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Building as a Power Plant

Dr Sara Walker, Dr Haris Patsios, Dr Mohammad Royapoor, Dr Peter Davison, Dr Mehdi Pazhoohesh

Newcastle University

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The concept of BaaPP

- Local electricity distribution networks may need to be managed in a more active way
- Demand side management is one of the active management methods
- DSM is usually done by large industrial loads, at electricity grid scale
- There is the potential for an individual building to offer services to the local electricity distribution network
- The Urban Sciences Building is an interesting case study since it includes electricity generation, storage and demand, and thermal generation, storage and demand

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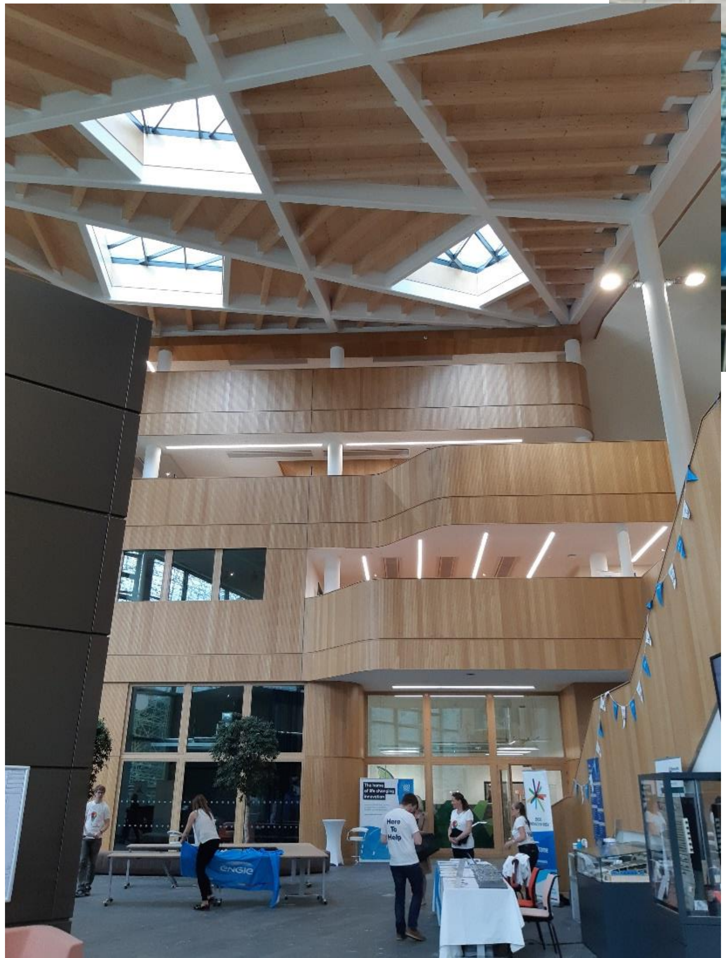
The building



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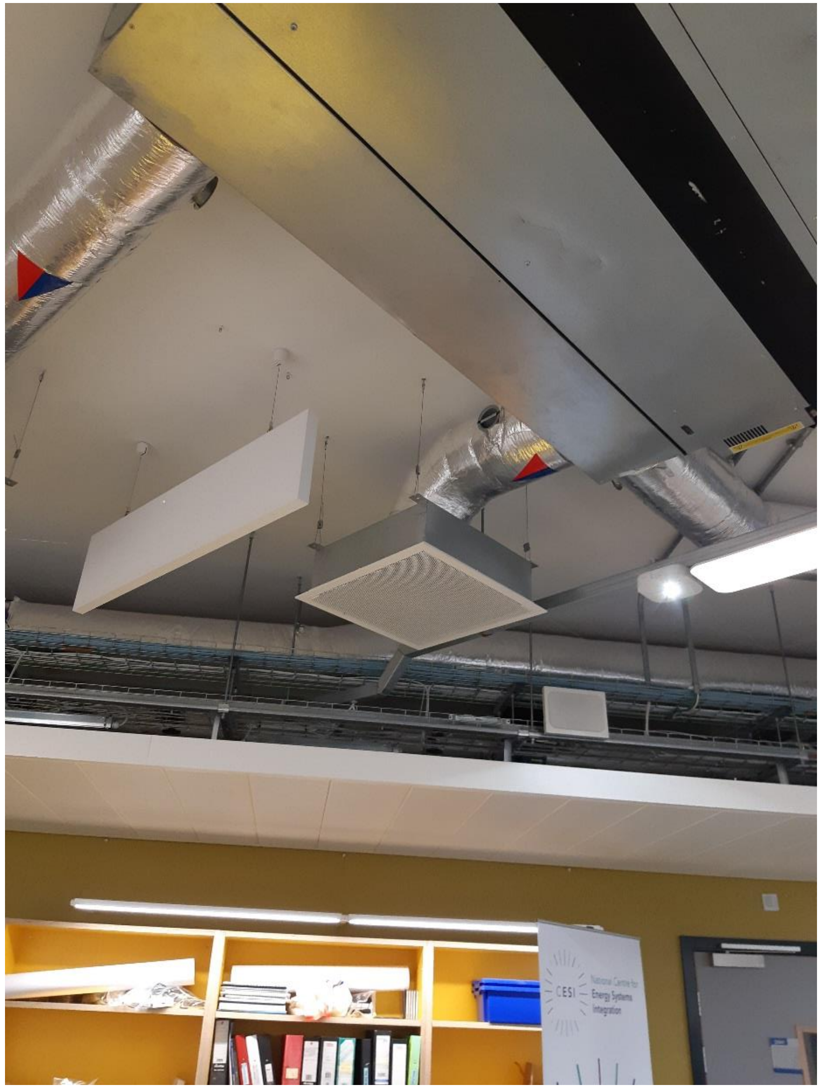
The building



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The building

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The building

- 6 storey with basement and roof access, 12,800m^2 floor area
- 22 AHUs adjustable to 90% design duty (i.e. 10% reduction from full duty)
- 25 Heat Pumps
- A Siemens Desigo CC BMS system supervises all M+E actions via a KNX Open Protocol 'medium' for communication and monitoring under a 'Field Bus' control system
- Therefore the BMS data is not encrypted and accessible

AHU configurations

Level	AHU	WC Extract fan	HRU
Basement		1 (Air compressor)	
L 00 (Ground)	3	6	9
L 01	4	3	
L 02	3	3	
L 03	4	3	
L 04	4	3	
L 05	2	2	
L 06	2	2	
Roof		1 (SUDs working area)	
Total	22	24	9

Heat pumps

Swegon Teal range (R410a) with a total of 25 units at 51.5 kW to 112.3kW heating capacity. All reversible except for 3 rooftop units that are configured to heat DHW only.

Level	Heat pumps
L 00 (Ground)	3
L 01	4
L 02	3
L 03	4
L 04	4
L 05	2
L 06	2
Roof	3 (DHW)
Total	25

Capacity :

- 445.9kW (W_c) / 1542.4kW (Clg) / 1975.7kW (Hng)
- CoP : Heating: 4.4 Cooling: 3.46

Of the above heating capacity 166.5 kW (or 8.4%) is for domestic hot water.

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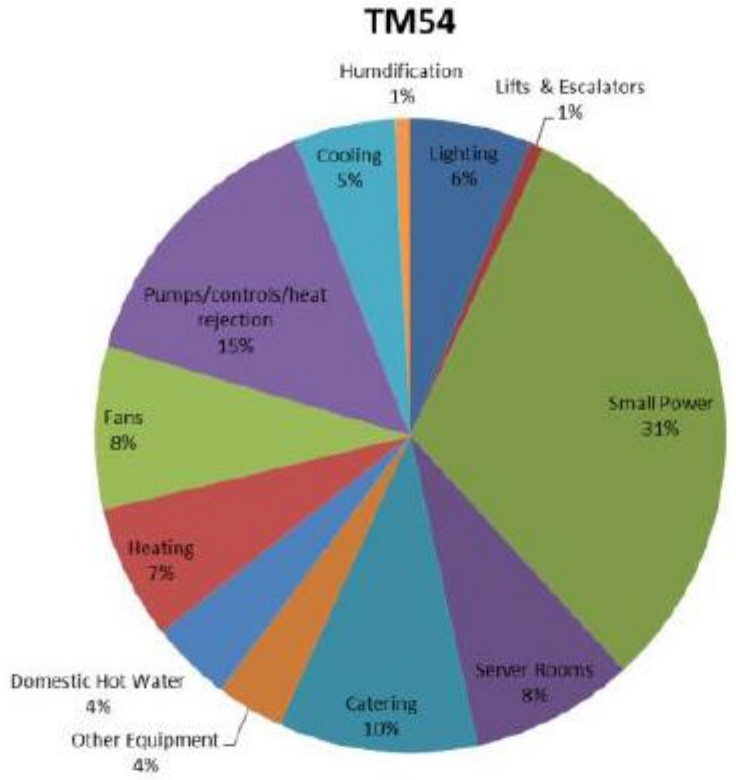
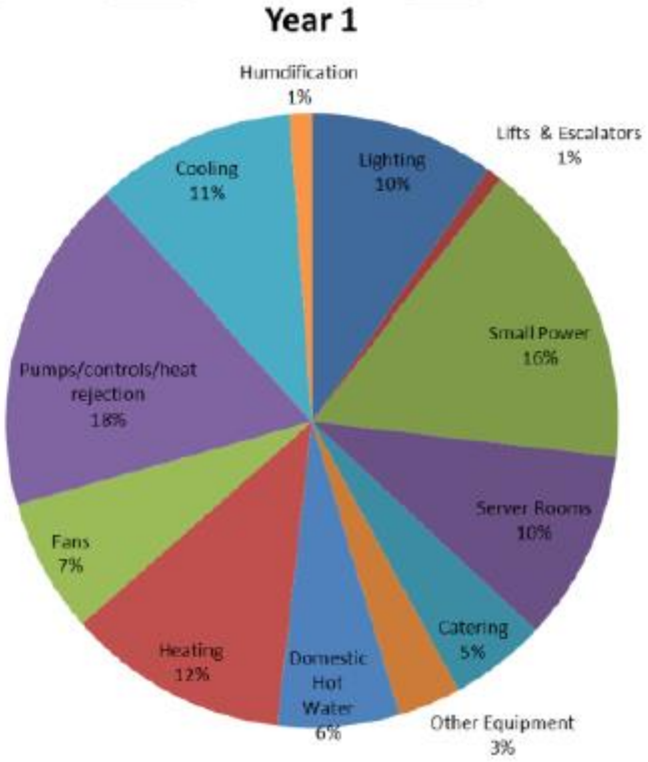
Year 1 performance

- Predicted (TM54) demand 2,075MWh
- Actual demand 2,061 MWh





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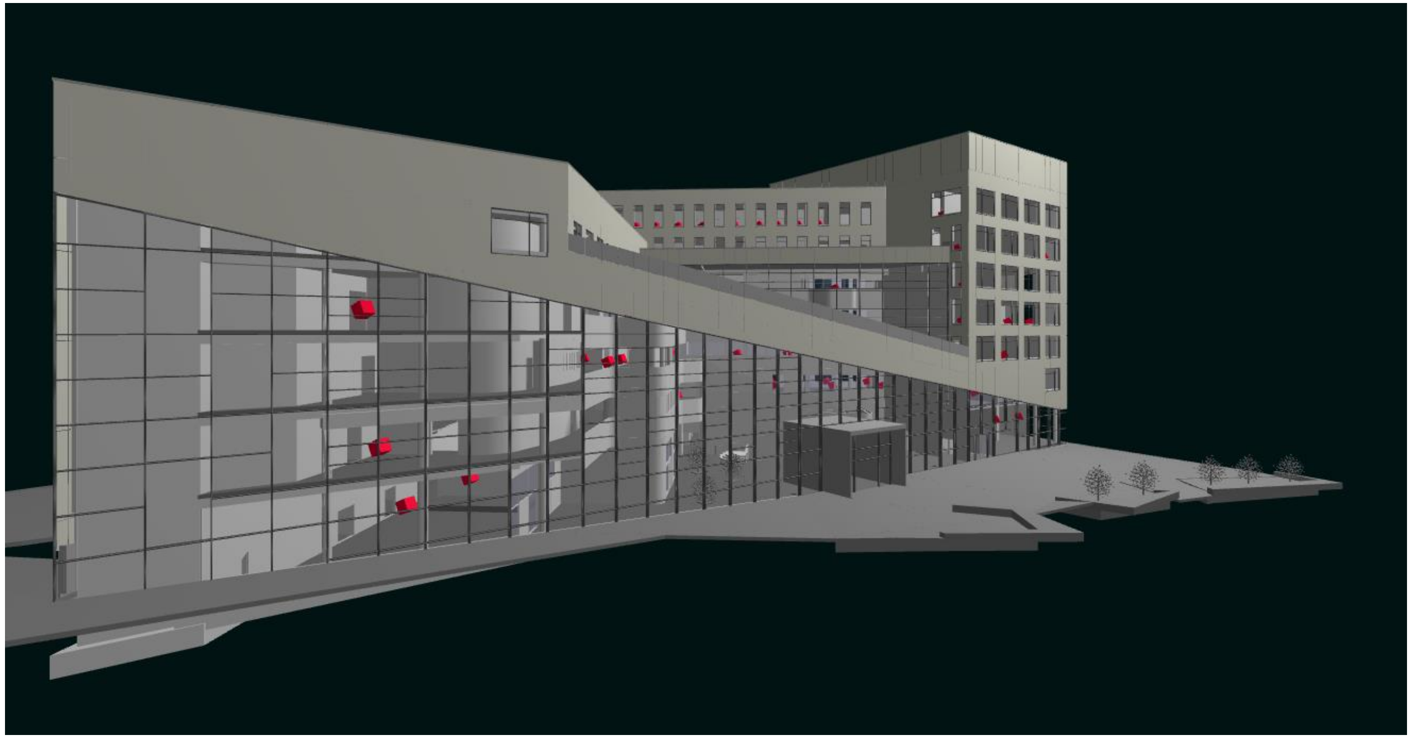
Figures from Buro Happold

The building monitoring

- https://3d.usb.urbanobservatory.ac.uk/



Human comfort and DR

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	Description	No	Load reduction possible	Share of building load (%)	Advance time needed	Current control	DR duration	Threshold for reversal of DR action
[1]	Heat pumps	25	100%		0	OAT compensation-altering HP discharge temperatures with 5 minutes circulating pump overrun	Maximum 4 hour	If 19°C<T_{space} <28°C 0.5°C per hour of ramp
2	Terminal side circulating pumps	21 HTG 20 CHW	100%		0		Maximum 4 hour	None
[3]	Primary circulating pumps *	12	100%		5-10 minutes		Maximum 4 hour	Need to be shut 5 minutes before and 5 minutes after HP are turned on/off
4	AHU	22	50%		0		Maximum 4 hour	Will be boosted back at 1000ppm CO_2
[5]	Lighting		14%-24% [37]		0		Perhaps a design stage philosophy to incorporate a safe setback point similar to Hng for DR (i.e. dropping to 150 lux)	Minimum recommended values of 100 Lux in office areas, 50 Lux in kitchens and 5 Lux in circulations areas Labs excluded
6	Lifts		100%		0			
7	EV charger		100%		0			

[1] - ANSI/ASHRAE Standard 55, *Thermal Environmental Conditions for Human Occupancy*. 2010: Atlanta, Georgia.

[3] ASHRAE 62.1-2016, *Ventilation for Acceptable Indoor Air Quality*. 2016: Atlanta, USA

[3] Chartered Institution of Building Services Engineers, *KS17: Indoor Air Quality & Ventilation*. Oct 2011: London.

[5] Newsham, G. and B. Birt, *Demand-responsive lighting - A field study.* LEUKOS - Journal of Illuminating Engineering Society of North America, 2010. **6**(3): p. 203-226.

[5] David, S.W., et al. *Strategies for Demand Response in Commercial Buildings*. in *2006 ACEEE Summer Study on Energy Efficiency in Buildings*. Pacific Grove, CA.

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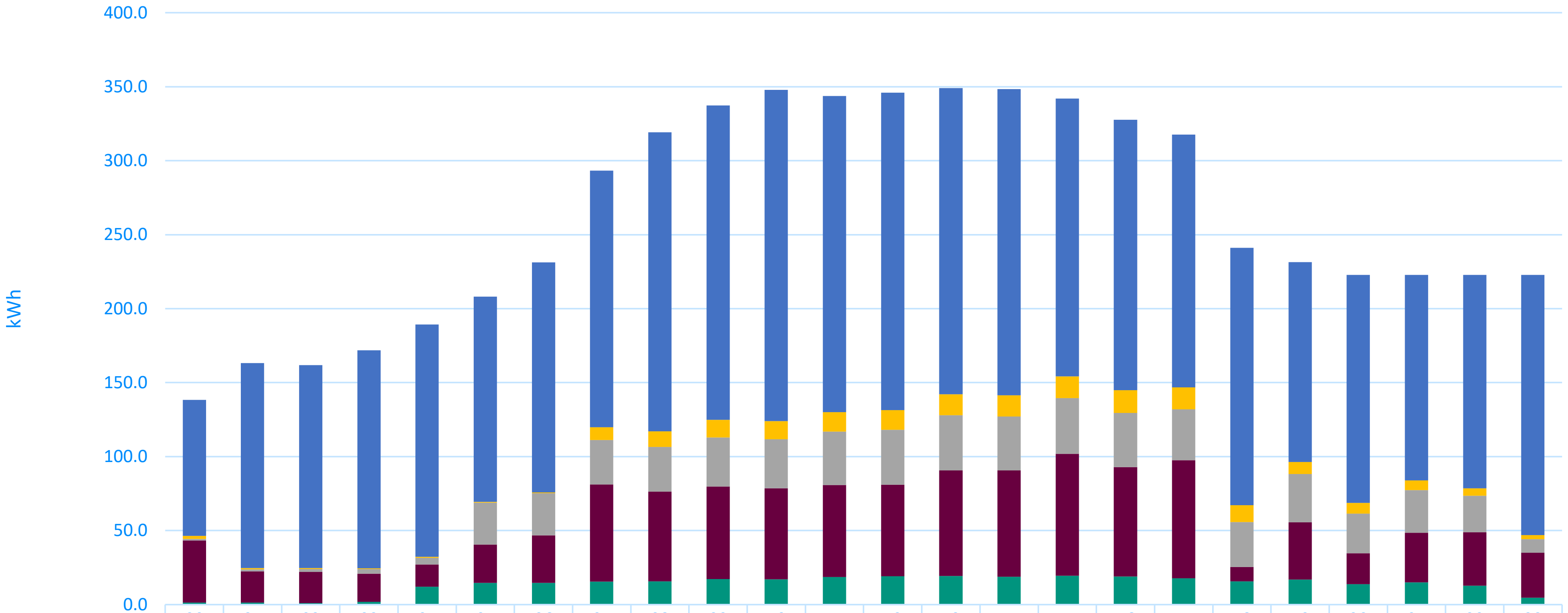
USB electrical energy consumption – Feb 2018 average hourly data



	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
None deferrable	91.9	138.6	137.2	147.3	157.0	138.8	155.4	173.5	202.1	212.4	223.8	213.7	214.6	206.9	207.0	187.9	182.7	170.8	174.0	135.1	154.1	139.0	144.3	175.9
Lighting	2.1	0.8	0.6	0.5	0.7	0.5	0.6	8.6	10.6	11.9	12.3	13.1	13.3	14.2	14.3	14.7	15.4	14.9	11.4	8.2	7.3	6.4	5.0	2.9
AHUs	1.1	1.4	2.0	3.2	4.5	28.3	28.4	30.1	30.3	33.2	33.2	36.0	37.0	37.3	36.5	37.7	36.8	34.4	30.5	32.5	26.7	28.9	24.8	9.0
HPs	42.0	21.0	21.0	19.0	15.0	26.0	32.1	65.7	60.6	62.7	61.4	62.3	61.9	71.4	71.8	82.5	73.8	79.8	9.6	38.8	20.9	33.5	36.0	30.4
Cir. Pumps	1.3	1.4	1.1	1.8	12.1	14.6	14.7	15.5	15.6	17.1	17.1	18.6	19.1	19.3	18.8	19.4	19.0	17.7	15.7	16.8	13.8	14.9	12.8	4.7

Cir. Pumps ■ HPs ■ AHUs ■ Lighting ■ None deferrable

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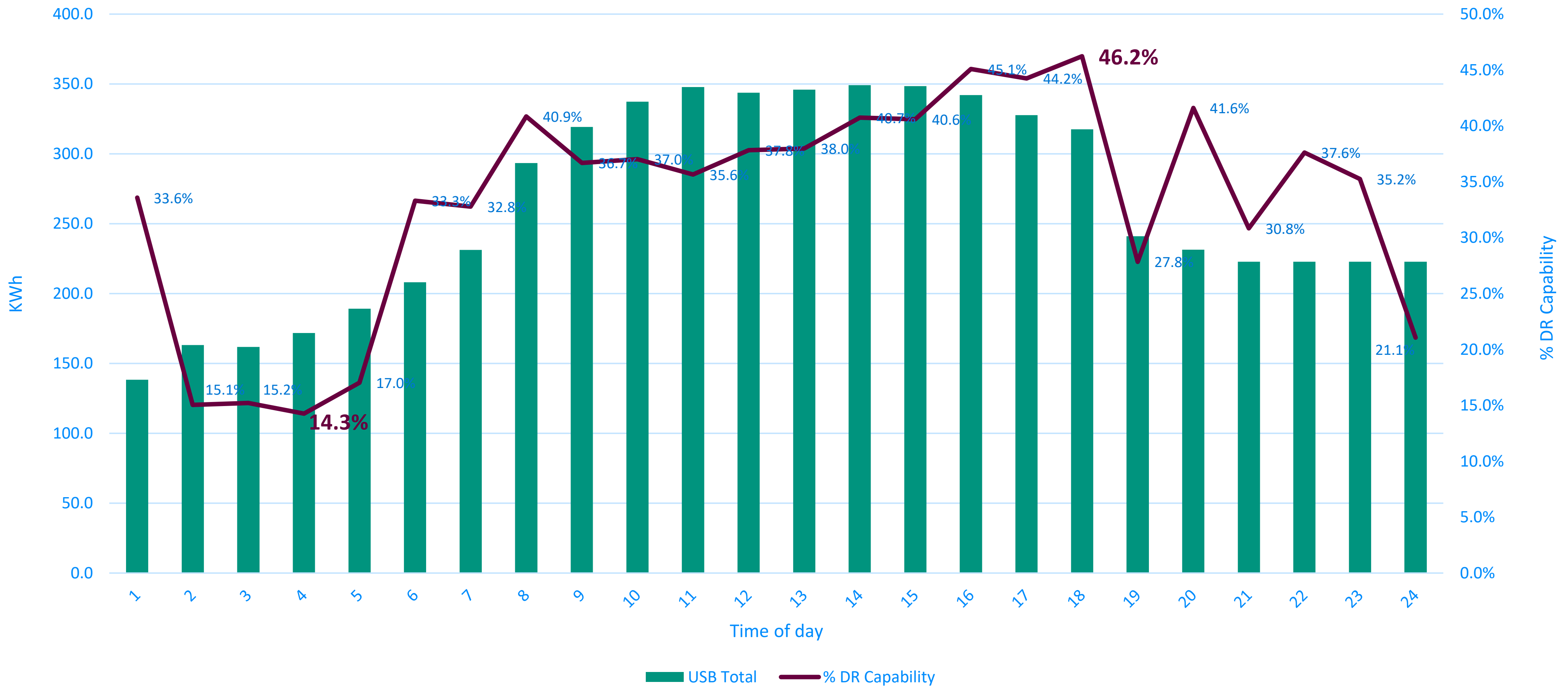
Total USB electricity consumption vs. % DR capability

Feb 2018 average hourly results

Extracted from **2.9m** data points



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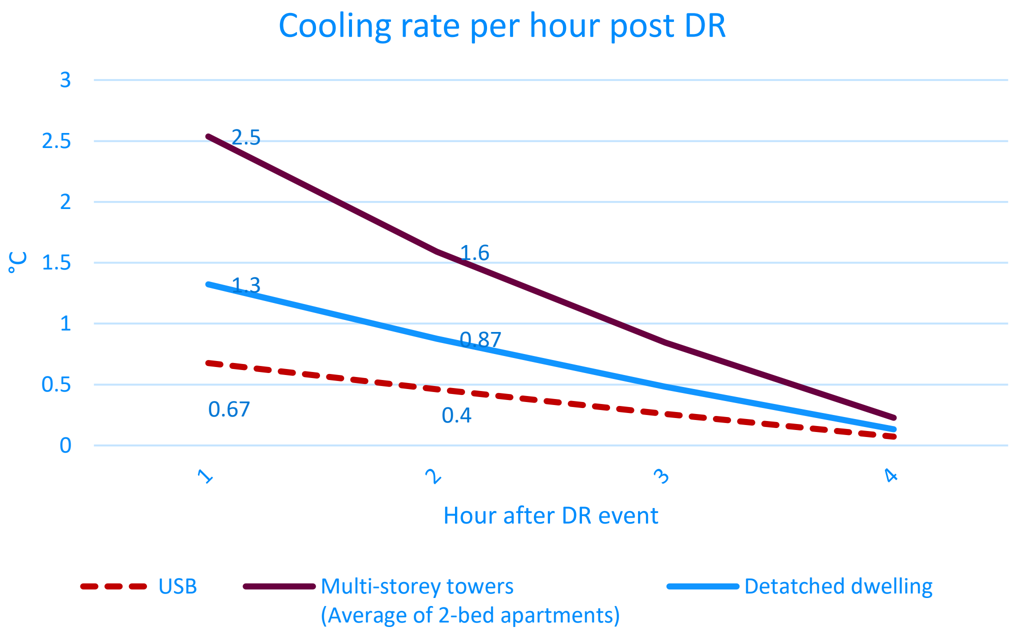
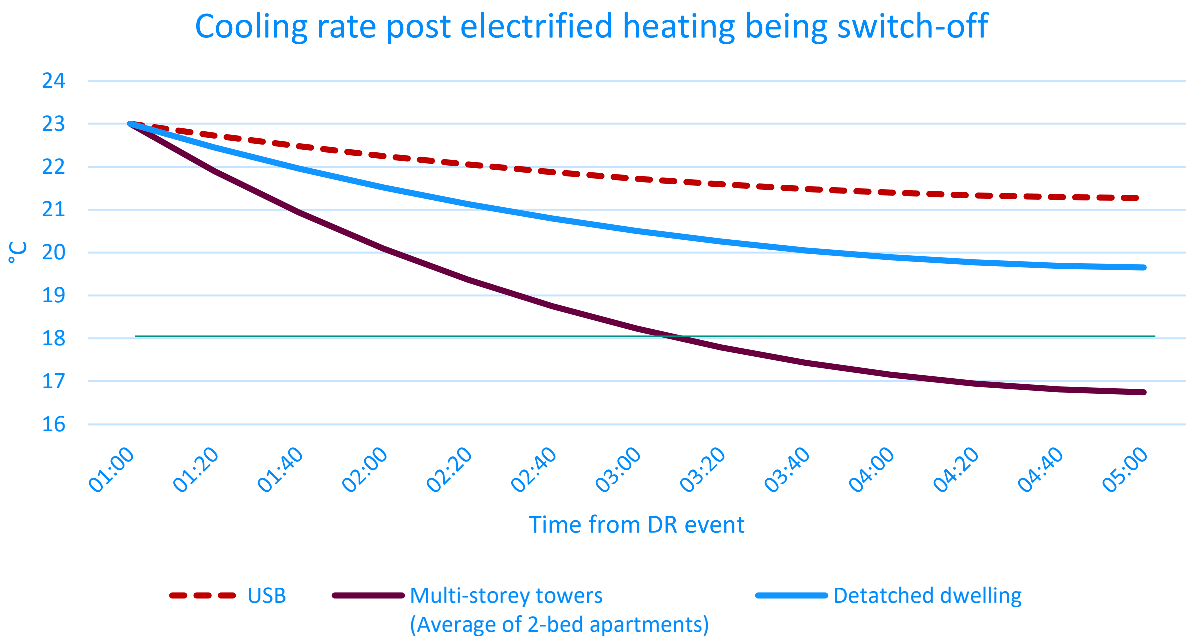
DR impact on building thermal comfort
TRY weather-file : DR @ average external condition of -1.4°C





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Summary

- Building can offer flexibility within the comfort envelope of occupants
- New avenue of processing for missing data
- Good learning on building systems
- Commodity cost by far the biggest part of the building energy bill
- Building loads at such a scale to be too small for CURRENT markets, or too small in revenue terms to be valuable to the building
- Aggregation, or new markets, could be of interest

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Active Building Principles

1. **Building fabric and passive design –** integrated engineering and architecture design approach including consideration of orientation and massing, fabric efficiency, natural daylighting and natural ventilation. Designed for occupant comfort and low energy by following passive design principles

2. **Energy efficient systems** - intelligently controlled & energy efficient systems to minimise loads - HVAC, lighting, vertical transportation. Data capture via inbuilt monitoring & standard naming schemas to enable optimisation and refinement of predictive control strategies

3. **On-site renewable energy generation -** renewable energy generation be incorporated where appropriate. Renewable technologies should be selected holistically, given site conditions and building load profiles

4. **Energy storage** - thermal and electrical storage should be considered to mitigate peak demand, reduce the requirement to oversize systems, and enable greater control

5. **Electric vehicle integration -** where appropriate Active Buildings integrate electric vehicle charging. As technology develops, bi-directional charging will allow electric vehicles to deliver energy to buildings as required

6. **Intelligently manage integration with micro-grids & national energy network** – in addition to intelligent controls, Active Buildings manage their interaction with wider energy networks, e.g. demand side response, load shifting & predictive control methods

Active Building Centre

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Active Building Framework