



Top-down and bottom-up analysis of energy performance trends in schools

Insights for achieving net-zero performance in use

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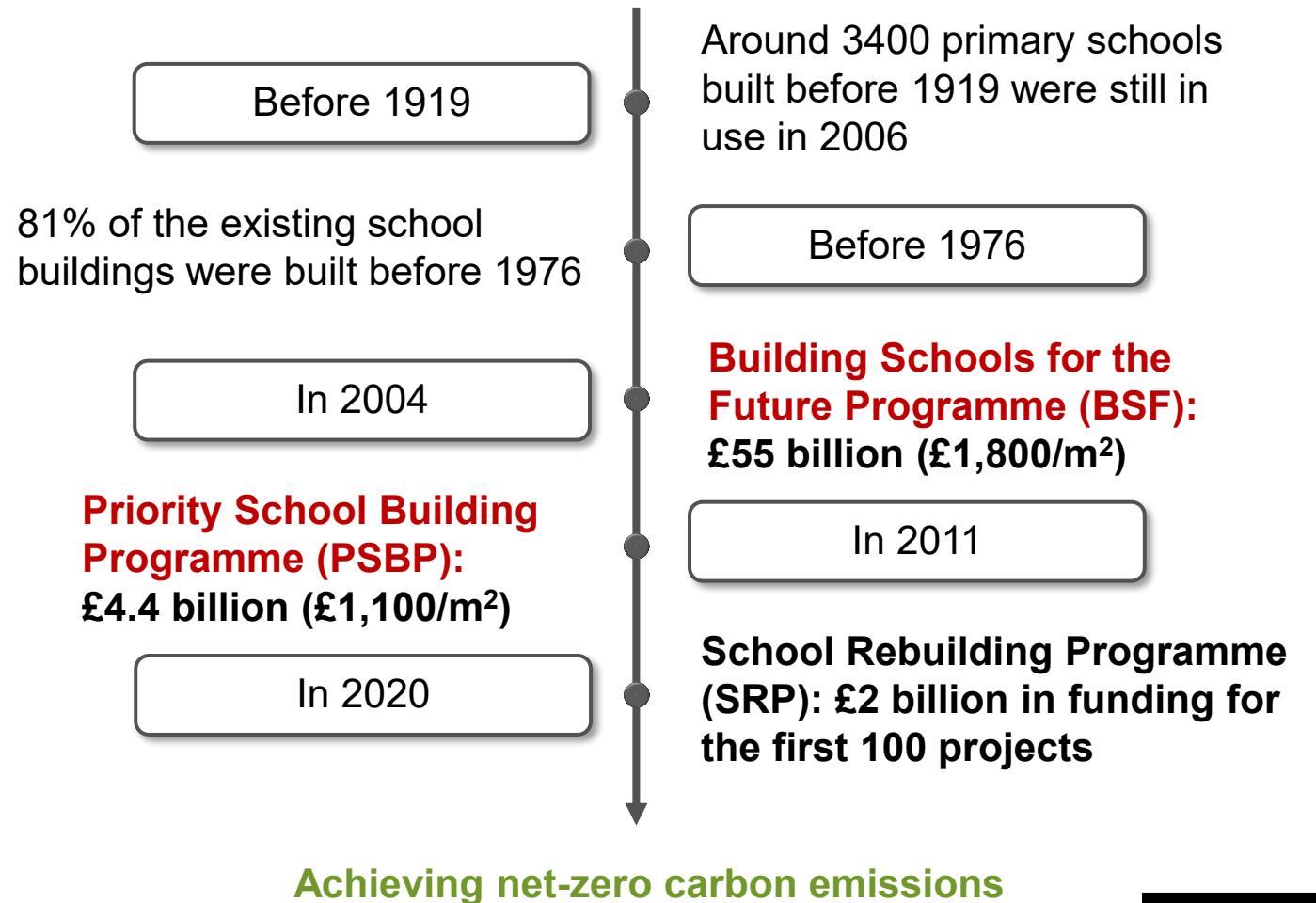
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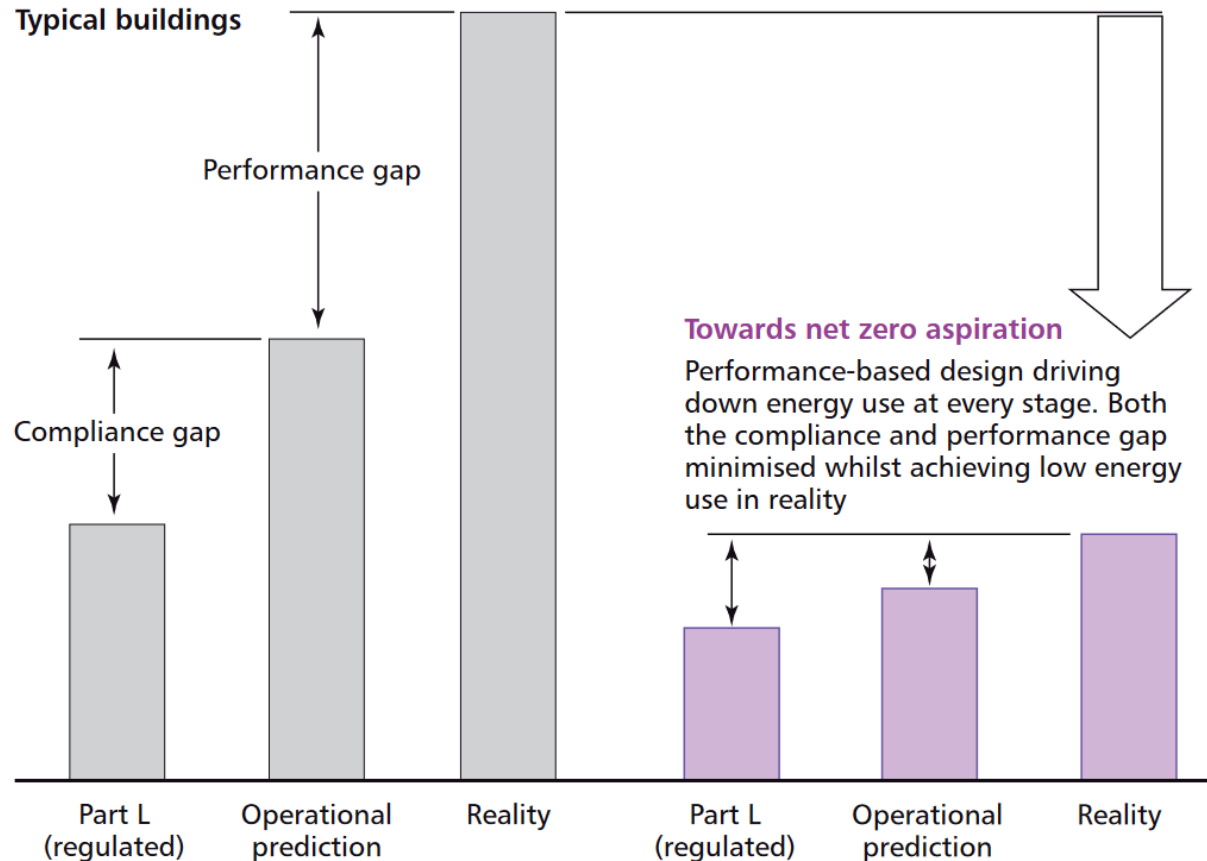


Background

- **15%** of the public sector's carbon emissions were generated by school buildings (DfE, 2012).
- The dominant energy consumers are **primary and secondary schools** (BEIS, 2016).
- Annual school financial reports: energy expenditure in 2023/24 was around £1200 million, doubling that of the 2018/19 academic year (DfE, 2024)

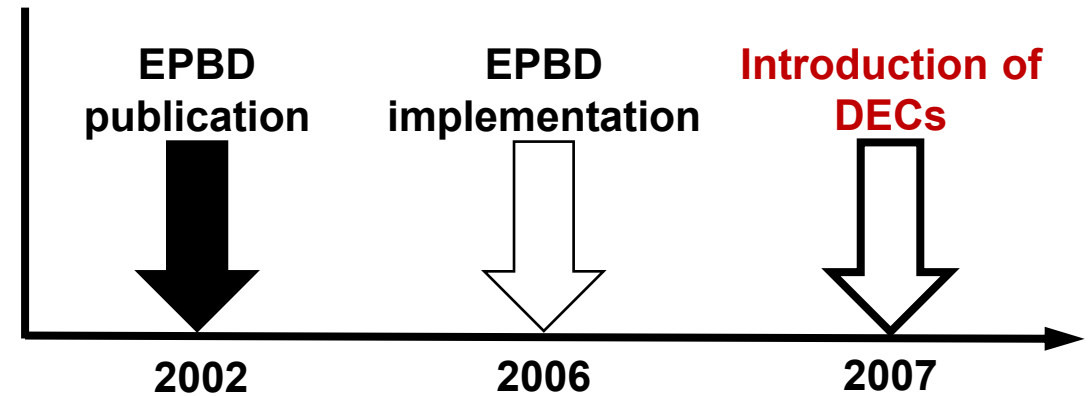


Display Energy Certificate



(CIBSE TM54, 2022)

The actual operational performance of school buildings generally **did not** match the design expectations.



DECs: To record energy consumption and carbon emissions in public buildings

The need to display a DEC for public buildings over 250 m² in England and Wales has been a mandatory requirement since July 2015 (DCLG, 2012).

Aim and Objectives

- Aim: To inform further improvements in the energy performance of the school building stock by analysing the characteristics of school energy use from both a top-down and bottom-up analysis.
- Objectives:
 - **Top-down analysis:** Using the DEC database to quantify the latest energy performance of primary and secondary school buildings in England and to review trends in energy consumption patterns over the period 2018-2023.

Three databases were developed: The **All School Building Stock**, the **BSF School Building Stock** and the **PSBP School Building Stock**.

- **Bottom-up analysis:** A school building selected as a case study for performance modelling and scenario testing. The underlying causes of differences between the model based on design expectations and the calibrated model outputs were investigated and the potential for operational performance of the building was explored.



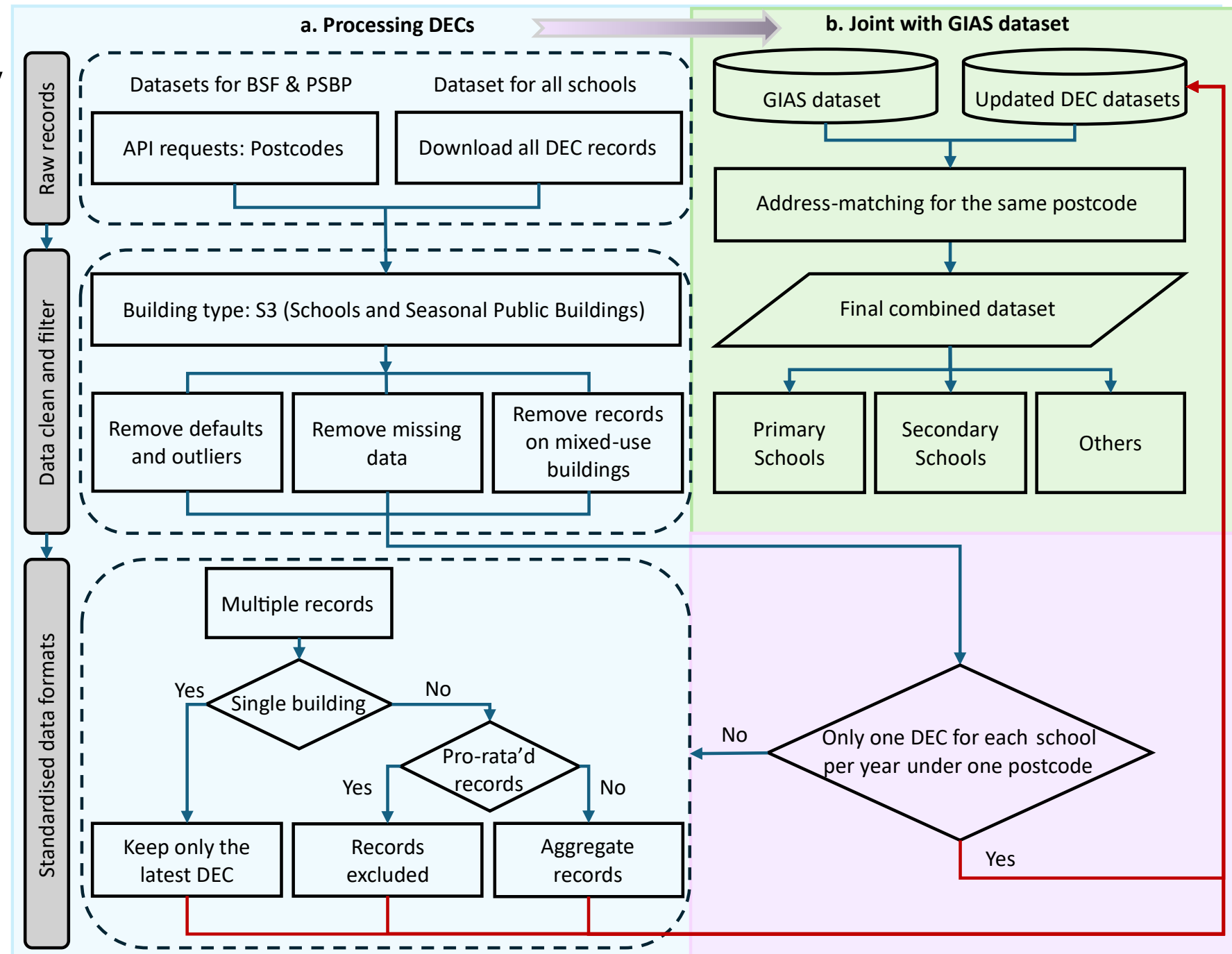
Methodology

(1) Data sources and collection

- **Display Energy Certificates (DECs):** The dataset contains annual electricity and fossil thermal energy consumption in addition to address, postcode, building type, floor area, main HVAC type and main heating fuel (DCLG, 2012).
- **Get Information About Schools (GIAS):** GIAS is a national public dataset provided by the DfE containing the registration records of all educational establishments in England and Wales, which includes the unique reference number (URN), name, address, postcode, status (open or closed), educational phase (e.g. primary or secondary), and school capacity for each establishment (DfE, 2024).

Methodology

(2) Data processing and integration



Methodology

(3) Creation of unified datasets and their subsets

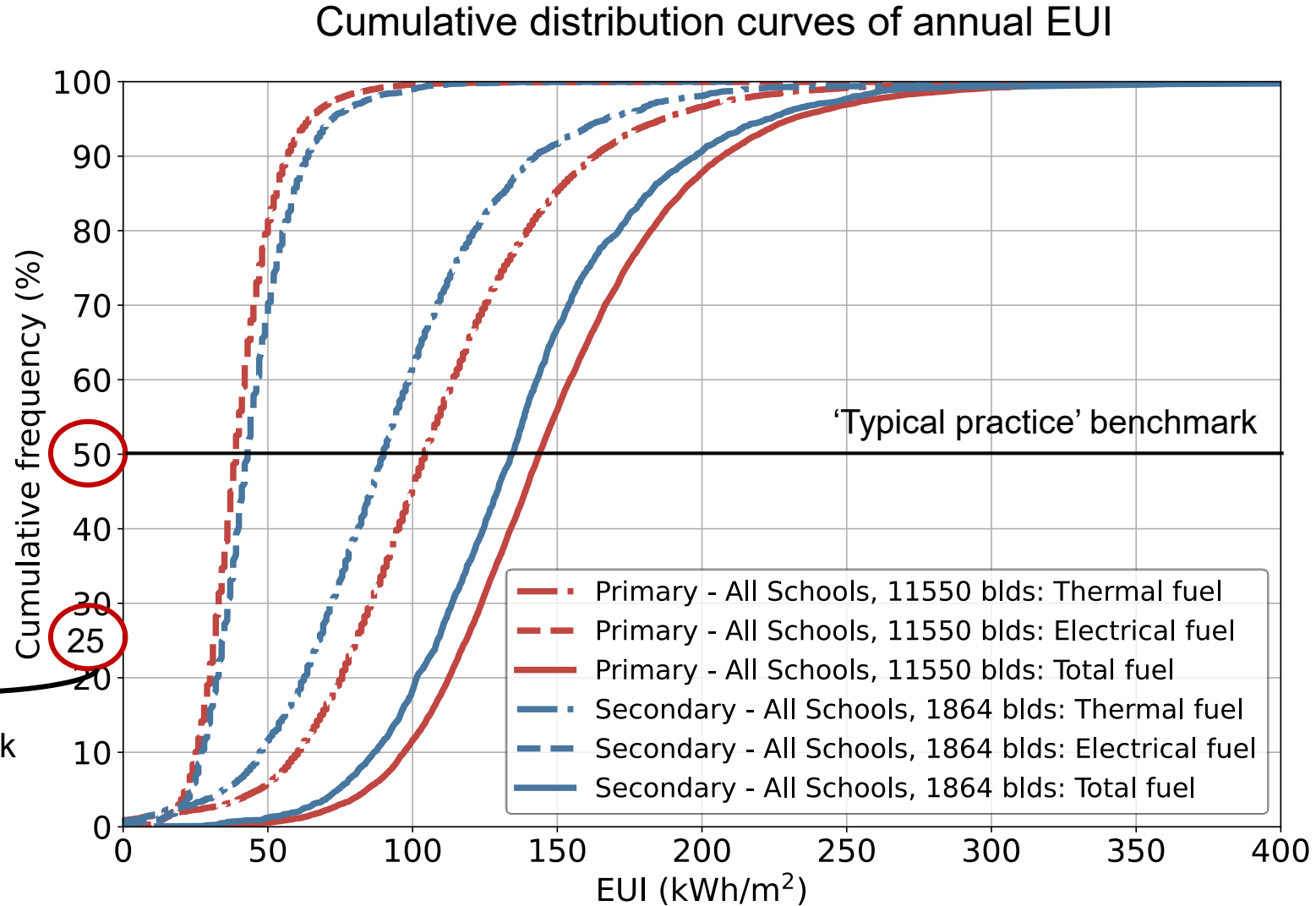
Year	Primary schools			Secondary schools			Other schools		
	BSF	PSBP	All	BSF	PSBP	All	BSF	PSBP	All
	schools	schools	schools	schools	schools	schools	schools	schools	schools
2018	0	88	7551	207	89	1223	47	12	811
2019	0	119	8152	226	102	1343	54	18	976
2020	0	108	7694	235	95	1276	45	15	890
2021	0	155	8480	240	113	1367	61	14	864
2022	0	168	8685	231	121	1349	63	20	1045
2023	0	159	8632	254	114	1355	67	23	1119
2024	0	86	5525	123	46	769	41	9	579
Latest	0	205	11550	316	156	1864	83	31	1553

Number of schools by school type in the final unified dataset

Results

Overall school performance

- Electricity consumption was higher in **secondary schools** than in **primary schools**.
- Fossil thermal energy consumption was higher in **primary schools** than in **secondary schools**.



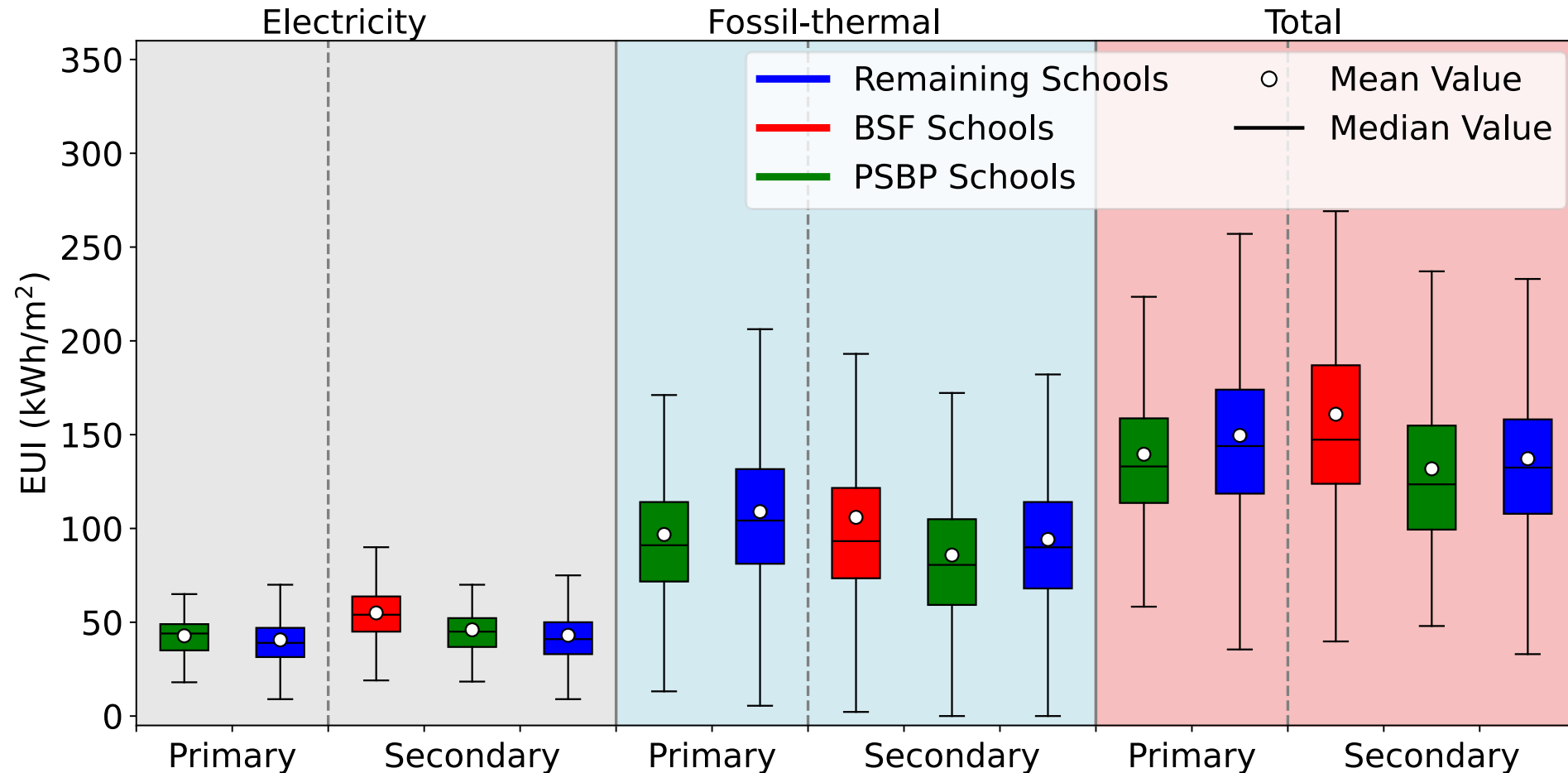
← 'Good practice' benchmark

The 25th percentile: 'Good practice' benchmark

The 50th percentile: 'Typical practice' benchmark

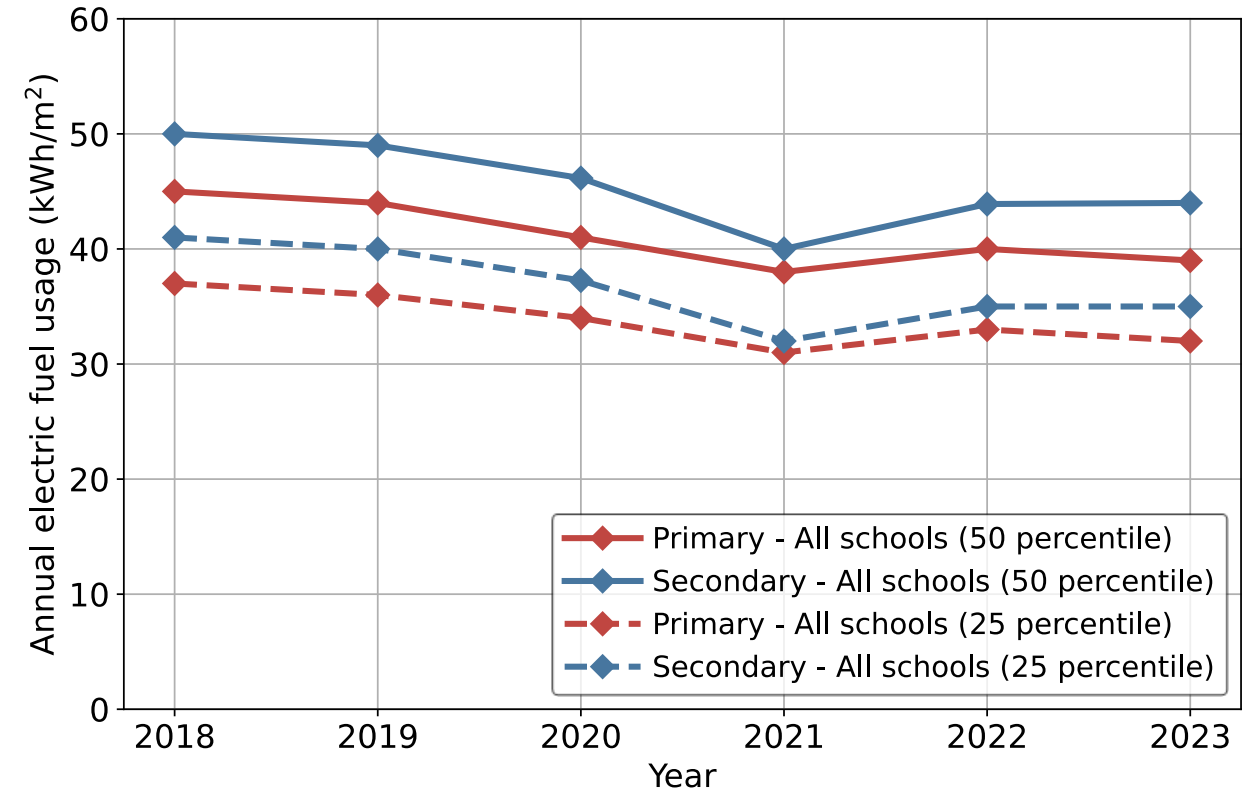
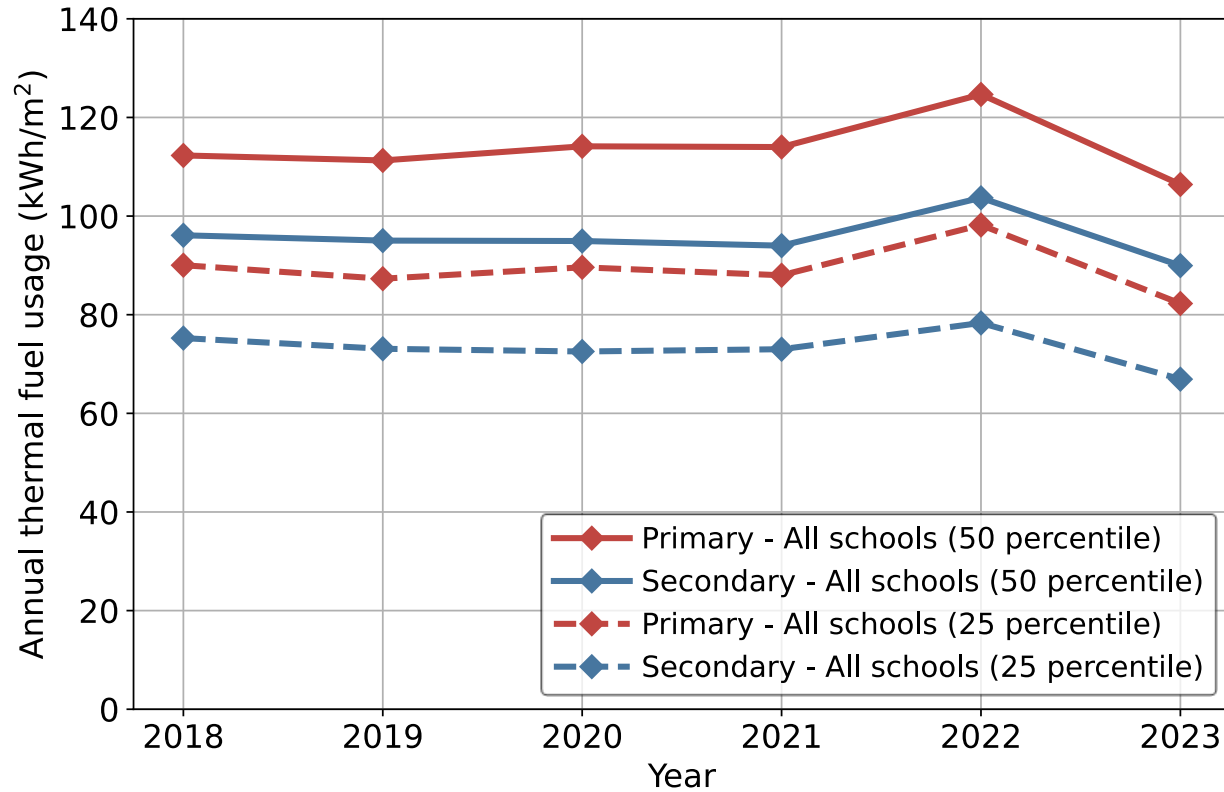
Secondary schools have more energy-intensive activities and energy-consuming equipment than **primary schools** (EFA, 2015; BEIS, 2016).

Comparison of EUI in three school building stock clusters



- The operational energy performance of **PSBP schools** was relatively **better** than that of the **remaining school building stock**.
- The operational energy performance of **BSF schools** was **worse** than that of the **remaining school building stock**.

Variation in thermal fuel (left) and electricity (right) use over time



2018-2019: Pre-Covid19 pandemic period

2020-2021: Lockdown period

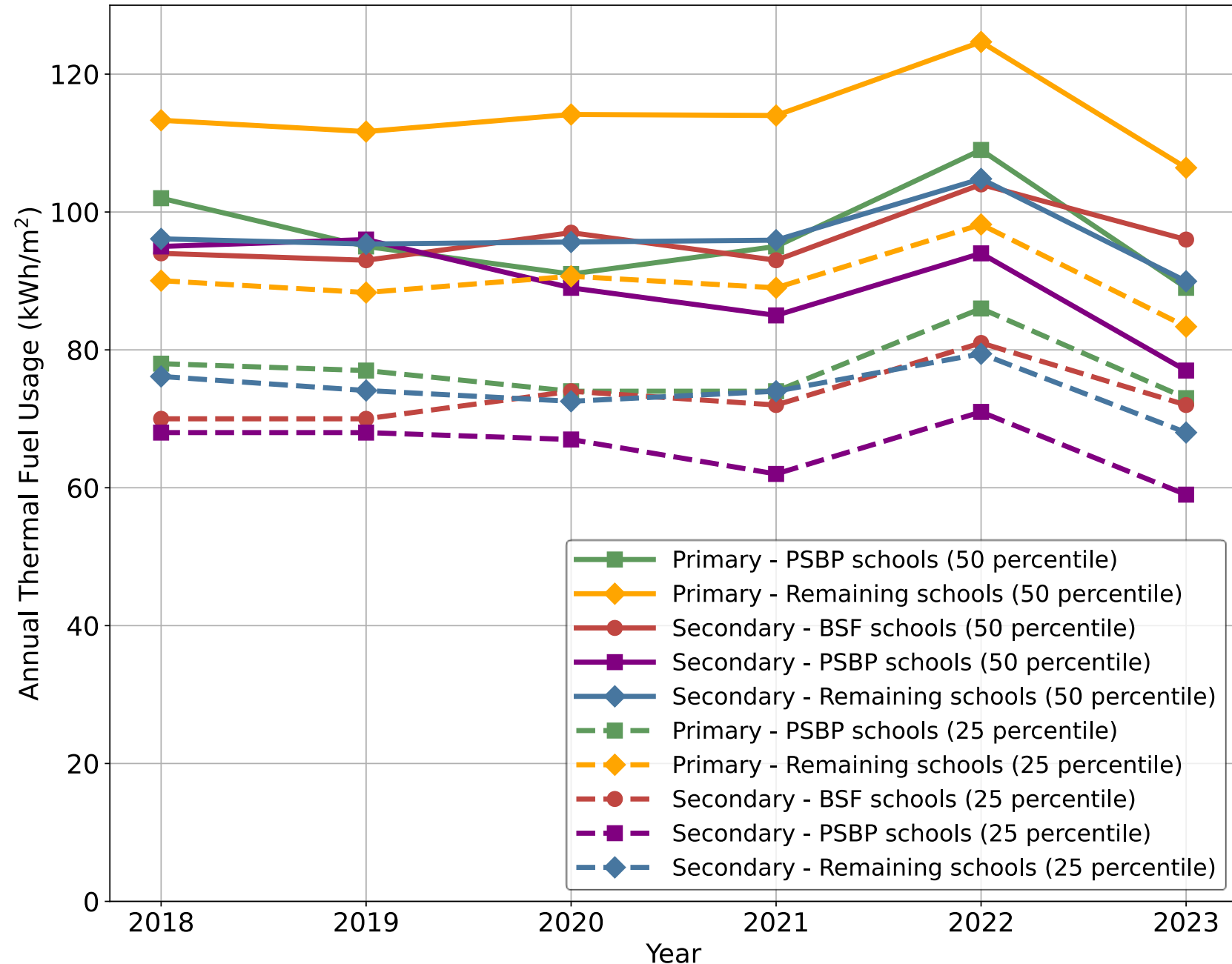
2022-2023: Post-pandemic period

The 25th percentile: 'Good practice' benchmark

The 50th percentile: 'Typical practice' benchmark

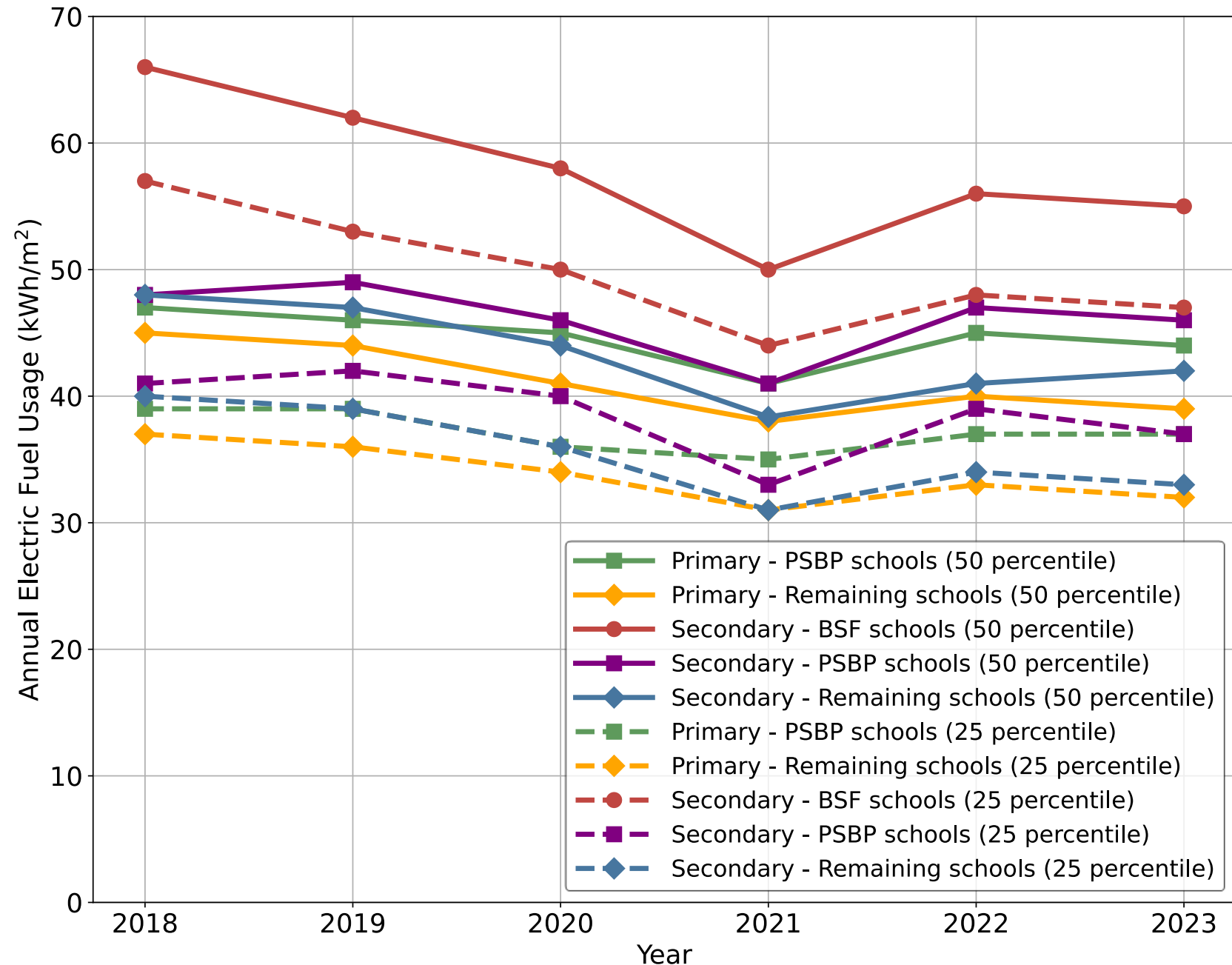
Variation in thermal fuel use over time

- **Remaining primary school buildings** have consistently consumed the highest amount of thermal fuel over the past six years.
- **BSF Schools** currently has the highest fossil thermal EUI under typical practice of the three secondary school building clusters. However, in the pre-pandemic period (2018-2019) the **BSF Schools** had the lowest fossil thermal EUI.



Variation in electricity use over time

- **BSF schools** were consistently the cluster with the highest electricity consumption over the past six years.
- **BSF schools** at the good practice level consumed even more electricity than PSBP schools and the remaining schools at typical practice.




Top-down assessment of the energy performance of the English school stock: National trends and analysis of school rebuilding programmes

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Top-down assessment of the energy performance of the English school stock: National trends and analysis of school rebuilding programmes

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ABSTRACT

To reach the legal target of net zero by 2050, the UK Department for Education (DfE) is responding to this challenge by retrofitting existing buildings and designing new buildings to reduce carbon emissions. Assessing and reporting on the operational energy performance of these rebuilding programs can help to further inform and drive evidence-based decarbonisation initiatives. This study utilises the Display Energy Certificate (DEC) dataset and the Get Information About Schools (GIAS) dataset to create a combined database, aiming to analyse and compare the energy usage of school buildings constructed under two school rebuilding programs: Building Schools for the Future (BSF) and the Priority School Building Program (PSBP). It also investigates the latest energy consumption of English primary and secondary school buildings and trends over the period 2018 to 2023, specifically the impact of COVID-19 pandemic on energy use. Additionally, it explores the energy consumption patterns of school buildings when using different types of heating, ventilation and air conditioning (HVAC) systems and main heating fuels. A total of 13,569 schools are covered, representing approximately 69% of primary schools and 58% of secondary schools in England. This study found that the energy performance of the higher-cost BSF schools is not only inferior to that of lower-cost PSBP schools but also lags behind the remaining school building stock. There are differences in both fossil thermal energy and electricity consumption between primary and secondary school buildings. Furthermore, variations in building characteristics can contribute to differences in energy use patterns. This study can inform the quantification of energy performance in various sectors and guide the development of future energy upgrade measures and emission reduction policies.

1. Introduction

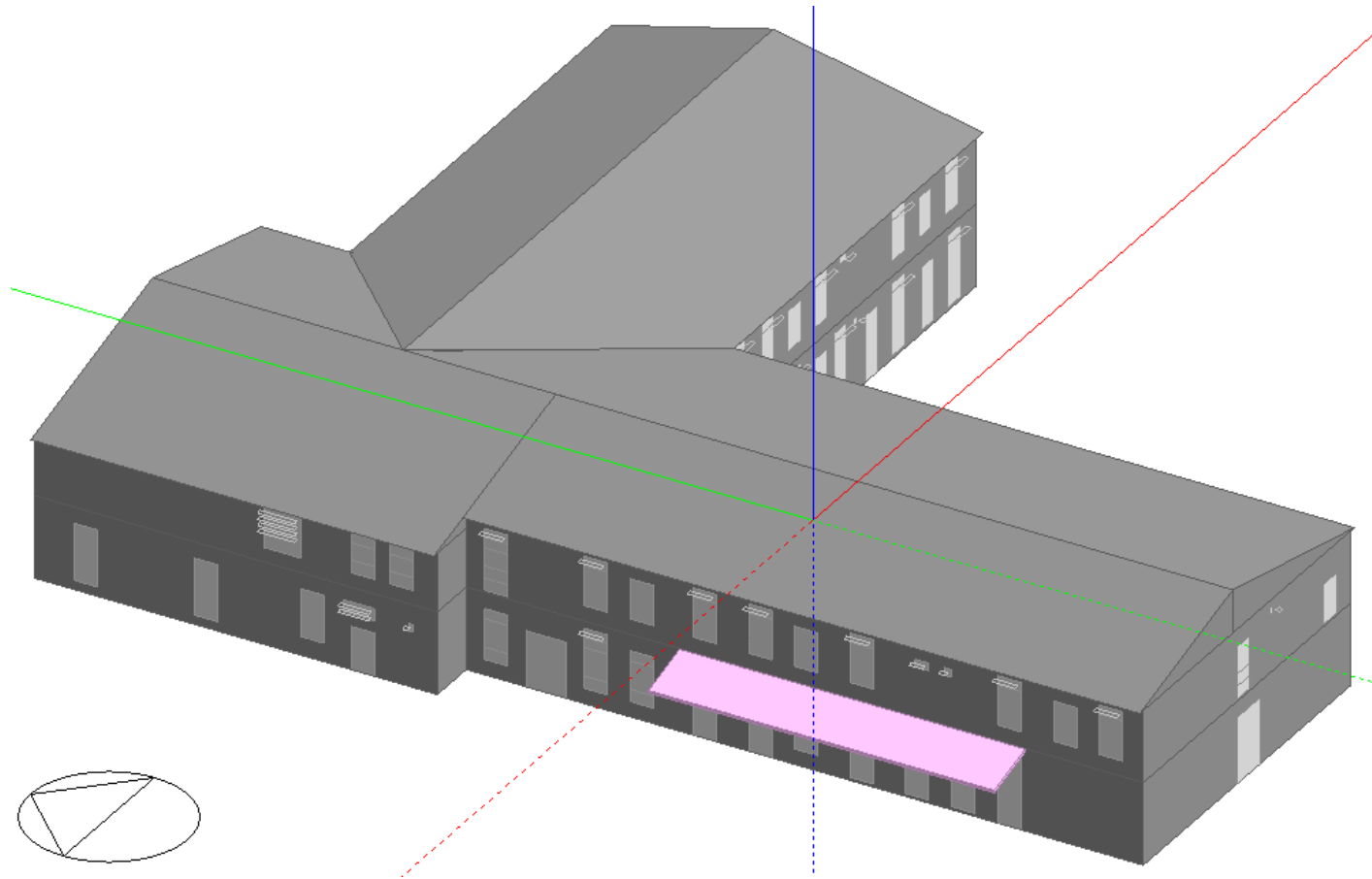
Buildings in the UK produced 89 MtCO₂e of greenhouse gases (GHGs), which accounted for 20 % of the national total and was the second largest source of emissions in the country [1]. Of these, 15 % of public sector carbon emissions were from school buildings [2]. An analysis of annual school financial reports revealed that energy expenditure in 2023/24 was around £1200 million, doubling that of the 2018/19 academic year [3]. The Carbon Trust [4] stated that upgrading UK school buildings has the ability to reduce annual energy bills by £44 million and prevent the production of 625,000 tonnes of CO₂.

The UK DfE has launched three major school rebuilding programmes in a continuous and overlapping cycle over the last 20 years, all of them aiming to construct or refurbish school buildings to improve building performance in line with the newly issued school design guidelines. Building Schools for the Future (BSF) is a programme with a £55 billion total budget, launched in 2004, which expected to refurbish or rebuild every secondary school in England over the next 15 years [5]. The average budget allocated to school buildings under this programme was £1,850/m² and required a minimum BREEAM 'very good' rating to ensure environmental sustainability [6,7]. However, this programme was stopped in 2010 for a number of reasons, including insufficient progress and cost overruns, and only 559 schools were rebuilt or refurbished, which is around 17 % of all secondary schools in England [8,9]. Then the government allocated £4.4 billion to create the Priority School Building Programme (PSBP) in 2011 to deal quickly and cost-effectively with 537 schools in urgent need of repair [10,11]. The average total capital cost for each PSBP school was £1,113/m² [12]. Compared to BSF schools, PSBP schools reduced overall scale while maintaining the same number and area of teaching spaces, saving an average of £6 million per secondary school [13]. Meanwhile, the baseline design requirements for the programme set operational energy consumption targets of less than 60 kWh/m² and 50 kWh/m² for fossil fuel and electricity use respectively [14]. The School Rebuilding

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Case study: A PSBP Primary School



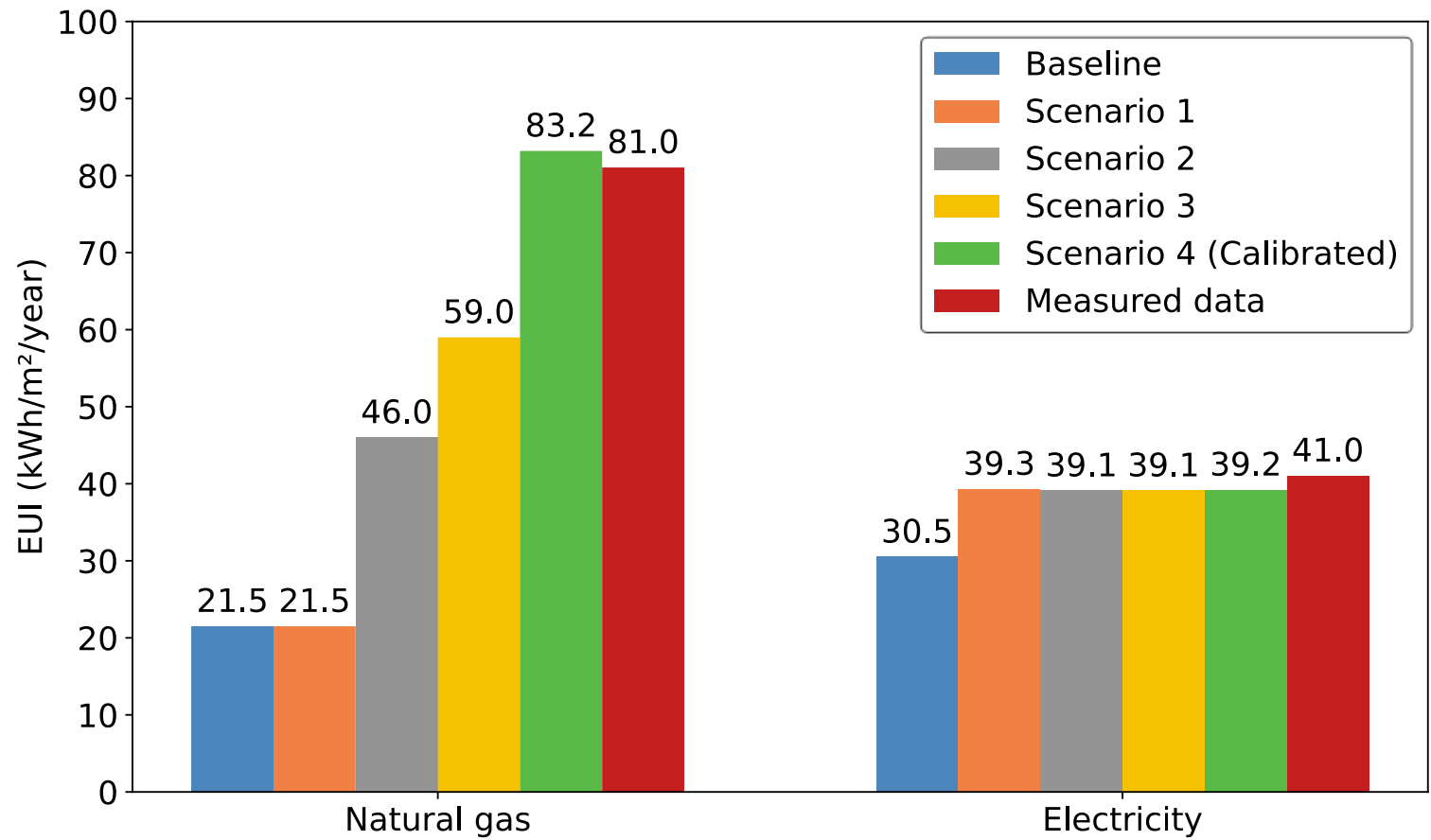
The school, located in the North of England and opened in 2019, is a L-shaped two-storey building with about 2400 m² of floor area.

Scenario 1: Equipment heat gain in the server room: 50 W/m² (NCM) → 250 W/m² (latest DfE guidelines)

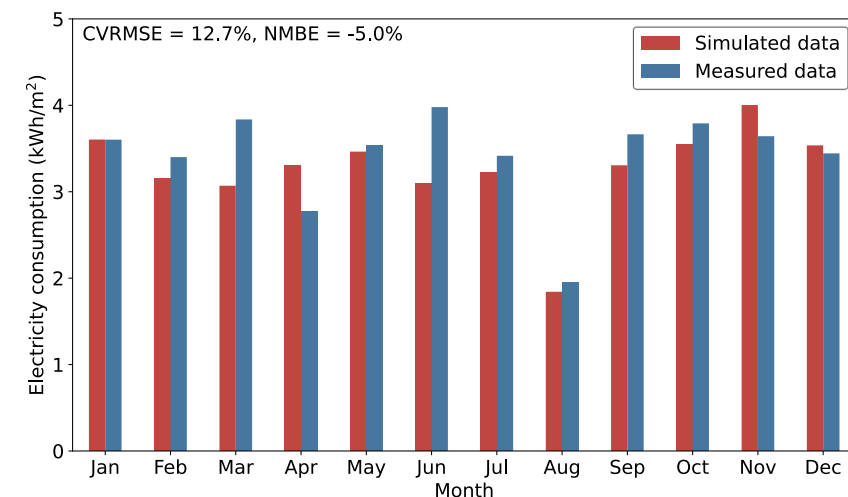
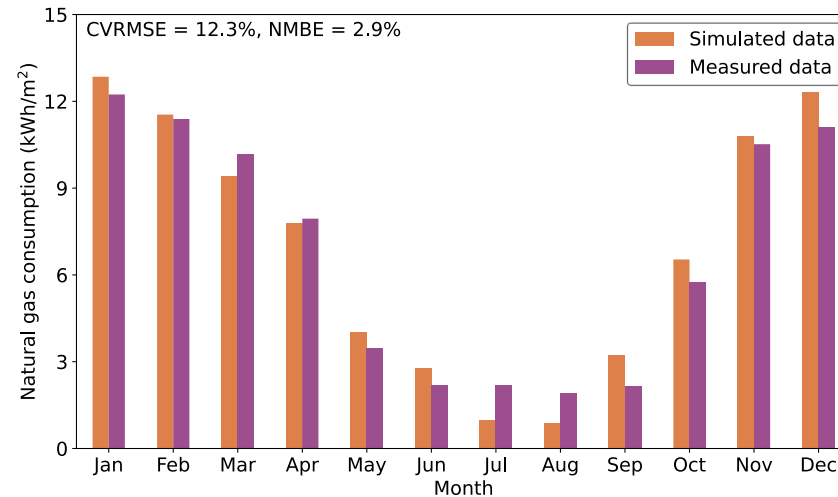
Scenarios 2: Building background ventilation rate to 0.5 ACH.

Scenarios 3: Extending the operating hours of the heating system during half-term breaks in the heating season.

Scenario 4: Heating setpoint temperature: 22°C.



Calibrated model →



Conclusion

- The study found that BSF schools with high financial investment had poor energy performance, while PSBP schools with compact designs had more efficient building operations.
 - Total EUI (50th percentile): 147 kWh/m² for the BSF secondary schools, 124 kWh/m² for the PSBP secondary schools and 132 kWh/m² for the remaining secondary schools.
 - PSBP schools reduced project costs by 1/3 compared to BSF schools, while improving construction efficiency (DfE, 2015).
 - The space design of PSBP primary and secondary schools was reduced by 15% and 5%, respectively, compared to BSF schools (DfE and EFA, 2012).
- However, an investigation of a PSBP primary school at the individual building level still identified significant gaps between the actual operation of the building and the design expectations.
- The scenario testing revealed even without refurbishing the building, there were a variety of practical measures that could be taken to further reduce the operational energy consumption of the building.
- **Limitation:** only one building in one cluster was used as a case study, and in the future more cases will be introduced for further comparative studies.

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Thank you for listening

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