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Energy Efficiency in Domestic Appliances and Lighting

Prediction of Net Energy Demand for the Management of Transactive Energy Communities

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Introduction

- **From Consumers to Prosumers**
  - Significant increase in the use of solar PV generation in buildings and communities.
  - Buildings become active market participants by both consuming and generating electricity.
- **Temporal Mismatch**
  - Discrepancy between PV generation and residential energy demand timings.
  - Need for innovative solutions to coordinate generation with demand.
- **Energy Flexibility Solutions**
  - Battery Storage, Demand Response and EV Charging Management:
  - These solutions can optimize self-consumption and costs at building and community levels.

Introduction

- **Transactive Energy Communities**
  - TECs utilize economic and control mechanisms to manage energy generation and consumption.
  - Enable end-use energy trading for improved grid reliability and efficiency.
- **Role of Local Energy Markets**
  - Incentivize buildings to use their flexibility resources.
  - Optimize energy use within the community.
- **Architectural Models**
  - P2P (Peer-to-Peer)
  - Central Coordinator
  - Hybrid Models

Introduction

- **Importance of Accurate Predictions**
  - Effective planning and scheduling of energy flexibility and trading rely on reliable net energy demand predictions.
  - Predictions typically use aggregated net metering data, but more precise forecasts require individual building data.
  - Collecting such data can pose privacy concerns, as it includes sensitive information like occupancy and schedules.
- **Overcoming Data Sharing Barriers**
  - Local training can protect privacy but lacks collaboration benefits.
  - Collaborative training is crucial for better model accuracy and adaptability.
  - Federated Learning (FL) enables collaborative model training across multiple buildings without sharing private data.

Objectives

- Assessment of various alternatives for predicting net energy demand and managing TECs.
- Characterization and comparison of different architectures for local energy market management.
- Comparison of different methods for predicting necessary data for TEC management.

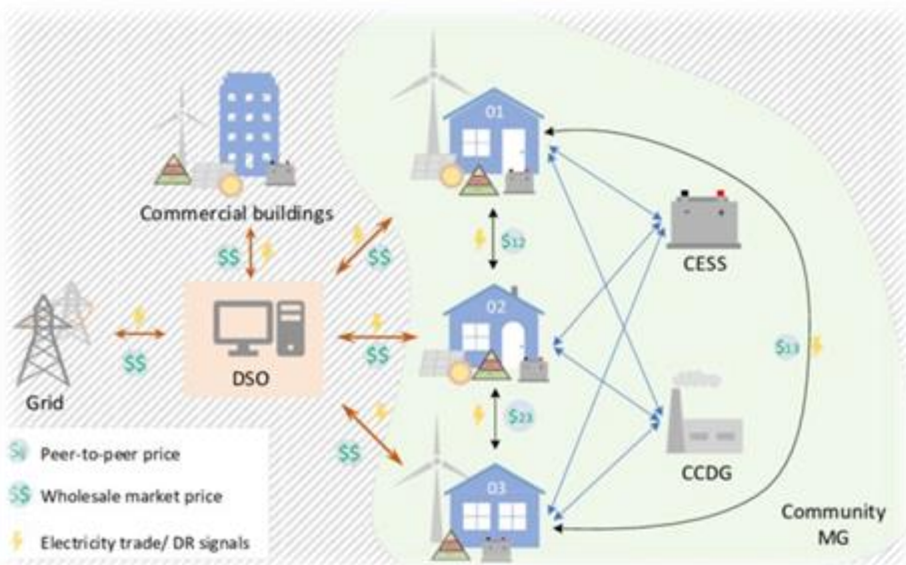
- Comparison based on:
  - Accuracy and Adaptability
  - Complexity
  - Privacy Requirements

Market Architectures

- **System Flexibility & Management**
  - Renewable energy and EV growth require flexible management systems in TECs.
  - ICT enables demand response, aligning demand with renewable generation.
  - Energy Storage Systems (ESS) like EVs and batteries help balance energy needs.
- **Transactive Energy Framework**
  - TECs connect end-users to the grid, optimizing energy use and integration.
  - Effective management maximizes renewable usage and market interaction.
- **End-User Focus**
  - Ensuring privacy and cost reduction is essential.
  - Advances in technology support better TEC optimization and management.

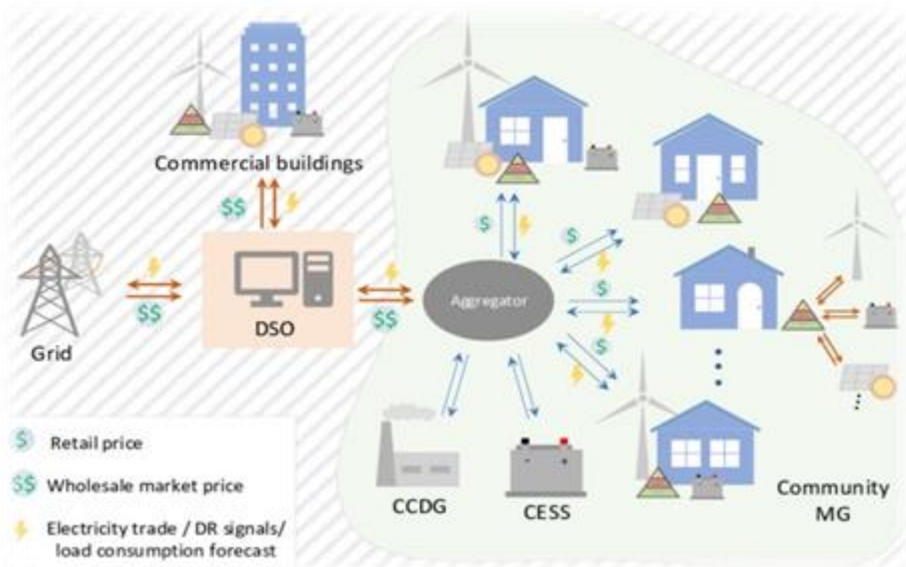
Market Architectures

- **Without a central coordinator (P2P Architecture)**
  - Connections are established at the same level within the community.
  - Aligning more closely with the goals of participants.
  - High privacy and user interaction.
  - Encourages novel algorithms (e.g., blockchain).



Market Architectures

- **With a central coordinator (Aggregator Architecture)**
  - A central entity connects multiple parties with clearly defined levels.
  - It can enhance social cooperation between the participants.
  - Better resource coordination and flexibility.
  - Supports advanced energy management strategies.



Market Architectures

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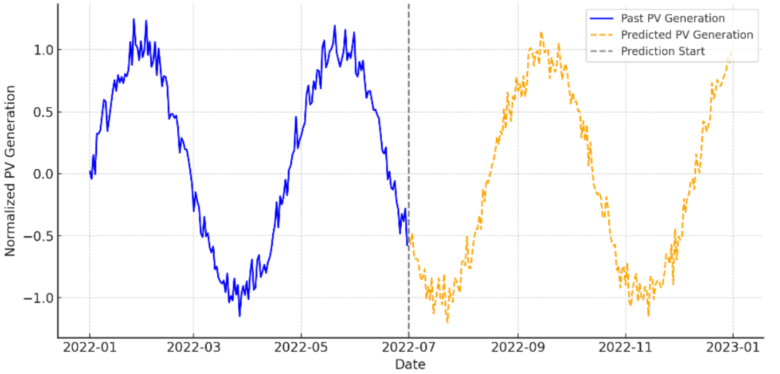
- **Optimization of Flexibility**
  - Use of distributed energy resources and local markets to improve system flexibility.
  - Incentives for efficient power system operations.
- **Batteries as flexibility sources in different market designs**
  - Decentralized: Individual batteries at each house.
  - Centralized: One battery unit supporting the entire community.
  - Vehicle-to-building and building-to-vehicle strategies
- **Energy Price Optimization**
  - Fuzzy System
  - Reinforcement Learning
  - Using predictions

Prediction Methods

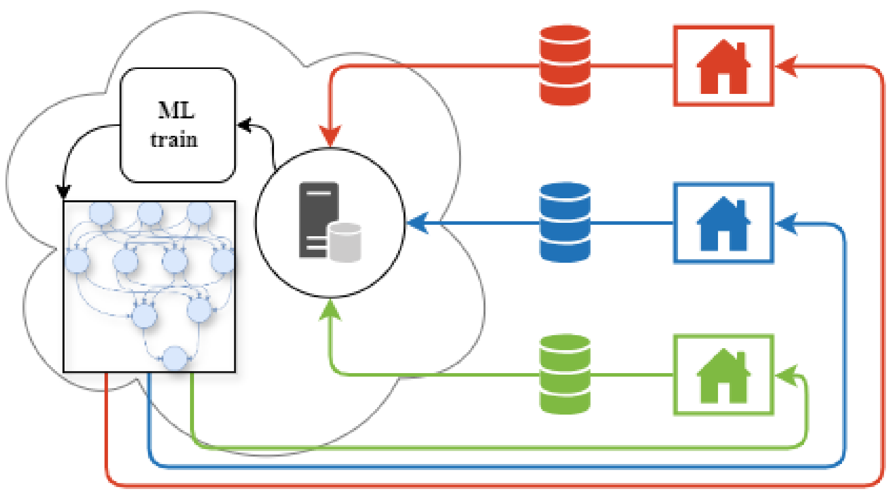
- **Artificial Intelligence for Load Forecasting**
  - Machine Learning models like ANNs provide high accuracy.
  - Regression models offer better interpretability.



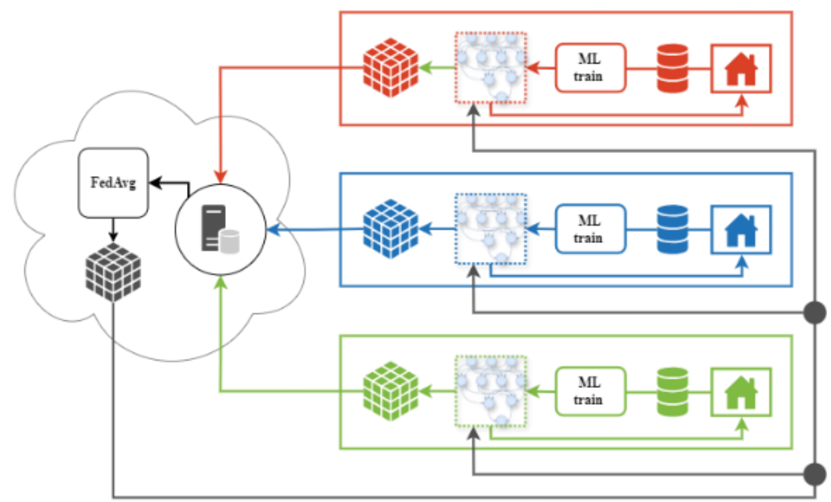
- **Electricity Demand Forecasting**
  - Utilized by TEC management for planning next hours or day-ahead.
  - Hybrid models like CNN and LSTM improve forecasting accuracy.
- **Forecasting Local Generation**
  - Forecasting solar output for prosumers.
  - Combining demand and generation forecasting improves efficiency.
- **Challenges and Solutions**
  - Limited data sharing impacts model accuracy.
  - Local training or collaborative learning can enhance model performance.

Federated Learning

- Trains models locally, sharing only model weights to a central server.
  - Centralized Training: Sends client data to the server for a single model.
  - Federated Learning: Data stays on devices, only weights are shared.
- Enhances privacy while enabling collaborative model training.
- A promising solution for training ML models while protecting user data in TECs.



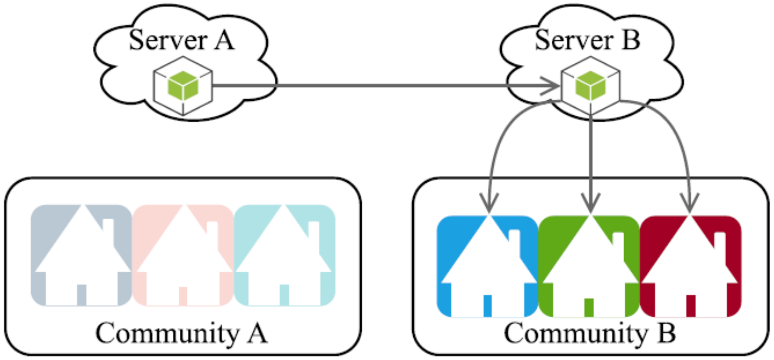
Centralized Approach



Federated Learning Approach

Federated Learning

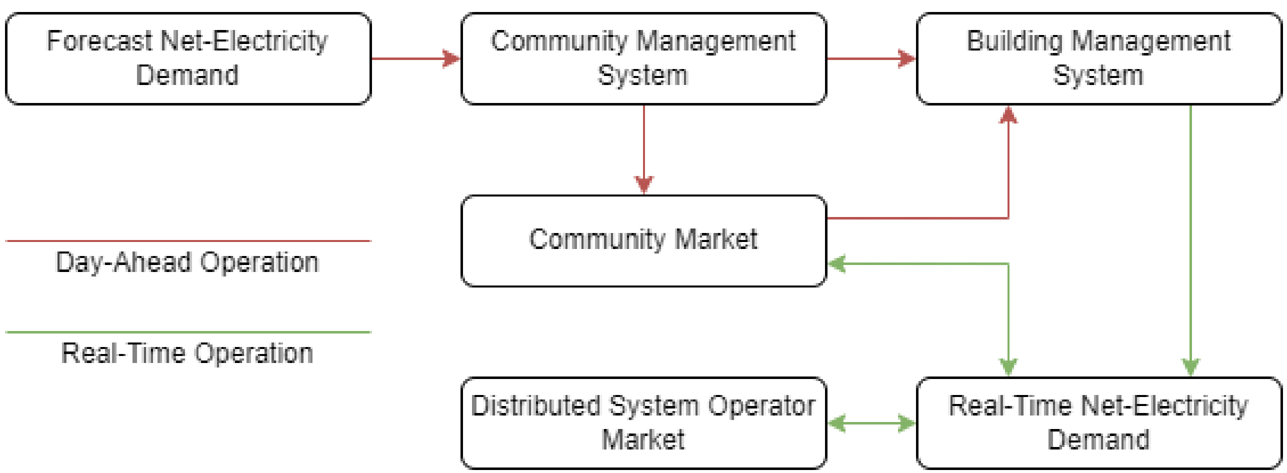
- **Transfer FL (TFL) System**
  - Achieves accurate models with minimal data.
  - Can work with traditional FL architectures.



- **Advantages for New TEC Members**
  - New buildings without data or ICT can immediately use global weights from the aggregator.
  - No need to wait for data collection to start benefiting from accurate forecasts.
- **Use Cases**
  - Integration of new members in existing TECs.
  - Fast deployment in new communities or regions compared to traditional methods.

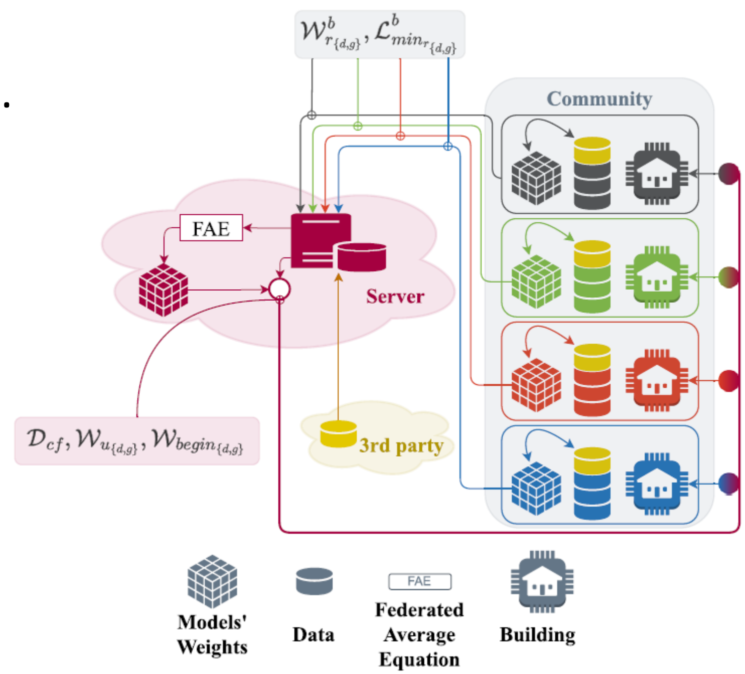
Federated Learning

- Forecasting electricity demand is the first step to optimizing community operations.
- The goal is to reduce electricity costs by aligning local generation with demand.
- Energy trades are managed by a community system, with tariffs set based on forecasted needs.
- Errors in forecasts impact decision-making and system efficiency.



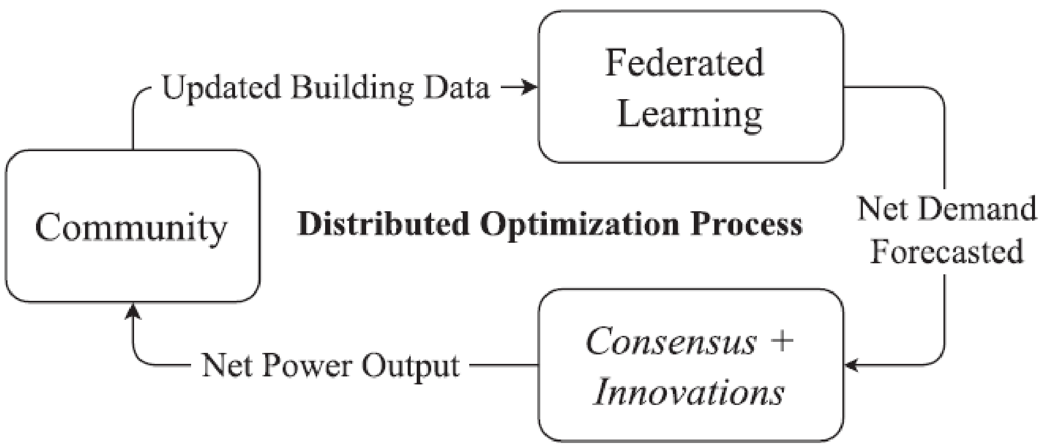
Federated Learning

- **Proposed Framework**
  - Predicts net energy demand using independent demand and generation systems.
  - Ensures collaborative learning without sharing private data.
  - Central server coordinates forecasts of demand, generation, and net energy.
- **Federated Transfer Learning**
  - Enhances forecast accuracy for new communities.
  - Adapts to different variables and scenarios, including seasonal changes.
- **Test Results**
  - Applied to 2 communities (100 and 25 buildings).
  - Demonstrated high accuracy and adaptability.
- More details: doi.org/10.1016/j.segan.2024.101522



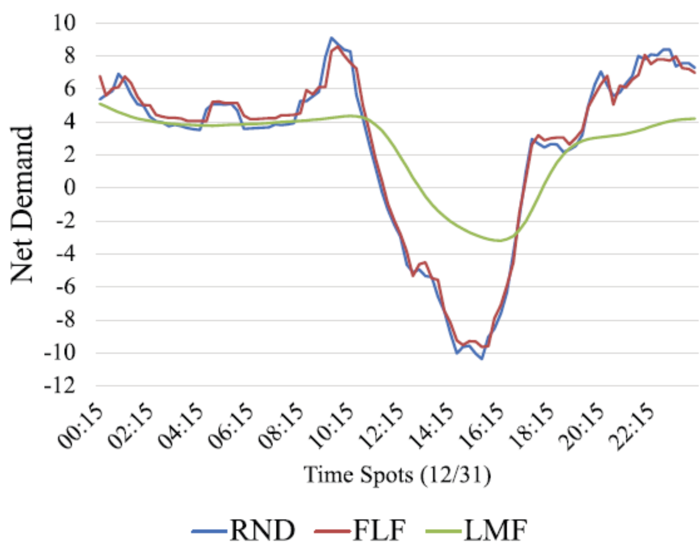
Federated Learning

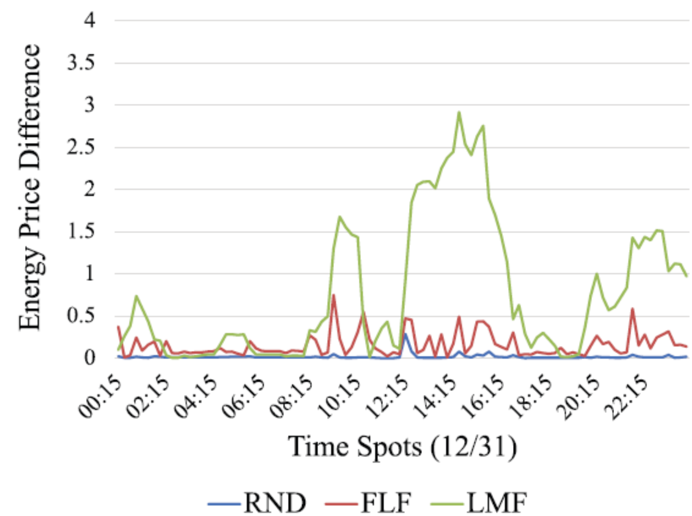
- Optimization of energy transactions between a TEC and VPPs.
  - FL used to predict local energy generation and demand for agents.
  - Use of FTL between communities.
  - FL-assisted distributed consensus + innovations method.
  - FL Accelerates distributed decision-making in TECs.
  - Enhances energy aggregation and coordination.



Federated Learning

- **Results**
  - Significant reduction in net power demand prediction errors.
  - Improved forecast accuracy leads to better optimization and faster convergence.
  - The FL-assisted consensus + innovations approach is proficient at model transfer to similar systems with less historical data.





- More details: doi.org/10.1049/rpg2.13101

Conclusions

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- **Importance of Prediction Models**
  - Crucial for managing energy flexibility in TECs.
  - Accurate predictions drive better technical and economic outcomes.
- **Data Requirements**
  - Large historical datasets for generation and demand.
  - Enhanced with detailed data like weather and occupancy.
- **Federated Learning**
  - Combines local and central training benefits.
  - Maintains privacy while enabling collaboration.
  - TFL achieves accurate models with minimal data.
  - Limited research on its use in energy management systems.

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