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Integrated Optimisation of Photovoltaics and Storage Systems for UK commercial Buildings

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AIM

Develop an optimisation model applied to UK commercial buildings allowing to identify the optimum capacity, technology and operation for a photovoltaic and battery system while presenting business cases based on project finance indicators.

BACKGROUND

Growing concerns about climate change, new decarbonisation agenda and rising electricity prices have led industries to rethink their energy consumption. In this context, major stakeholders in the UK food retail market are investigating pathways to reduce their carbon footprint using low-carbon energy production such as photovoltaic system coupled with batteries. It was identified that there was a gap for an analytical and practical tool that could be developed as guidance for decision making to assess and compare business cases related to those projects. A partnership has been established between Imperial College and Sainsbury's in order to develop projects through collaboration. Therefore, this research is mainly based on real measured data.

KEY QUESTIONS

- For a commercial building, what is the information required to realise an optimisation analysis for photovoltaics and battery systems?
- What are the optimum capacity, technology and operation for the system that would help build the strongest investment possible for each building?
- What are the impacts of key parameters uncertainties on the financial feasibility of a project?

METHOD

In order to realise a fair assessment of the system's specifications and economics, data had to be gathered in order to be used as input for the model.

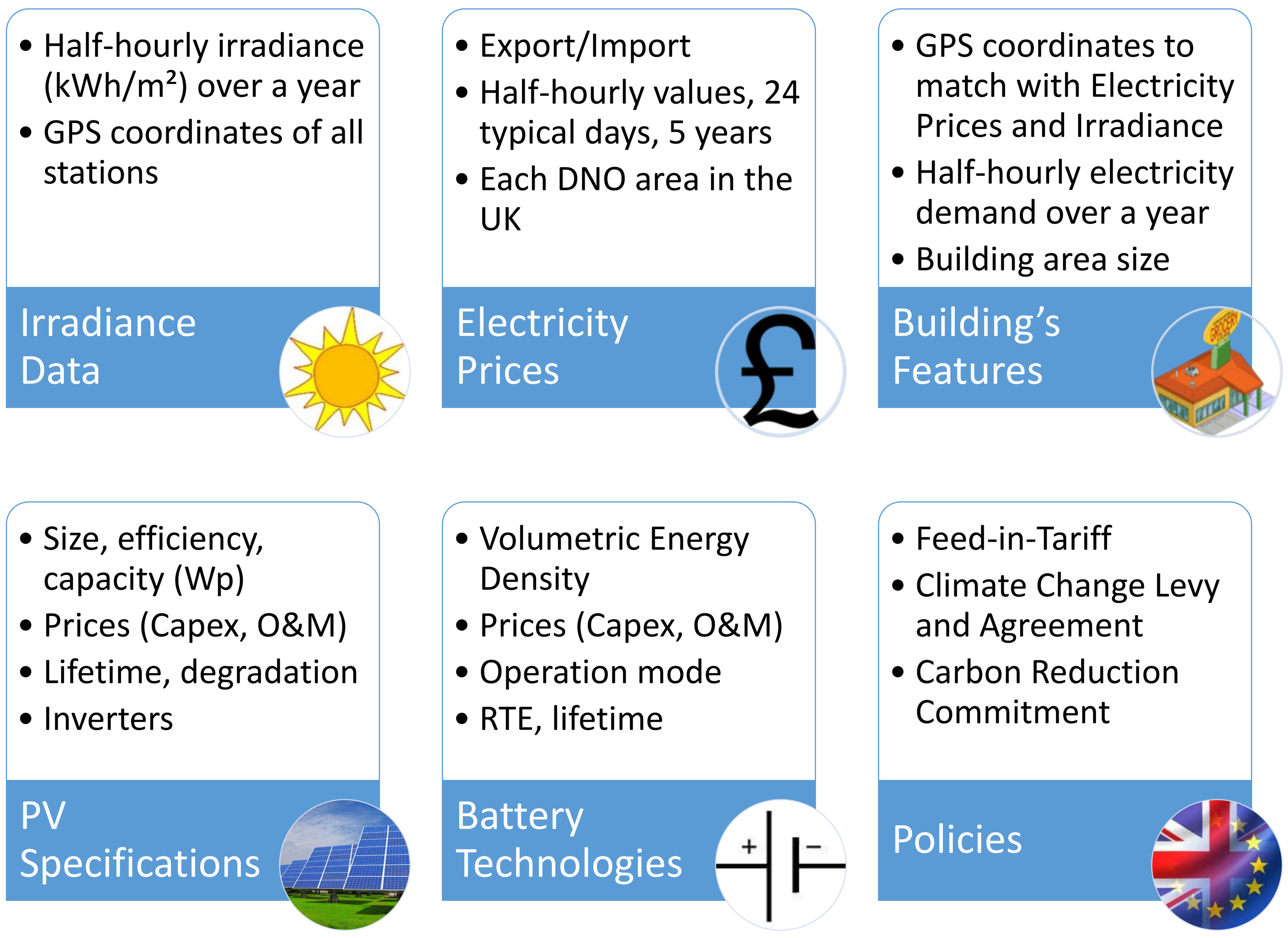

Figure 1: Data gathered for the model. The first three categories depend on the building on which the optimisation is realised. Most of the parameters are also time dependent and change over years.

The mixed integer non-linear programming optimisation model aims to minimise the objective function of total costs, using sets of inequality and equality constraints. The objective function is comprised of different components such as the capital costs, maintenance costs and operating costs (earnings) from both photovoltaics and battery systems, as well as the carbon costs.

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RESULTS

As an example, part of the analysis for a selected Distribution Centre is presented.

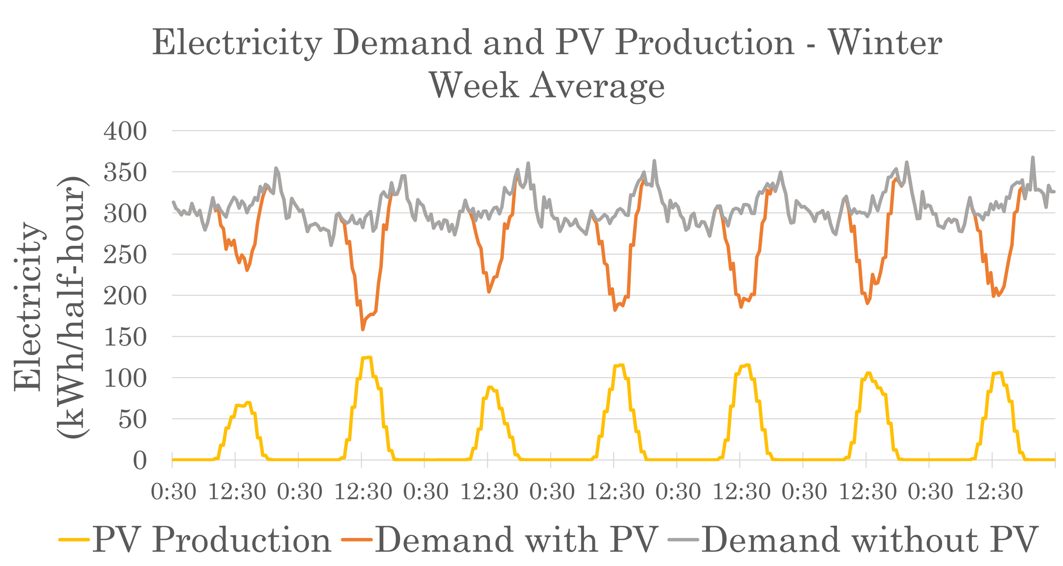

Figure 2: Weekly average over winter for Electricity demand and photovoltaic production. Optimised Capacity of the photovoltaic system is around 900kWp, technology chosen is CIGS. All the electricity produced from the solar panels is fully used on-site at production time.

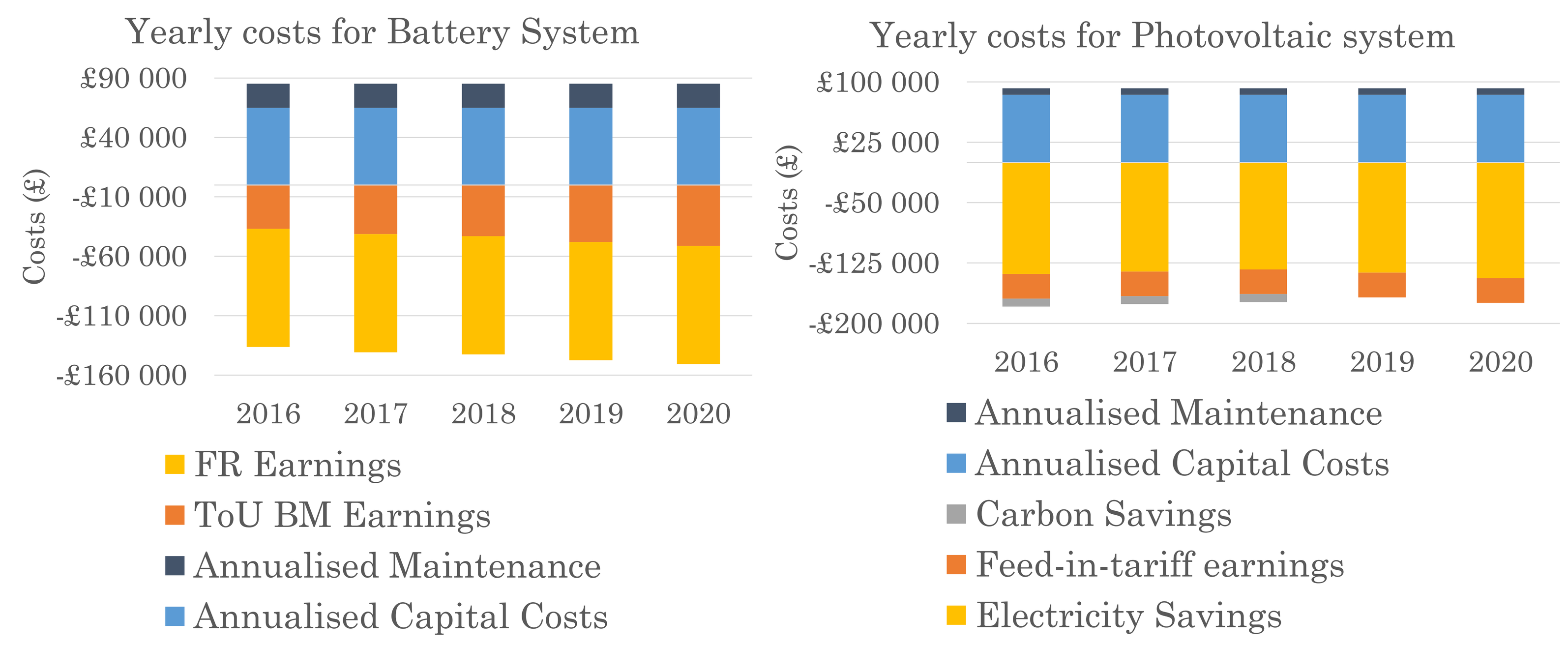

Figure 3: Breakdown of costs associated with the battery (left) and solar (right) systems. For photovoltaics, major savings are generated by avoiding to purchase grid electricity. The optimised 1.2MW/1.8MWh Lead-acid Battery system generates most of its revenues by providing a combination of Frequency Response (FR) and Time-Of-Use Bill Management (ToU BM).

Payback Period	5 years
Internal Rate of Return	20%
Return On Investment	91%
Initial Investment at year 0	- £1,285,222
Cumulative cash flow after 20 years	£2,952,976

Table 1: Financial Indicators for the overall project. It allows to compare different projects and to identify investment sequences.

SENSITIVITY ANALYSES

Parameter variation	Impacts on	Payback Period	IRR	ROI
Electricity prices +7%	- Increased Savings from PV production - Improved Earnings from battery ToU BM	5 years	20%	93%
Aggregator's share in Frequency Response from 40% to 0%	- Improved Earnings from battery FR	4 years	25%	126%
Irradiance level -15%	- Reduced Savings from PV production - Reduced Earnings from FiT - Reduced Savings in carbon costs	5 years	17%	72%
Starting year from 2016 to 2018	- Small impact on almost all components	5 years	21%	108%
photovoltaics prices -20%	- Reduced capital investment	5 years	22%	108%
Battery prices -20%	- Reduced capital investment	5 years	21%	99%

Table 2: Impact of inputs variations on the revenue streams and financial results

KEY FINDINGS

Properly designed and managed photovoltaics and storage systems can constitute financially attractive investments and help decrease carbon footprint of businesses. Due to the high number of inputs and the diversity of the components of the objective function, individual variations of parameters have a relatively small impact on the overall project economics.

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