AGENT-BASED MICRO-STORAGE MANAGEMENT FOR THE SMART GRID

POWER AGENT:

Salman Kahrobaee, Rasheed Rajabzadeh, Jordan Wiebe

Source

- Vytelingum, P., T. D. Voice, S. D. Ramchurn, A. Rogers, and N. R. Jennings (2010). Agent-Based Micro-Storage Management for the Smart Grid, *Proceedings of the International Joint Conference of Autonomous Agents and Multiagent Systems (AAMAS'2010)*, pp. 39-46.

Outline

- Introduction
- Model Description
- Game-Theoretic Analysis
- Storage Strategy
- Case study results
- Conclusion
- Our discussion
- Questions

Introduction

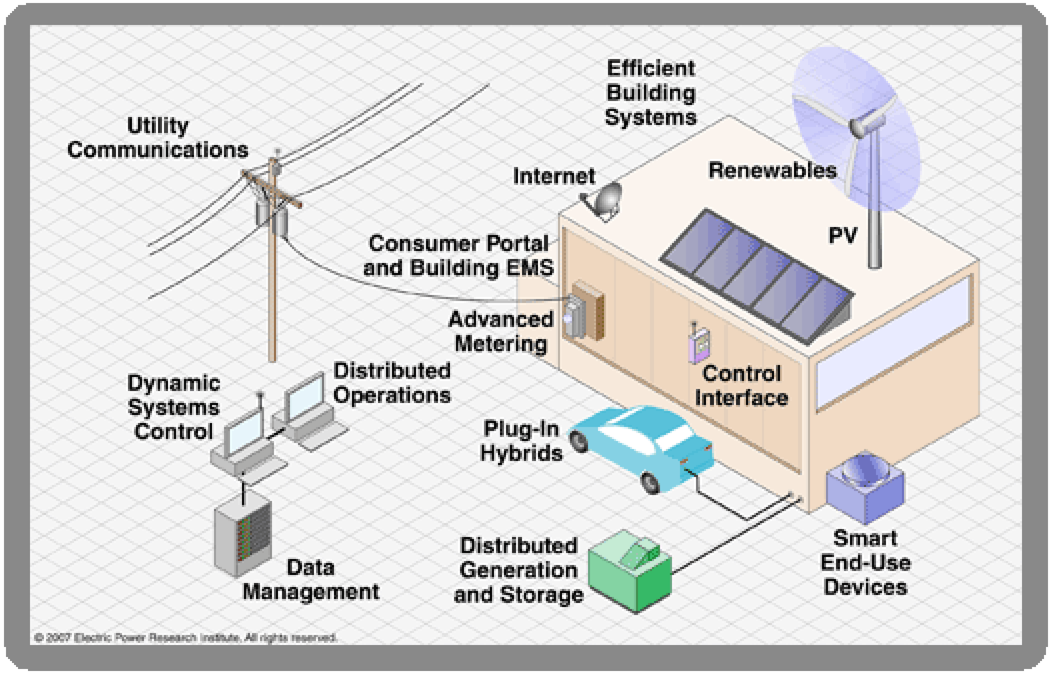
Introduction

Need for Smart grid :

- Increasing demand
- High aggregate losses
- Ageing assets
- Environmental concerns
- Demanding customers
- Higher efficiency

Smart grid drivers:

- Communication and IT infrastructure
- Renewable generation
- Energy storage system
- Efficient building systems



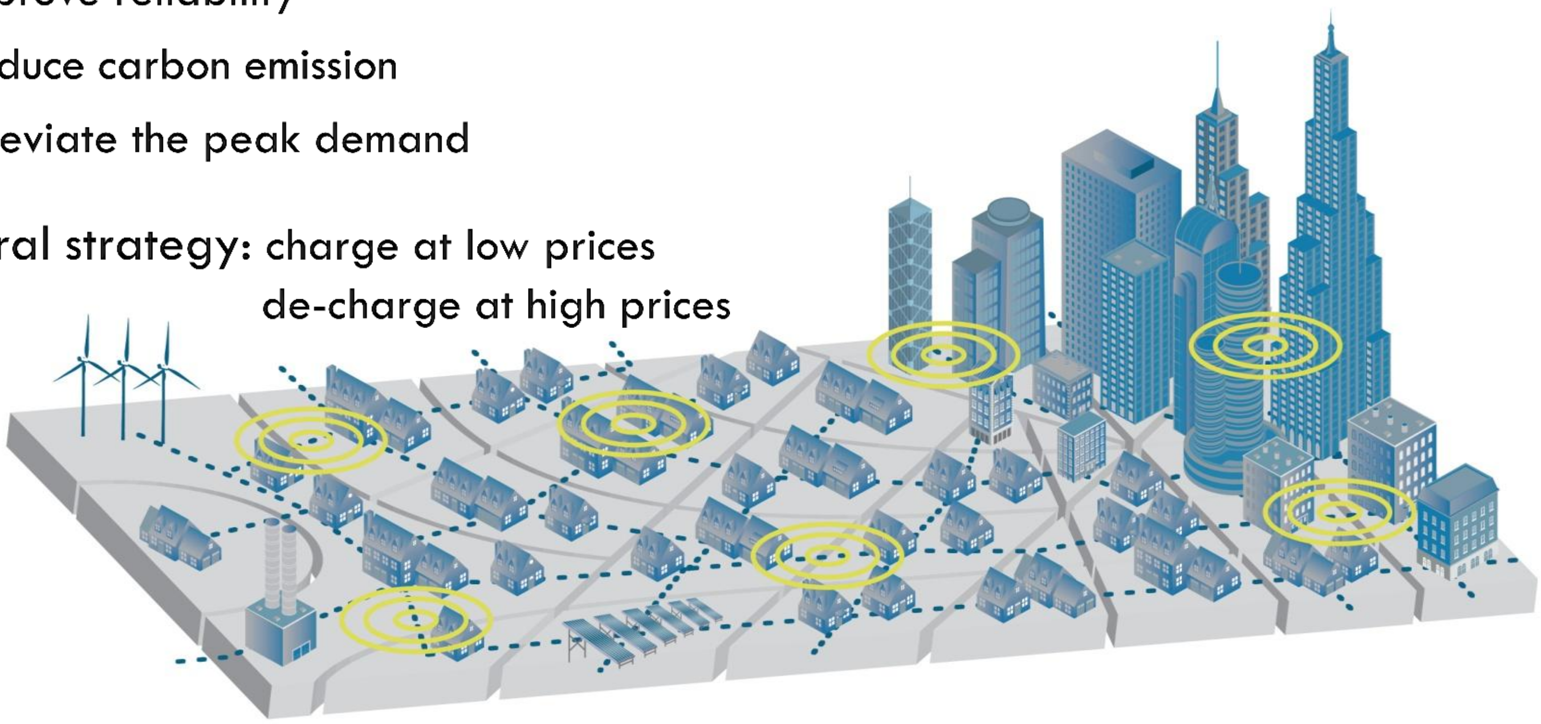
Source: http://smartgrid.epri.com

Introduction

Energy storage devices:

- Save electricity
- Save money
- Improve reliability
- Reduce carbon emission
- Alleviate the peak demand

General strategy: charge at low prices
de-charge at high prices



Introduction

- System's goal:

  To alleviate the overall peak of the homes' electricity demand

- Home's goal:

  To minimize the cost developing an optimal storage strategy given:

  - The normal electricity usage profiles
  - Electricity market price

Model Description

Model Description

- The paper models the smart homes as follows:
  - Each “house” is an agent
  - Each agent purchases electricity from suppliers in the electricity market
  - Time is discrete, in half-hour increments
  - Home agents making autonomous decisions on:
    - Charging their batteries
    - Using their stored electricity
    - Buying electricity from the grid

Model Description

- Game theoretic framework to reach to Nash equilibrium

- Social welfare metrics:
  - **Diversity Factor:** ratio of sum of maximum individual consumer demands to maximum total system demand
  - **Load Factor:** average power divided by peak power (low Load Factor suggests peaks)
  - **The Grid Carbon Content intensity:** The carbon produced to generate the required electricity

Game-Theoretic Analysis

Game-Theoretic Analysis

- Game is played over a 24-hour period
- Agent's Cost = The total cost of purchasing electricity during the game
- Assumptions:
  - Agents are rational
  - Agents have complete information about the market

Game-Theoretic Analysis

- Minimize:

$$\sum_{i \in I} p_i (b_i^{a+} - b_i^{a-} + l_i^a) + c^a e^a$$

- Where for agent a and interval i:
  - I is the duration of the study
  - p_i is market price function
  - b_i^{a+} is the battery charging profile
  - b_i^{a-} is the battery de-charging profile
  - l_i^a is the load demand
  - c^a is the operation cost of per unit battery
  - e^a is the battery

- Constraints:
  - Storage efficiency
  - Charging / discharging limits
  - No reselling allowed

Storage Strategy

Storage Strategy

- Learn to adapt the storage:

$$e^a(t+1) = e^a(t) + \beta(e_U^{a*} - e^a(t))$$

- Where on each day t:
  - $e^a(t)$ is the storage capacity of the agent
  - β is the learning rate of the storage capacity
  - e_U^{a*} is the desired capacity to minimize the agent's cost

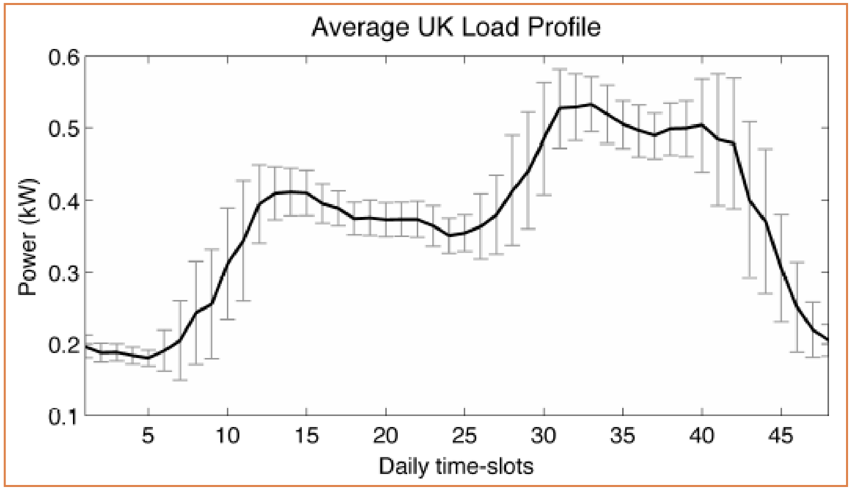
- Adapts to the continuously changing market prices
- Gradually adapts the storage profile of the agent
- **Slow enough storage adaption leads to Nash equilibrium**

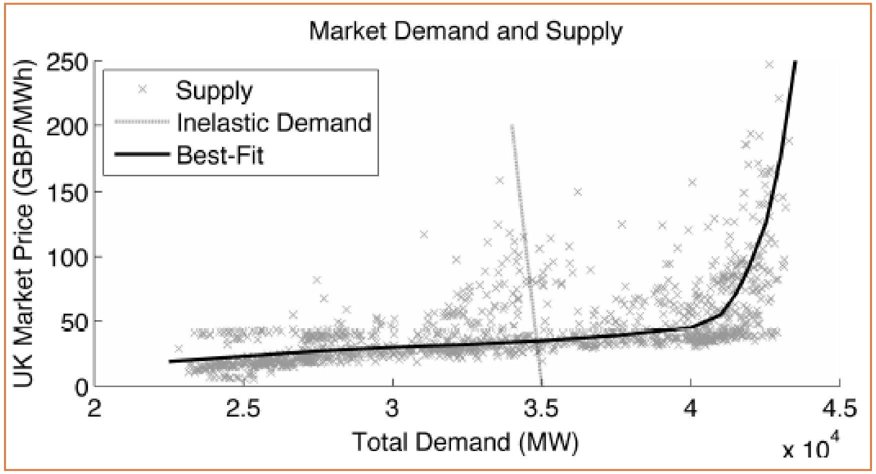
Case study results

Case study results

- Analysis within UK market environment

Representative load profile





UK market model

Case study results

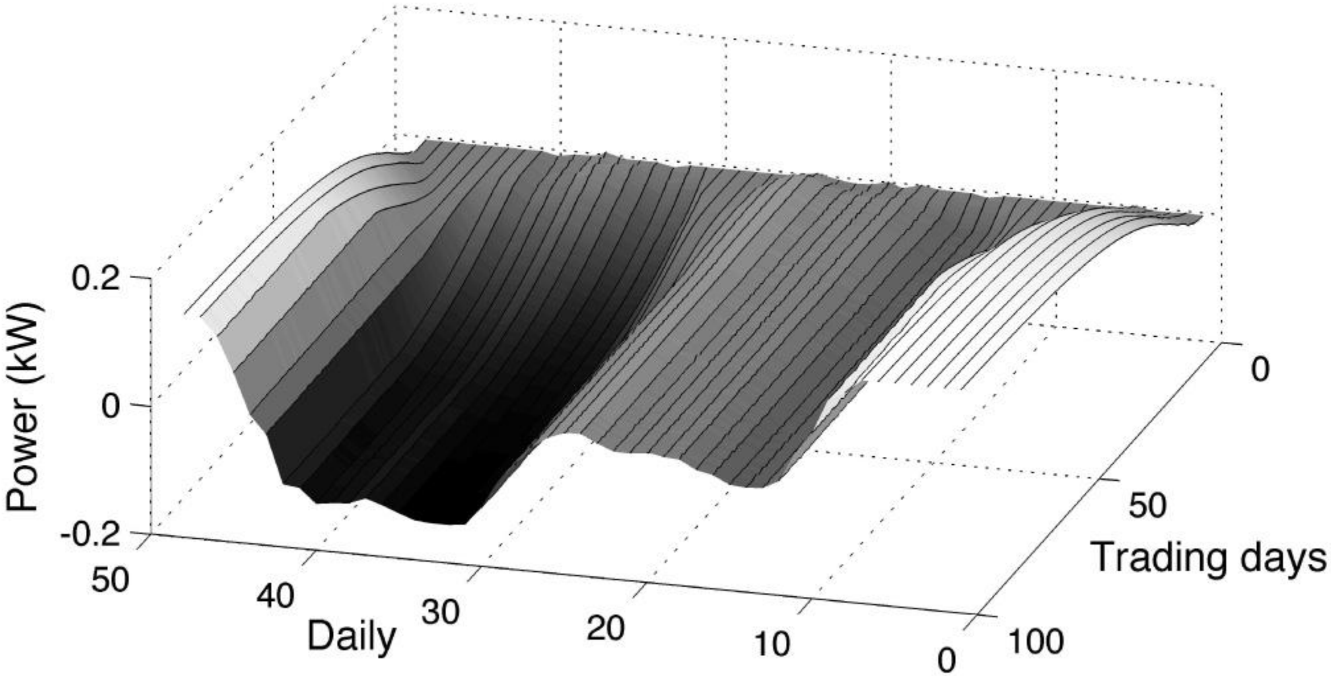


Figure 6: Average Storage Profile converging to Nash Equilibrium.

Case study results

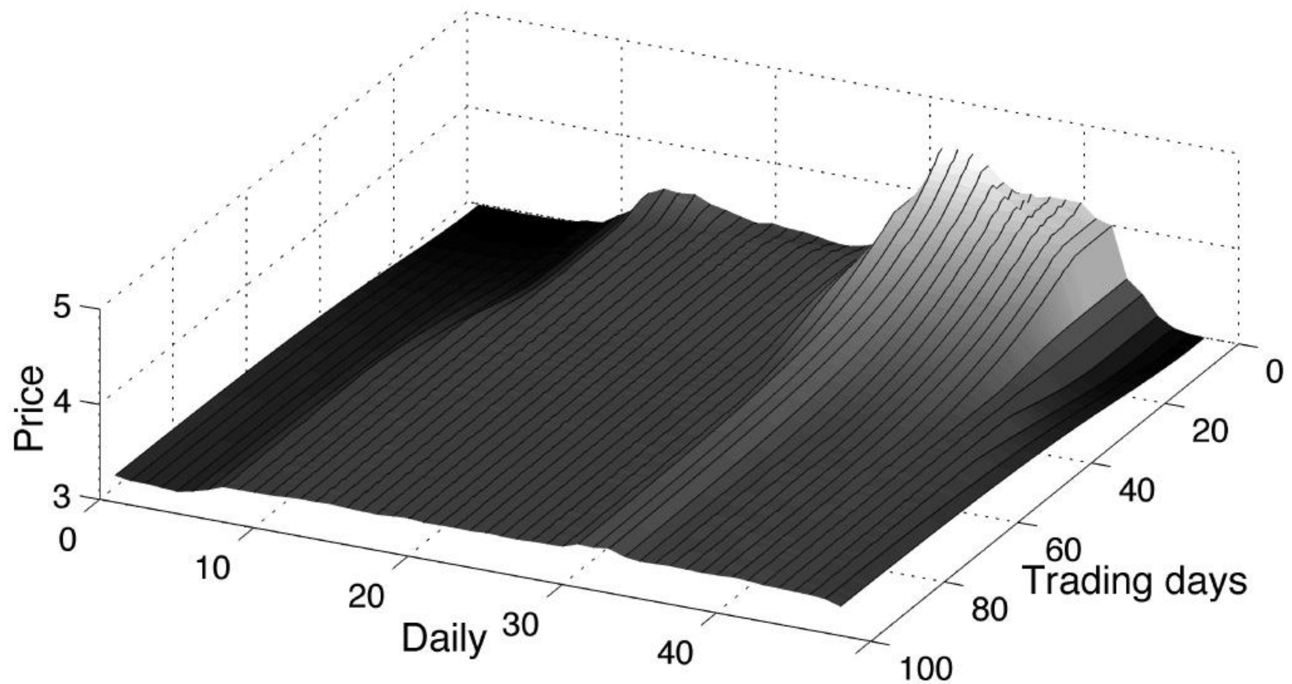
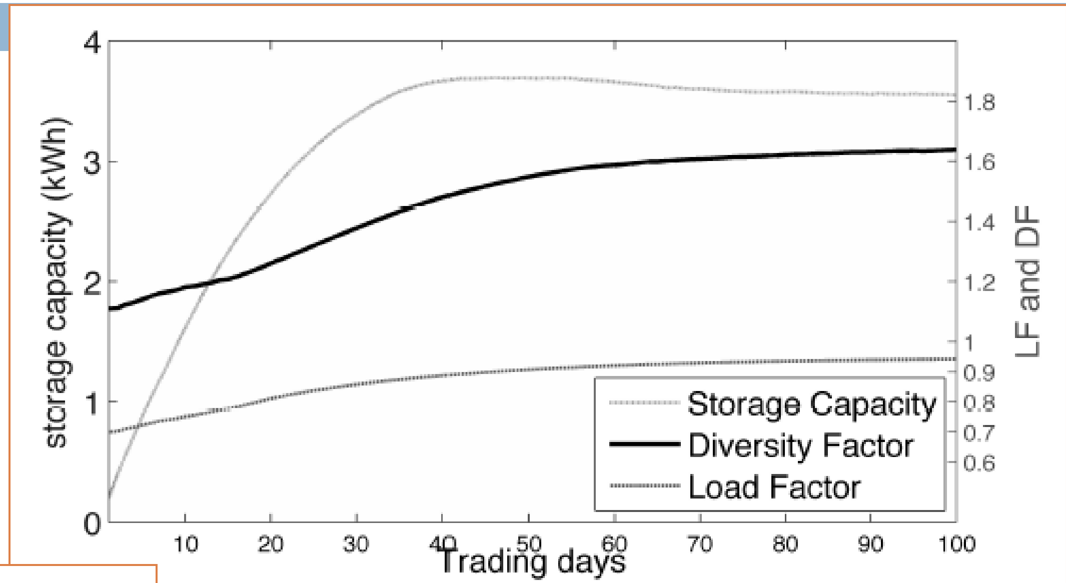


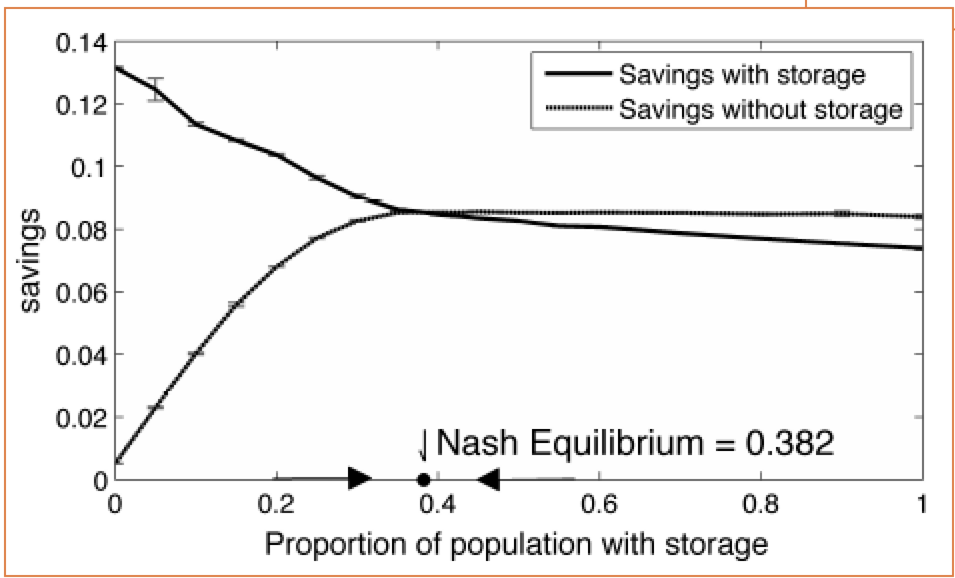
Figure 7: Changing Market Prices (market prices eventually flatten).

Conclusion

Conclusion

Social welfare of the system





Savings with and without storage

Conclusion

- The proposed strategy resulted in:
  - Carbon content was reduced by up to 7% by using storage system
  - A maximum savings of up to 13% as compared to a no-storage system
  - Flattened aggregated Peak load
  - Nash equilibrium through storage adaption
  - Maximum social welfare with 38% of the population adopting storage

Our discussion

Our discussion

- Some characteristics of this paper's problem

  - Day-ahead decisions (based on the electricity market price)
  - Not dynamic (changes are sequential and not fast)
  - Discrete (charge/de-charge/buy electricity)
  - Non episodic (battery adaption)
  - Deterministic market/Uncertain battery types
  - Incomplete information (home loads and battery types)

Our discussion

- Drawbacks
  - Not realistic
    - Myopic agents
    - averaged electricity market price
    - No communication between agents
    - The autonomy of the home agents was ignored.
    - The generation capability of the homes was not included.
    - Electricity trade between neighbours was not considered.
    - Sell-to-grid possibility for the homes was not modelled.
    - There was no flexibility in the home's demand based on the electricity price.
  - Battery adaption is not a true learning gained by the agent. It is like a social rule restricting the agents autonomy.

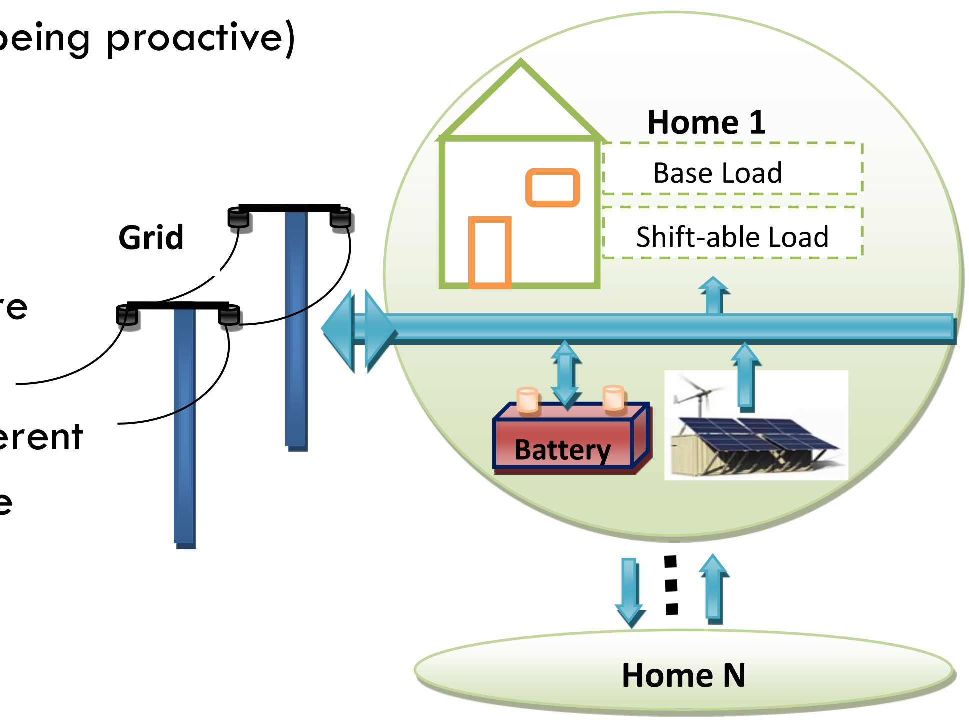
Our discussion

- While autonomy of the individual home agent is important, establishing some rules, like the gradual storage adaption in this paper, is sometimes suitable to obtain a desired emergent behaviour.

- In this problem limiting the autonomy of the agents may not affect the scalability of the solution but it degrades the addictiveness of it.

Our discussion

- Improvement made in our project:
  - Rational homes decide to maximize their benefits based on:
    - Utility of trade with the grid (agents can sell to the grid)
    - Utility of trade with the neighbour (being social)
    - Utility of the home’s load priority (autonomy for the agents)
    - Utility of storing electricity (being proactive)
  - Two different types of load
  - Generation capability
  - Objectives:
    - To maximize the social welfare of the system
    - Determine the effects of different loads and the electricity price



Questions?