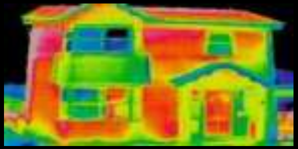
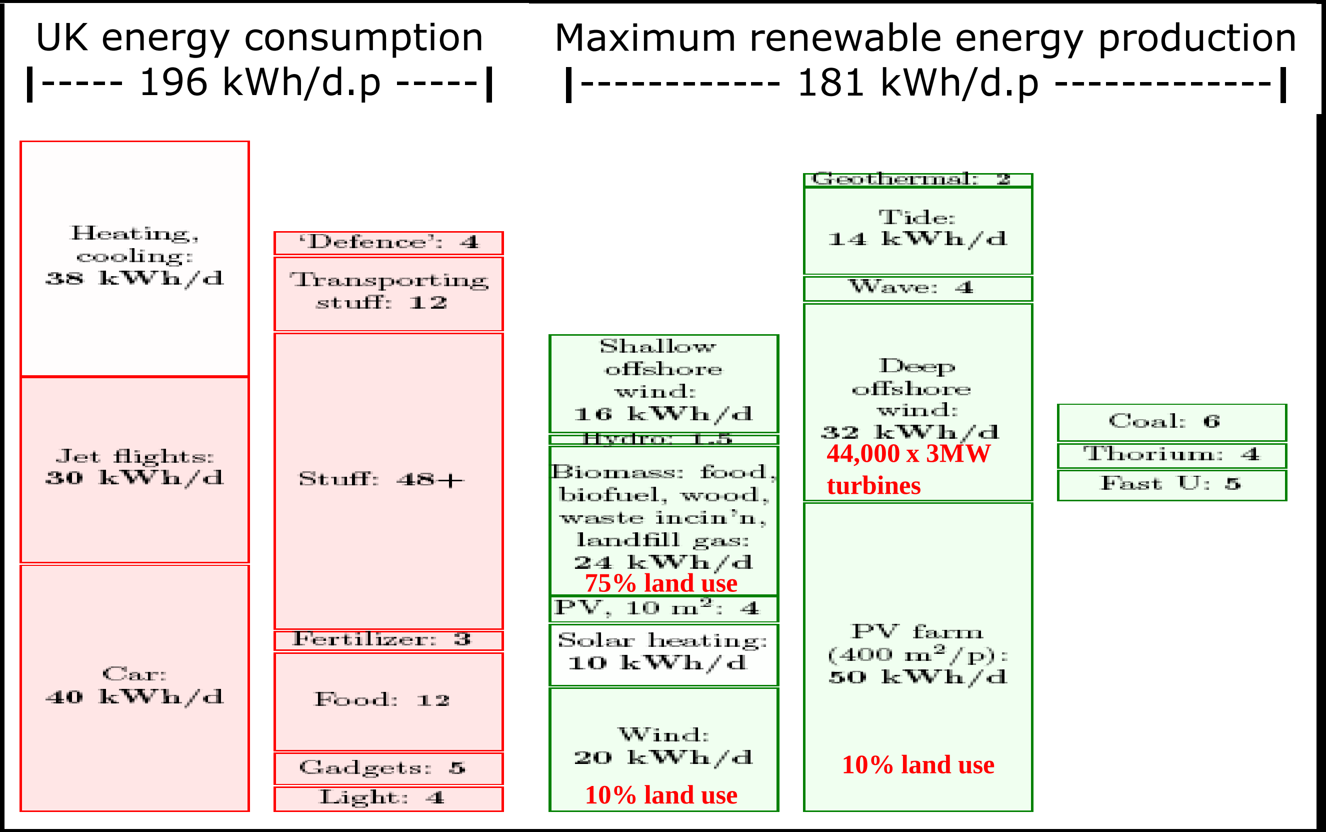
Assessing the potential for community low carbon energy provision

Joe Clarke
Energy Systems Research Unit
and
BRE Centre for Energy Utilisation
University of Strathclyde

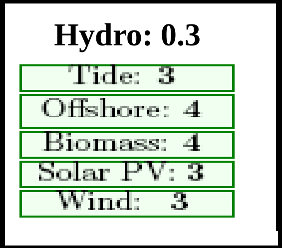





The demand/supply dilemma



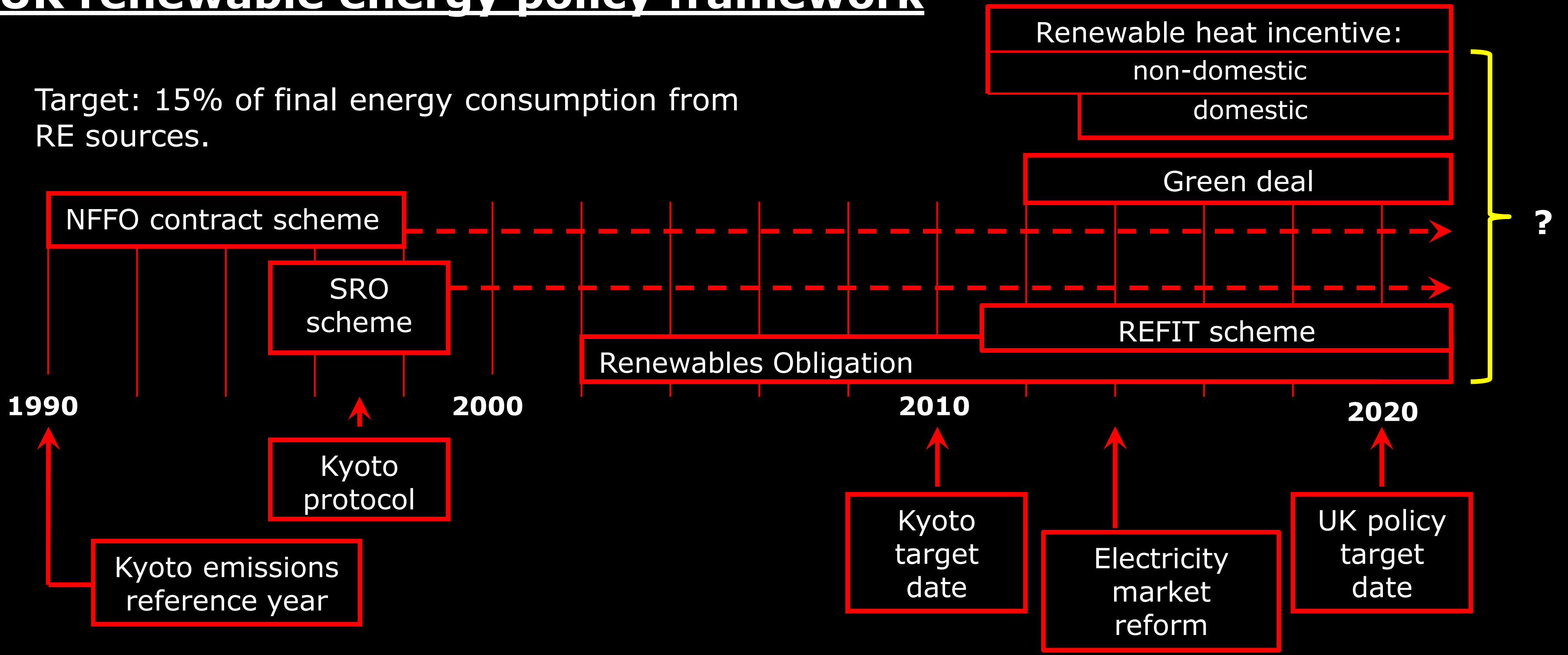
Likely resource
17 kWh/d.p



Source: MacKay, www.withouthotair.com

UK renewable energy policy framework

Target: 15% of final energy consumption from RE sources.



Target backed by only fiscal measures.
What about technical feasibility and myriad impacts?

Problems with the fiscal measures approach

- results in unreliable systems
- increases demand/supply gap
- worsens the cost burden
- gives unintentional impacts
- leads to inappropriate infrastructure
- causes disaffected population

Good solutions require whole systems thinking

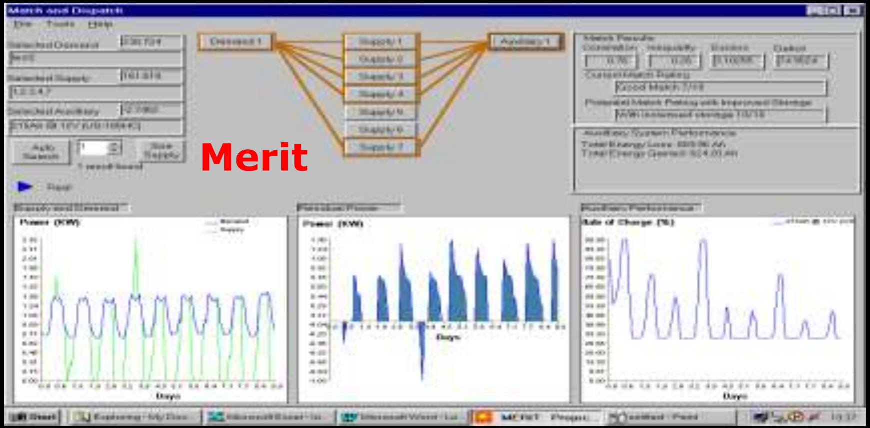
If you can't simulate it, don't build it.

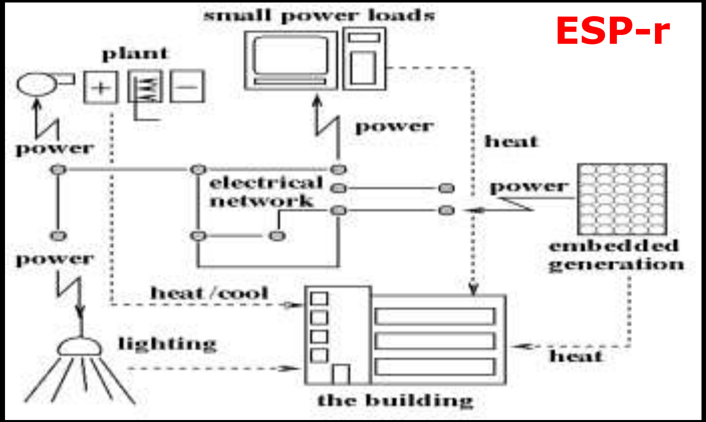
Hybrid system sizing

Stage 1:

- identify mix of supply technologies (by type and capacity) that best match the anticipated demand profiles;

- equates to a rational sizing procedure for hybrid low carbon supplies as opposed to the arbitrary selection of a technology mix based on exogenous factors.



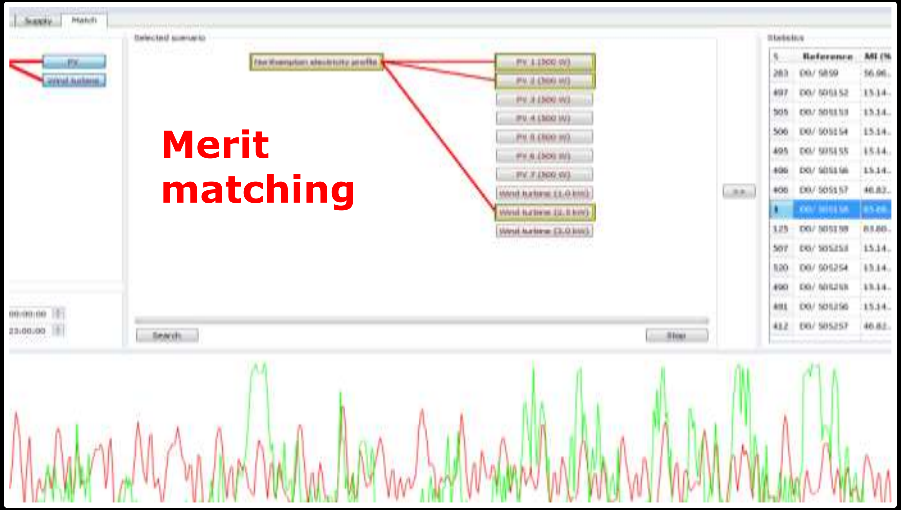


Stage 2:

- for best match, generate a multi-dwelling and supply model for detailed simulation;

- use model to appraise the feasibility of the embedded generation scheme in terms of criteria such as indoor comfort, system controllability, power quality, energy use and emissions.

Stage 1: chunking process



- Method commences with knowledge of the community energy demands to be matched.

- User identifies supply technologies of interest (PV, CHP, Wind, BioM, HP, FC).

- Capacity of each technology is set to an arbitrary initial value equal to a multiple of the peak demand.

- The initial capacities are 'chunked', e.g.:
  - 1 MW of PV may be represented as 100 x 10 kW because outputs are additive;
  - 1 MW of wind may be represented as turbines of different capacity (e.g. 1 x 1 MW, 5 x 200 kW, 50 x 20 kW, 100 x 10 kW *etc*.) because the rated power affects the capacity coefficient;
  - chunk size can vary as a function of the required accuracy.

- The best match combination of technology chunks defines the required hybrid system component capacities.

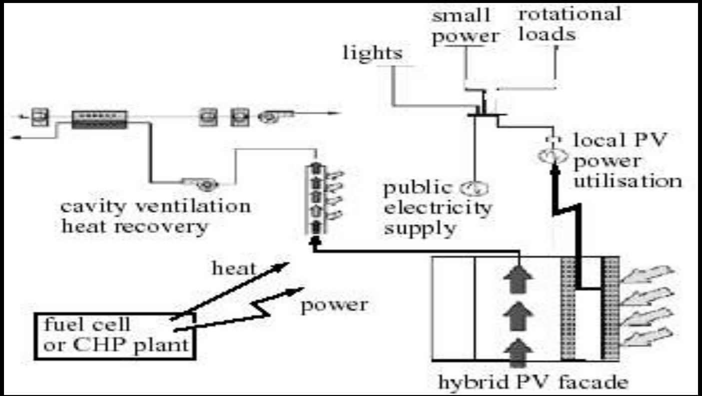
Stage 2: feasibility assessement

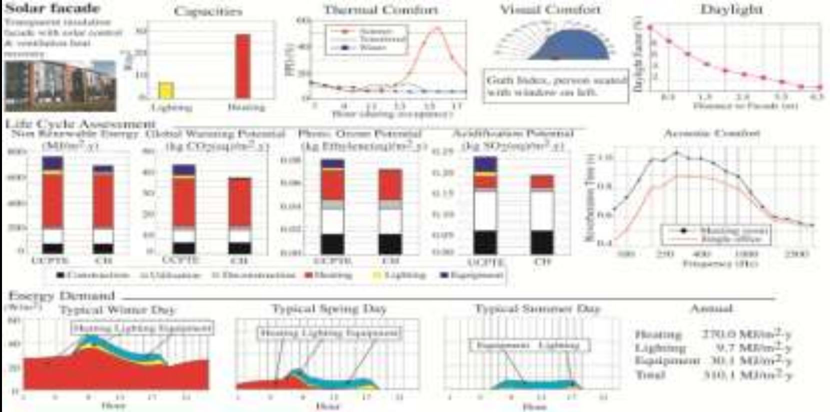
- An acceptable scheme identified in Stage 1 is semi-automatically transformed to an ESP-r model for simulation.

- Prototype dwelling models are selected on the basis of descriptive parameters related to the targeted estate – age of dwellings, construction types *etc*.

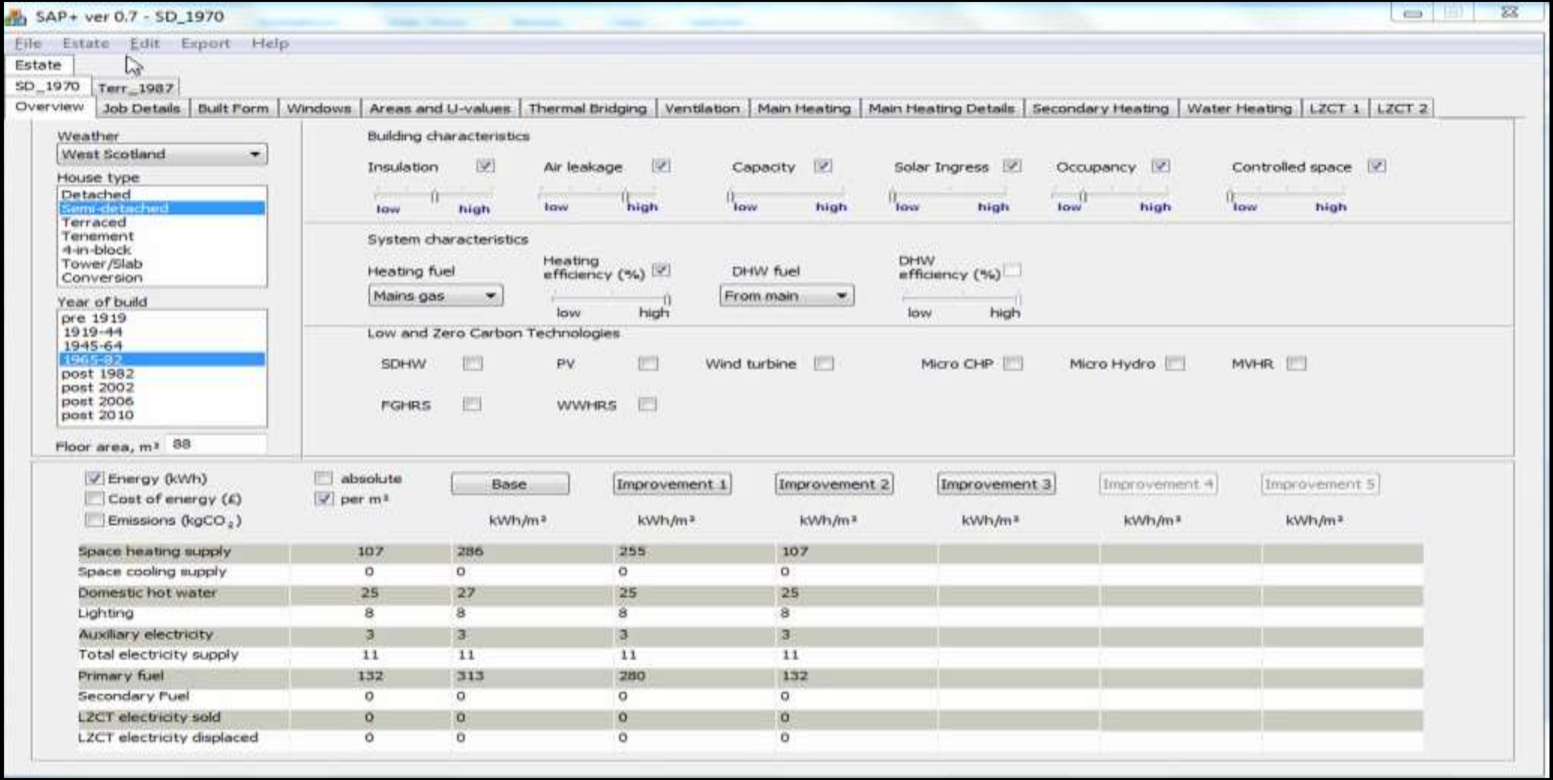
- The hybrid supply system is represented as electricity/heat flow networks connected to dwelling loads.

- While this estate model could be user generated, this is exactly what the reported method is trying to avoid because of the complexities associated with estate size.





Estate definition



		Base	Improvement 1	Improvement 2	Improvement 3	Improvement 4	Improvement 5
		kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²
Space heating supply	107	286	255	107			
Space cooling supply	0	0	0	0			
Domestic hot water	25	27	25	25			
Lighting	8	8	8	8			
Auxiliary electricity	3	3	3	3			
Total electricity supply	11	11	11	11			
Primary fuel	132	313	280	132			
Secondary Fuel	0	0	0	0			
LZCT electricity sold	0	0	0	0			
LZCT electricity displaced	0	0	0	0			

Example application

- The Upton low carbon community at Northampton, UK is under the control of *English Partnerships*, a national regeneration agency.

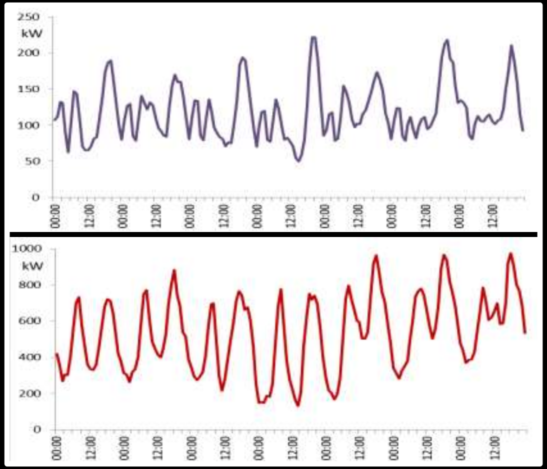
- Based to its size and structure, it is considered a model for future sustainable community development in the UK.

- Case study focused on Site A, a developed residential neighbourhood occupying a total area of 3.7 hectares and accommodating 214 dwellings.

- The total measured annual electricity and heating energy demand of the site is 817,187 kWh and 3,106,098 kWh respectively, with corresponding peak demands of 311 kW and 1,278 kW.

- The low carbon supply technologies considered were PV and wind turbines for electricity, and solar thermal and heat pumps for heating.

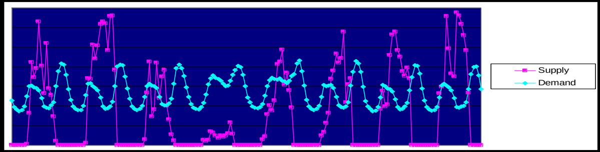
The Upton low carbon community.

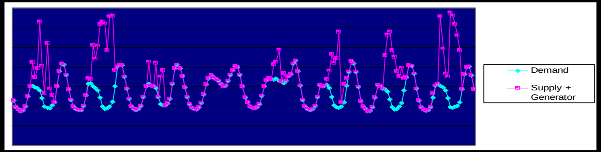


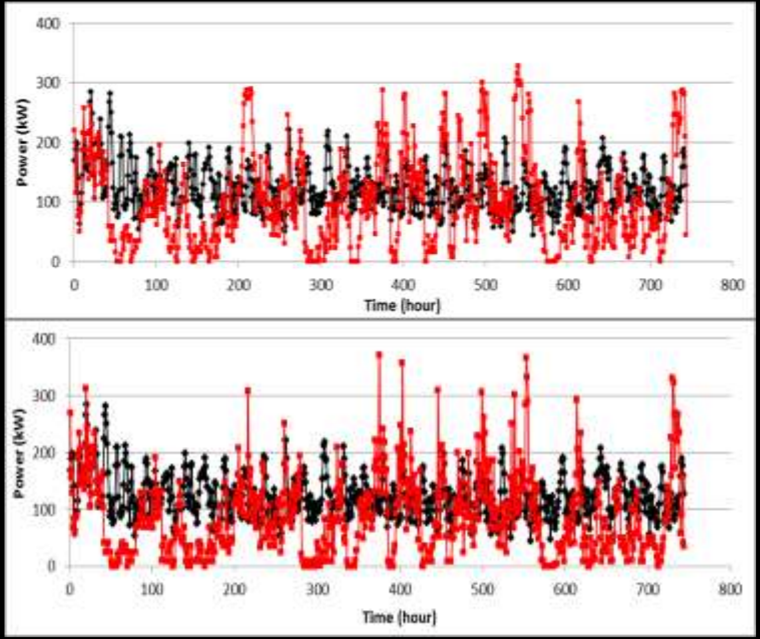
Electricity (top) and heating profiles for an average winter week.

Outcome from Stage 1

- The PV was chunked into 700 x 500 W capacity units, while wind power was chunked into multiple turbines: 10 kW, 30 kW, 50 kW… 290 kW, 310 kW and 330 kW. The number of supply/demand permutations searched by MERIT was 131,771.
- The top two rated matches for electricity are shown here.
- Possible to repeat the search with load shifting superimposed.





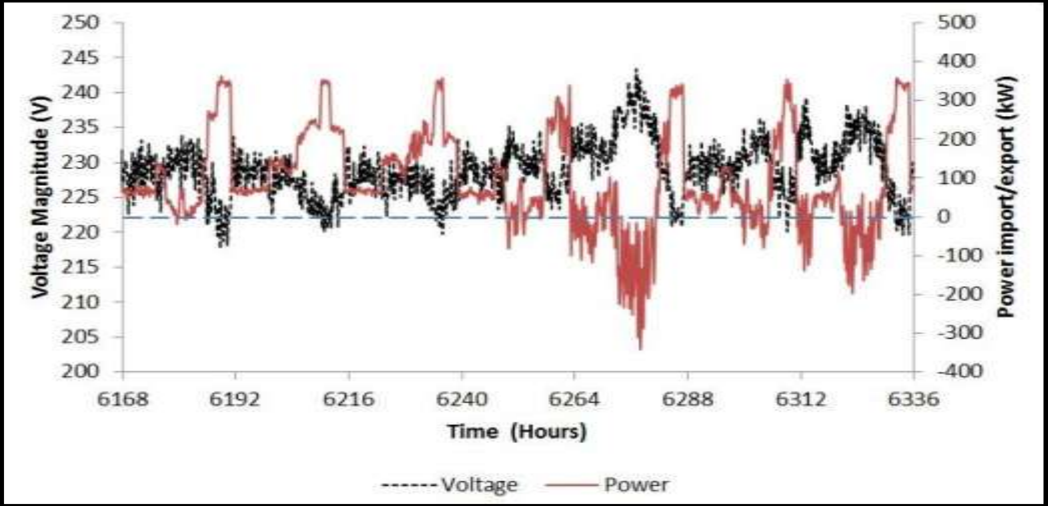


Match statistics and hybrid supply capacities.		
	Match 1	Match 2
RCC	0.07	0.07
IC	0.34	0.37
PM	65.7	63.4
Solar PV capacity (kW)	100	50
Wind turbine capacity (kW)	250	300

Outcome from Stage 2: match

- Two options exist for the creation of the supply model: as a community scheme by which the supply is connected to aggregate load profiles (as here), or as a building-integrated scheme by which the hybrid supply is apportioned to individual dwellings.

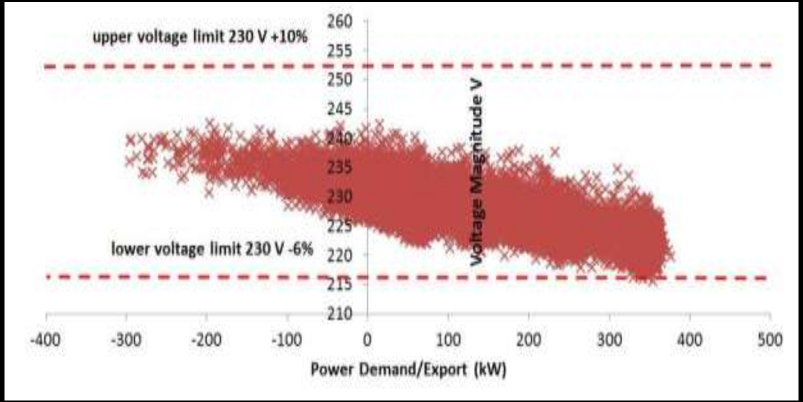
- The network consists of a series of supply cables, each of which accommodates approximately 50 dwellings connected radially to a local supply substation, which is the boundary of the analysed system.

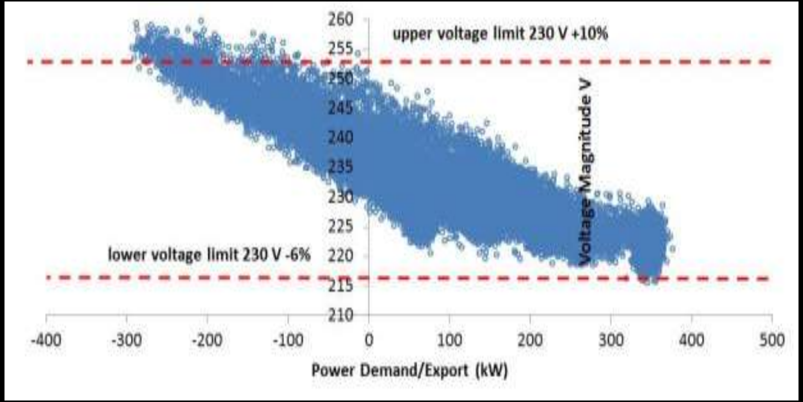


- The graph shows the predicted voltage levels and power import/export for a selected dwelling:
    - -ve flows indicate export to the LV network;
    - voltage is influenced by the performance of the local generation and demand;
    - as the demand increases, the voltage drops below the nominal network supply voltage (230 V);
    - as the supply from local generation increases, voltage rises.

Outcome from Stage 2: Power quality

- Upper: Voltage variation v. power export for best match (PV + Wind) with UK voltage constraints superimposed (230 V +10%/-6%).
- Results confirm that the suggested best match results in voltage excursions within limits.
- In terms of power quality, the suggested technology mix is feasible and does not result in specific problems.
- Lower: Voltage variation v. power export for PV only.
- Results confirm that the upper voltage constraint is frequently breached.





City low carbon opportunity mapping