National Taiwan University 國立臺灣大學

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Artificial Intelligence Applications in Hourly Energy Use Intensity Prediction

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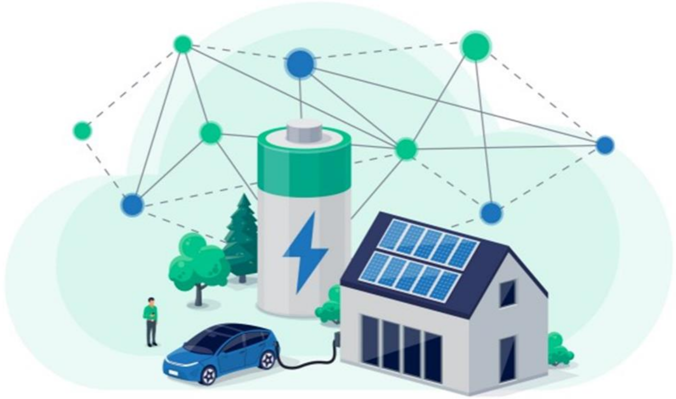

Outline

1. **Background**
    a. On the road to Net Zero by 2050
    b. The Building Sector
2. **Methods**
    a. Why Artificial Intelligence?
    b. Data Collection
    c. Model Development
3. **Results**
    a. Model Performance Evaluation Metrics
    b. Predicted and Actual Plot
    c. Residual Analysis Results
4. **Applications**
    a. Internet of Energy (IoE)
    b. Vehicle-to-building (V2B) Strategy

Part 1 - Background

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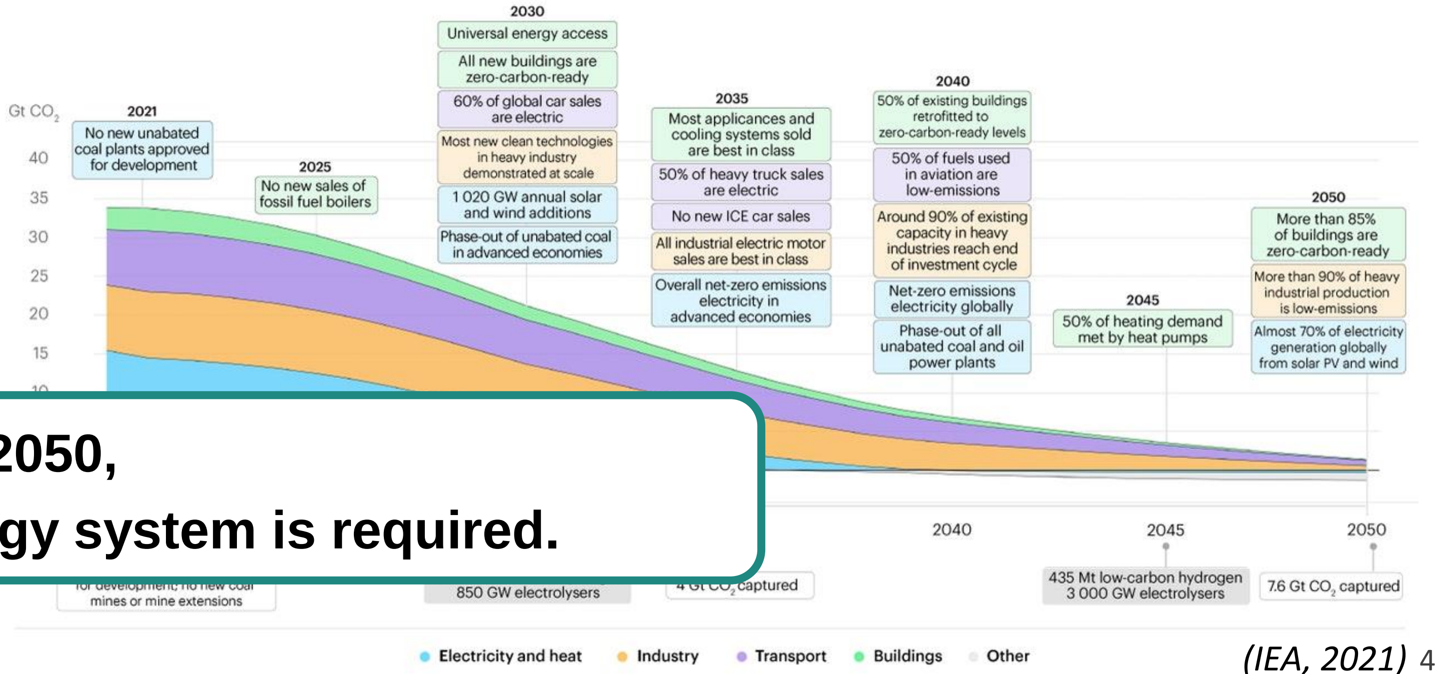
Background: On the road to *Net Zero* by 2050

- Paris Agreement:
  - ■ Global warming ≤ 1.5°C above pre-industrial levels to avert the worst of climate change.
  - ■ Global carbon emissions should be reduced by 45% by 2030 and reach net zero by 2050.
- The world consumes nearly 3 times primary energy and increases per capita energy consumption by 62% compared to 1965 *(OWID, 2020).*

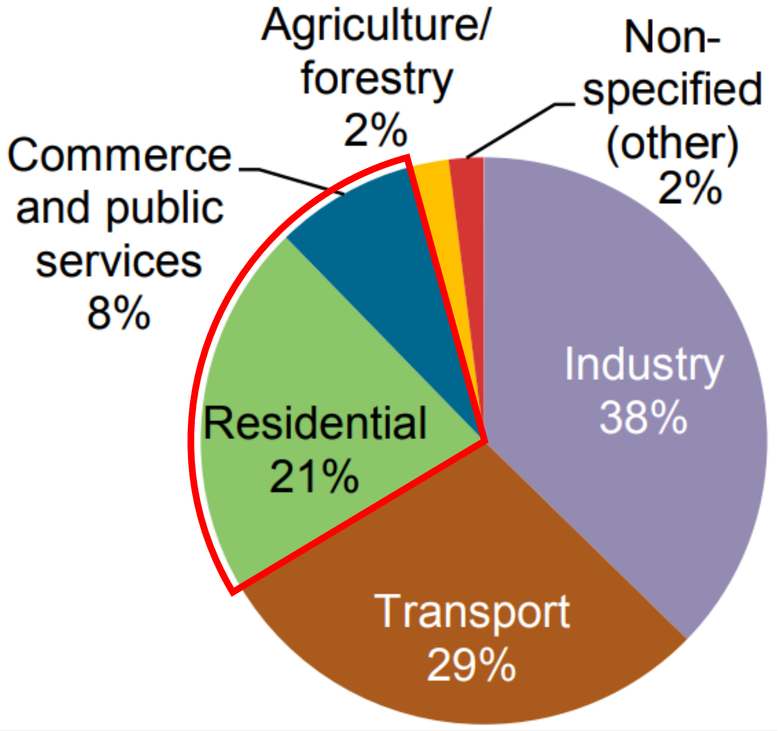


To achieve carbon neutrality by 2050,
a complete transition of the energy system is required.

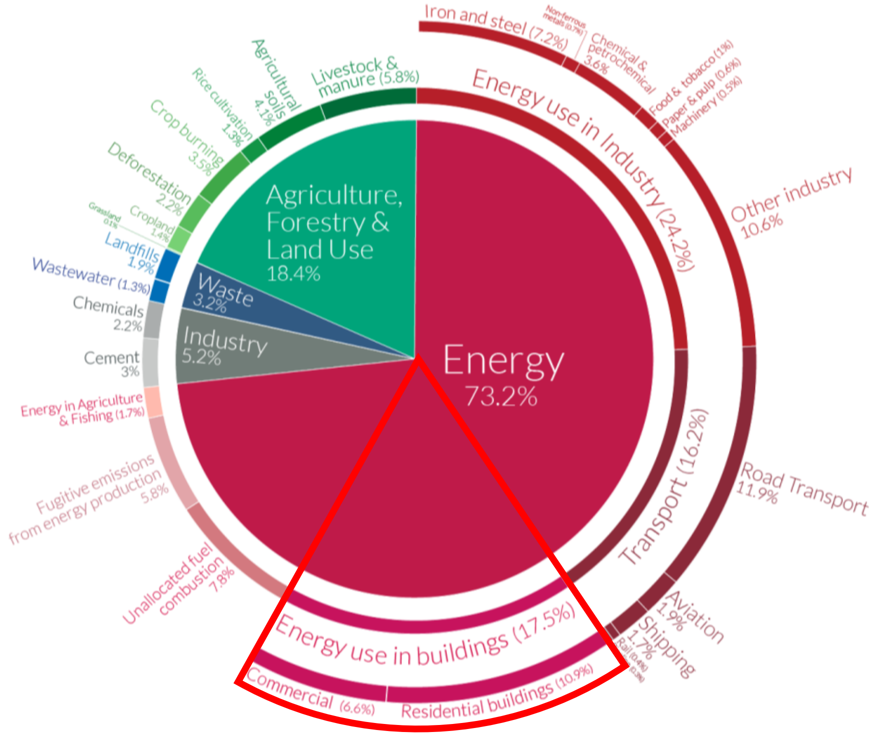
(IEA, 2021)

The Building Sector: Challenges as Opportunities

- Buildings contribute a substantial share to world energy consumption and greenhouse gas emissions, providing significant energy saving potentials.
- Accurate forecasting of building energy demand will help building energy management and conservation, reducing emissions while simultaneously satisfying the growing energy demand.



World total final consumption by sector *(IEA, 2020)*



Global greenhouse gas emissions by sector *(OWID, 2020)*

Part 2 - Methods

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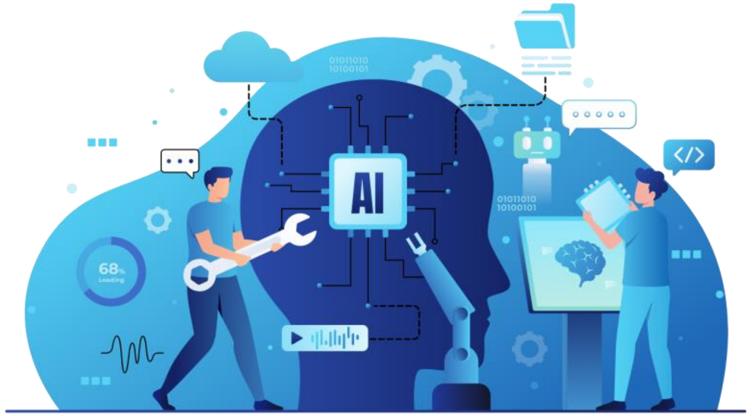
Why Artificial Intelligence?

- Artificial intelligence (AI) technologies are able to learn with experience and provide a high level of capability in handling a range of complex tasks in many spheres of life.

High-precise building energy prediction is difficult to achieve:

- Building characteristics (e.g. building type, age, floor area, orientation)
- Lighting
- Habitual behavior
- Weather conditions
- Appliance(e.g. sustainable designs)

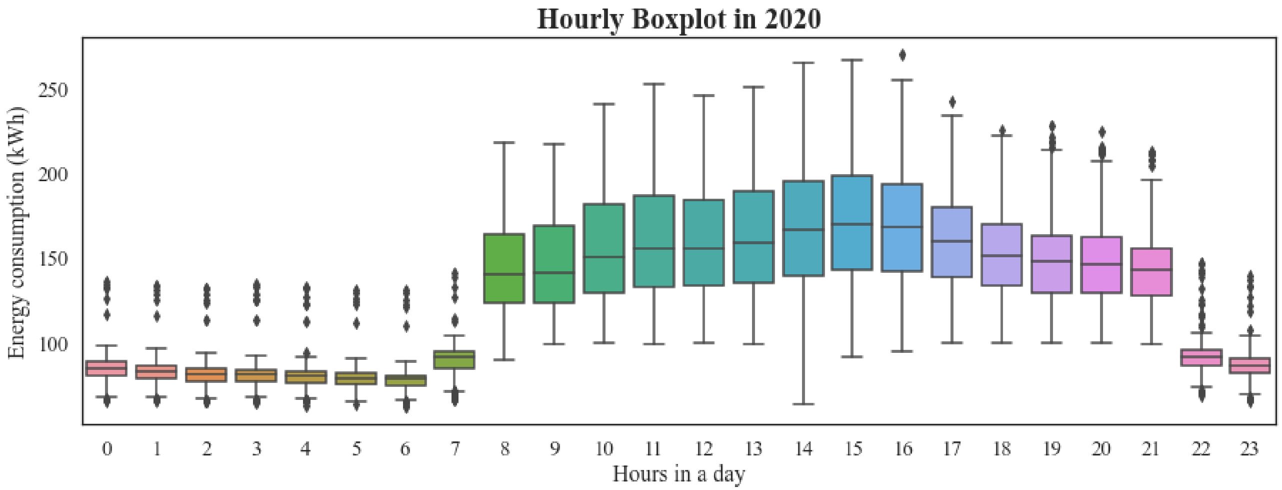


Applying AI methods to time series overcomes various limitations:

- The poor generalization capability
- The sensitivity to model parameters
- The unsuitability of large-scale and non-linear predictive analysis for traditional statistical modeling

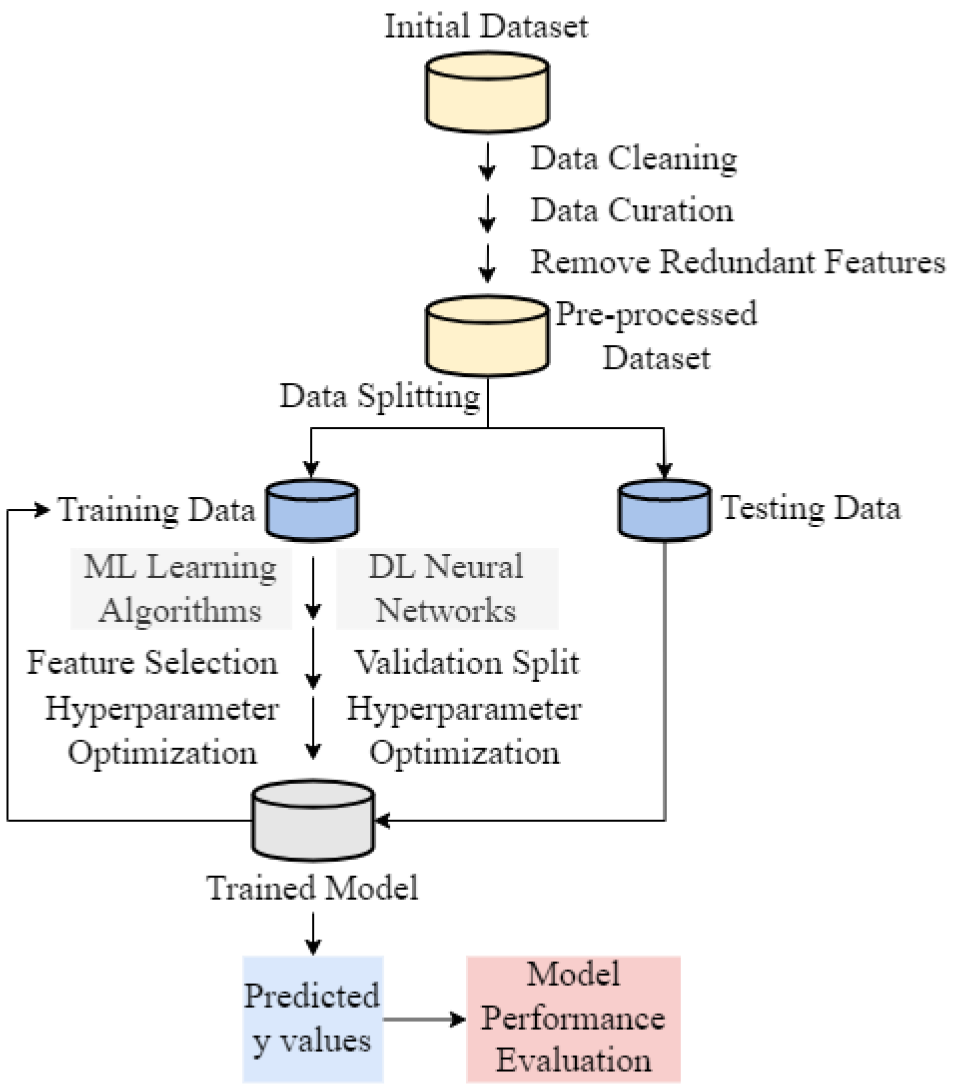
Data Collection

- Case study:
  - ■ Civil Engineering Research Building of National Taiwan University, located in Da’an Dist., Taipei City in Taiwan.
  - ■ A ten-stories building (including one underground story and nine overground stories)
  - ■ Total floor area: 10,084 m^2
  - ■ Time period: 2014/01/01 to 2020/12/31 (7 years)
  - ■ Time resolution: one hour
  - ■ Years 2014 to 2019 as training data and the year 2020 as testing data



Model Development

- Seven artificial intelligence-based approaches are implemented to project the building energy consumption at one-hour resolution
- We normalize the building energy performance to ***energy use intensity (EUI)*** (i.e. the electricity consumption per square floor area) as model inputs to avoid scaling bias, which is more suitable for evaluating the prediction performance between different buildings.



Part 3 - Results

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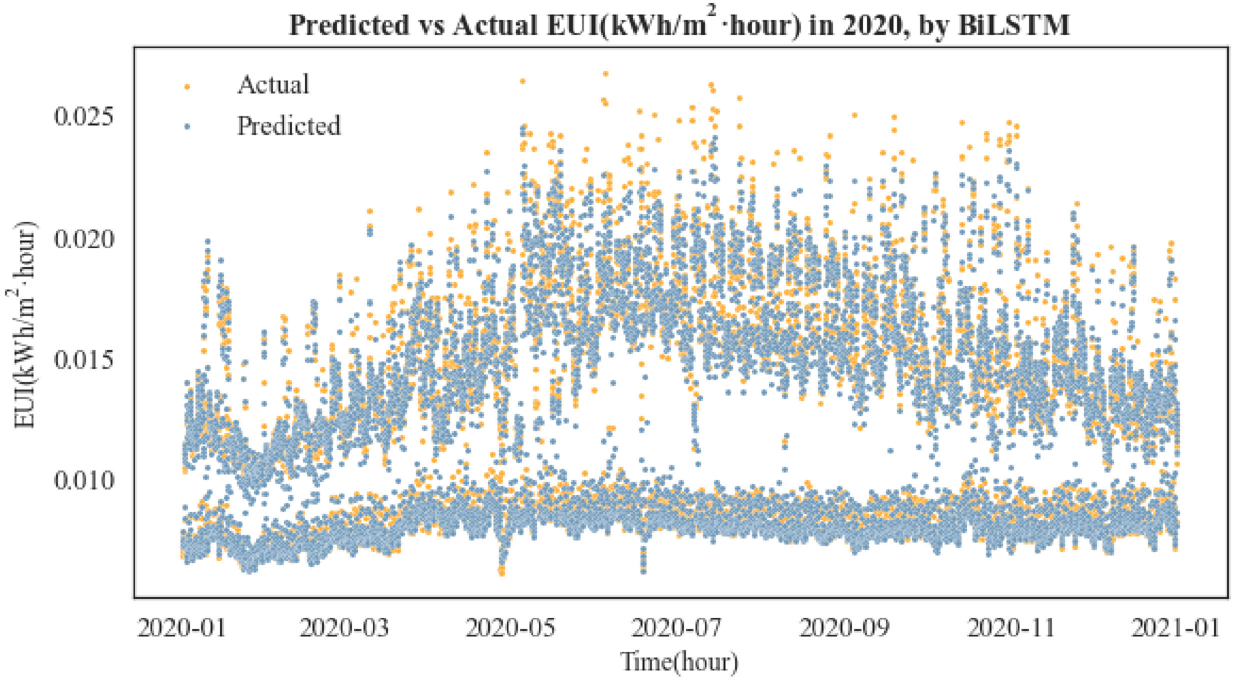
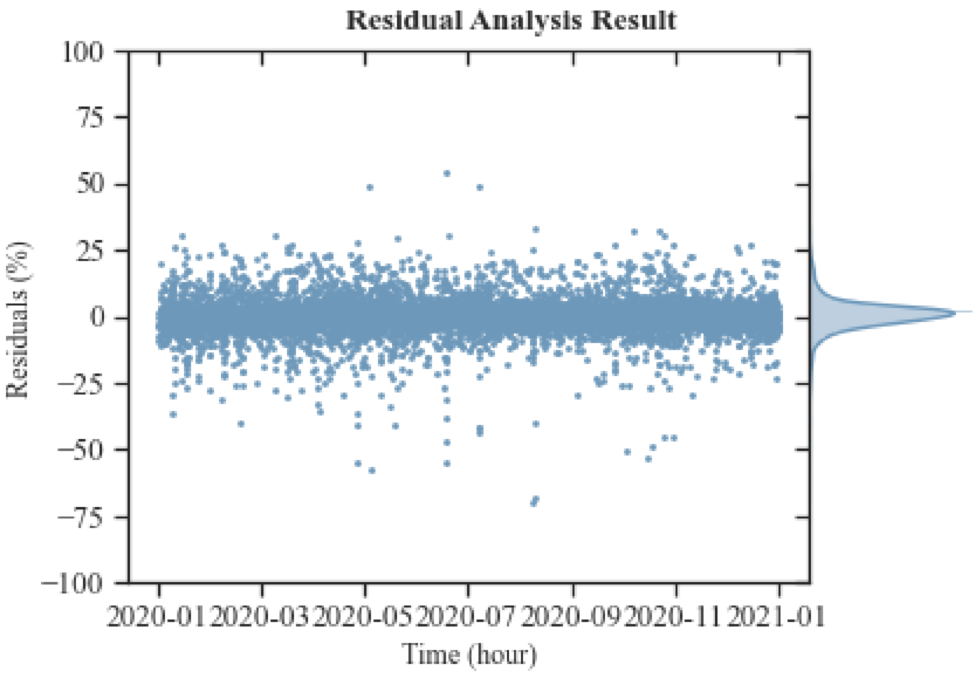
Prediction Results

- BiLSTM model best fits with testing data

	Machine Learning		Deep Learning				
Model	XGBoost	Prophet	SimpleRNN	LSTM	BiLSTM	GRU	BiGRU
RMSE	0.00189	0.00202	0.00107	0.00103	0.00097	0.00102	0.00100
MAE	0.00132	0.00158	0.00069	0.00062	0.00055	0.00063	0.00058
MAPE	10.677%	13.513%	5.495%	4.798%	4.075%	4.857%	4.527%
R^2	0.806	0.779	0.934	0.943	0.949	0.943	0.946





Part 4 - Applications

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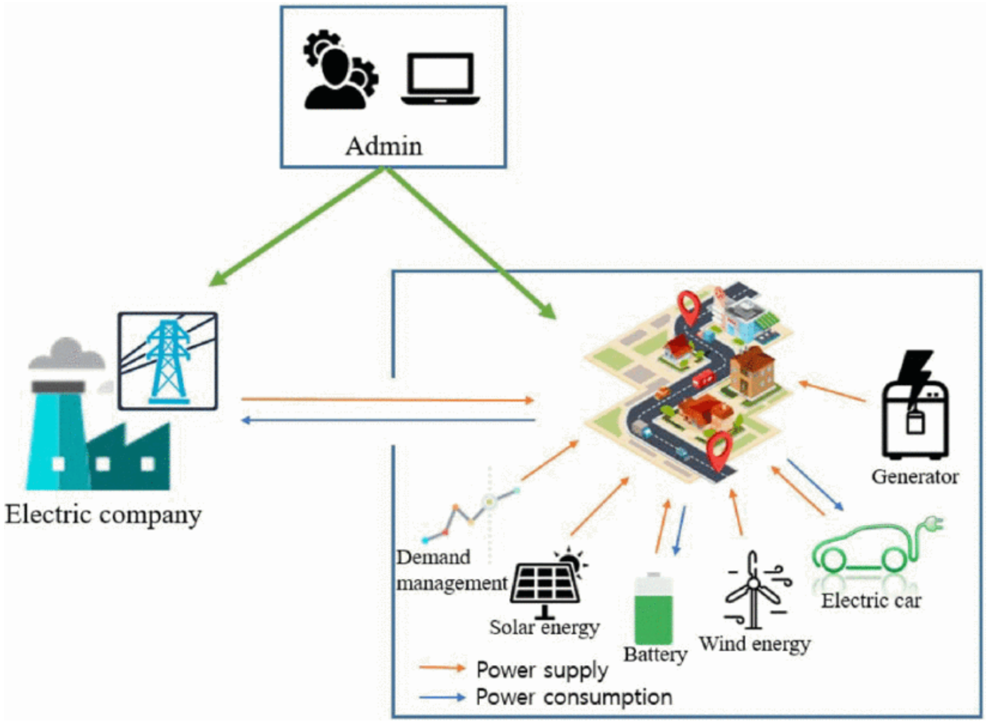
Applications: Internet of Energy (IoE)

Traditional Microgrid System:



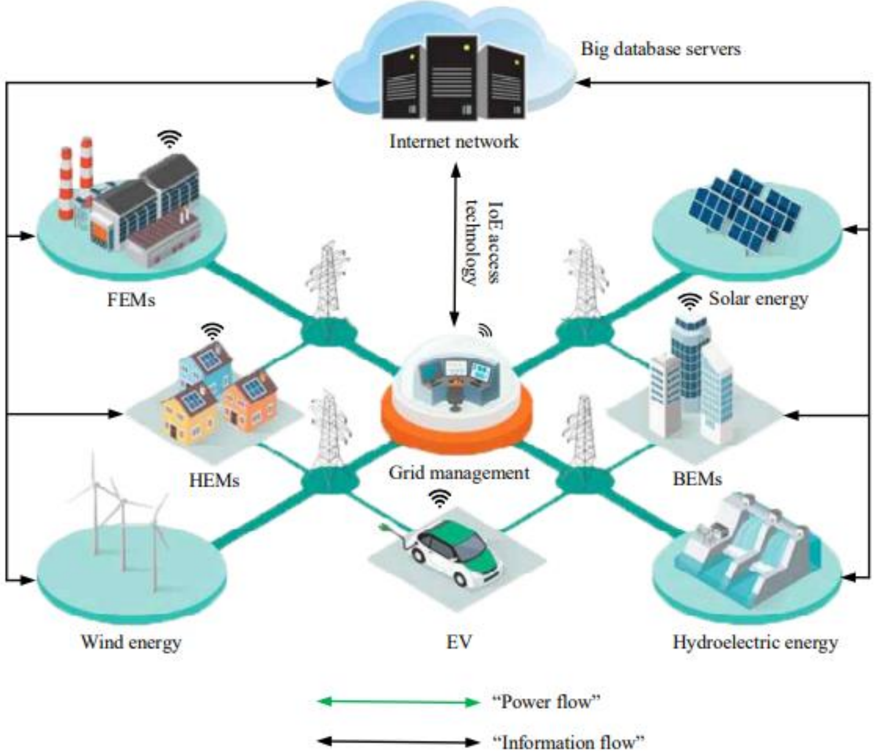
(G. Kim, J. Park and J. Ryou., 2018)

Applications: Internet of Energy (IoE)

- **IoE (Internet of Energy) = Smart Grid + IoT (Internet of Things):**
  - By connecting the grid to the internet, IoE is able to **customize intelligent energy management solutions** according to the real-time energy load through bi-directional data exchange.

- With the developed AI-based models for building energy consumption:
  - Utilize real-time hourly energy demand forecasts
  - Realize systematic real-time energy management among different building clusters
  - Form a local energy community or urban energy internet

Internet of Energy (IoE):

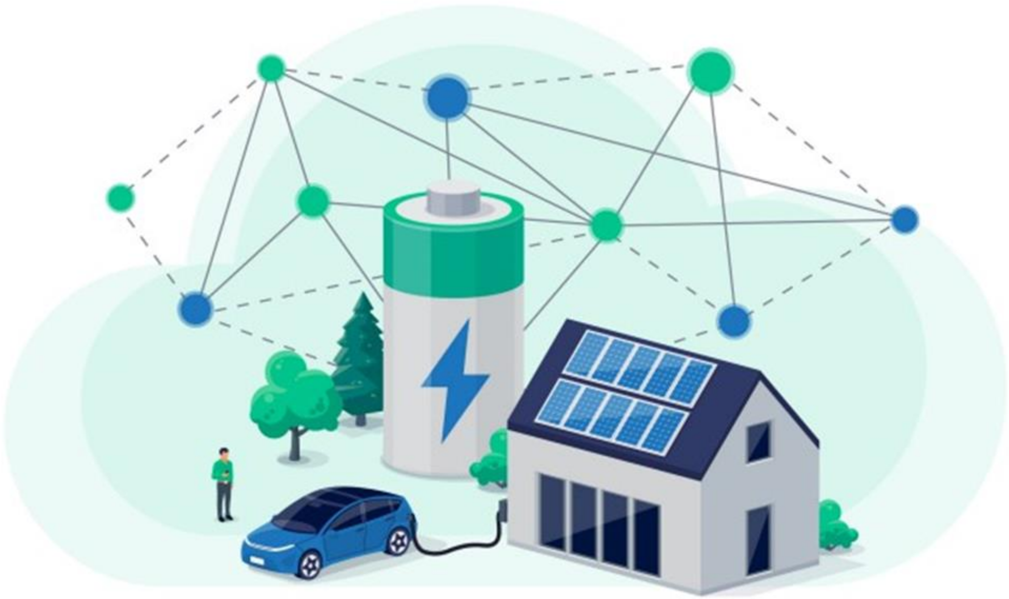


(V. T. Nguyen, T. Luan Vu, N. T. Le and Y. Min Jang., 2018)

Applications: Vehicle-to-building (V2B) Strategy

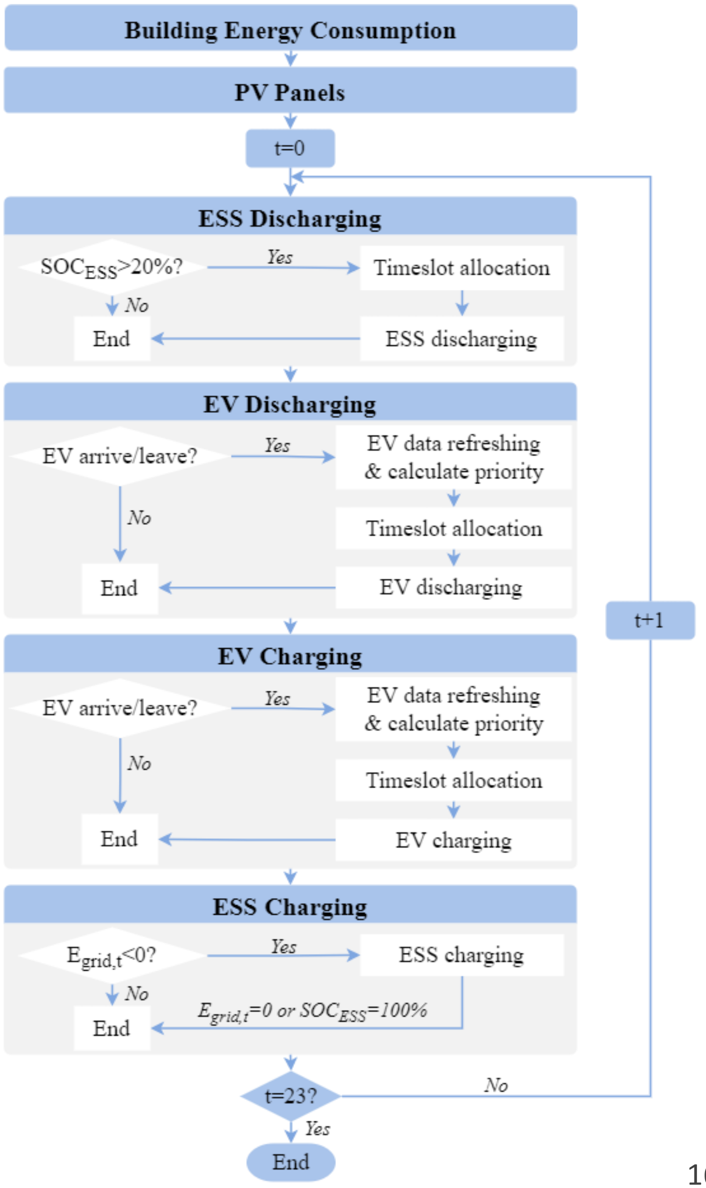
- AI-based building energy consumption prediction models can also be leveraged to reduce peak power demand in buildings through vehicle to building (V2B) strategy:
  - Vehicles are parked most of the time
  - As vehicles are electrified, they can serve as **flexible energy storage batteries** to moderate the variability of renewable generation and building energy use

- Having a reliable building energy use prediction would increase the effectiveness of V2B strategy, and thus reducing power surges and power outages without additional investment.



Applications: Vehicle-to-building (V2B) Strategy

- Further study about real-time charging management of V2B strategy is being conducted.
- The research findings can be used as the guideline and criteria of building energy management process to facilitate transitions towards ***nearly zero-energy building (NZEB).***



github.com/AllisonnLo/IAEE-InternationalConference-2022
Check here for full abstract.

Thank you!

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