wbs
WARWICK BUSINESS SCHOOL
THE UNIVERSITY OF WARWICK

For the Change Makers

Professor David Elmes
Warwick Business School
9th September 2020

London South Bank University
Loughborough University
Ulster University
WARWICK
LoT-NET
UKRI UK Research and Innovation

LoT-NET AB MC: WP4

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Agenda

- Scope and Update
- Initial Transactive Energy Study
- Warwick Campus: a rather large “lab scale demonstrator of integrated technologies”
  - Net Zero Goals, the Energy & Infrastructure Strategy and workstreams
  - Smart Square demonstrator
- EnergyREV Sprint Reviews on the policy and regulatory landscape
  - Digital Energy Systems (completed)
  - Heating and Cooling (in write-up)
- Related Programmes & Dissemination
- Summary

WP4: Determine key end use and business requirements for timely adoption

- **WP4.1: Understanding household priorities** [**LDS** Year *2*]
  - Determine what a low-temperature network needs to deliver to users, including service requirements such as comfort, hygiene, affordability and barriers / enablers
- **WP4.2: From user requirements into technology design** [**LDS** Year 2-3]
  - Identify user requirements to inform technology development and design
- **WP4.3: Consumer engagement with low carbon heating and cooling** [**LDS** Year 2-3]
  - Determine information provision to assist consumers in their engagement with low-temperature heating and cooling systems and how this might impact on demand shifting
- **WP4.4: Energy transitions and competing for investment** [**WBS** Year 1, 4]
  - Low temperature networks as competing investments in the energy transition
- **WP4.5: Low temp heat networks as an innovation system** [**WBS** Year 2-4]
  - Assessing market penetration for low temperature networks as an innovation system requiring the cooperation and participation of a network of organisations along with policy and regulatory frameworks, standards and skills development.

WP4: AB3/MC7 Update

- **WP4.1: Understanding household priorities** [**LDS** Year *2*]
- **WP4.2: From user requirements into technology design** [**LDS** Year 2-3]
- **WP4.3: Consumer engagement with low carbon heating and cooling** [**LDS** Year 2-3]
  - WP4.1-3 pending LDS recruitment – update from Vicky
- **WP4.4: Energy transitions and competing for investment** [**WBS** Year 1, 4]
  - Y1 work: Competing Investments presented at AB2, further work on the collapse in O&G profitability completed
- **WP4.5: Low temp heat networks as an innovation system** [**WBS** Year 2-4]
  - Moved ahead early with a research programme oriented to large scale trials:
    - Concluded initial Transactive Energy study: Collaboration between WBS, WISC, Warwick's Estates and Fetch.AI
    - Warwick Campus: Low temperature heating plus cooling as part of a multi-vectoral, smart local energy system
      - More than the "lab scale demonstrators of integrated technologies" planned from Y3 onwards
      - Smart Square as the opportunity to develop a LoT-NET
      - Reassigning resources from lab-based research when halted by Covid-19
    - EnergyREV Rapid Reviews: Digital Energy Systems (published), Heating and Cooling (in progress)
  - PDRA recruitment
    - Revised focus on TE agreed at AB2. Recruitment delayed for a Q1 2021 start
  - Further awards, links with other programmes and dissemination
    - Blockchain for Europe Summit at the European Parliament, 2nd Feb 2020: Blockchain Cooptition in the Energy Space
    - ERA Seminar, 6th July 2020: ERA: Towards Smart and Decarbonised University Campuses
    - Regional Energy Systems Operator: Detailed Design project for the Prospering from the Energy Revolution programme with Coventry, WMCA, etc.
    - IEA TCP on User-Centred Energy Systems: Global Observatory on Peer-to Peer, Community Self-consumption and Transactive Energy Models (GO-P2P)

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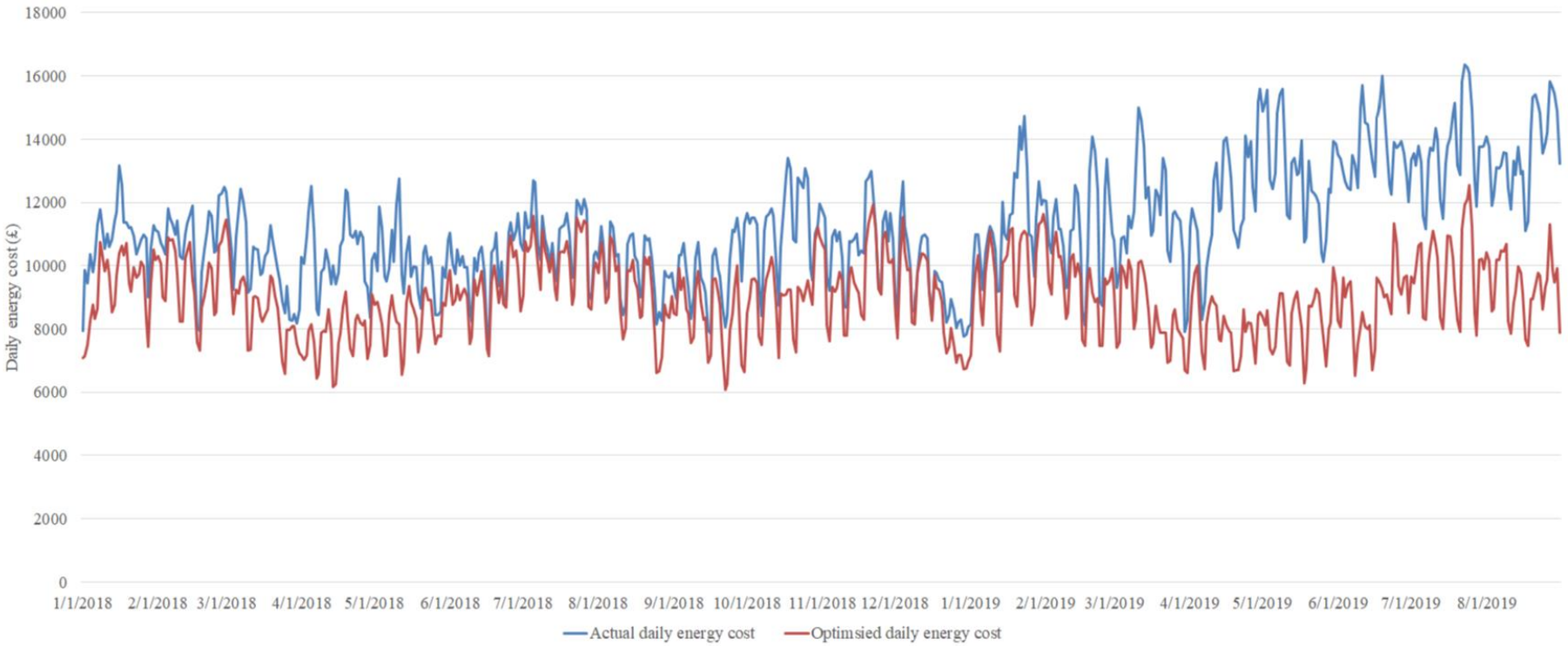
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Daily energy cost (£)
1/1/2018
2/1/2018
3/1/2018
4/1/2018
5/1/2018
6/1/2018
7/1/2018
8/1/2018
9/1/2018
10/1/2018
11/1/2018
12/1/2018
1/1/2019
2/1/2019
3/1/2019
4/1/2019
5/1/2019
6/1/2019
7/1/2019
8/1/2019
Actual daily energy cost
Optimsied daily energy cost

Initial development of model-free, machine learning agents working on a virtual, transactive energy platform

- Uses multi-agent reinforcement learning to give a model-free, data driven approach
- AI agents representing key energy assets across the campus learn the optimal control policy from real-world historical data
- A virtual twin can then run alongside the real system to demonstrate the different energy management strategies that arise from the AI approach
- Initial scope: combined heat and power engines, thermal storage and the demand for heat and electricity
  - Over 200,000 data points across 16 sensors to give energy costing at the hourly level
  - During Jan 2018-Aug 2019: 18.5% reduction in energy costs, but CHPs have been down for repair in 2019!
  - During Jan 2018-Dec 2018: Cost savings of 12.8%
    - Cost of Gas increases 21.8%
    - Cost of electricity imported decreased 46.5%

WBS News

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core insights:
Sustainability

How do you persuade

Optimising energy use with machine learning

22 January 2020

- **Collaboration with Fetch.ai explores machine learning in energy systems**
- **Initial results from a 'virtual twin' reduced energy costs by up to 18 per cent**
- **It could optimise heat and power production and use across campus**
- **Model-free AI approach learns the optimal control policy from historical data**

In September this year, the University of Warwick declared a Climate Emergency and set ambitious “net zero” goals for emissions.

Achieving this involves using less energy on the campus, and paying attention to energy used in heating, cooling and transport as well as the usual focus on electricity.

Considering the supply, storage and use of energy across multiple energy vectors rapidly becomes complex. Different existing control systems model separate energy vectors across different parts of the campus.

Artificial intelligence and machine learning are enabling a transactive energy approach where key parts of the energy system react and respond in ways not previously possible.

WBS Professors of Practice David Elmes and Mark Skilton have collaborated with Fetch.ai, one of the leading companies in the use of AI, to offer a decentralised connectivity platform that enables devices to connect directly with digital agents delivering autonomous solutions to complex tasks.

Development of the machine learning approach is led by Dr Yujian Ye, of Fetch.ai, in collaboration with Chris Conlan, a data science PhD student in the Warwick Institute for the Science of Cities, together with Joel Cardinal and Mark Jarvis of the University of Warwick Estates department.

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Warwick's Campus – a 24/7, 365 town of 30,000

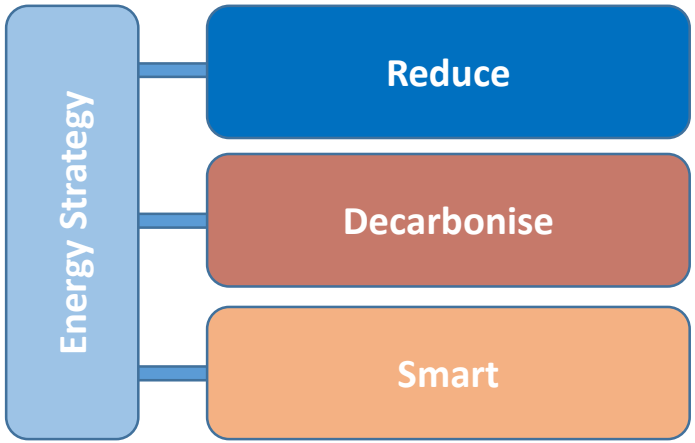
- A nationally recognized energy system
  - 560,000m^2 buildings, mixed uses, 22km heating & cooling network, self generate > 60% heat & power, 11kV network, …
  - Case Study in DECC's 2013 "The Future of Heating" strategy
  - Nominated for the ADE's Public Sector Project of the Decade in 2017
  - 2018 BEIS Heat Network Case Study
  - Reduced emissions per unit income by 46% since 2005/6
  - Invested £11.5M since 2009 to reduced energy & water costs by £3M per annum.
- Our commitment for the future
  - Warwick's September 2019 Climate Emergency declaration
  - WMCA/Coventry Regional Energy System Operator project, funded by the Industrial Strategy's Prospering from the Energy Revolution programme

290 hectares of Research, Teaching, Residential, Conferences and Business

215 hectares of research, business and farming

Warwick's Energy and Infrastructure Strategy

- "A transformation from fossil fuels to renewable energy"
- "Increased on-site energy generation and storage"
- "Ultra low energy buildings"
  - New Warwick standards
- "Smart local energy system governance structure"
  - A local, District System Operator
- "Enhanced campus resilience"
  - Flexibility & incremental investments

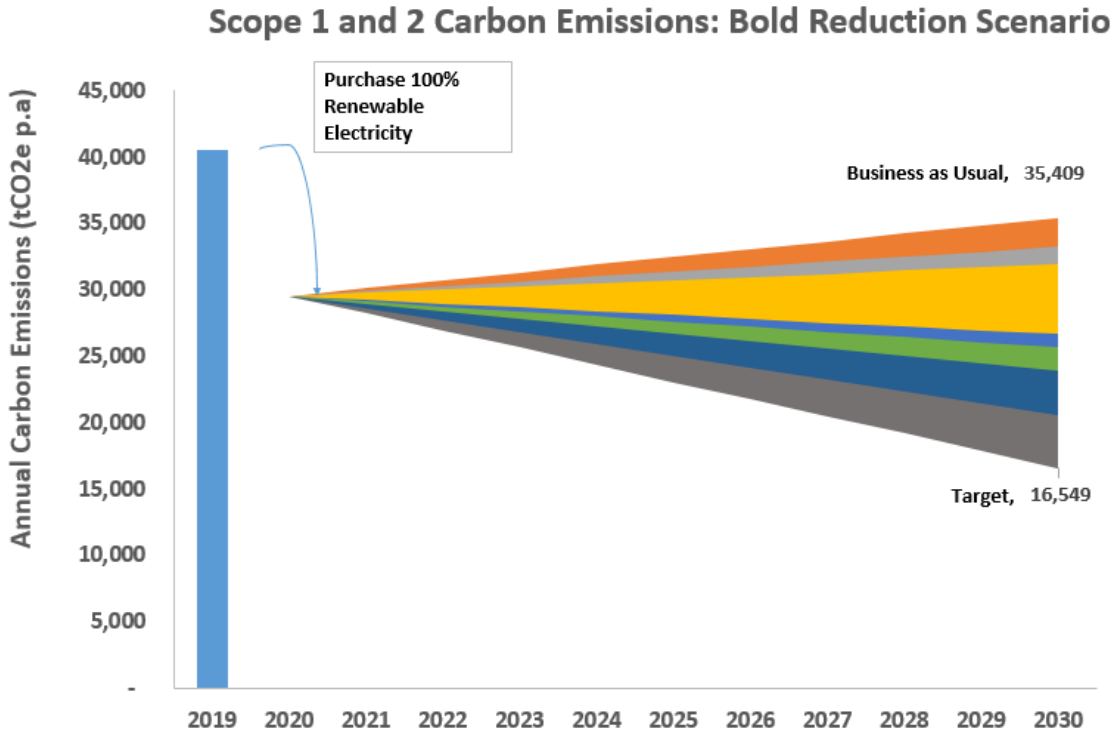


9 Work streams to Transform the Energy System

Workstream	Headline
Energy 2020	Renewable power (PV) and Energy Storage
Smart Local Energy System	Pilot integration scheme at 'Smart Square'
The Warwick Standard	Improved Building Standards: new and retrofit
Quick Wins and Optimisation	Operational Efficiencies
Management of Energy Networks	Organisational Review to become our own smart, multi-vector system operator

Workstream	Headline
Low Carbon Technologies	Ongoing Horizon Scanning to add new projects as they become affordable
Electrical Network Improvements	Supporting Campus Masterplan and Net Zero goals
Sustainable Drainage Strategy	Supporting Campus Masterplan Biodiversity goals
Financing	Reduce Utilities costs and explore Finance options and partnerships

Plans for 60% of our 2030 goal with the ideas for more



	tCO_2
·Energy Network 2020 Project	2,200
·SMART Integrated Local Energy Network & Buildings	1,311
·The Warwick Standard	5,277
·Quick Wins	1,000
·Governance and Management	1,770
·Low Carbon Technologies	3,282
Space Utilisation	4,021

Smart Square: Demonstrating what a smart local energy system can achieve

- A 5th generation energy network
  - Multi-vectoral energy system: integrating supply, storage and use across power, heating, cooling and transport (via EVs).
- A lower temperature heat network
  - Explore waste heat recovery, local heat pump use, thermal as well as electrical storage
- Smart building demonstrator
  - Demand side management at scale, across energy vectors and using building dynamics
- Transactive energy platform
  - Transactions between the key energy assets across the square to be more flexible; reducing and flattening energy use

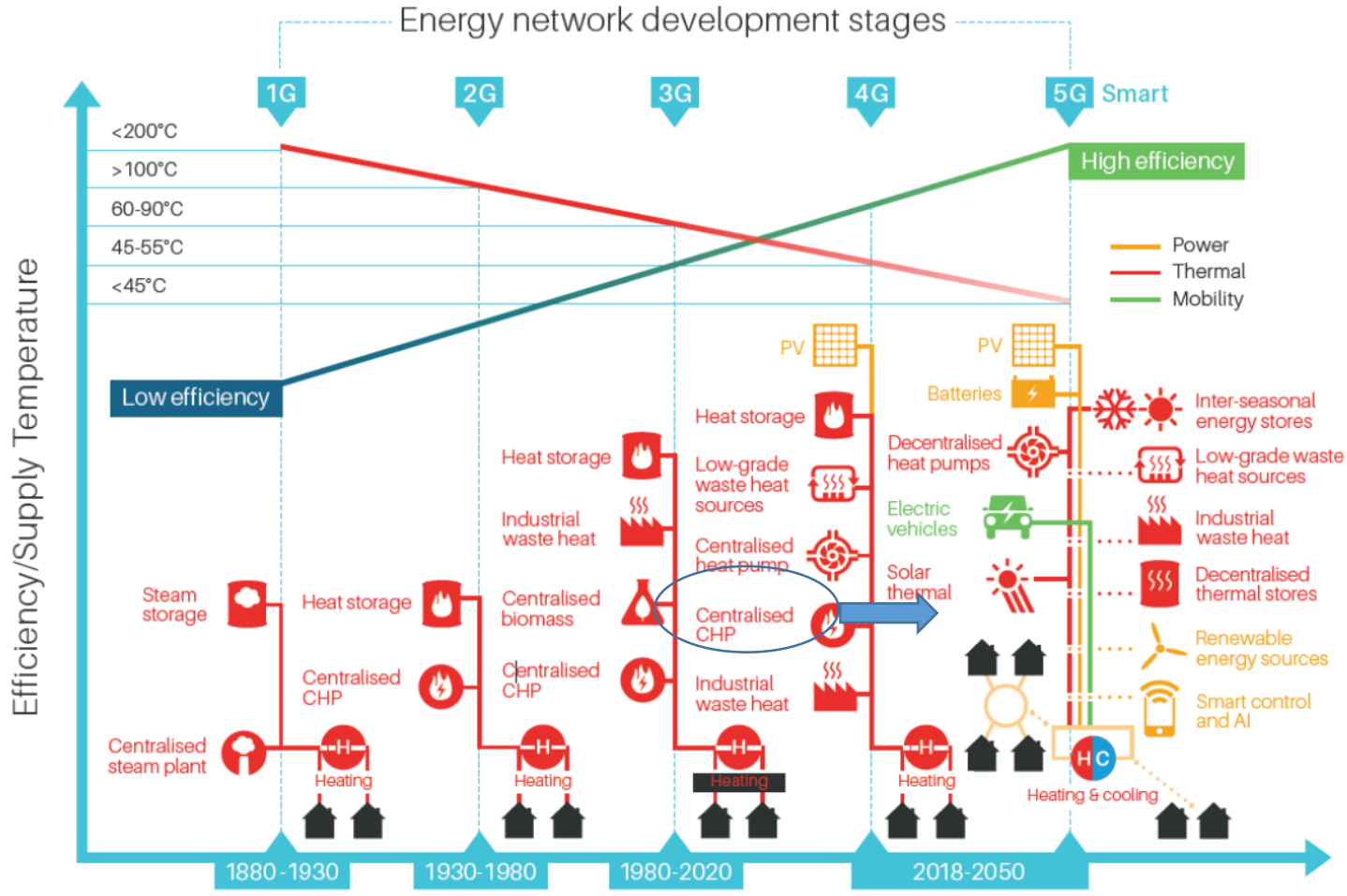


Figure 1 Energy network development stages and 5G smart energy network concept (Revesz et.al. 2019)


LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4
LEVEL 5
EFFICIENCY/USER EXPERIENCE
AUGMENTED REALITY AR
VIRTUAL REALITY VR
VOICE ACTIVATION VA
PERSONAL CONTROL / PROFILES PP
DYNAMIC INTEGRATED NETWORK DIN
DIGITAL TWINS DT
SYSTEM TO SYSTEM COMMUNICATION SSC
REPORTING & ANALYTICS R&A
WAYFINDING WF
SINGLE PANE OF GLASS SPOG
PREDICTIVE OPERATIONS PO
OCCUPANCY / SPACE UTILISATION OU
METERING SYSTEM MS
AUTOMTIC CONTROL AC
MANUAL CONTROL MC
1880 - 2000
2000 - 2020
2020 - 2030


Capital Plan 2022
New Build
Refurbishment
Demolition
Vacancy

SMART

The buildings in Smart Square use about 10% of campus energy at a cost of ~£1M per year

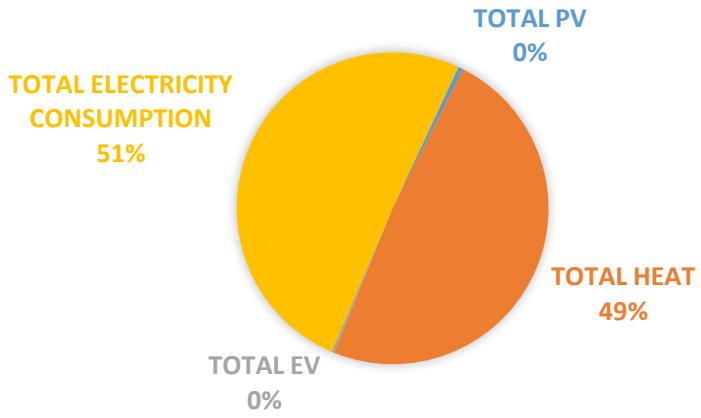
01.091	Car Park: 8	1992
01.054	IMC (International Manufacturing Centre)	1994
1.19	Claycroft 1	1994
01.098	Car Park: 15	1995
1.191	Claycroft 2	1996
1.192	Claycroft 3	1997
01.008	Computer Science Building	2000
01.009	Zeeman Building (aka Mathematics and Statistics)	2003
01.254	IDL (International Digital Laboratory)	2008
01.309	IIPSI (aka APC)	2012
01.323	Phytobiology Facility	2013
01.364	IINM (International Institute Nanocomposite Manufacturing Centre)	2014
01.177	AMMC (Advanced Manufacturing and Materials Centre)	2016
01.298	Car Park: Lynchgate	2017
01.336	MSB (Mathematical Science Building)	2018
01.381	MEC (Materials Engineering Centre)	2018
01.421	DAC (Degree Apprentice Centre)	2019

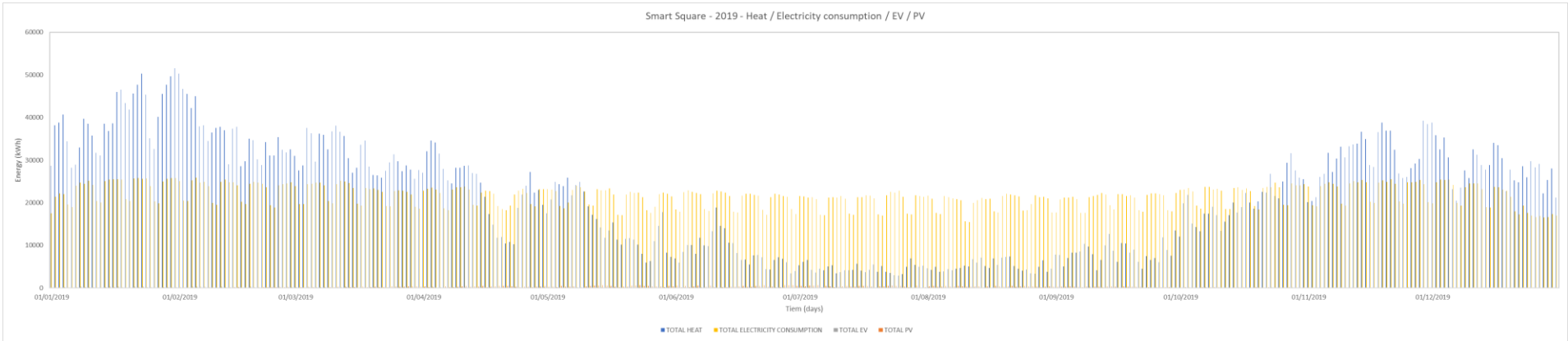
Metering Data for the Year to 31.10.19: still gaps!

Site name	Floor Area (m2)	Elec (kWh)	PV (kWh)	EV (kWh)	Gas (kWh)	Heat (kWh)	Cool (kWh)	Total (kWh)	Total/Floor Area (kWh/m2)	Network Elec / Floor Area (kWh/m2)	Total Elec / Floor Area (kWh/m2)	Heat / Floor Area (kWh/m2)
Phytobiology Facility	1211	629,731	-	-	-	298,790	92,800	1,021,321	843	520	520	247
Computer Science Building	3438	736,184	-	-	630,842	-	-	1,200,403	349	214	214	216
IIPSI	2389	363,437	-	-	-	275,700	105,680	744,817	312	152	152	115
Riley Court	3848	277,162	-	-	-	392,200	0.00	1,367,026	355	72	72	102
Materials Engineering Centre (MEC)	3031	482,219	35,472	-	-	399,800	-	882,019	291	159	171	132
International Manufacturing Centre	11237	1,794,688	-	-	-	1,222,400	-	3,017,088	268	160	160	109
IINM	1101	281,245	10,595	-	-	-	-	281,245	255	255	265	-
AMMC	1599	307,214	-	-	-	89,330	-	396,544	248	192	192	56
Claycroft 2	6219	369,529	-	-	408,816	541,400	-	1,319,745	212	59	59	164
Claycroft 3	4549	231,308	-	-	329,489	404,300	-	965,097	212	51	51	174
Digital Laboratory	5604	725,084	-	-	-	417,440	6,892	1,149,416	205	129	129	74
Claycroft 1	6490	330,258	-	-	296,725	682,400	-	1,309,383	202	51	51	159
Mathematical Science Building	6321	381,358	5,624	-	-	510,500	172,300	1,064,158	168	60	61	81
Degree Apprenticeship Centre	2696	122,500		-	-	-	-	424,191	157	45	45	-
Zeeman Building	9911	856,191	-	-	-	-	-	916,191	92	86	86	-
Lynchgate Car Park	15234	111,857	30,170	36,715	-	-	-	408,539	27	7	12	-
	84878							16,467,183				

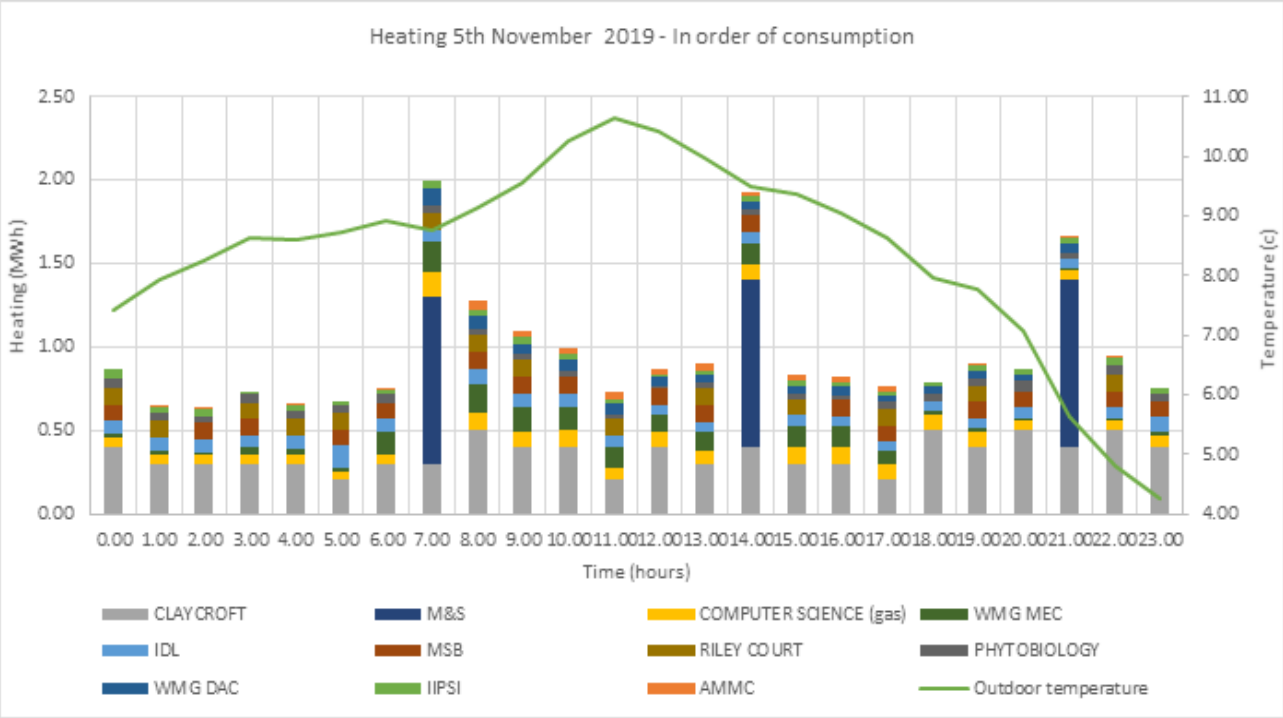
Smart Square energy over 2019:

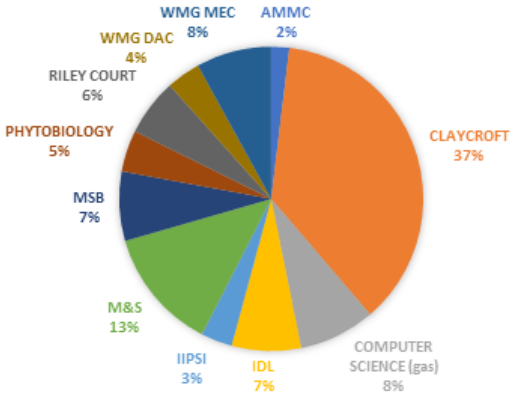
Heat use, Building Electricity use, PV generation, EV use



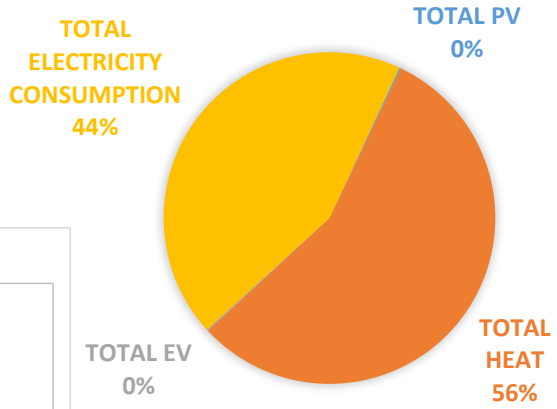


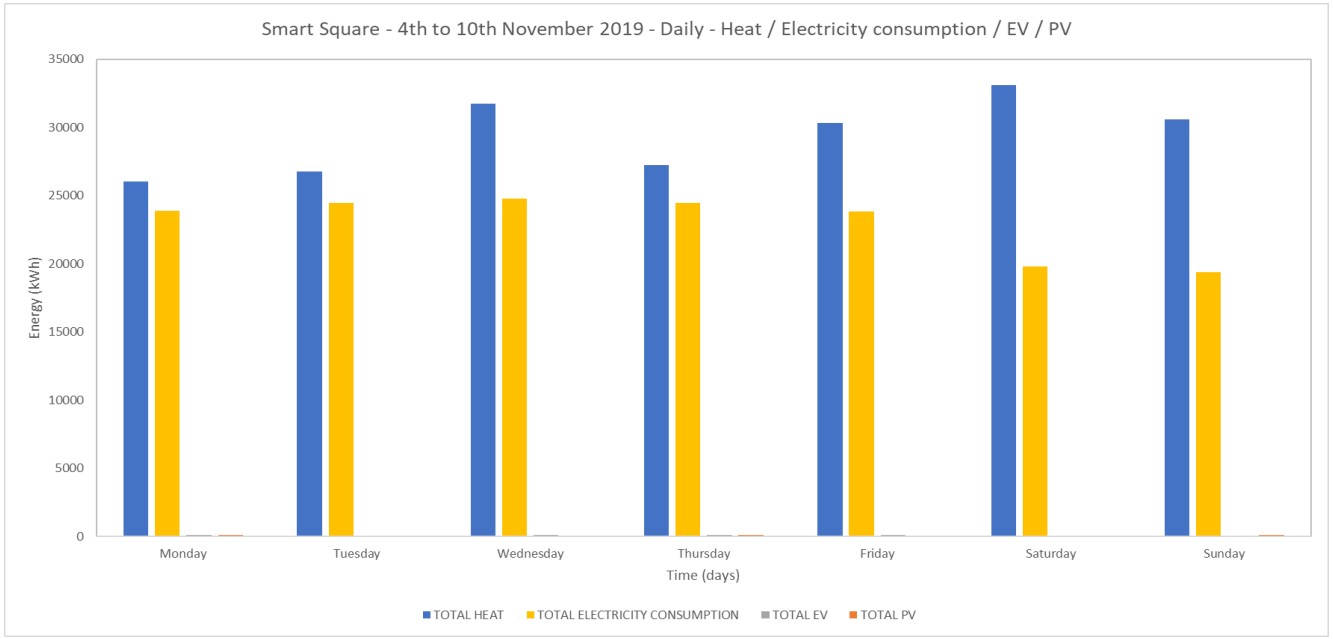
When it's cold: Smart Square heat use on 5/11/19



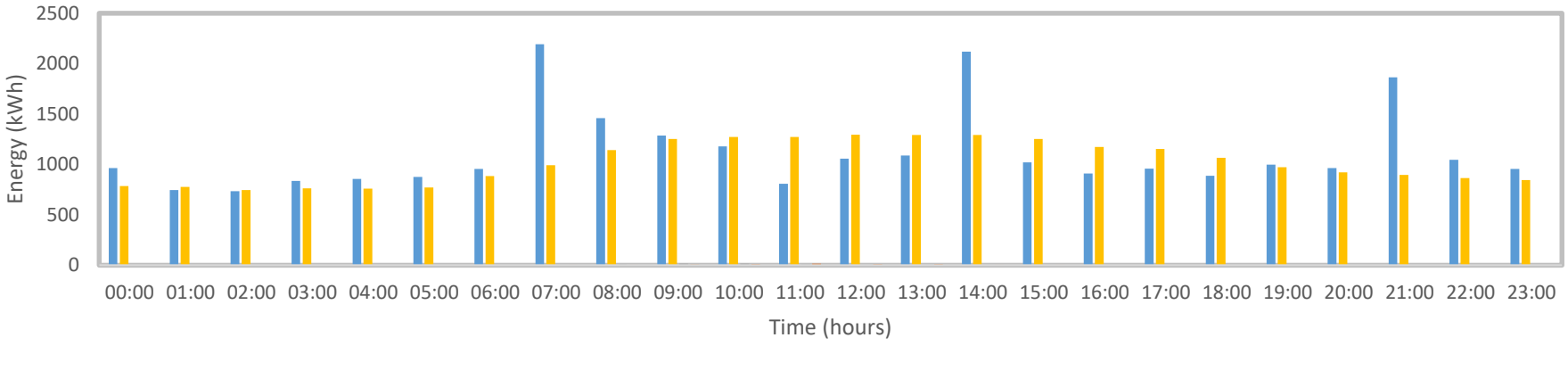


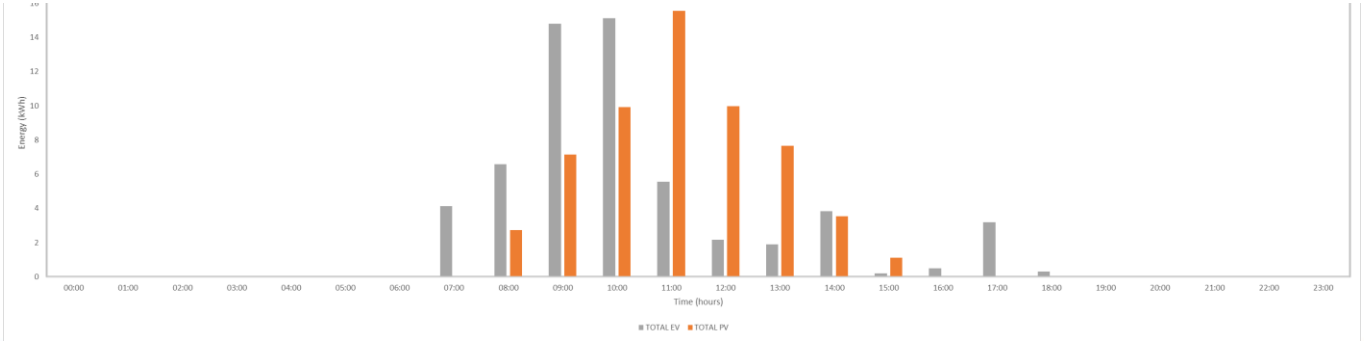
When its cold: Smart Square energy over a week in November



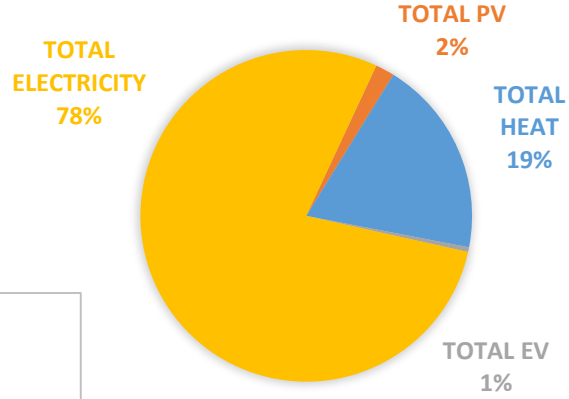


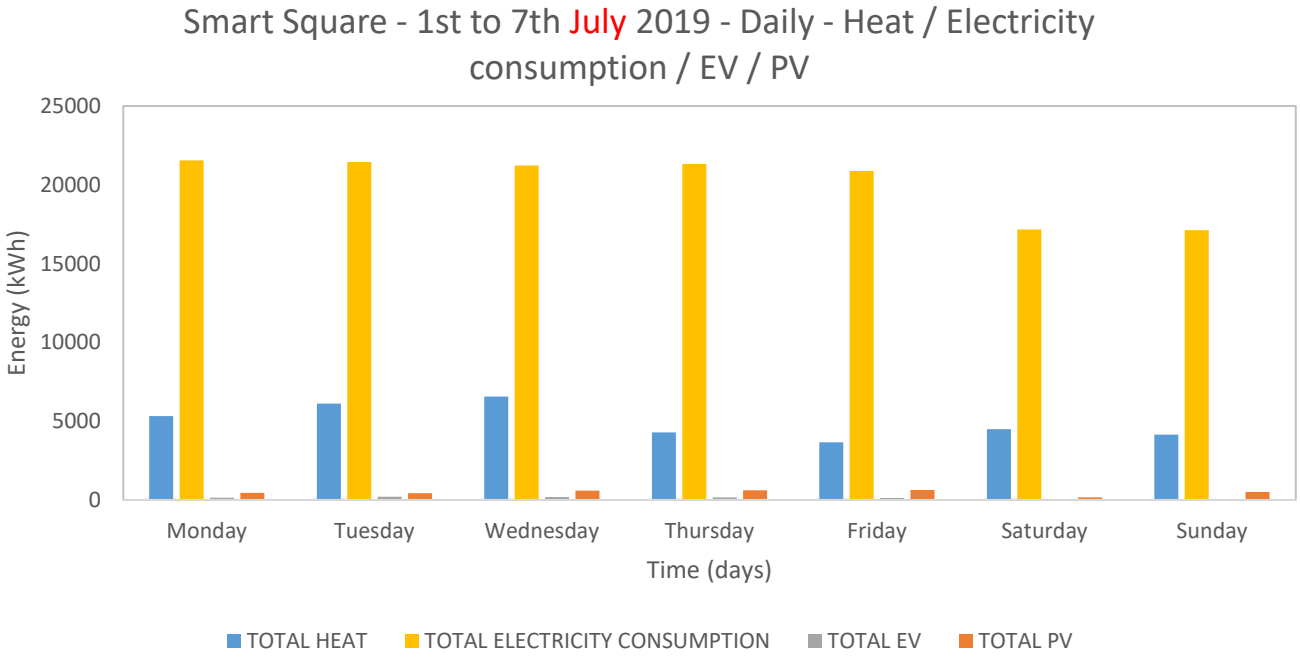
When its cold: Smart Square energy over a day in November





When its hot: Smart Square energy over a week in July





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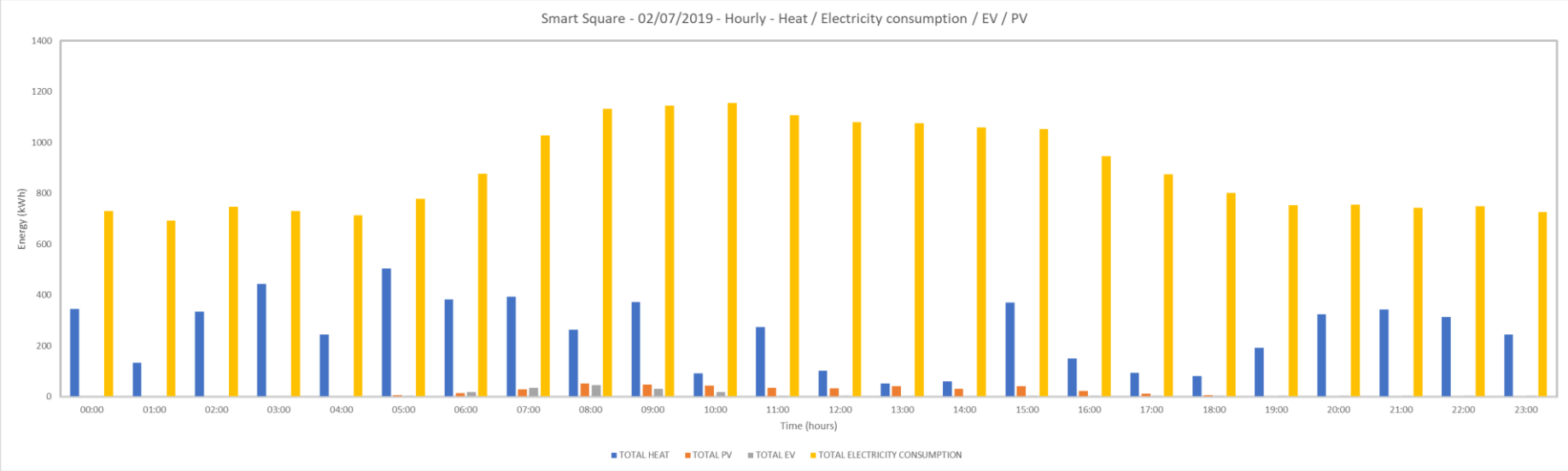
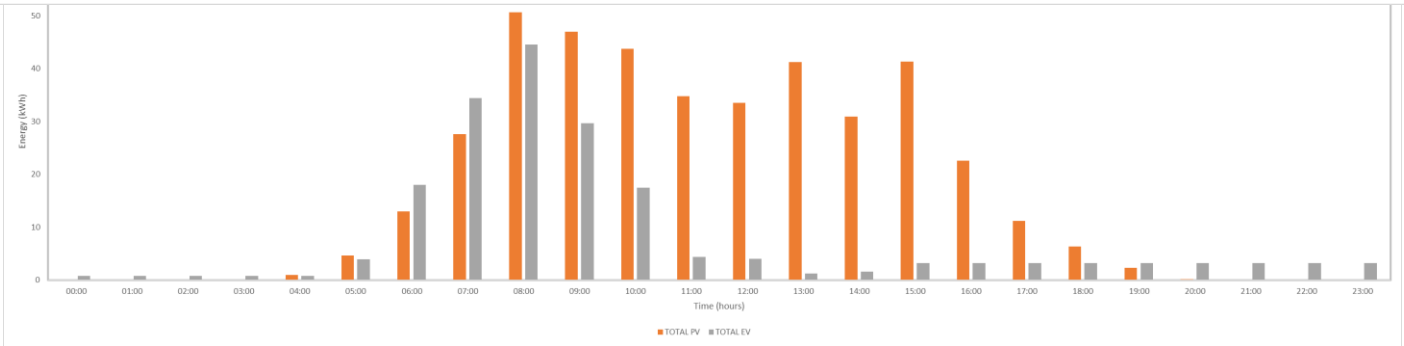
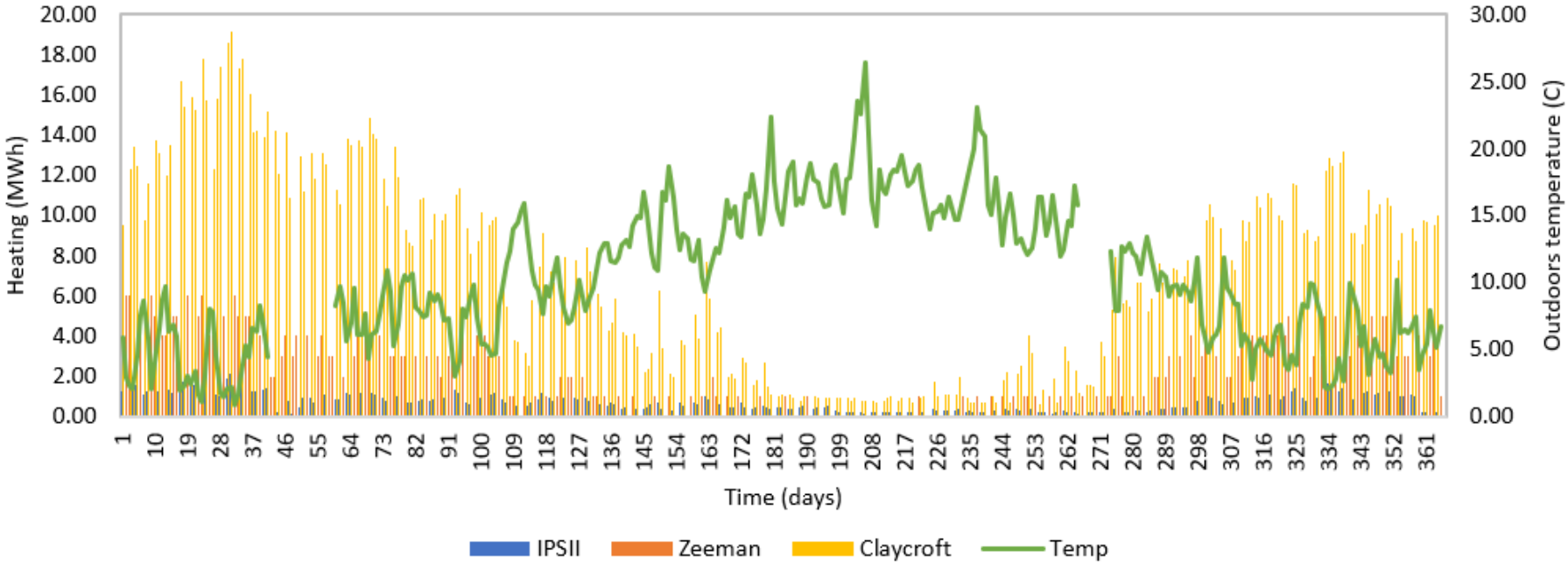




Looking at heat use in Claycroft (residence), Zeeman (older offices) & IIPSI (newer offices) over 2019…



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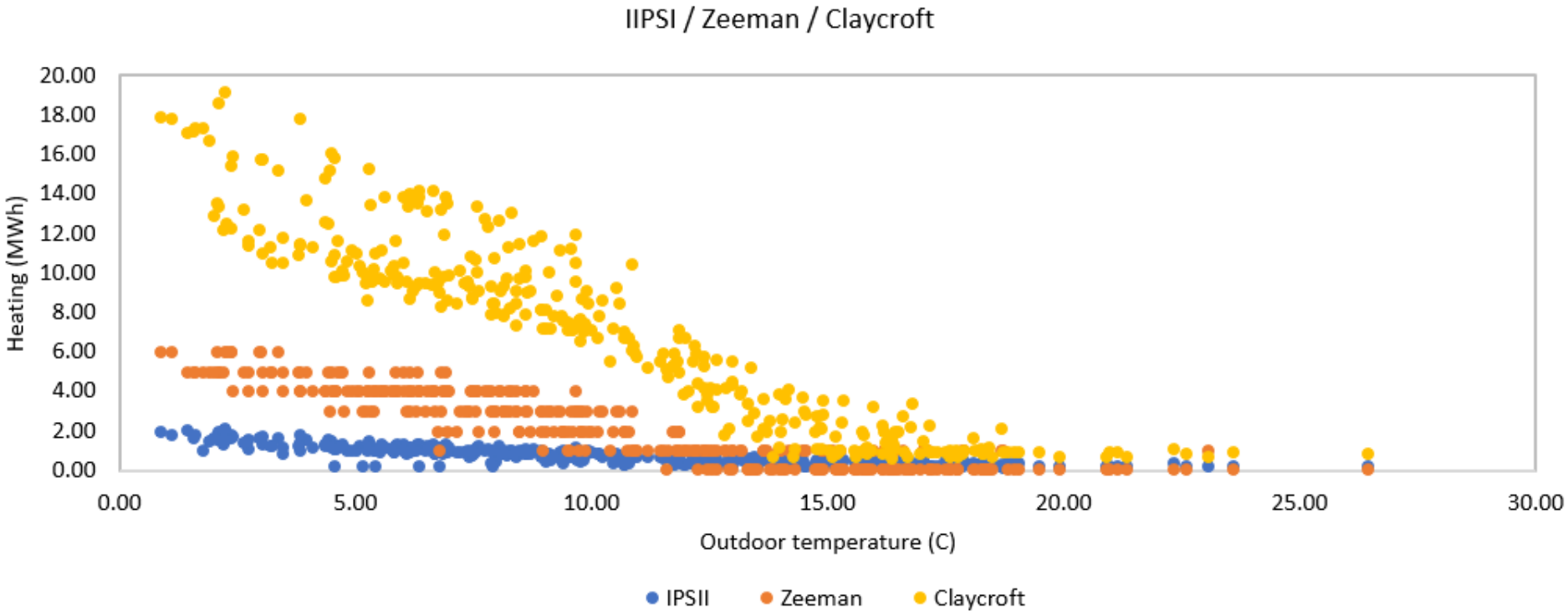
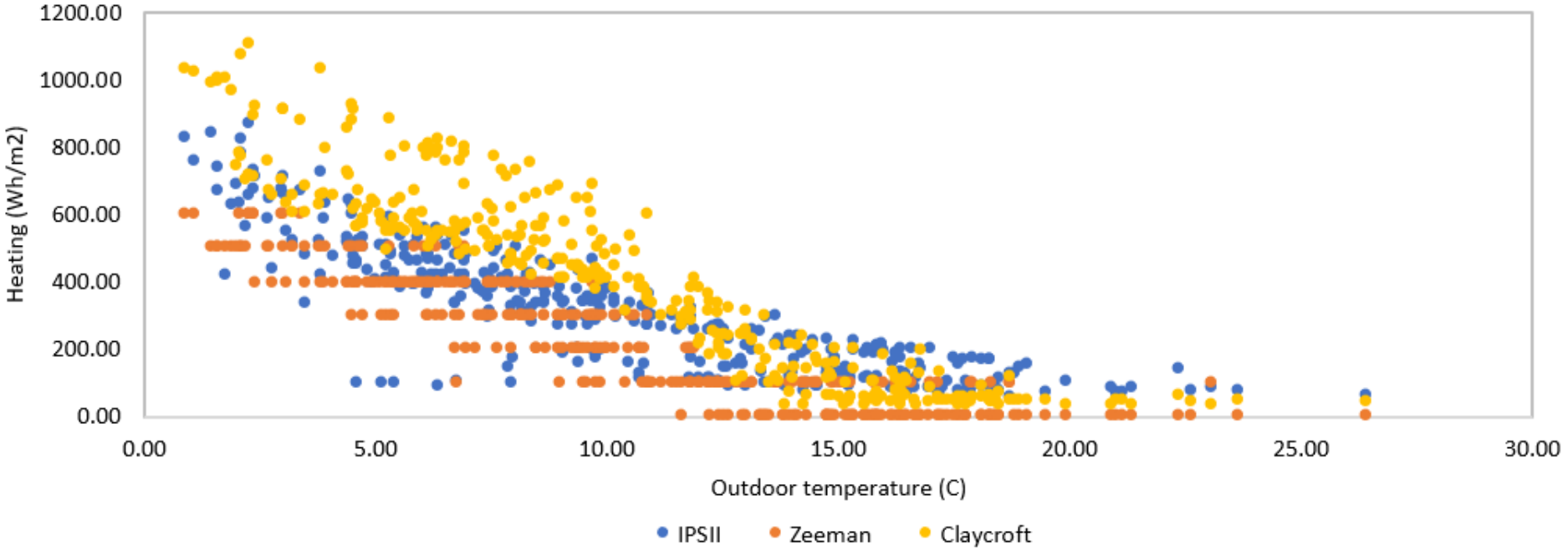


Looking at heat use per m^2 in Claycroft (residence), Zeeman (older offices) & IIPSI (newer offices) over 2019…



Next steps: continuing the collaboration between operations & research

Estates focus

- Data: Operational Quick Wins
- Top 10s: despatch/shift/store?
- Smart Buildings? - Gap Analysis
- Integrated Network Analysis
- Building Fabric Upgrades
- Plant Upgrades

Lot-NET Focus

- Data: Overview but also Granularity
- Metering & Control Adjustments
- “Flexibility Index”
- Developing the Smart□ LoT-NET
- Top 10s: Agent characterisation
- Transactive platform across Smart□

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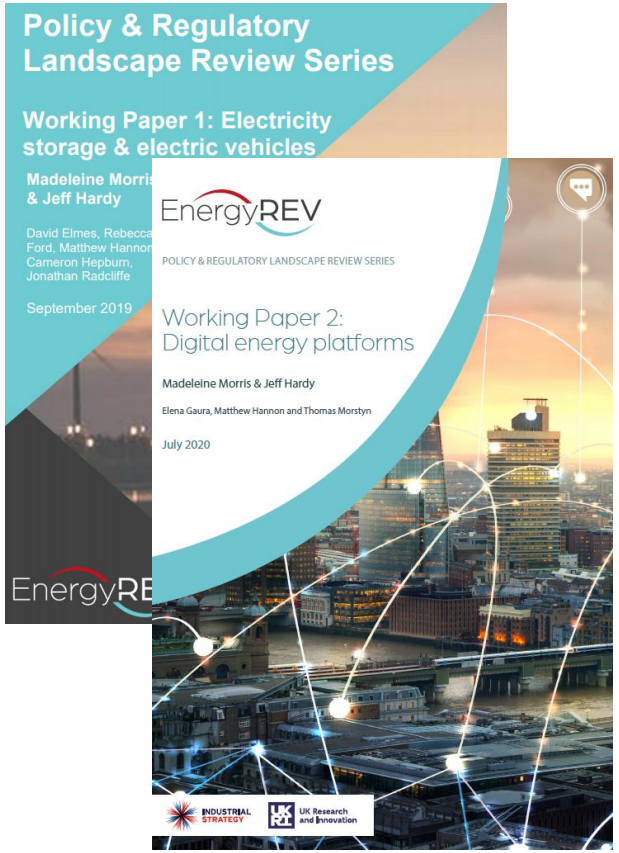
EnergyREV Policy & Regulation “Sprint Reviews”

- Alternative to the usual, initial Lit Review
- Faster & consultative
- Explicitly wider than academic lit
- Includes crowdsourcing

- Initial reviews
  - Electricity Storage & Electric Vehicles – published
  - Digital Energy Platforms – published
- Current review…
  - **Heating and Cooling: demand, supply and storage**



Digital energy platforms: SLES implications & insights

- Data & digital energy platforms
  - If energy industry doesn't act, government and regulator will step in
  - Either way, emergence of digital energy platforms will be affected
- Markets
  - SLES have important role in provision of essential future energy services – digital platforms are a key component but only if value can be realised
- Policy and regulation
  - Digitalisation of energy is a balancing act for policymakers: a goldilocks dilemma. Acting to soon or too late could stifle or lock-in consumer harm. But when is the right time to act?
  - Digital energy platforms could unlock the potential of distributed energy resources and consumers, but only if there is trust, routes to market and commensurate value in the platforms
  - System operation is likely to become more complicated in the future and many more parties will be involved in providing essential services – local vs. national balance yet to emerge
  - Government and Ofgem will take decisions that could impact on SLES (+ve or –ve)
  - Feedback loops are needed so that more agile approaches to regulation can be implemented and compliance monitored

Themes proposed for the Heating and Cooling Review

- Why does heating (let alone cooling) receive much less attention than electricity?
- Why is regulating the supply of heating so far behind that of electricity and gas?
- Why are the behaviours associated with heating and cooling more difficult to research and understand than, say, switching?
  - Experiments on single behaviours vs field trials at scale covering multiple concepts

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BLOCKCHAIN FOR EUROPE
MAKING DISRUPTION AN EVOLUTION!

HOME NEWS ABOUT MEMBERSHIP EVENTS MATERIALS CONTACT US

EVENT

Blockchain for Europe Summit 2020

05.02.2020 | Brussels, Belgium

The Blockchain for Europe Summit took place on 5 February 2020 in the European Parliament in Brussels, Belgium.

Fireside Chat – "Blockchain-coopetition in the energy space"

ENERGY RESEARCH ACCELERATOR

At the forefront of energy transformation

Towards Smart and Decarbonised University Campuses

6 July 2020

Delivered by MIDLANDS INNOVATION

Funded by UKRI Innovate UK

Aston University BIRMINGHAM UK

UNIVERSITY OF BIRMINGHAM

Cranfield University

Keele UNIVERSITY

UNIVERSITY OF LEICESTER

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WARWICK THE UNIVERSITY OF WARWICK

British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL

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WP4 Summary

- Early transition to study of a rather large “lab scale demonstrator of integrated technologies”
- Redeployment of PDRA staff from lab based research
  - Need to progress LUDS & WBS further PDRA recruitment
- Links/collaboration with multiple, related programmes

- Main themes over next period
  - What is the LoT-NET for Smart Square?
  - What is the “Flexibility Index” for Smart Square?
  - What value can a transactive energy platform add to Smart Square & the campus, and what is the partnership to achieve this?