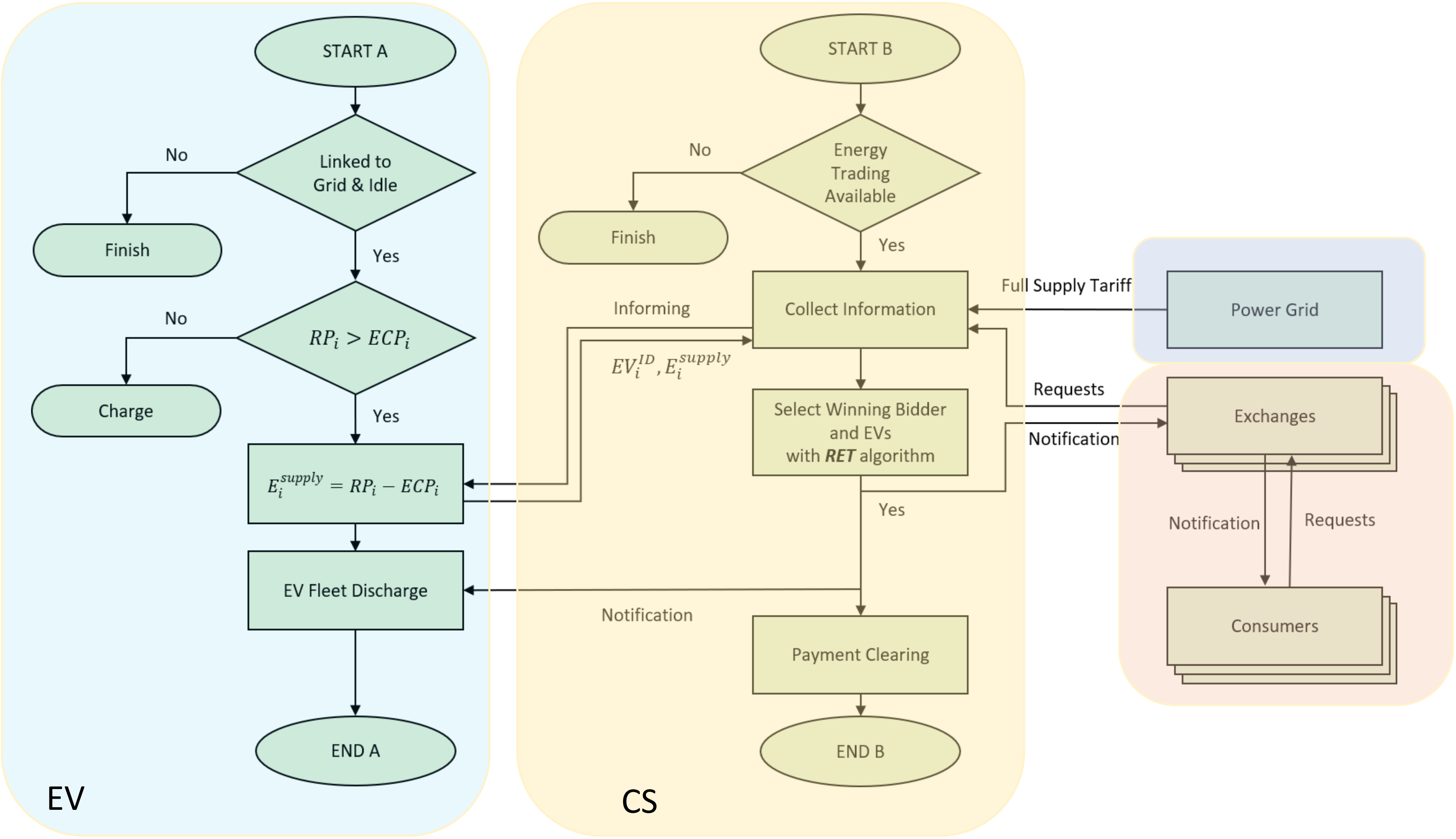
- In BoEV, the offer lists (EVs to CS) and notification of discharge tasks (CS to EVs) are transmitted.
  BoEVでは、提供リスト（EVからCSへ）と放電タスクの通知（CSからEVへ）が伝達されます。

- Only necessary trading data is uploaded to keep privacy and shorten the chaining latency.
  必要な取引データのみがアップロードされ、プライバシーを保護し、チェーンの遅延を短縮します。



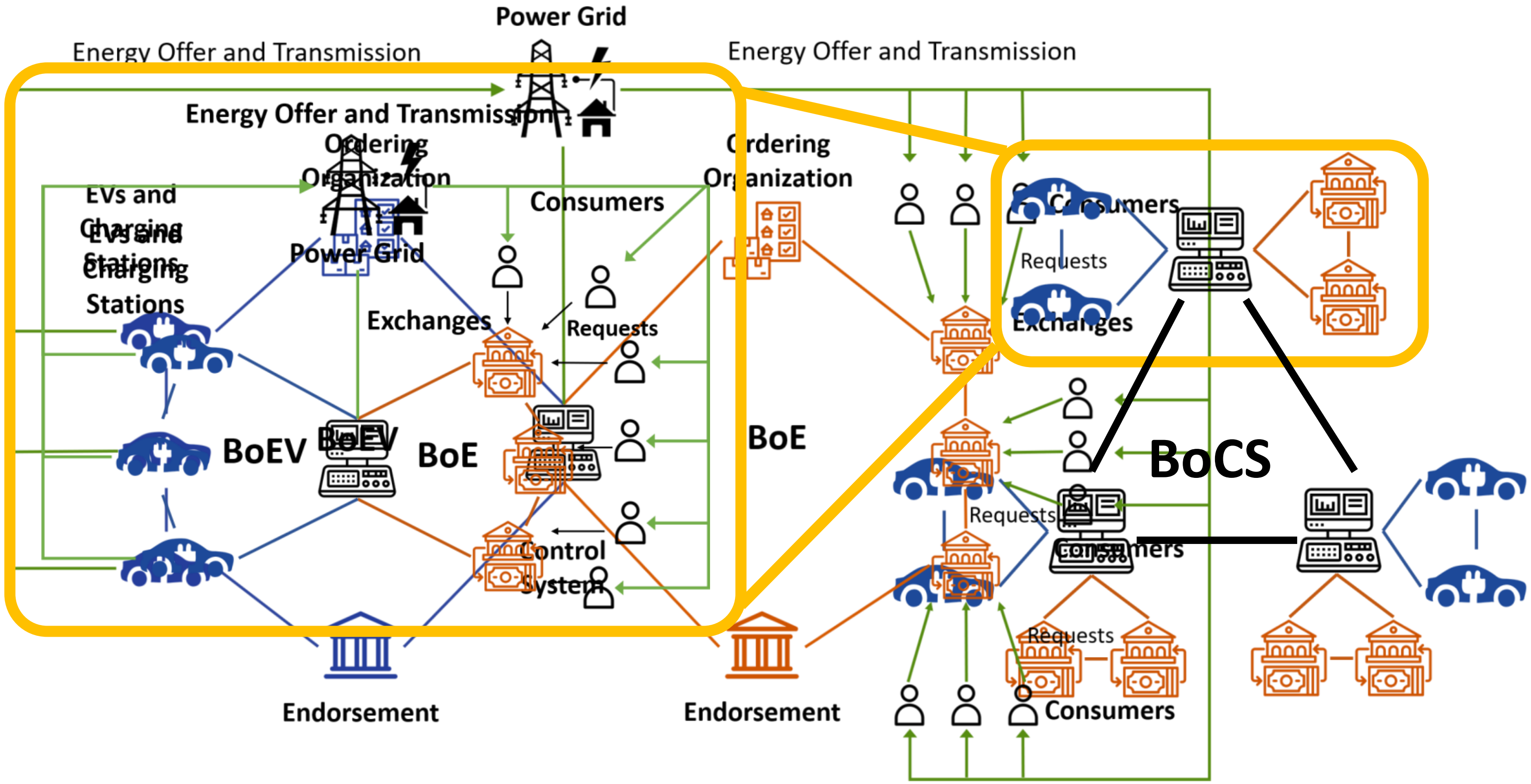
Overview of V2GNet for energy trading in a campus V2G network.

V2G Energy Trading: Building Trust in the Grid
V2Gエネルギー取引：グリッドにおける信頼構築



Flowchart for V2GNet Trading Algorithm.

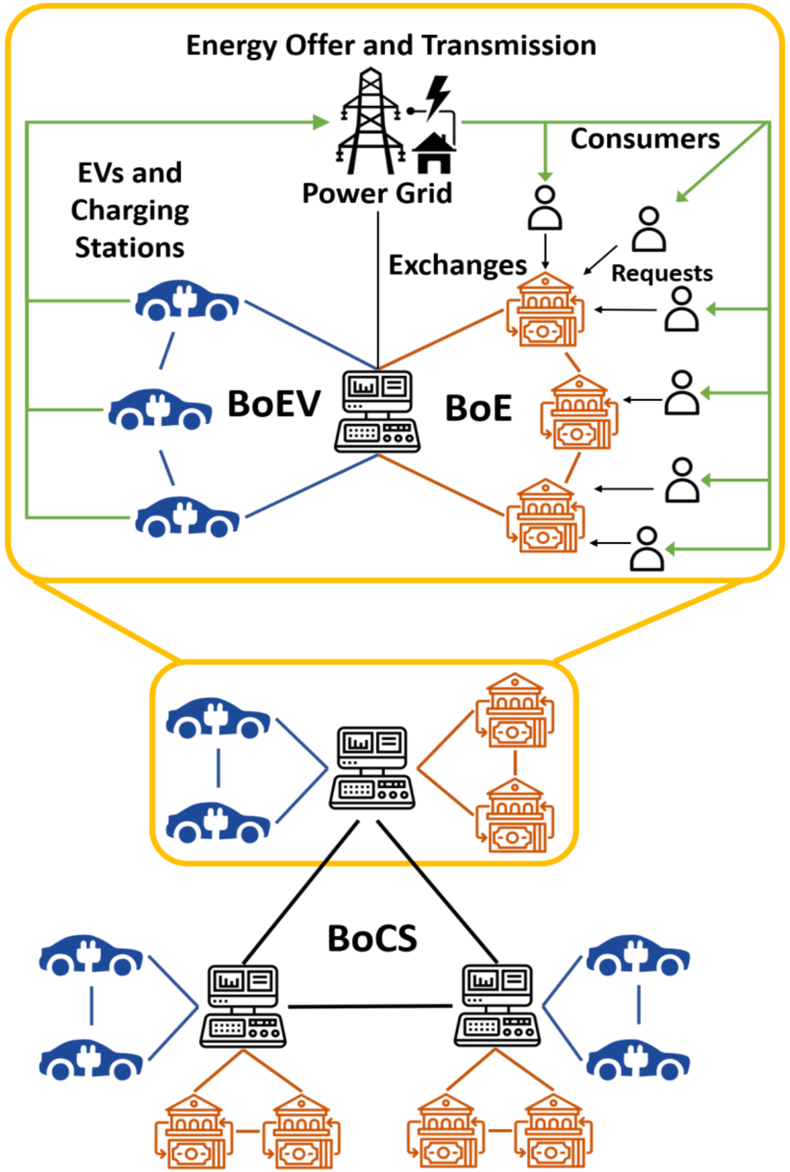
V2G Energy Trading: Building Trust in the Grid
V2Gエネルギー取引：グリッドにおける信頼構築



Overview of the proposed blockchain of campus control systems (BoCS) among campuses based on the CS of each V2GNet.

- The BoCS is where inter-campus energy trading is planned and recorded, and each CS is a node of the BoCS. Besides, each campus's CS serves as a blockchain connection between the BoEV and the BoE for that campus.

V2G Energy Trading: Building Trust in the Grid
V2Gエネルギー取引：グリッドにおける信頼構築



1. Upload unselected EV suppliers and energy requests.
2. Download the overall request list and EV supplier list.
3. Compete on trading planning SRET mechanism and uploading the outcome back to BoCS.
4. Download and record the new block from BoCS. Arrange energy trading accordingly.

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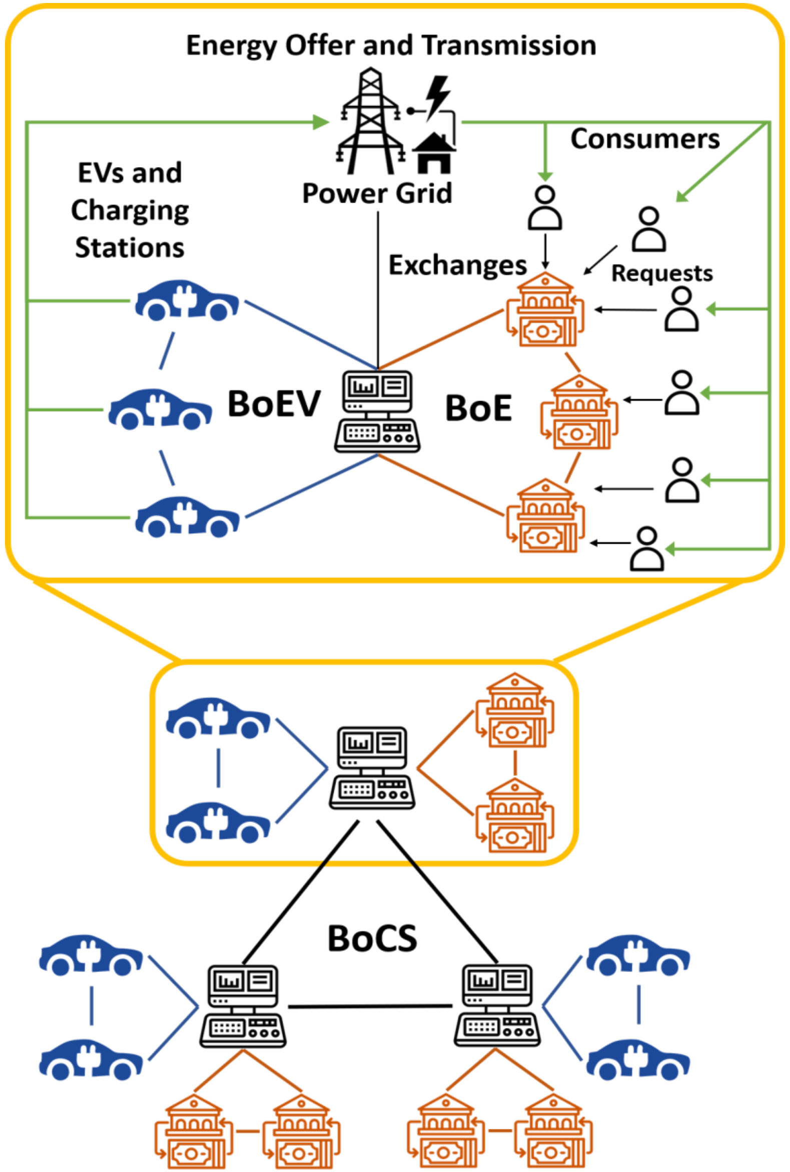

1. **The initial step in BoCS begins once any CS completes and uploads the local trading plan to its BoE and BoEV. The CS packs the data for its unselected EVs and requests into a transaction, then broadcasts it on BoCS. Once enough transactions are collected within any pool, the corresponding CS dispatch them for endorsement and ordering, then package into a block. The block is broadcast across BoCS for verification.**
2. Download the overall request list and EV supplier list.
3. Compete on trading planning SRET mechanism and uploading the outcome back to BoCS.
4. Download and record the new block from BoCS. Arrange energy trading accordingly.

Overview of the proposed blockchain of campus control systems (BoCS) among campuses based on the CS of each V2GNet.

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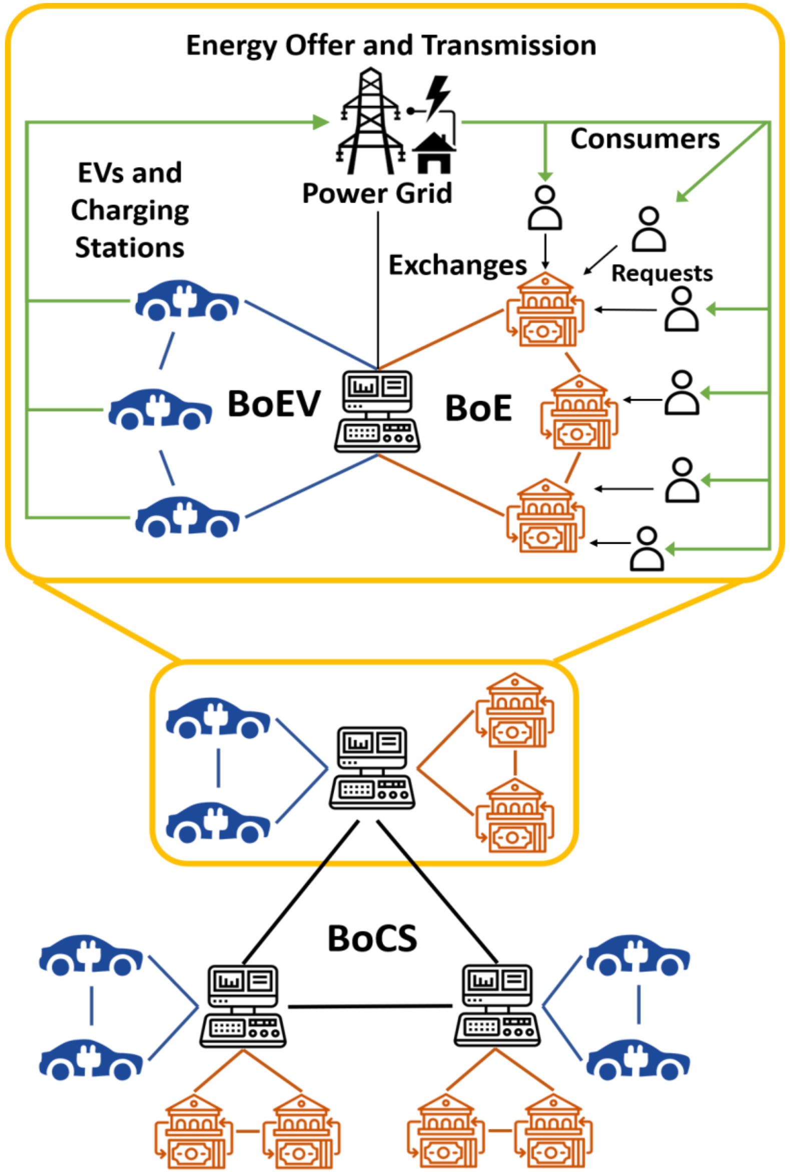

1. Upload unselected EV suppliers and energy requests.
2. **After the block is verified, each node of the BoCS proceeds to download the block, extracting the associated lists and consolidating these lists into an overall request list and an overall EV supplier list.**
3. Compete on trading planning SRET mechanism and uploading the outcome back to BoCS.
4. Download and record the new block from BoCS. Arrange energy trading accordingly.

Overview of the proposed blockchain of campus control systems (BoCS) among campuses based on the CS of each V2GNet.

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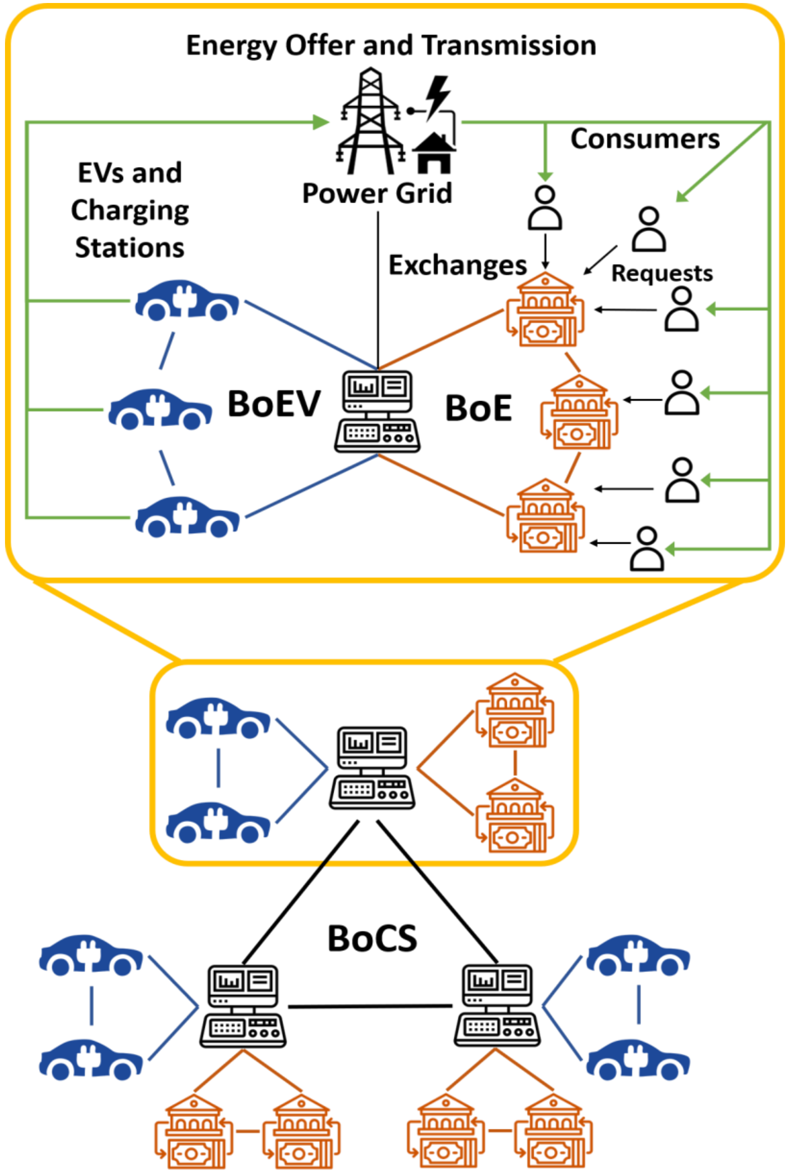

1. Upload unselected EV suppliers and energy requests.
2. Download the overall request list and EV supplier list.
3. **Each CS then competes on working out all the feasible trading plans across request and EV lists with Smart and Robust Energy Trading (SRET) mechanism and uploading the outcome back to BoCS. Only one transaction can be successfully endorsed, packaged into a block, and systematically verified.**
4. Download and record the new block from BoCS. Arrange energy trading accordingly.

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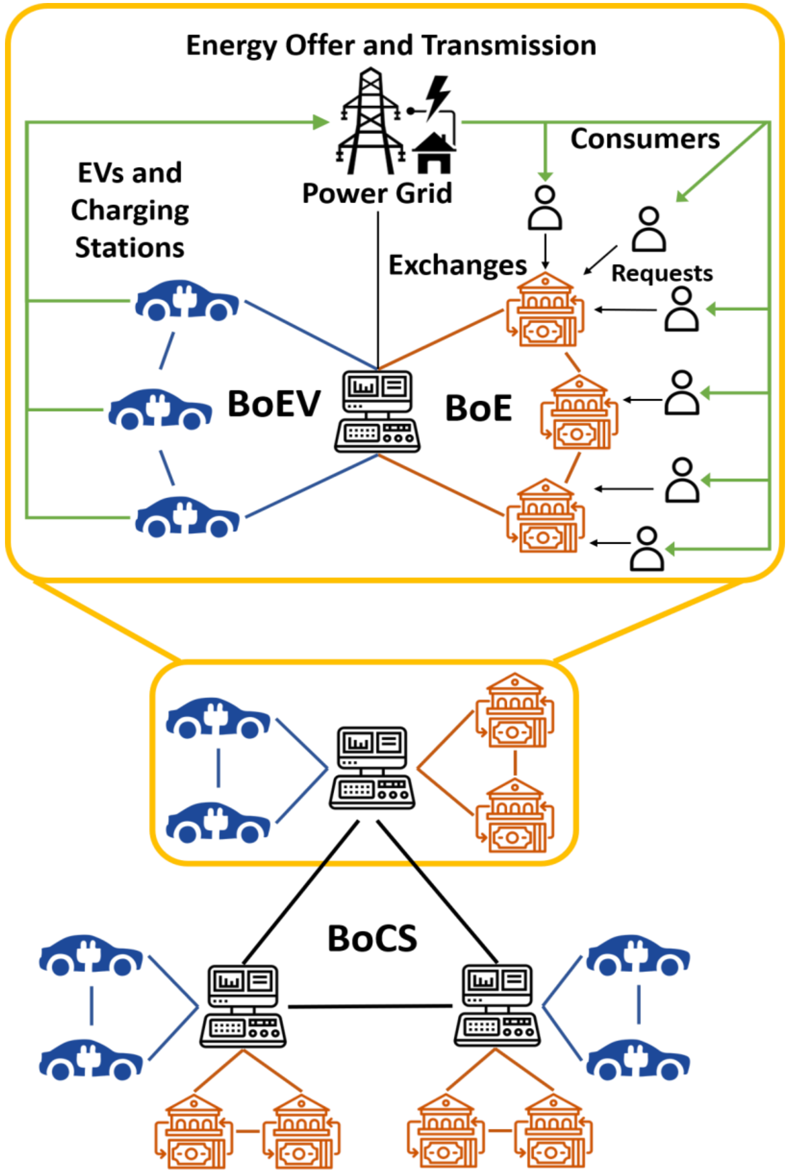


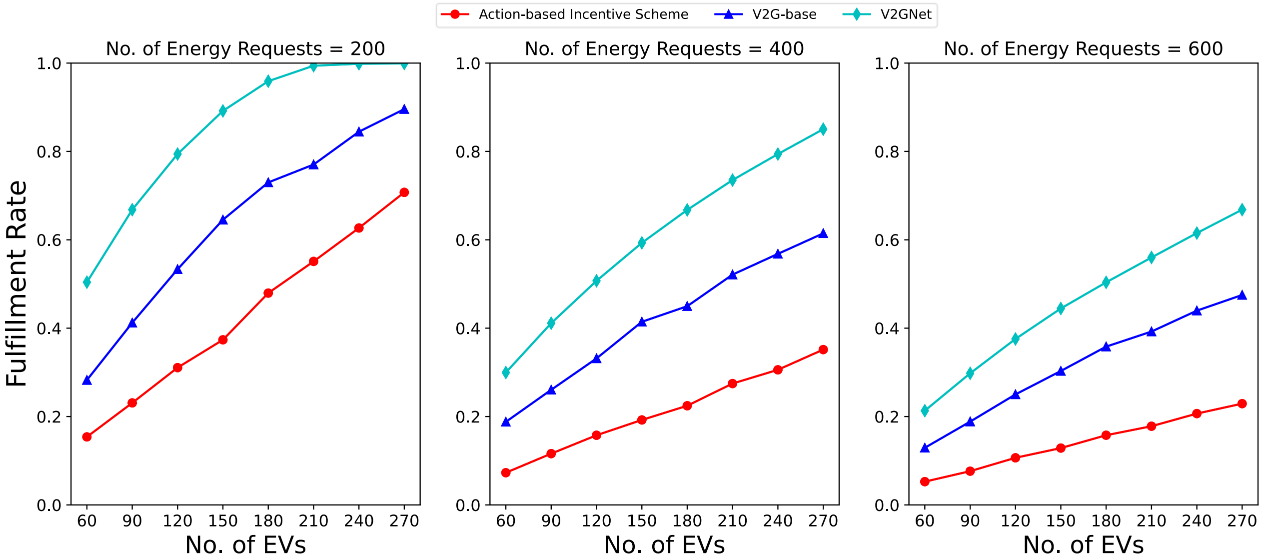
1. Upload unselected EV suppliers and energy requests.
2. Download the overall request list and EV supplier list.
3. Compete on trading planning SRET mechanism and uploading the outcome back to BoCS.
4. **The new block is downloaded and permanently recorded by all CS nodes of BoCS network. From the block, each CS extracts the cross-campus energy trading outcomes and notifies the relevant consumers and EVs of their specific trading details accordingly.**

Overview of the proposed blockchain of campus control systems (BoCS) among campuses based on the CS of each V2GNet.

V2G Energy Trading: Building Trust in the Grid
V2Gエネルギー取引：グリッドにおける信頼構築

The number of requests and EVs is equal, and demand can be almost entirely covered
要求数とEVの台数は同数であり、需要はほぼ完全に賄うことができます。

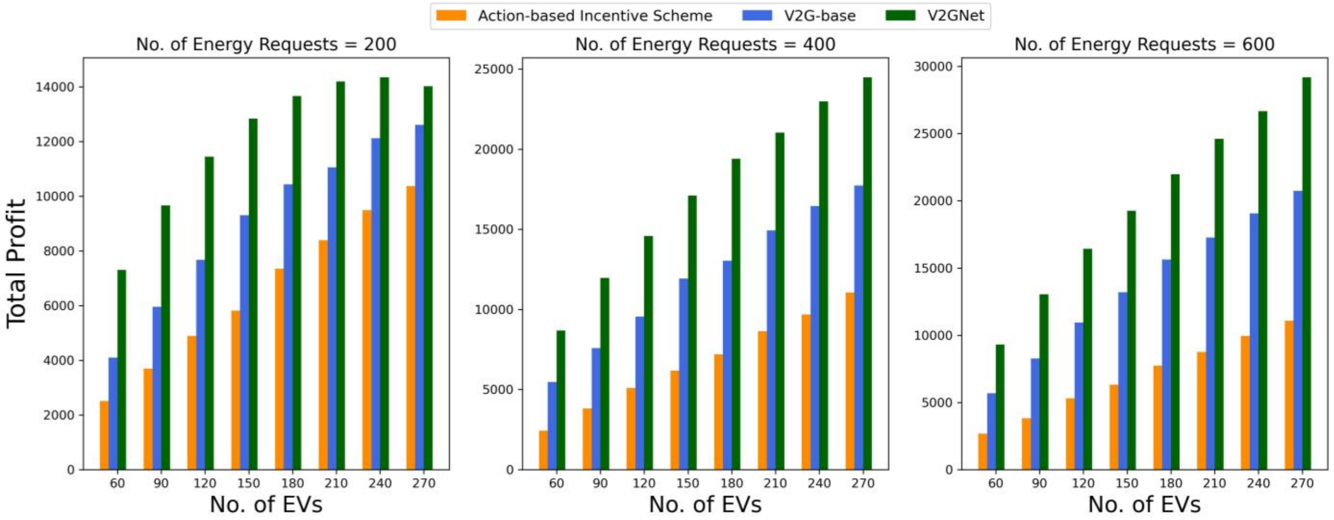
The number of EVs is half, but they can still cover more than 60% of demand.
EVの台数は半分ですが、それでも需要の60%以上を賄うことができます。



Evaluation of the fulfillment rate of a single energy trading round across three trading strategies.

An **action-based incentive scheme** in EV grid energy trading rewards electric vehicle (EV) owners or aggregators for their actual participation and actions in energy trading—such as charging, discharging, or providing grid services—rather than just for availability.

Achieves 45% more total profit of a single energy trading round, compared to the baseline methods.
基準手法と比較して、単一のエネルギー取引ラウンドにおいて総利益を45%多く達成します。



Evaluation of the total profit (JPY) of a single energy trading round across three trading strategies.

Y. Liang, Z. Wang and A. B. Abdallah, "V2GNet: Robust Blockchain-Based Energy Trading Method and Implementation in Vehicle-to-Grid Network," in IEEE Access, 2022
.Liang, Z. Wang and A. B. Abdallah, "Robust Vehicle-to-Grid Energy Trading Method Based on Smart Forecast and Multi-Blockchain Network," in IEEE Access, 2024

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Concluding Remarks/結論的考察

- ✓**Storage Reliability**: Battery lifespan, safety, and cost-effectiveness
  ストレージの信頼性：バッテリー寿命、安全性、費用対効果
- ✓**Energy Variability**: Managing solar intermittency and unpredictable EV demand
  エネルギーの変動性：太陽光の断続性と予測困難なEV需要の管理
- ✓**System Integration**: Seamless coordination of PV, storage, AI, and EVs
  システム統合：太陽光発電（PV）、蓄電、AI、EVのシームレスな協調
- ✓**Scalability**: Modular design and lack of standardization
  スケーラビリティ：モジュール設計と標準化の欠如
- ✓**Cybersecurity**: Protecting data and control systems in AI-driven platforms
  サイバーセキュリティ：AI駆動型プラットフォームにおけるデータと制御システムの保護
- ✓**Opportunity:** A blueprint for sustainable, intelligent, and decentralized energy ecosystems
  機会：持続可能で知的かつ分散型エネルギーエコシステムの青写真

Related Patents and Publications (関連特許・出版物)

Patents (特 許)

1. [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]“,
2. 特願2020-033678号 (2020.02.28) 8. 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 9.
3. 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2023-020162

Papers (論文):

1. Z. Wang, Y. Liang, A. Ben Ahmed, K. , Dang, A. Ben Abdallah, ''Edge-Driven Dynamic Two-Tier Blockchain for Energy Trading in Vehicle-To-Grid Networks,'' in IEEE Transactions on Vehicular Technology, 2025, doi: 10.1109/TVT.2025.3620034
2. Y. Liang, Z. Wang and A. Ben Abdallah, ''Robust Vehicle-to-Grid Energy Trading Method Based on Smart Forecast and MultiBlockchain Network'', in IEEE Access, vol. 12, pp. 8135-8153, 2024, doi: 10.1109/ACCESS.2024.3352631. 2. Y. Liang, Z. Wang and A. Ben Abdallah, "V2GNet: Robust Blockchain-Based Energy Trading Method and Implementation in Vehicle-to-Grid Network," in IEEE Access, vol. 10, pp. 131442-131455, 2022, doi: 10.1109/ACCESS.2022.3229432.
3. 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.

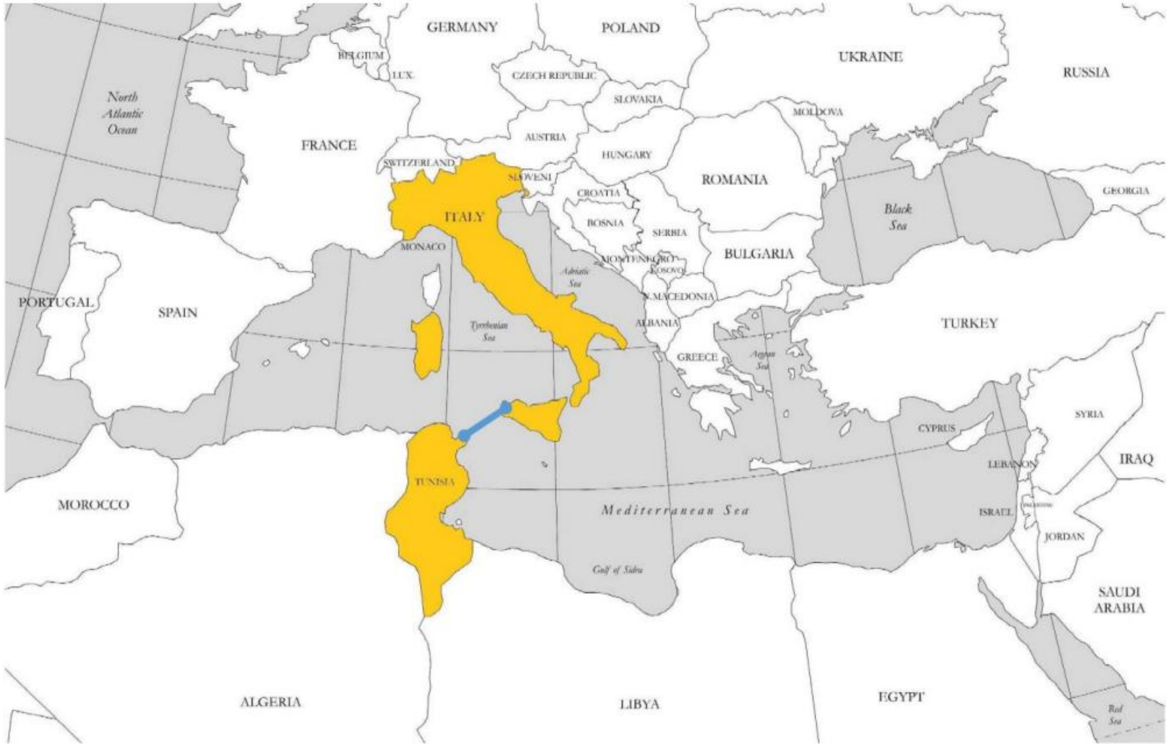
ご清聴ありがとうございました。

From Sun to Grid: ELMED's Role in Euro-Mediterranean Energy Security

1. **Tunisia-Sicily-EU grid corridor**, known as the **ELMED project**, is the first electricity interconnection using a High-Voltage Direct Current (HVDC) submarine cable to link the European and North African electricity gridsa.
    - The project is a joint effort between the Tunisian electricity grid operator, Société Tunisienne de l'Electricité et du Gaz (STEG), and the Italian grid operator, Terna.
    - The project is a "Project of Common Interest" (PCI) for the EU and has received significant funding, including a €307 million grant from the EU's Connecting Europe Facility (CEF) program. Construction is expected to complete by 2028.
    - **Energy Security & Diversification:** It will enhance Europe's energy security by diversifying supply sources and providing access to potential future green electricity from North Africa.

TECHNICAL DETAILS

600 MW	500 KV	220 KM	800 M
CAPACITY	VOLTAGE	LENGHT	DEPTH



Reference: https://elmedproject.com/