Smart energy management for unlocking demand response in residential applications

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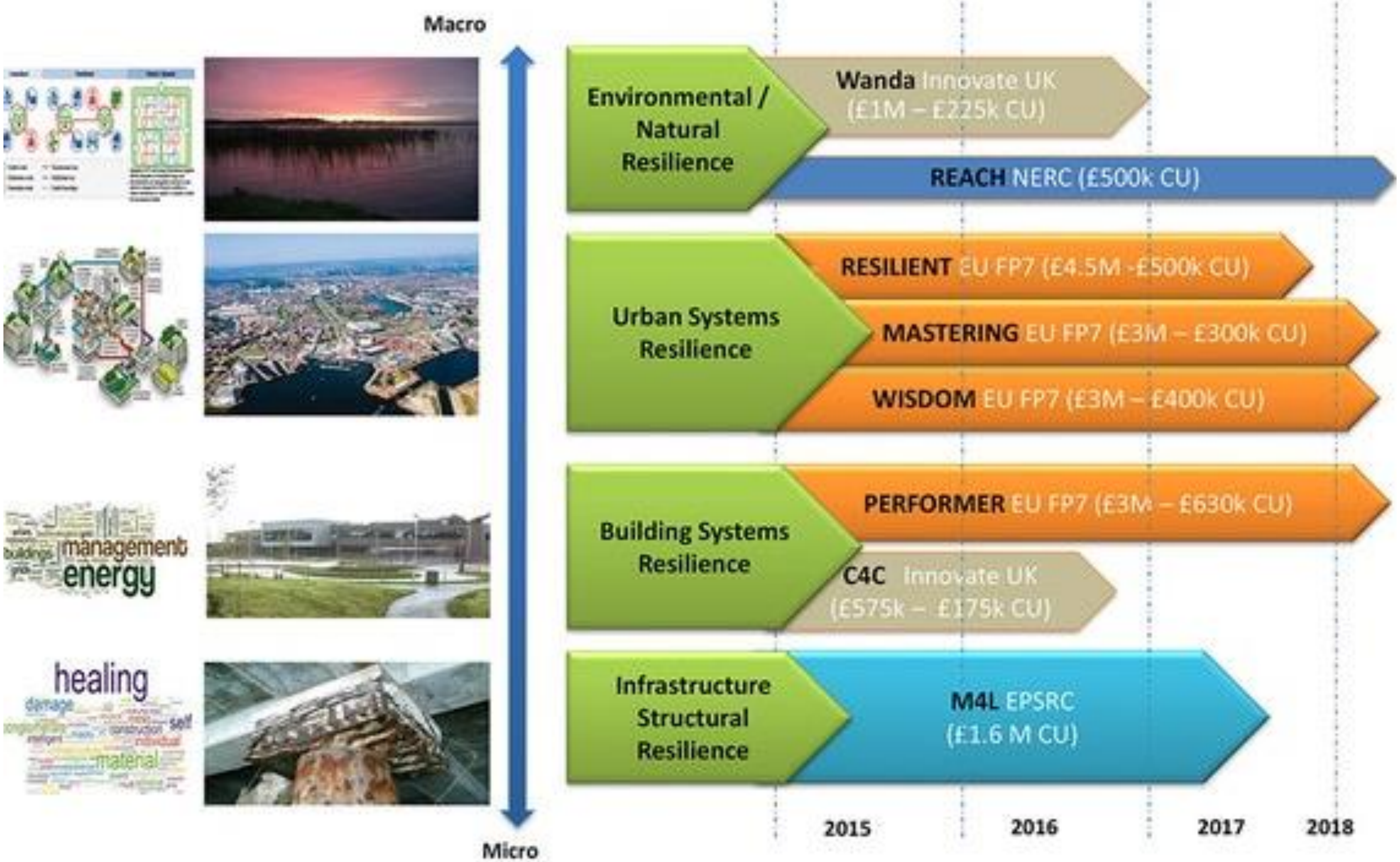

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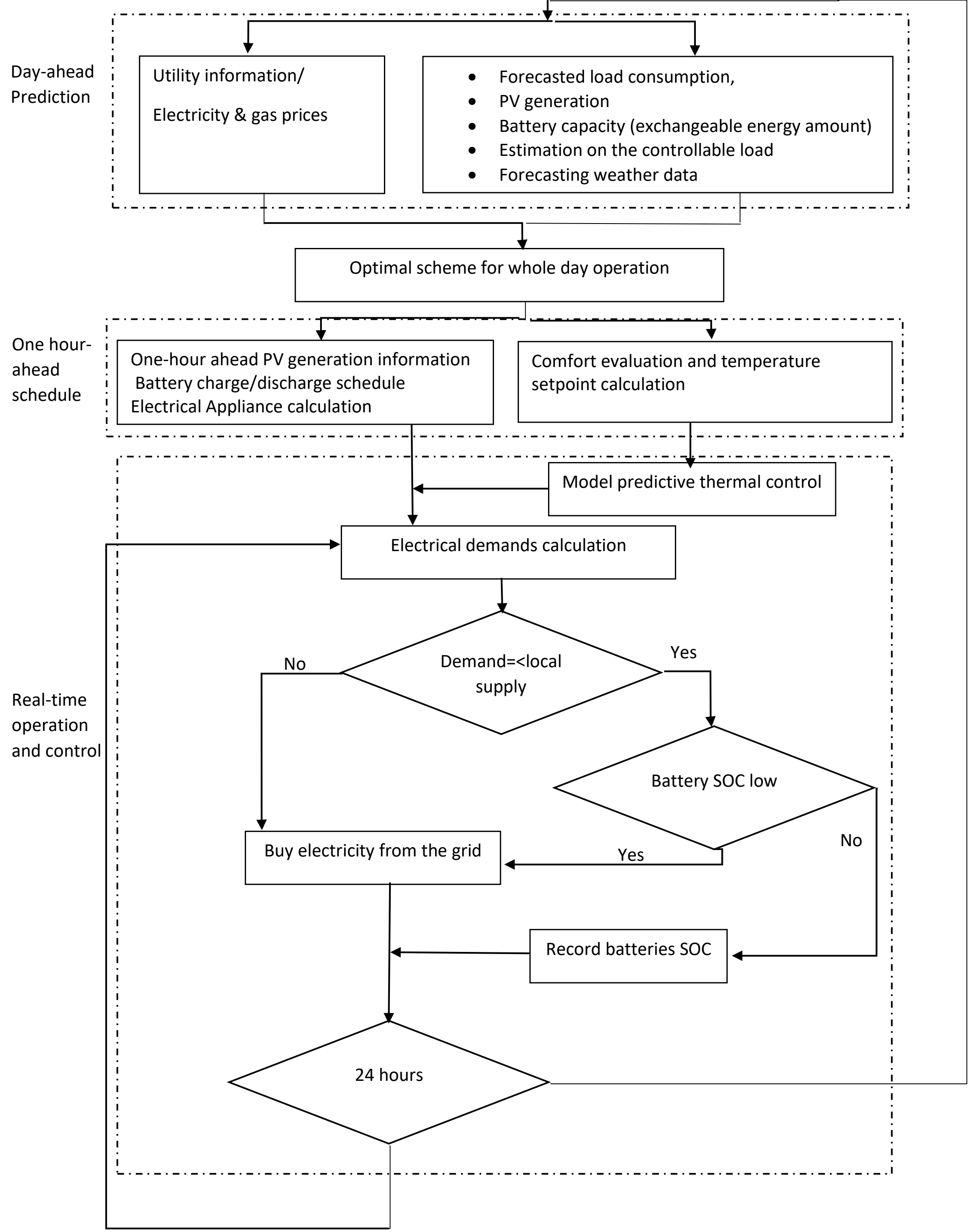
Abstract

This paper presents a smart energy management system which is primarily designed for the residential applications in the UK. First of all, a 24-hour ahead demand profile is scheduled by shafting potential flexible load. And then both one-hour energy demand and supplying flow are estimated. The real-time electrical demand is satisfied by the combined renewable energy sources/grid electricity/batteries with minimal cost.

Flow chart of energy management strategy



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Methodology:

- First of all, we forecast weather and predict the overall energy consumption, state of energy storage, electricity price. The load are categorised into non-shiftable, time shiftable and power shiftable load groups afterwards. Therefore, day-ahead facility operation scheme is decided;
- One-hour ahead supply estimation and comfort setting are defined to configure the energy consumption profile;
- Dynamic programming framework is used to optimise the real-time operation where PV, battery and grid electricity are combined to configure optimal supplying flow to balance the real-time electrical demand under the objective proposed.

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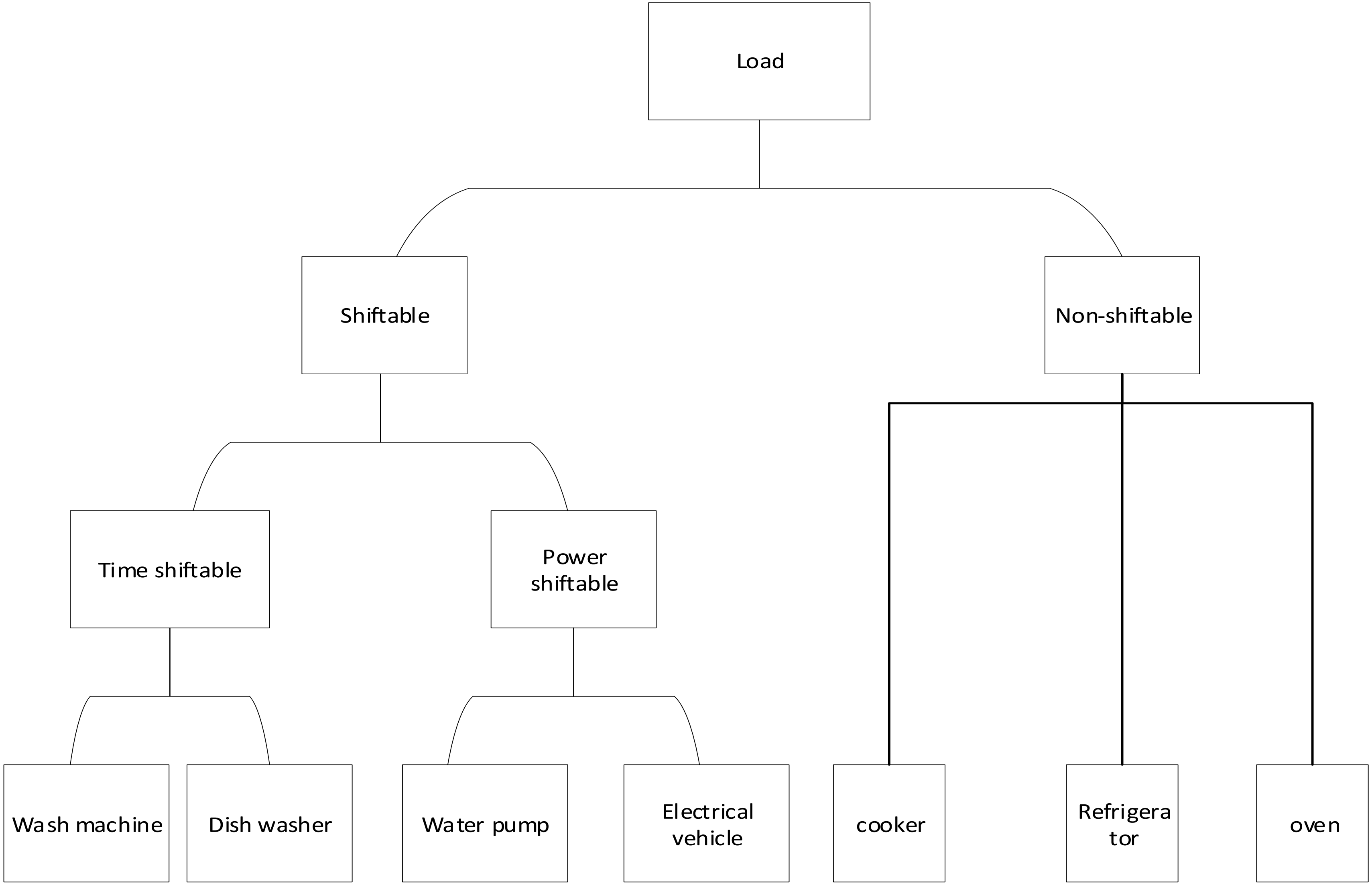

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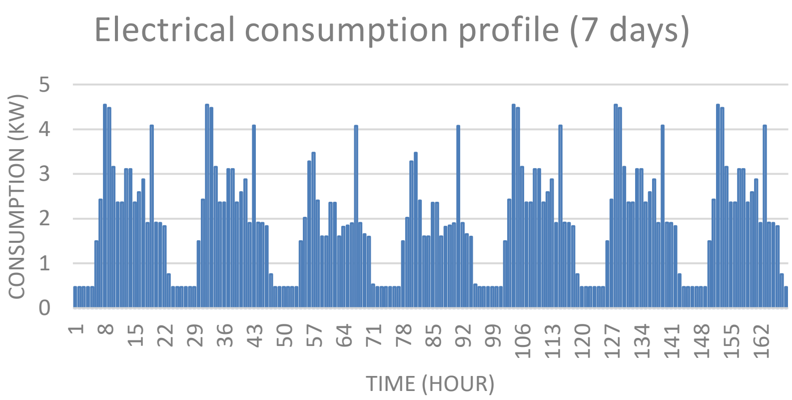

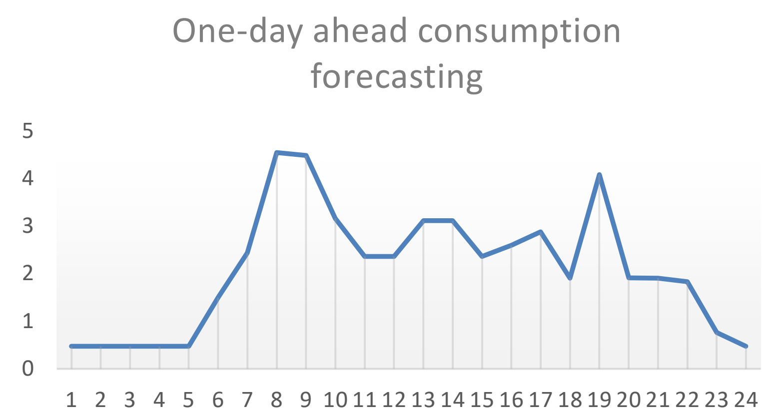

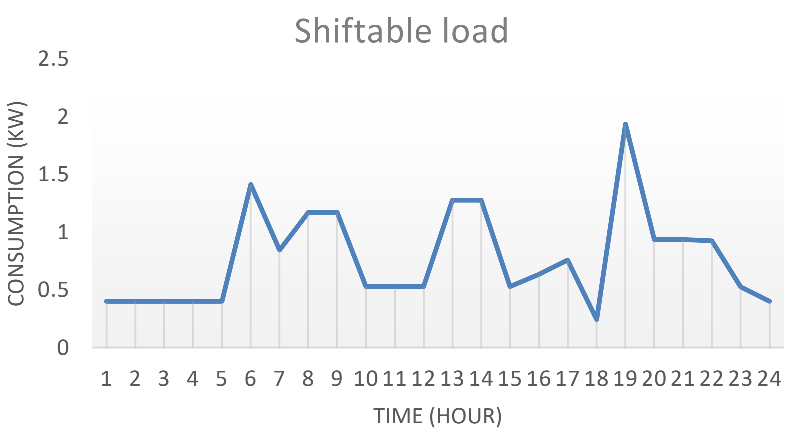

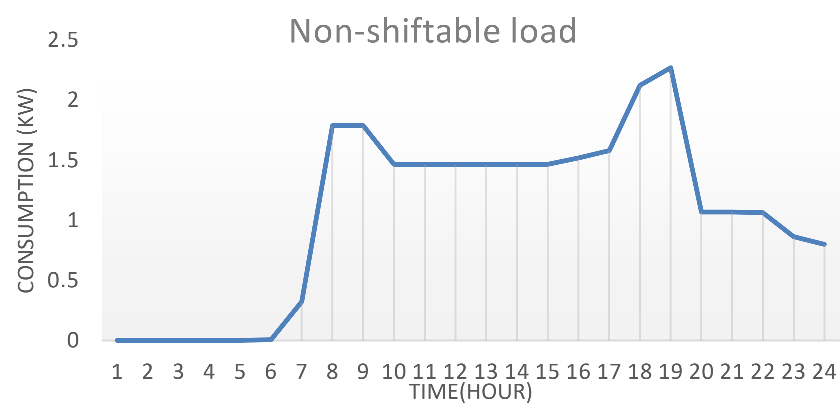

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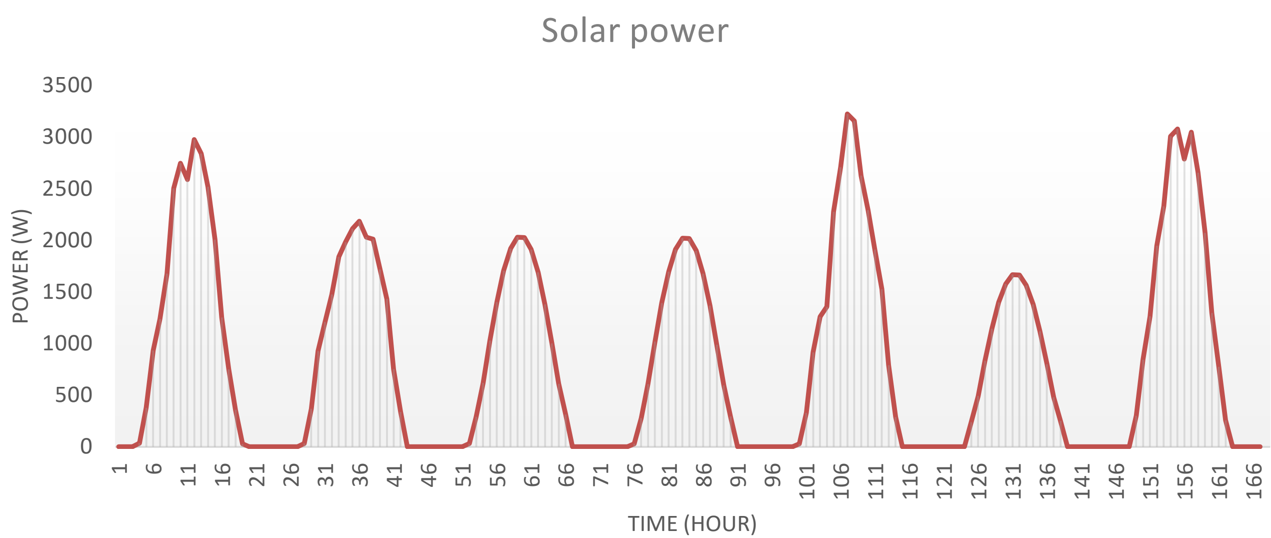
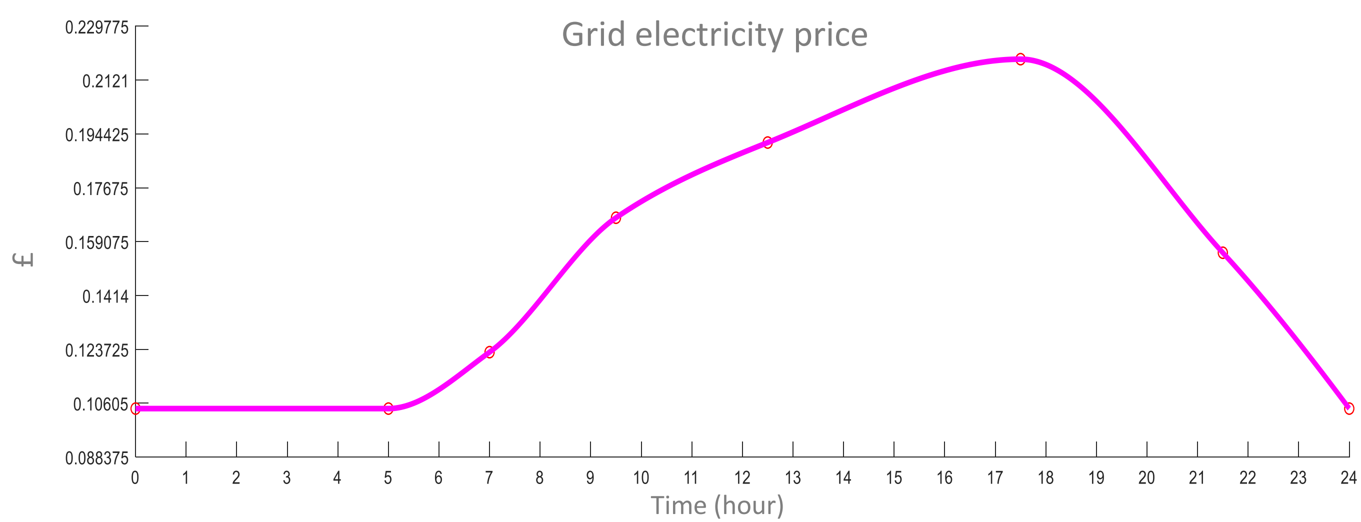
Energy supply





- By re-scheduling the usage of shiftable appliances, the energy cost can be reduced to some extent. However, it could deteriorate the users’ conform. Furthermore, the high electrical demand takes place between 17’oclock and 21’oclock when grid price gradually increase to its peaks.
- There is a need to adopt better adjustable method to satisfy both comfort and economic requirement for the domestic users.

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- Energy storage systems, such as batteries are the good option for domestic electricity demand shifting/shedding/peak reduction. They can be regarded as either time shiftable/power shiftable loads or power supply resource.
- In this study, batteries are used for adjustment method to balance demand and supply which in turn minimize both the discomfort and the cost.

- Real-time operation

$$J = min \sum (C_1 \cdot (w_{grid}(\mathrm{t})) \cdot h_1(t) + \left(\alpha \cdot \; (w_{batteries}(t)\right) \cdot h_2\;(t) + \left(\beta \cdot \; (w_{PV}(t)\right)) \cdot h_3\;(t))$$

S.t.

$$0 < w_{pv} < w_{max}$$

$$SOC_{max} < SOC < SOC_{min}$$

$$C_{gridmin} < C_1 < C_{gridmax}$$

$$w_{load} = w_{grid}(t) + w_{pv}(t) + w_{battery}(t)$$

- # Case Study

The optimal strategy is validated via the energy system in a detached 3-bedroom house. The house is located in London with 101.25 m2 space. Simulation is executed within 168 hours in a summer week. A daily energy consumption and supplies are evaluated as follows,

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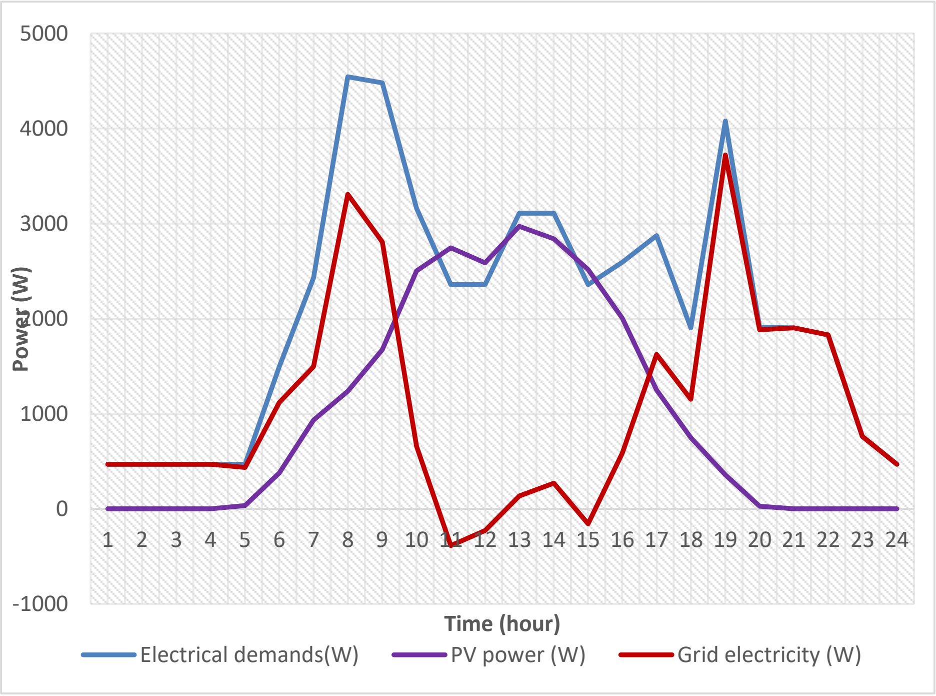
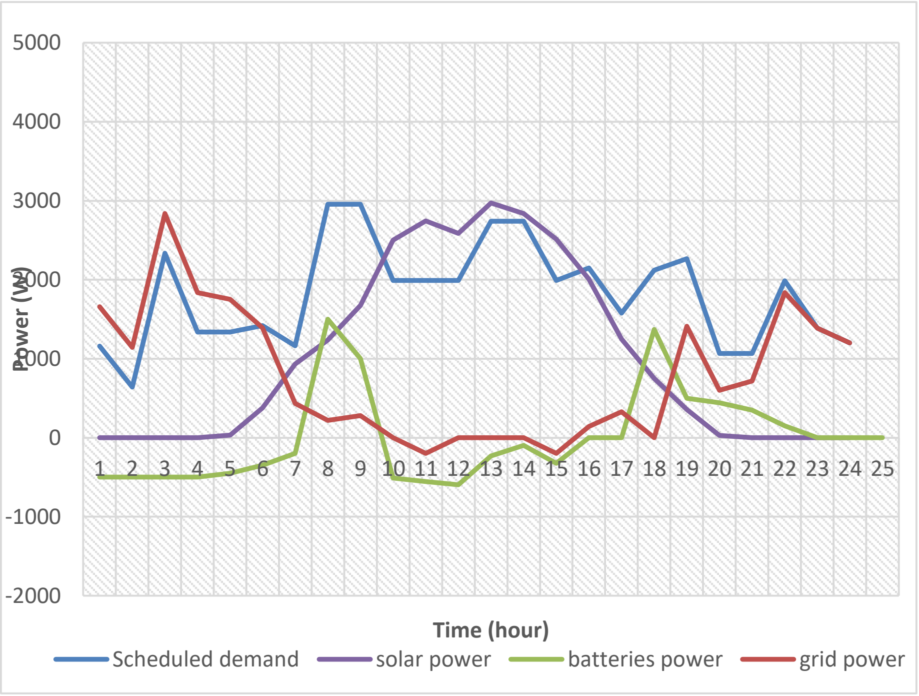
Case Study





A daily demand and supplies (a) without optimisation (b)with optimisation

Case Study

	without optimisation	with optimisation
Demand(kWh)	43.59	43.59
Electricity bought(kWh)	21.49	19.18
Electricity sold(kWh)	2.71	0.4
PV energy(kWh)	24.81	24.81
Peak demand (kW)	4.21	2.84
Electricity cost(£)	2.98	1.95

Conclusion:

This study developed an optimal operation scheme for a energy system in a domestic house. The highlights are summarised as follows:

1. Load shifting/load shedding are realised through a day-ahead scheming;
2. Energy storage assistants the realisation of peak shafting;
3. The costs for buying electricity are reduced;
4. CO2 emission will be considered in the future research.

Thanks