BAXI

Schools and the heat decarbonisation challenge

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Commercial heating and hot water solutions

Contents

Introduction

The UK government has committed to reducing 78% of greenhouse gas emissions by 2035, compared to 1990 levels, and to becoming a net zero economy by 2050.

This requires significant effort across every sector of society and progress has been made to achieve our interim carbon budgets. But much more remains to be done.

> "Heat decarbonisation is a huge challenge, particularly for schools"

Heating is one of the UK's primary sources of emissions, accounting for over a third of the nation's total greenhouse gas emissions. Decarbonising heat in buildings is therefore key to achieving the ambitious targets ahead – and school buildings are no exception.

UK school buildings

Date of construction	% of existing schools
Pre-1919	13%
1920 - 1944	8%
1945 - 1966	25%
1967 - 1976	19%
Post-1976	35%

Source: Property Data Summary Programme Summary Report

Manufacturers of heating equipment have risen to the challenge, providing a mix of low carbon technologies and techniques, including heat pumps, for use now while innovating with future solutions, such as hydrogen boilers, to prepare for the energy transition.

But this is a huge challenge, particularly for schools. While new school buildings must now be designed to be net zero, many UK schools are ageing, as the table (left) shows. 65% of UK school buildings were constructed before 1976, and 46% before 1966, so the existing stock is likely to overshadow the sector for many years to come.

In this guide our aim is to:

Explore
the available options to achieve more sustainable heating in older primary and secondary school buildings

Understand
the value of planning phased refurbishment programmes to achieve optimal outcomes and long-term goals

Illustrate
the carbon and energy savings from a stepwise approach

Demonstrate
the value of early collaboration with heat experts to achieve the best solution

Clearly, heat pumps have a huge role to play in the energy transition. But as low carbon technologies perform best in buildings designed from the ground up to use low temperature heating effectively, it's unlikely that full decarbonisation will be achieved overnight in hard to heat school buildings.

A more realistic approach, given the complexity of the challenge ahead – and further compounded by financial limitations and soaring energy costs – is to plan a stepwise path to net zero. With different needs and constraints, each building will require a bespoke solution to achieve the best possible outcome.

As experts in heating systems and controls, we at Baxi understand both the potential problems and the opportunities facing schools. Working with consultant engineers, M&E contractors and school estates managers, we can help to identify the options and deliver the right solution at the right time.

This guide sets out to assess the different heating technologies, solutions and approaches that will need to be available to prioritise performance and so achieve the required comfort levels and emissions reduction within school buildings.

Putting sustainability at the heart of education

Climate change is the most important challenge of our generation and schools have a vital role to play in influencing and informing future generations.

In its sixth assessment report[1], the UN's Intergovernmental Panel on Climate Change (IPCC) issued a stark warning that there must be "rapid, deep and immediate" cuts in carbon dioxide emissions this decade to minimise the risk of exceeding a 1.5°C temperature increase and avoid dangerous climate change.

> Heating and hot water make up a large proportion of schools' costs and are the main source of energy use in their buildings

At COP26, the Department for Education (DfE) announced its commitment to put climate change at the heart of education[2] and keep the education system at the forefront of sustainability and innovation. DfE aims to support teachers in delivering world-leading climate change education that will engage all young people in the importance of conserving and protecting our planet, as well as developing the skills needed to solve the problems.

But if schools are to be truly sustainable in their operations and lead by example, they also need practical solutions to improve the energy performance of their buildings and heating systems.

Environment

In 2019, the UK government amended the Climate Change Act to commit the nation to achieving net zero by 2050, compared to the previous target of an 80% reduction in emissions by the same year.

One of the UK's primary sources of emissions is heating. It accounts for 37% of the country's greenhouse gas emissions and is, therefore, a natural target for decarbonisation.

The need for action is particularly pressing in the UK's circa 32,000 schools, many of which are ageing and with inefficient and wasteful heating systems that emit significant emissions. Refurbishing these systems and improving the energy performance of these buildings is a central factor in the journey to greater sustainability for these schools.

The carbon, cost and comfort drivers

1 https://www.ipcc.ch/report/ar6/wg3/
2 https://educationhub.blog.gov.uk/2021/11/09/cop-26-everything-you-need-to-know-about-the-departments-quest-to-put-climate-change-at-the-heart-of-education/

Managing tight budgets

According to the Carbon Trust[3], heating is usually the largest and most expensive energy user in a school building.

What's more, heating and hot water are buildings critical services and if they fail, the building faces avoidable term-time closures. Post pandemic, it's more important than ever to keep schools open where possible to help students catch up with the curriculum and continue their education.

Old and inefficient heating systems add an unnecessary financial burden for schools. Improving system performance will help avoid costly emergency call outs, disruption and downtime.

The strain on school budgets is further exacerbated by today's soaring energy prices. Taking action now to reduce heat losses, improve the efficiency of the system and meet heat demand more sustainably will help mitigate rising heating bills.

Wellbeing and productivity

Schools have a duty of care to meet comfort needs and ensure the health, safety and wellbeing of students and teachers.

In the last year or so, the focus for schools has understandably centred on improving building ventilation which is a key element of the government's 'Living with Covid' strategy. However, thermal comfort is also linked to health, wellbeing and productivity and is one of seven factors measured by the WELL Building Standard to create a productive and soothing indoor environment[4]. This makes thermal comfort particularly important in school buildings.

Until October 2012, legal requirements relating to temperatures in school classrooms, as set out in the Education (School Premises) Regulations 1999[5], specified a minimum temperature of 18°C.

This requirement still applies in Wales. In England, the minimum temperature in a workplace (or classroom) "should normally be at least 16°C", according to the Health and Safety Executive.

An efficient, well-controlled and well-maintained heating system will ensure that the required comfort levels are consistently met, improving concentration and wellbeing.

3 https://czone.eastsussex.gov.uk/media/1952/ctv019-schools-overview.pdf
4 https://standard.wellcertified.com/well
5 https://www.legislation.gov.uk/uksi/1999/2/contents/made

UK schools and heat pumps

Heating our school buildings more sustainably is essential to reduce unnecessarily high emission levels, optimise learning conditions for the benefit of students and teachers, and mitigate soaring energy costs.

In new and well-insulated school buildings, the merits of low carbon heat pumps like our new Remeha E-HP AW Air Source Heat Pump (ASHP) range are well established.

Powered by the UK's rapidly decarbonising electricity grid, heat pumps can provide a highly efficient, sustainable method of supplying low carbon heating or indirect hot water requirements for a range of new school building stock.

But new build is just the tip of the iceberg. Retrofitting heat pumps in older, poorly insulated premises is a more complex matter.

> Most existing school buildings will need to be adapted, through a series of steps, to make them heat pump ready

If a solution is simply tailored around the heat pump rather than the retrofit challenges in the building, the anticipated outcome will not be achieved.

Instead, most existing school buildings will need to be adapted, through a series of steps, to make them heat pump ready. We can help. By taking a holistic design approach, identifying the problems and the options, we can help balance client needs against outcomes and budget to achieve the best solution.

In the next section, we outline some of the achievable improvement options within existing school buildings that will lay the foundations for full decarbonisation and set schools on their net zero journey.

The challenges

Capital expenditure

Tight budgets mean that schools are frequently limited as to the extent to which they can adapt and retrofit the school estate. Without considerable funding, they typically won't have endless budget to carry out all the work required to make the building net zero overnight.

High air infiltration

Many older schools are draughty. For heat pumps to work most effectively, the building they are heating should be well insulated. Energy efficiency improvements should be implemented before making changes to the heating system.

Available electricity supply

It is likely that additional power requirements will be required to site which will bring further cost implications for schools.

Circulating temperatures

Older heating systems are likely to be designed and operated at either 82°C/71°C flow and return or 80°C/60°C flow and return temperatures while heat pumps perform best at lower temperatures. Additional changes will therefore be required before retrofitting heat pumps.

Heat emitters

Larger radiators may be required due to the lower circulating temperatures, bringing added costs.

Government support

School Rebuilding Programme – UK schools are ageing. Recognising the issue, the government introduced its 10-year, multi-wave rebuilding programme in 2020 to replace poor-condition and ageing school buildings with modern, energy-efficient designs. There are currently 100 projects in the programme, with buildings prioritised according to their condition. Up to 300 further schools will be prioritised in 2022-23, with a delivery rate of 50 per year[6].

The UK government has pledged for every new school delivered under the Department of Education's (DfE) School Rebuilding Programme to be cleaner, greener and net-zero in operation.

Public Sector Decarbonisation Scheme – The UK government has included schools in the Public Sector Decarbonisation Scheme to help them with energy efficiency and low carbon heating measures.

Maintained schools within the state education system, including academies, Multi-Academy Trusts and free schools are eligible to apply for funding. Applications opened in September 2022 for phase 3b of the Public Sector Decarbonisation Scheme (PSDS) and up to £635 million is available. This is to be spent across financial years 2023/24 (£402 million of funding) to 2024/25 (£233 million of funding)[7].

SCA and CIF – Funding is allocated each year by the Department of Education[8] to help maintain and improve the condition of school buildings through:

School Condition Allocations (SCA) – funds are paid to eligible bodies responsible for maintaining schools.

Condition Improvement Fund (CIF) – a bidding round with funds paid directly to single academy trusts, small multi-academy trusts, small voluntary aided bodies and sixth form colleges. The fund prioritises keeping school buildings safe and in good working order[9].

In 2021-22 the allocation for England was around £1.6 billion, 19% higher in real terms (2021-22 prices) than in 2015-16. However, there are large differences in how this funding has changed between different types of schools with funding shifting from maintained schools to academies due to the process of academisation over this period (see table).

According to the School buildings and capital funding (England) report[10], overall, between 2009-10 and 2021-22, capital spending declined by 25% in cash terms and 29% after adjusting for inflation.

6 https://www.gov.uk/government/publications/school-rebuilding-programme/school-rebuilding-programme
7 https://www.salixfinance.co.uk/sites/default/files/Phase%203b%20PSDS%20Guidance%20Notes%20v.2%20%281%29.pdf
8 https://www.gov.uk/guidance/school-capital-funding
9 https://www.gov.uk/guidance/condition-improvement-fund
10 https://commonslibrary.parliament.uk/research-briefings/cbp-7375/

School condition allocations
England, £ millions, real terms (2021-22)

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	% change over period
Local authority maintained schools	602	572	523	476	433	413	528	-12%
Voluntary aided schools	160	153	145	137	129	113	134	-16%
Multi-academy trusts and sponsors receiving SCA	76	107	140	193	244	288	405	+435%
Institutions eligible for condition improvement fund	481	485	494	484	467	446	502	+5%
Non-maintained special schools	2	1	1	1	1	1	3	+80%
Specialist post-16 institutions	1	1	1	1	1	2	4	+238%
Total	**1,321**	**1,319**	**1,304**	**1,292**	**1,276**	**1,262**	**1,576**	**+19%**

Notes: Institutions eligible for condition improvement fund includes single academies, small multi-academies, small multi-academy trusts and sixth form colleges. **Sources:** Department for Education, School Capital Funding (accessed 25/10/2021); HM Treasury, GDP Deflators at market prices, and money GDP; September 2021; OBR, Economic and fiscal outlook, 3 Mar 2021 (table 1.7 of supplementary economy tables)

Source: House of Commons Library School buildings and capital funding (England)

Stepwise approach

As we have seen, full decarbonisation will realistically not happen overnight in many existing schools due to a range of retrofit challenges. But we can help them plot a pathway to net zero and set them on their journey.

By adopting a phased approach to refurbishment, schools can plan and budget ahead to achieve their immediate and long-term requirements and avoid mid-term disruption.

Our expert team will be able to work with you to plan a stepwise refurbishment programme that will prioritise performance at every stage.

The starting point should be to reduce energy demand through improved energy efficiency. Ask us to carry out a free site visit, 'triage' the problems and assess the most appropriate options.

> "Full decarbonisation realistically won't happen overnight in existing schools..."

Replacing any older heating plant with future-ready low NOx condensing models that are up to 20% more efficient is proven to significantly reduce energy consumption and associated emissions while improving reliability of the service.

Once the building and heating system have been brought up to code, a natural progression would be to integrate Air Source Heat Pumps and future-proof condensing boilers in a multivalent system. Multivalent heat pump solutions offer an effective solution to overcome the complexities currently associated with retrofit projects for more sustainable heat generation.

Factors to consider before embarking on a refurbishment programme

Time
How urgent is the need for refurbishment? How much time is there to complete the work? This will determine which solutions should be delivered and when to achieve the desired outcomes.

Suitability
When considering installing heat pumps, there are a number of additional considerations.

Budget
This is a significant factor for schools and understanding what offers the most beneficial impact within budget is critical to prioritise performance.

Is the building sufficiently airtight?
Low carbon technologies perform best in well-insulated buildings.

Is there sufficient electricity supply?
Or will this require additional budget?

Is space limited?
Your preferred manufacturer may offer the option to make on-site installation easier with bespoke pre-packaged rigs and/or full turnkey-enabled plant rooms.

Tips for quick wins

Minimise heat loss

Reduce energy demand through increased energy efficiency. Simple actions like ensuring that pipework in unheated areas is well lagged is a practical step that will minimise heat loss within the building.

Test the water quality

Water quality has a significant impact on the performance of heating and hot water systems. Scale build up, settled sludge and microbiological contamination in a closed-circuit system can lead to inefficiencies, poor performance and potential equipment failure after even a relatively short period of time. Testing water quality at regular intervals can highlight any issues early on, helping to save money in the long run.

When installing new boilers, air and dirt separators should be specified as part of the system to ensure proper long-term operation. It is also useful to consider the use of a Plate Heat Exchanger (PHE) to achieve hydraulic separation between the boiler circuit and heating circuit.

Check the controls

Higher than expected energy consumption in buildings is often due to issues with Building Management Systems and controls, so this is an area where quick-win reductions in energy use and emissions can be made.

With new condensing boilers, we recommend including time, optimisation, full temperature control, weather compensation and sequencing controls which must be fully integrated into the Building Management System to maximise efficiency.

It's also worth reassessing the current use of the building so that heating times can be accurately matched to occupancy. Are any rooms not being used? Will the thermal temperature hold in the building for the last hour of the school day? If so, it might be possible to turn the heating off a little earlier. Similarly, while it's important to warm the building fabric before the start of the day, a slightly later start time might be an option. Turning the thermostat down by just 1°C could reduce heating bills by 10%, according to the Energy Saving Trust.

Fabric first

In its Heat and Buildings Strategy, the government recognises energy efficiency and heat pumps as key focus areas in the short term for decarbonising heat, while longer-term technologies like green hydrogen scale up.

Energy efficiency is absolutely critical to reducing emissions and should always be the first consideration when addressing existing school buildings – the cleanest and cheapest kWh of heat is, after all, the one we don't use.

What's more, as we have established, in order to make low carbon heat a viable proposition in many existing school estates, it's essential first to reduce the energy consumption in the building and ensure that the fabric is suitable.

One of the easiest ways to achieve this is to reduce heat loss and lower heat demand.

In simple terms, heat energy escapes from a building either via transfer or infiltration.

Transfer is a factor of the internal and external temperature difference and the U-values of the wall, doors, etc. that are insulating against heat loss. The colder it is outside, and the hotter inside, the faster heat will transfer. U-values are used to measure how effective the fabric is at slowing the rate of heat transfer from inside to outside and are measured in watts or kilowatts. The lower the U-value, the better the insulation.

Infiltration refers to how draughty the building is. Let's say we want the temperature in a classroom to be 18°C. If holes or gaps in the building fabric allow in cold outside air at 9°C (that is not controlled), more heat will be required to sustain the optimal temperature.

All buildings require a certain level of ventilation for air quality, damp prevention and general well-being – with new guidelines around building ventilation now in place following the Covid pandemic.

Trickle vents on windows and air vents are all controllable to a degree, but even a small vent can chill the room in winter, requiring extra energy to offset the incoming cold air. MVHR (Mechanical Ventilation with Heat Recovery) allows us to extract stale air and bring in fresh, filtered air – while recovering the heat extracted into the fresh air. This tempers the airflow and reduces the additional energy required to keep the room to temperature. The speed of the fans can also be adjusted and controlled, meaning the building can be even more 'airtight'.

Recommendations on a building-by-building basis

It's important to note that a fabric first approach cannot be generic or prescriptive but will need to be calculated on a building-by-building basis. Take an historic, listed school building. It might have thick walls that give good U-values and retrofit triple glazing, but it won't necessarily be a low heat loss building. The air infiltration might be extremely high, and it might be nearly impossible to find and plug all the gaps.

> "The cleanest and cheapest kWh of heat is the one we don't use"

Similarly, a hermetically sealed lightweight off-site fabricated building with MVHR won't necessarily be a low heat loss building as the U-values of the lightweight construction might not be very good.

The recommended action and when it should be carried out for maximum effectiveness will need to be based on budget, building type and invasiveness.

We encourage early engagement with our in-house team of experts, so that we can gain a full understanding of the problems, identify all the options, and support the project throughout – from design to completion and into maintenance – to deliver the most effective bespoke approach for each individual school building.

Laying firm foundations

Taking immediate action to reduce heating-related energy usage and emissions in older school buildings is key, both to support the UK's climate goals and to help protect tight school budgets against spiralling energy costs.

In school buildings where heat pumps are not currently an option, it's important to seize any achievable opportunities within the project parameters to use the fuel source more efficiently and lower energy consumption. One example is to install a more efficient system.

Upgrading an inefficient or ageing heating plant to more energy-efficient equipment is both relatively easy and economical and will deliver immediate impacts. Replacing older boilers with modern condensing boilers that are up to 20% more efficient than non-condensing units will enable schools to make immediate and ongoing energy and carbon savings.

As the heat generation plant is typically the heart of the system generating the heat, it can have a significant impact on energy and emission savings.

Retrofitting more energy-efficient technology will also provide an immediate solution for schools that face inadequate heating and hot water provision, improving comfort levels and removing an unnecessary financial burden due to faulty or failing equipment.

Operating temperatures

On most projects it should be possible to address the system's distribution pipework and heat emitters to operate at lower temperatures than the traditional 82°C/71°C or 80°C/60°C flow and return system designs. This will allow the condensing boilers to operate in condensing mode, where they achieve their maximum efficiencies. It will also future proof the building and prepare the heating system for the integration of low carbon technologies at a later stage, as these operate most efficiently at low temperature outputs.

Future-ready boilers

Schools will understandably want to ensure that any technologies installed today are both future-proof and future-ready.

So where does this leave gas boilers? We see hydrogen as a key pillar of the energy transition (and are one of only a few manufacturers to have developed a 100% hydrogen boiler) and another option to decarbonise our heating and hot water. But it's important to note that the first stage of the energy transition is expected to be the introduction of a 20% hydrogen blend into the natural gas mix.

> "We see hydrogen as a key pillar of the energy transition and another option to decarbonise our heating and hot water"

Modern condensing boilers are able to run on this blend. For added assurance of a future-proof installation, our Remeha Quinta Ace and Gas 320/620 Ace condensing boiler ranges have independent certification of their ability to operate on the proposed 20% hydrogen blend. For more information on hydrogen for heat and the projected timelines, download our free guide.

Maximum BREEAM points

Nitrogen oxide (NOx) emission levels are likely to be a further consideration when selecting boiler replacement models to optimise the sustainability of the installation.

Why the focus on NOx? Air quality in schools is a key environmental issue due to the established link between poor air quality and health and wellbeing. While road traffic has been identified as a major source of NOx emissions, almost all buildings emit air pollution due to combustion in their heating, cooling or electricity generation systems.

BREEAM 2018, the widely adopted building sustainability assessment scheme, awards a maximum of two credits for boilers with low NOx emissions below 24 mg/kWh in both high and low pollution areas.

Look for boiler models like our Remeha Quinta Ace and Gas 320/620 Ace ranges that can achieve NOx emissions below 24 mg/kWh at no cost to performance for maximum BREEAM credits.

In the next section, we assess the achievable savings from the first two steps of the phased refurbishment programme in both a primary and a secondary school using our sophisticated simulation software that allows us to plan, design and optimise holistic heating systems.

Primary school simulation

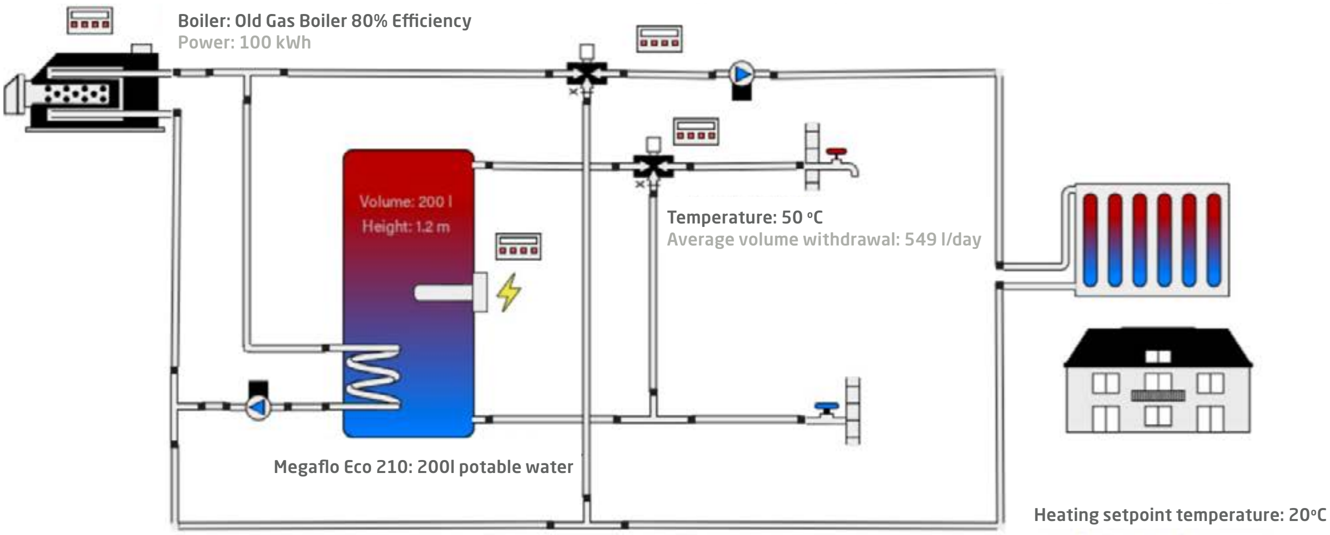
Let's consider the saving potential from improving the building fabric and carrying out a boiler replacement in a primary school.

Today

For the purpose of the comparison, we have assumed a small primary school with seven classrooms, corridors, an assembly hall /dining area, a kitchen, staff rooms and offices and toilets. The school has seven year groups with 30 children in each class, making 210 pupils in total, or approximately 200 with absences.

See appendix for full simulation

Primary school (pressure jet gas boiler, high/low operation)



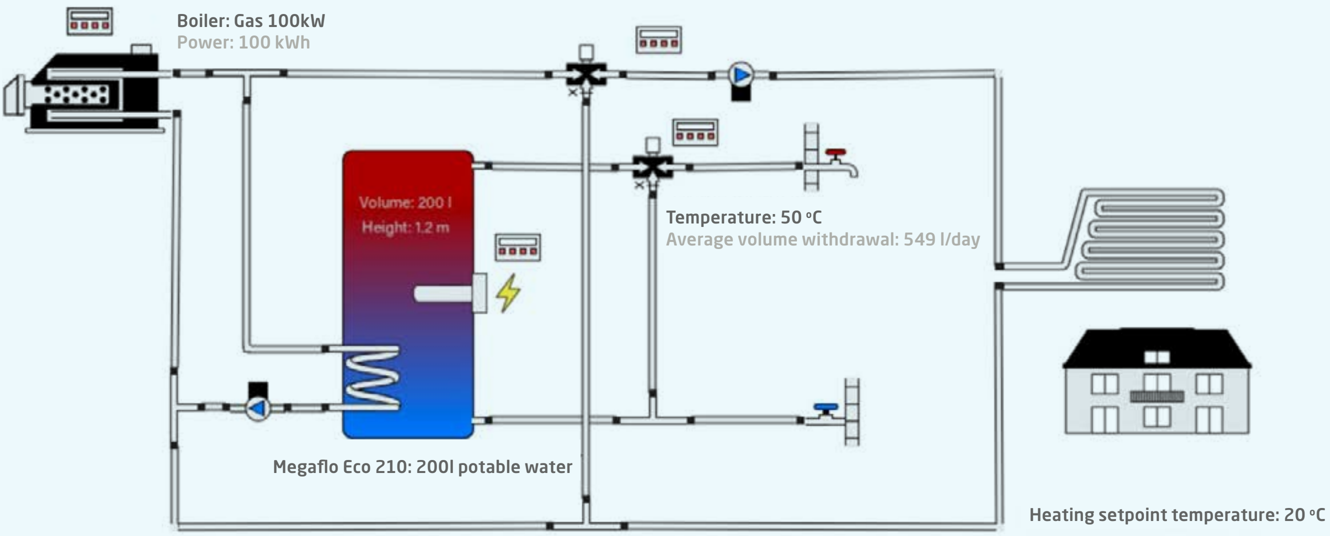
A typical installation for an existing school of this size will be an old 100 kW non-condensing gas boiler, running at 80% efficiency for heat, with a 200l indirect hot water cylinder. Our simulation software calculates the total annual fuel and/or electricity consumption of the system to be 234,797 kWh.

Phase One

If we follow the recommended stepwise approach, carry out fabric improvements and upgrade to modern, fully modulating pre-mix gas boilers, the calculations identify a fall in total annual fuel and/or electricity consumption of the system to 155,400 kWh.

That's a reduction in annual energy consumption of just under 34%. Using SAP 10.2 carbon intensity figures of 0.21 for gas and 0.136 for electric, we calculate that **the annual carbon savings from this approach are 16,673 kg**. See appendix for full simulation

Primary school (fabric first modern pre-mix gas boiler, modulating operation)



Primary school		Total annual fuel and/or electricity consumption of the system (kWh)	Total annual gas consumption (kWh)	Total annual electricity consumption (kWh)
Today	Old gas boiler 80% efficiency 100 kW with 200l Indirect water cylinder	234,797	234,679	118
Phase One	Fabric first improvements and upgrade to modern fully modulating pre-mix gas boiler 100 kW with 200l Indirect water cylinder	155,400	155,280	119

Note – Electrical consumption is based on usage of heating appliances and circulation pumps only.

Secondary school simulation

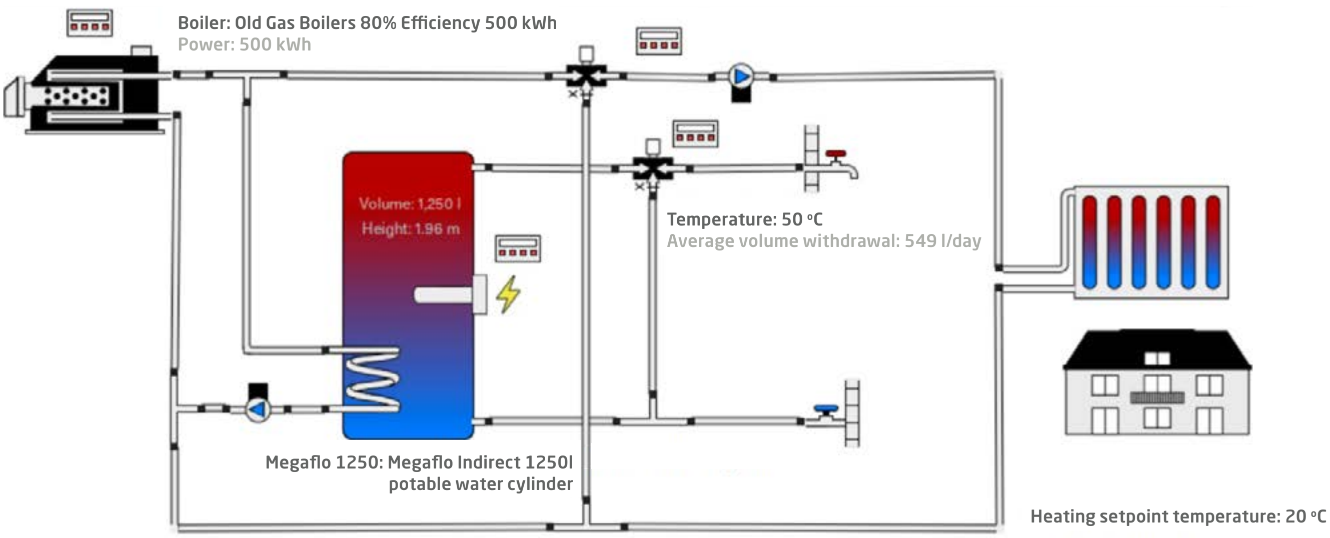
Today

Now let's carry out the same calculations for a secondary school. The assumption here is a secondary school with 40 classrooms, an assembly/sports hall, shower block with 10 showers and 10 changing rooms, a kitchen, dining area, offices and corridors. The school has 1,000 children enrolled.

The school relies on an old 500 kW non-condensing gas boiler, running at 80% efficiency for heat, with a 1,200l indirect hot water cylinder.

Our simulation software calculates the total annual fuel and/or electricity consumption of the system to be 1,081,994 kWh. See appendix for full simulation

Secondary school (pressure jet gas boiler, high/low operation)



Phase One

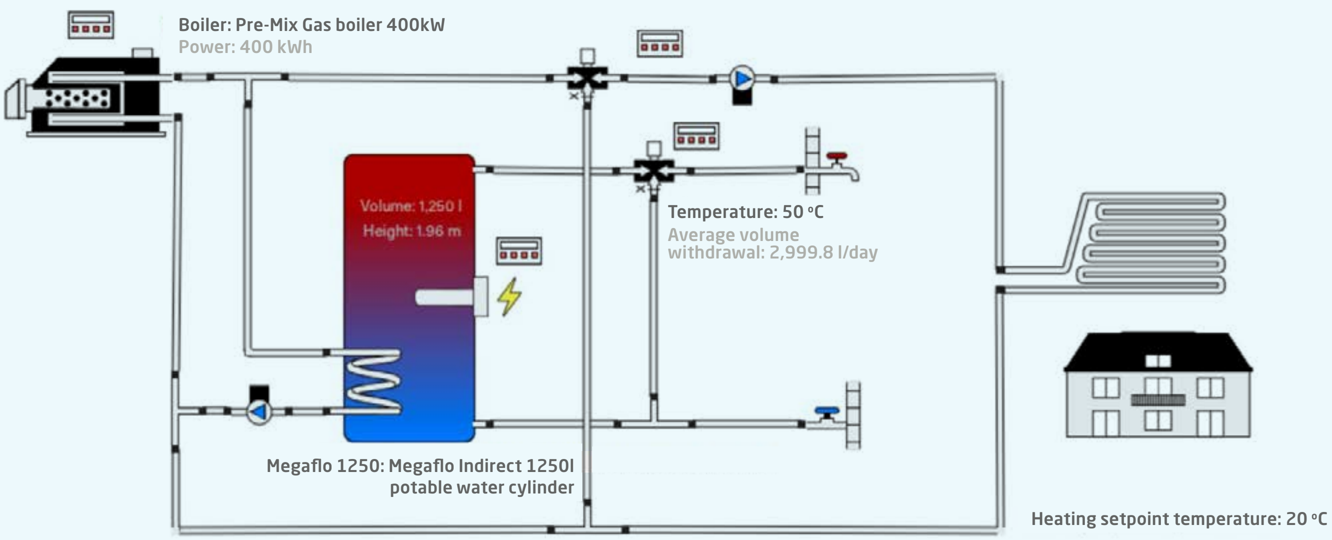
The same recommendation as used for the primary school simulation is applied, fabric improvements and the boiler replaced with modern, fully modulating pre-mix gas boilers with an output of 400 kW. This time, the software calculates **a fall in total annual fuel and/or electricity consumption of the system to 682,380 kWh**.

See appendix for full simulation

That's a reduction in annual energy consumption of just under 37%. Using SAP 10.2 carbon intensity figures of 0.21 for gas and 0.136 for electric, we calculate that **the annual carbon savings from this approach are 83,918 kg**.

These simulations demonstrate the value of carrying out relatively low cost, affordable measures to help schools improve conditions for students and teachers while mitigating building operating costs.

Secondary school fabric first (modern pre-mix gas boiler, modulating operation)



Secondary school		Total annual fuel and/or electricity consumption of the system (kWh)	Total annual gas consumption (kWh)	Total annual electricity consumption (kWh)
Today	Old non-condensing gas boilers, 80% efficiency, 500 kW Indirect 1,250 hot water cylinder	1,081,994	1,081,871	122
Phase One	Fabric first improvements, upgrade to 400 kW modern premix modulating gas condensing boiler Indirect 1,250 hot water cylinder	682,380	682,251	129

Note – Electrical consumption is based on usage of heating appliances and circulation pumps only.

Multivalent heat pump systems

Once the building and heating and hot water system have been successfully brought up to standard, we see multivalent systems as a natural progression on the path to net zero.

Multivalent heat pump systems are an effective means of overcoming typical project limitations in existing buildings and meeting heat demand more sustainably. In a well-designed system, they will reduce both greenhouse gas emissions and energy consumption, thereby helping schools meet their sustainability targets.

Utilising existing or new high efficiency combustion fuelled appliances like condensing boilers with heat pumps is time proven to decarbonise a large portion of the annual heat demand.

We are pleased to have added our Remeha E-HP AW Air Source Heat Pump range (44 kW, 88 kW and 168 kW outputs) to our sustainable heating and hot water product portfolio.

> “Multivalent heat pump systems are an effective means of overcoming typical project limitations in existing buildings and meeting heat demand more sustainably”

Multivalent heat pump system design

Technical design is a critical area where experienced manufacturers should be able to provide valuable support. For example, all too often we have seen a primary and secondary heat generation methods fight against each other, ultimately at the cost of system efficiency.

Considering the optimal operational design conditions of both technologies, including the hydronic design, is essential to maximise heat pump utilisation while maintaining system performance and overall efficiency.

A multivalent system working in perfect balance should only use condensing boilers to overcome limitations imposed by operational factors and to ensure building performance at all time.

To achieve this, we must firstly calculate a sizing proposal that maximises contribution performance while taking all constraints into account. These will not necessarily prevent the integration of heat pumps, but they will guide the sizing principles required to deliver best performance.

Secondly, we must ensure that hydronic integration with peak or back up heat generation does not penalise the efficiency or performance of the system.

Flow and return temperatures, temperature differentials (ΔTs), controls and ultimately the detailed design must be taken in careful consideration when blending the technologies.

The controls strategy is key to ensuring that multivalent systems perform and should be aligned as early as possible in the project. Care should also be taken in the selection of the thermal store, to one that avoids mixing by making use of baffles and sparge pipes etc.

Our expert team will be able to provide advice on these aspects to address and avoid any conflict and so ensure optimal outcomes.

Factors to consider when designing a multivalent heat pump system

1. Has the system been designed in such a way that it maximises heat pump contribution performance while taking into account project limitations?
2. Does the design optimise the efficiency of both technologies?
3. Have flow and return temperatures, ΔTs, controls and the detailed hydronic design been carefully considered when blending the technologies?
4. Ensure you consult with the manufacturer to benefit from specialist technical and product knowledge

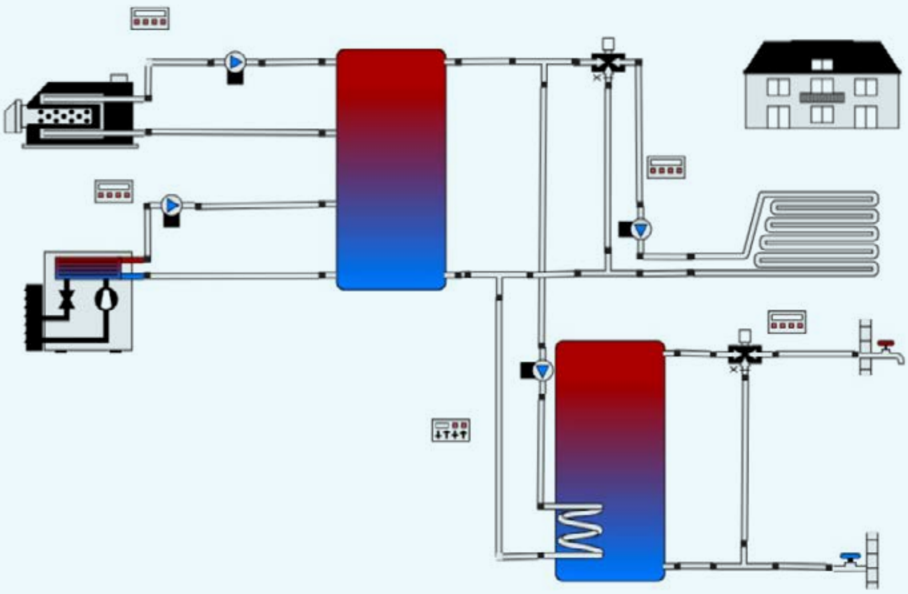
Multivalent simulation – primary school

Phase Two

To understand the potential carbon and kW savings from installing a multivalent heat pump system, let's return to the same primary and secondary schools. If we integrate a Remeha E-HP AW 44 kW Air Source Heat Pump into the system, the simulation reveals that **the annual savings from the heat pump are almost 72,000 kW at the primary school. The heat pump also achieves an annual carbon reduction of 38,500 kg**.

See appendix for full simulation

Primary school (fabric first, multivalent system)



Overview heat pump (annual values)	
Seasonal performance factor for air-to-water heat pump	3.1
Total electricity consumption when heating (Eaux)	33,831 kWh
Total energy savings	71,746 kWh
Total reduction on CO_2 emissions	38,484 kWh

Primary school		Total annual fuel and/or electricity consumption of the system (kWh)	Total annual gas consumption (kWh)	Total annual electricity consumption (kWh)
Today	Old non-condensing gas boilers, 80% efficiency, 100 kW Indirect 200l hot water cylinder	234,797	234,679	118
Phase One	Fabric first improvements, upgrade to 100 kW modern premix modulating gas condensing boiler Indirect 200l hot water cylinder	155,400	155,280	119
Phase Two	Fabric first improvements and multivalent system	75,332	41,398	33,934

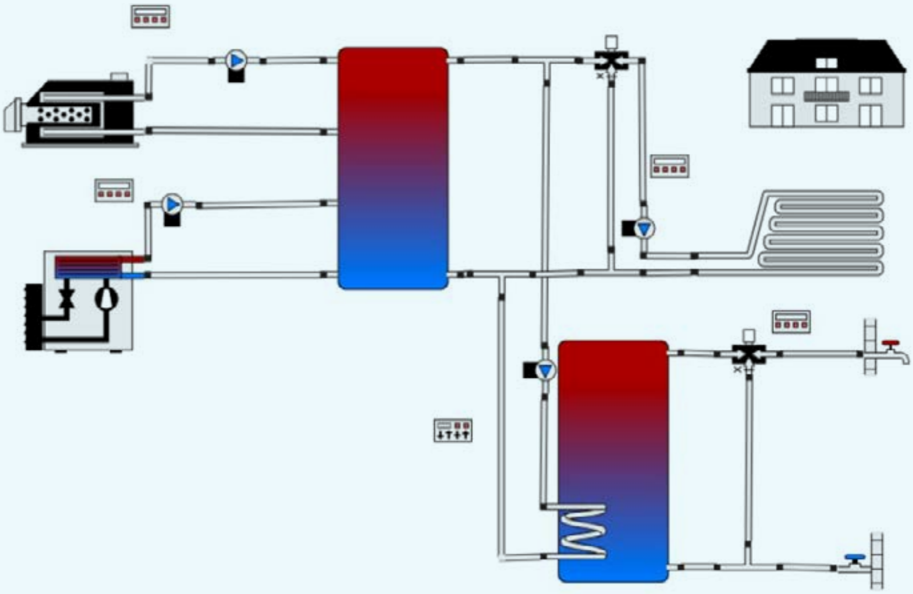
Multivalent simulation – secondary school

Phase Two

These simulations illustrate the importance of taking the appropriate steps at the right time and prioritising performance at every stage to deliver a successful decarbonisation programme. Taking a similar multivalent approach in the secondary school, **the annual energy savings from the heat pump amount to almost 134,000 kWh with an annual reduction in CO_2 of 235,006 kg**.

See appendix for full simulation

Secondary school (fabric first, multivalent system)



Overview heat pump (annual values)	
Seasonal performance factor for air-to-water heat pump	3.5
Total electricity consumption when heating (Eaux)	53,889 kWh
Total energy savings	133,724 kWh
Total reduction on CO_2 emissions	71,729 kWh

Secondary school		Total annual fuel and/or electricity consumption of the system (kWh)	Total annual gas consumption (kWh)	Total annual electricity consumption (kWh)
Today	Old non-condensing gas boilers, 80% efficiency, 500 kW Indirect 1,250 hot water cylinder	1,081,994	1,081,871	122
Phase One	Fabric first improvements, upgrade to 400 kW modern premix modulating gas condensing boiler Indirect 1,250 hot water cylinder	682,380	682,251	129
Phase Two	Fabric first improvements and multivalent system – 400 kW premix boiler and E-HP AW 44	561,318	54,105	507,213

Designing the future of heat

Every building will have its own individual requirements. Our expert Baxi team is at hand to advise and guide you towards designing the right solution, whatever the size or complexity of your project.

We not only have the technology to deliver the right solution for every school type but back it with years of experience supporting schools and their heating systems.

We also know how to maximise the efficiency and effectiveness of our sustainable heating and hot water technologies, which makes us a useful resource to utilise from the outset.

Here's a snapshot of our sustainable heating and hot water portfolio.

Air Source Heat Pumps	Remeha E-HP AW Air Source Heat Pump range – 44 kW, 88 kW, 168 kW	Tailor-made for stand-alone or multivalent installations. Quiet, smart and exceptionally energy efficient. Can be seamlessly integrated with other Remeha products and heat sources to provide sustainable heating and hot water solutions for new build and retrofit applications
Commercial thermal stores	Commercial hot water cylinders and buffer vessels	High performance range of hot water cylinders and buffer vessels to meet all commercial requirements for both new build and refurbishment applications
Aluminium condensing boilers	Remeha wall hung and floor standing range – 20% Hydrogen compatible, low NOx condensing boilers	Comprehensive, quality boiler range of Quinta Ace wall hung boilers and Gas series floor standing boilers. Cascade and bespoke rig options ensure compact footprint and time and space saving installation
Stainless steel condensing boilers	Potterton Commercial Sirius three FS and WH range – 20% Hydrogen compatible, low NOx condensing boilers with cascade options	Durable, dependable aluminium boiler range with cascade and rig options. Individual outputs from 50 to 525 kW
Direct fired water heaters	Andrews Water Heaters condensing water heater range	High quality, high performing gas fired water heater range that meets the higher efficiency standards required by changes to Part L
Hot water cylinders and electric boilers	Heatrae Sadia	Market-leading electric heating and hot water products for domestic and commercial hot water, and hygiene and drinking water solutions
Bespoke designed rig systems	Remeha Quinta Ace Remeha Gas 220 Ace cascade arrangement	Turnkey solutions designed bespoke to project requirements. Can include boilers, sized pump sets, sized PHE, dosing pot, pressurisation unit and expansion vessel. Perfect for projects with time or space constraints
Packaged solutions	Tailor-made, quality controlled, prefabricated modular systems	Complete packaged plantroom design and manufacture service for time and space saving solutions, and design and cost certainty

Working together in energy

Our schools can act now to make significant improvements to the performance of their vital heating and hot water systems and set their building on the path to net zero. But it's essential to take a holistic approach to system design and focus on solutions rather than products to prioritise performance and practicality.

School buildings are often challenging projects for refurbishment. Estates managers, consultant engineers, M&E contractors and installers can face an array of issues from working in a listed building to dealing with extremely tight project deadlines. Plotting an achievable pathway to improved sustainability can be vital to deliver successful outcomes in older buildings.

We at Baxi are here to work alongside you and provide specialist technical support. As experts in heating systems and controls, we understand both the potential problems facing schools and the opportunities for improvement. From specification and design to supply and technical support, our customer service is second to none.

A major advantage of engaging and working with experienced manufacturers is that we will be able to help identify and deliver a solution based around each individual building and bespoke to its unique requirements.

By asking the right questions, we can gain a clear understanding of the school's long-term goals and so help plan and set an achievable pathway to improved sustainability. Early engagement and collaborative working will make it easier to identify and deliver a solution based around each individual school building and bespoke to its unique requirements.

Our comprehensive portfolio of sustainable commercial heating and hot water solutions includes some of the best-known brands in the industry – Remeha, Andrews Water Heaters, Potterton Commercial and Heatrae Sadia.

Today, our continually expanding and evolving range encompasses commercial Air Source Heat Pumps low-NOx, certified 20% hydrogen blend compatible boilers, electric and gas water heaters, hot water cylinders, combined heat and power units, heat interface units, heat network equipment, and advanced controls. We also offer a bespoke design and manufacture service for pre-packaged rigs and full turnkey-enabled plant rooms for easy on-site installation and reduced health and safety risks.

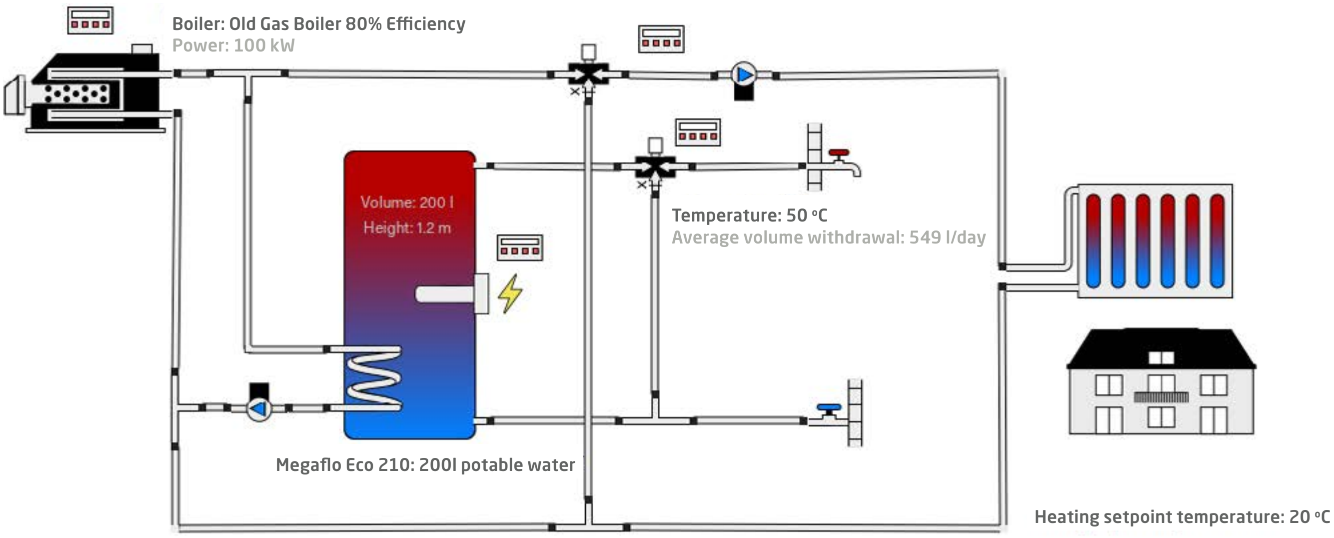
> “It's essential to take a holistic approach to system design and focus on solutions rather than products to prioritise performance and practicality”

Appendices

Primary and secondary schools scenarios

1 Today – Non-condensing boiler

Primary school (pressure jet gas boiler, high/low operation)



Location of the system

United Kingdom
Wokingham
Longitude: -0.83 °
Latitude: 51.42 °
Elevation: 52 m

System overview (annual values)	
Total fuel and/or electricity consumption of the system [Etot]	234,797 kWh
Total electricity consumption [Ecs]	118 kWh
Total gas consumption [Egas]	234,679 kWh
Total energy consumption [Quse]	184,989 kWh
System performance [(Quse+Einv) / (Eaux+Epar)]	0.79
Primary energy factor	1.4
Comfort demand	Energy demand covered

Meteorological data - overview	
Average outdoor temperature	10.8 °C
Global irradiation, annual sum	985 kWh/m²
Diffuse irradiation, annual sum	533 kWh/m²

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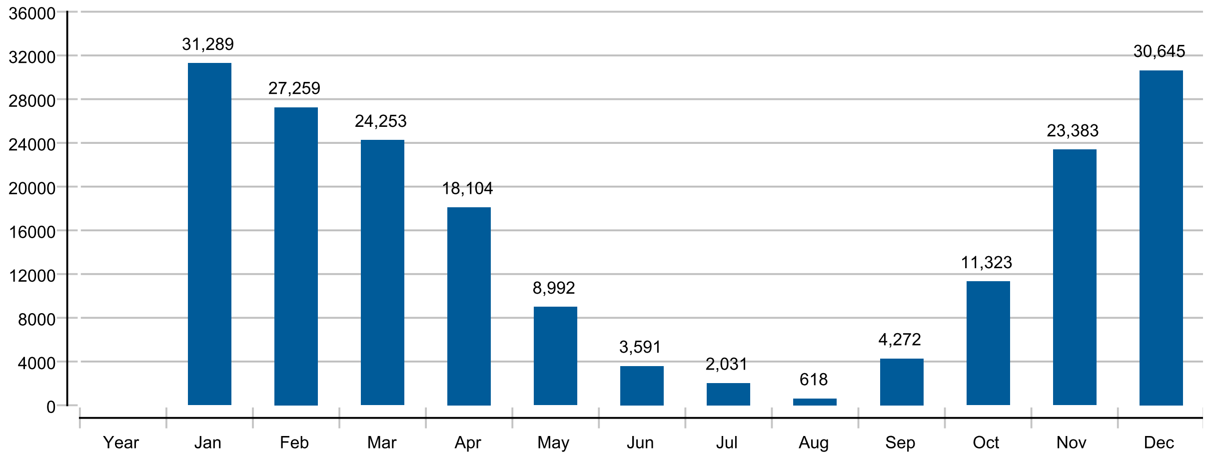
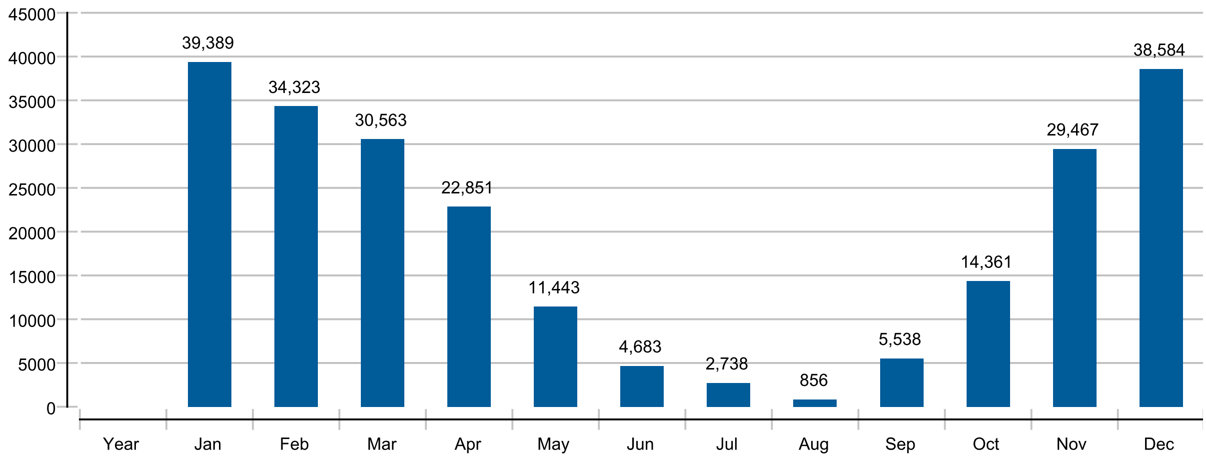
Professional report

Component overview (annual values)		
Boiler Old	**Gas boiler 80% efficiency**	
Power	kW	100
Total efficiency	%	79.2
Energy from/to the system [Qaux]	kWh	185,760
Fuel and electricity consumption [Eaux]	kWh	234,679
Fuel consumption of the back-up boiler [Baux]	m^3(gas)	22,350
Exhaust fumes losses [Qex]	kWh	46,936
Building	**-**	
Heating setpoint temperature	°C	20
Heating energy demand excluding DHW [Qdem]	kWh	184,800
Useful heat gain	kWh	369,600
Total energy losses	kWh	554,400
Heating/cooling element	**82-71C radiator system**	
Power per heating/cooling element under standard conditions	W	1,000
Nominal inlet temperature	°C	82
Nominal return temperature	°C	71
Net energy from/to heating/cooling modules	kWh	174,920
Hot water demand	**Daily peaks**	
Volume withdrawal/daily consumption	l/d	550
Temperature setting	°C	50
Energy demand [Qdem]	kWh	9,202
Pump heat source	**Eco, small**	
Circuit pressure drop	bar	0.243
Flow rate	l/h	620
Fuel and electricity consumption [Epar]	kWh	5.3
Pump heating loop	**Eco, medium**	
Circuit pressure drop	bar	1.603
Flow rate	l/h	10,920
Fuel and electricity consumption [Epar]	kWh	113
Storage tank potable water tank	**200l potable water**	
Volume	l	200
Height	m	1.2
Material		Stainless steel
Insulation		Rigid PU foam
Thickness of insulation	mm	80
Heat loss [Qhl]	kWh	207
Connection losses	kWh	160

Heat generator energy to the system (solar thermal energy not included) [Qaux] kWh



Total fuel and/or electricity consumption of the system [Etot] kWh



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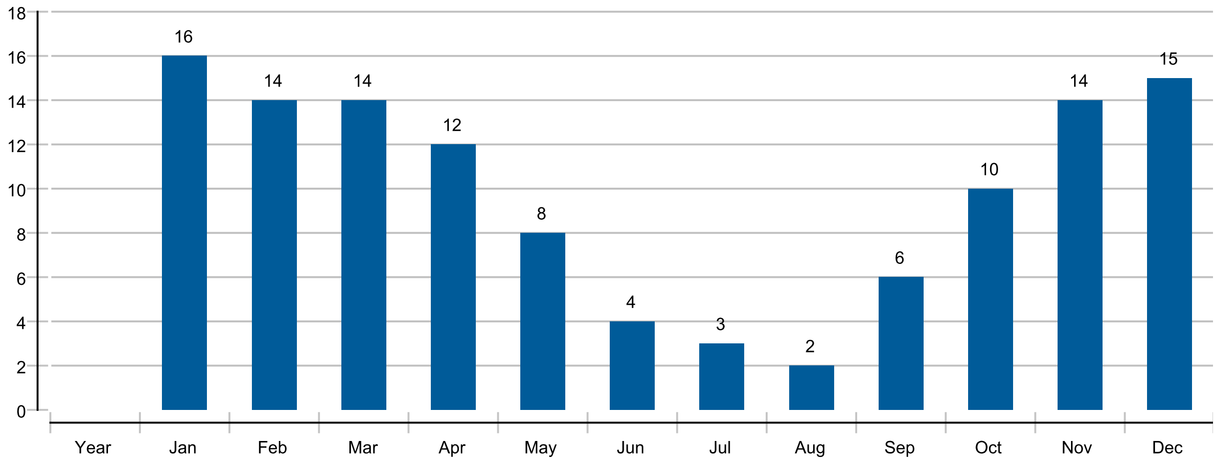
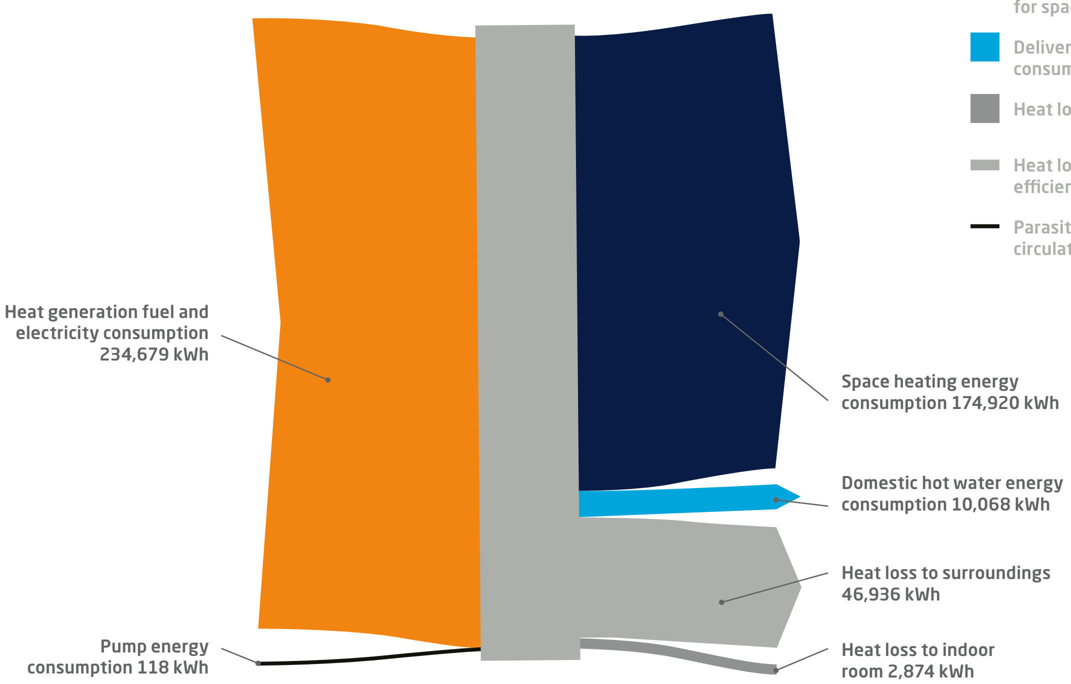
Total electricity consumption [Ecs]

kWh



Energy flow diagram (annual balance)

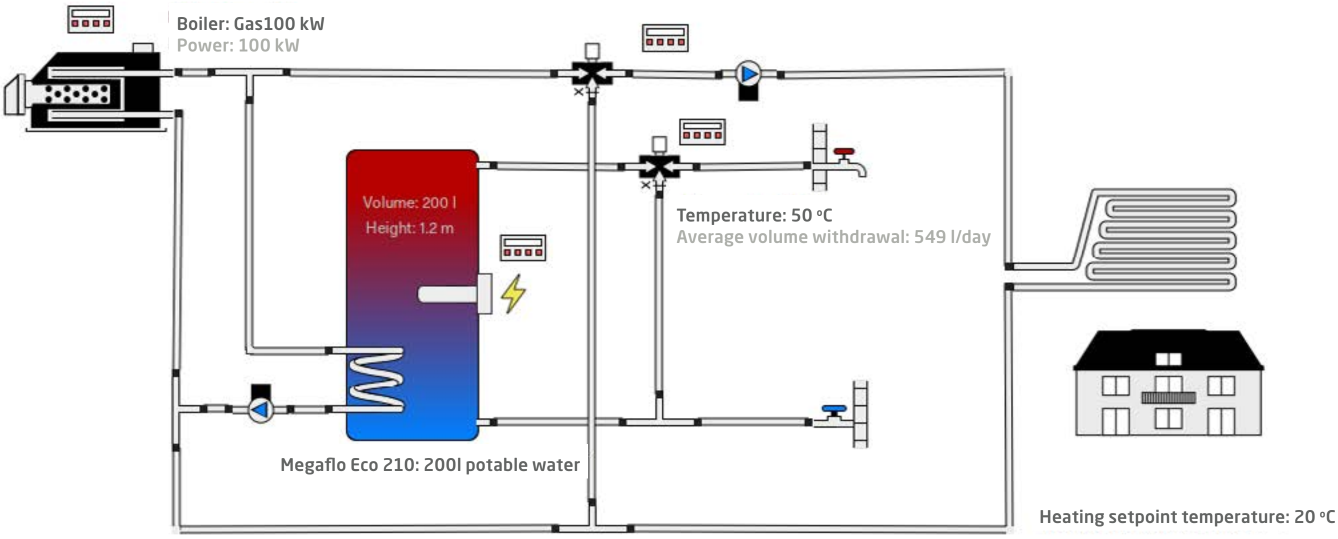


KEY

- Energy consumption natural gas
- Delivered energy to the building for space heating
- Delivered energy to the DHW consumption
- Heat loss to unheated areas
- Heat loss from building and boiler efficiency losses
- Parasitic energy usage from circulating pumps

[2] Phase One - Fabric first improvements, high efficiency replacement condensing boilers

Primary school (fabric first modern pre-mix gas boiler, modulating operation)



Location of the system

United Kingdom
Wokingham
Longitude: -0.83 °
Latitude: 51.42 °
Elevation: 52 m

System overview (annual values)	
Total fuel and/or electricity consumption of the system [Etot]	155,400 kWh
Total electricity consumption [Ecs]	119 kWh
Total gas consumption [Egas]	155,280 kWh
Total energy consumption [Quse]	137,688 kWh
System performance [(Quse+Einv) / (Eaux+Epar)]	0.89
Primary energy factor	1.24
Comfort demand	Energy demand covered

Meteorological data - overview	
Average outdoor temperature	10.8 °C
Global irradiation, annual sum	985 kWh/m^2
Diffuse irradiation, annual sum	533 kWh/m^2

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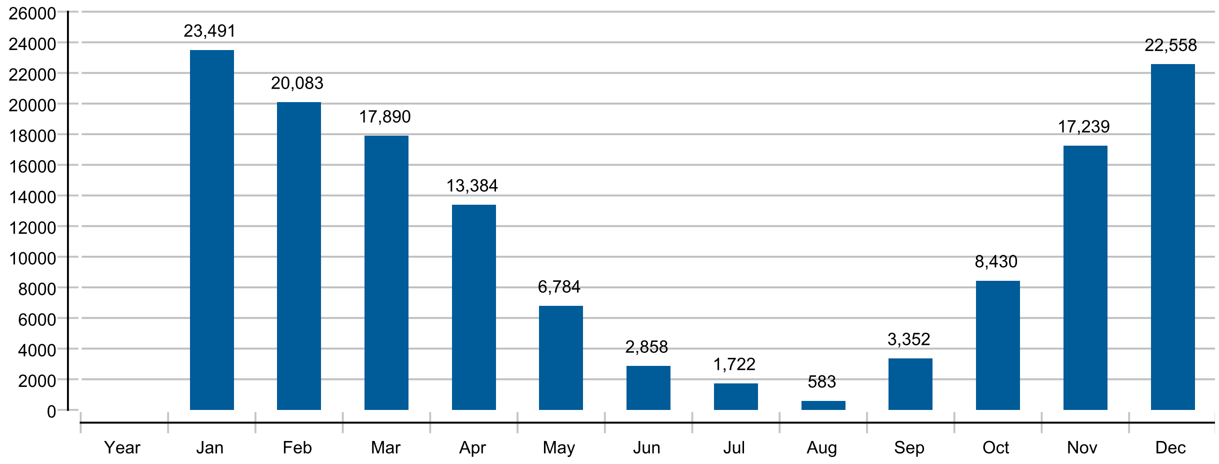
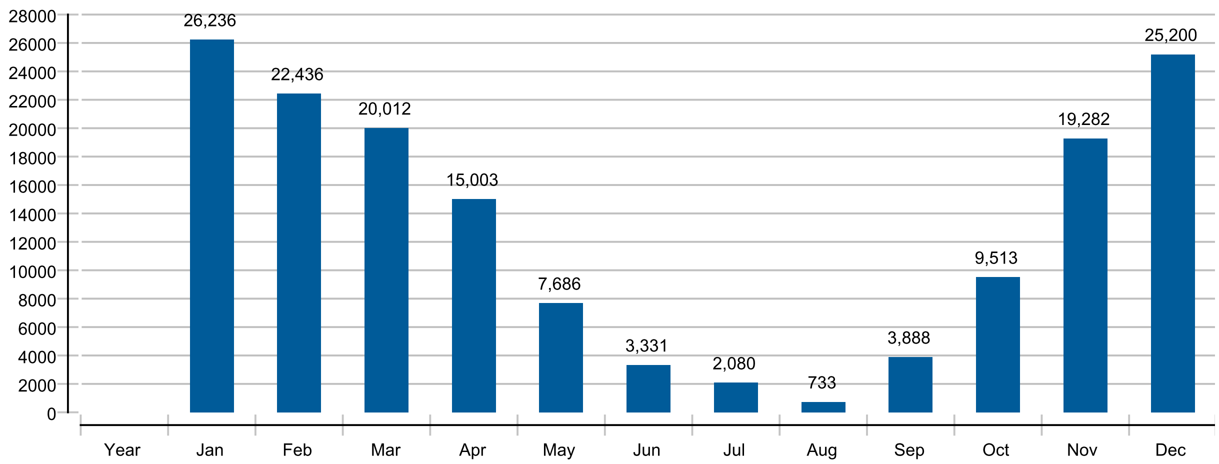
Professional report

Component overview (annual values)		
Boiler	**Gas 100kW**	
Power	kW	100
Total efficiency	%	89.1
Energy from/to the system [Qaux]	kWh	138,373
Fuel and electricity consumption [Eaux]	kWh	155,280
Fuel consumption of the back-up boiler [Baux]	m^3(gas)	14,789
Exhaust fumes losses [Qex]	kWh	15,528
Building	**-**	
Heating setpoint temperature	°C	20
Heating energy demand excluding DHW [Qdem]	kWh	138,600
Useful heat gain	kWh	277,200
Total energy losses	kWh	415,800
Heating/cooling element	**Floor heating**	
Power per heating/cooling element under standard conditions	W	1,000
Nominal inlet temperature	°C	40
Nominal return temperature	°C	35
Net energy from/to heating/cooling modules	kWh	127,471
Hot water demand	**Daily peaks**	
Volume withdrawal/daily consumption	l/d	550
Temperature setting	°C	50
Energy demand [Qdem]	kWh	9,202
Pump heat source	**Eco, small**	
Circuit pressure drop	bar	0.058
Flow rate	l/h	620
Fuel and electricity consumption [Epar]	kWh	6.1
Pump heating loop	**Eco, medium**	
Circuit pressure drop	bar	4.366
Flow rate	l/h	18,06
Fuel and electricity consumption [Epar]	kWh	113
Storage tank potable water tank	**200l potable water**	
Volume	l	200
Height	m	1.2
Material		Stainless steel
Insulation		Rigid PU foam
Thickness of insulation	mm	80
Heat loss [Qhl]	kWh	207
Connection losses	kWh	162

Heat generator energy to the system (solar thermal energy not included) [Qaux] kWh



Total fuel and/or electricity consumption of the system [Etot] kWh



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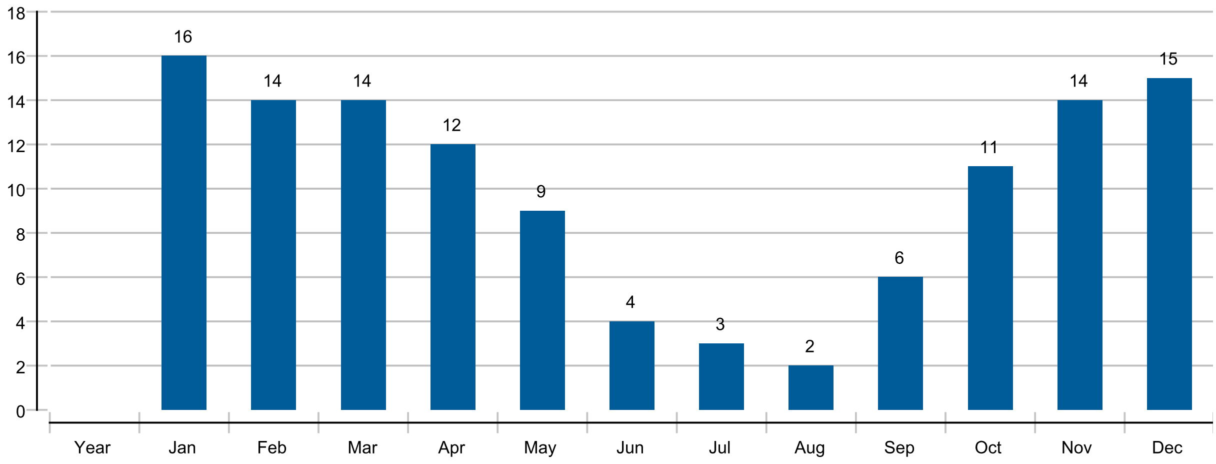
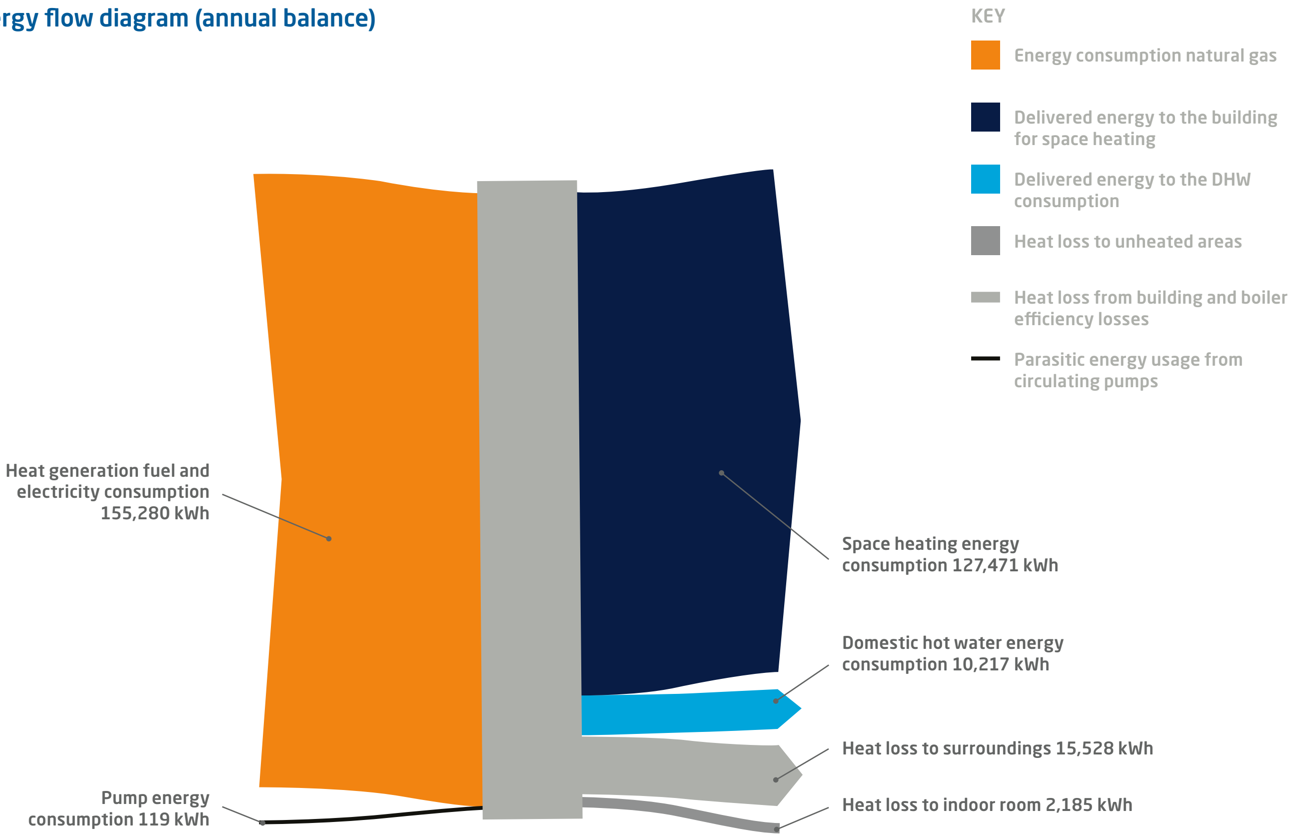
Total electricity consumption [Ecs]

kWh



Energy flow diagram (annual balance)



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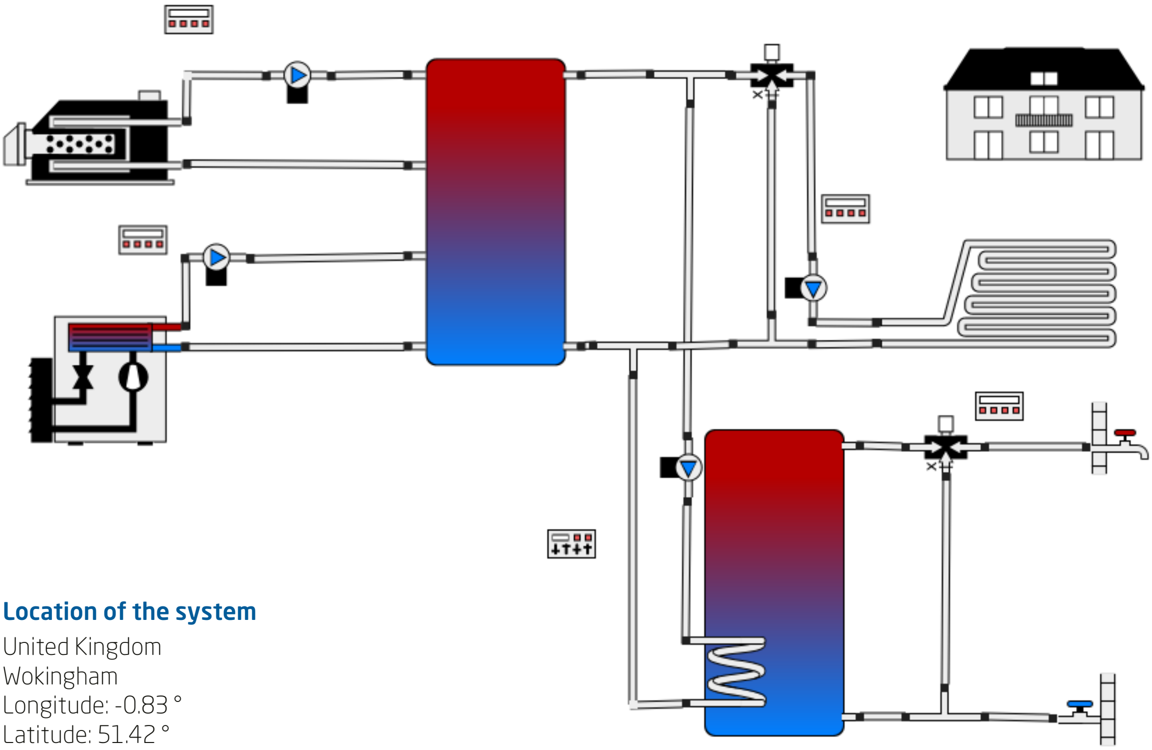
[3] Phase Two – Fabric first improvements, multivalent heat pump system

Primary school (fabric first, multivalent system)



Location of the system

United Kingdom
Wokingham
Longitude: -0.83 °
Latitude: 51.42 °
Elevation: 52 m

System overview (annual values)	
Total fuel and/or electricity consumption of the system [Etot]	75,332 kWh
Total electricity consumption [Ecs]	33,934 kWh
Total gas consumption [Egas]	41,398 kWh
Total energy consumption [Quse]	138,745 kWh
Seasonal performance factor (SPF-SHP)	1.8
Primary energy factor	0.77
Comfort demand	Energy demand covered

Overview heat pump (annual values)	
Seasonal performance factor for air-to-water heat pump	3.1
Total electricity consumption when heating [Eaux]	33,831 kWh
Total energy savings	71,746 kWh
Total reduction in CO_2 emissions	38,484 kg

Meteorological data – overview	
Average outdoor temperature	10.8 °C
Global irradiation, annual sum	985 kWh/m^2
Diffuse irradiation, annual sum	533 kWh/m^2

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Professional report

Component overview (annual values)		
Boiler electricity	**Gas 100kW**	
Power	kW	100
Total efficiency	%	86.2
Energy from/to the system [Qaux]	kWh	35,666
Fuel and electricity consumption [Eaux]	kWh	41,398
Fuel consumption of the back-up boiler [Baux]	m^3(gas)	3,943
Exhaust fumes losses [Qex]	kWh	4,140
Heat pump	**E-HP AW 44**	
Heating power at A2/W35	kW	30.4
Electrical power at A2/W35	kW	7.7
COP at A2/W35		3.9
DeltaT at A7/W35	K	5
Performance factor		3.12
Energy from/to the system [Qaux]	kWh	105,577
Fuel and electricity consumption [Eaux]	kWh	33,831
Energy savings heat pump	kWh	71,746
CO_2 savings heat pump	kg	38,484
Building 2	**-**	
Heating setpoint temperature	C	17
Heating energy demand excluding DHW [Qdem]	kWh	138,600
Useful heat gain	kWh	277,200
Total energy losses	kWh	415,800
Heating/cooling element 2	**Floor heating**	
Power per heating/cooling element under standard conditions	W	1,000
Nominal inlet temperature	°C	40
Nominal return temperature	°C	35
Net energy from/to heating/cooling modules	kWh	129,575
Hot water demand	**Daily peaks**	
Volume withdrawal/daily consumption	l/d	550
Temperature setting	°C	50
Energy demand [Qdem]	kWh	9,202
Pump 5	**Eco, small**	
Circuit pressure drop	bar	0.127
Flow rate	l/h	3,600
Fuel and electricity consumption [Epar]	kWh	2.5
Pump heating	**Eco, small**	
Circuit pressure drop	bar	5.446
Flow rate	l/h	23,392
Fuel and electricity consumption [Epar]	kWh	29.4

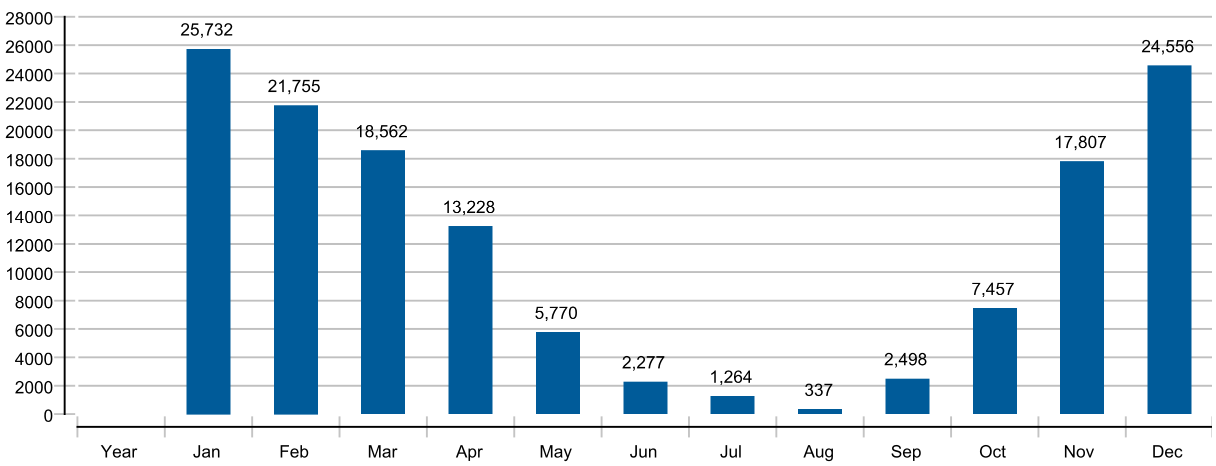
Pump heat pump loop	Eco, medium	
Circuit pressure drop	bar	0.714
Flow rate	l/h	7,540
Fuel and electricity consumption [Epar]	kWh	68.1

Pump 8	Eco, small	
Circuit pressure drop	bar	0.013
Flow rate	l/h	626
Fuel and electricity consumption [Epar]	kWh	2.8

Storage tank buffer	1500l buffer	
Volume	l	1,500
Height	m	2
Material		Steel
Insulation		Rigid PU foam
Thickness of insulation	mm	80
Heat loss [Qhl]	kWh	941
Connection losses	kWh	184

Storage tank 17	200l potable water	
Volume	l	200
Height	m	1.2
Material		Stainless steel
Insulation		Rigid PU foam
Thickness of insulation	mm	80
Heat loss [Qhl]	kWh	206
Connection losses	kWh	161

Heat generator energy to the system (solar thermal energy not included) [Qaux] **kWh**



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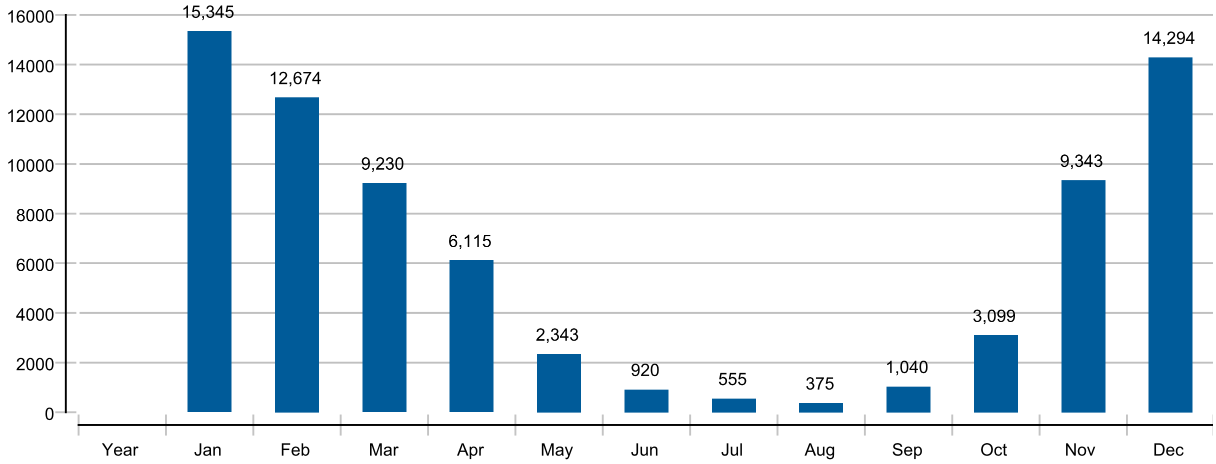
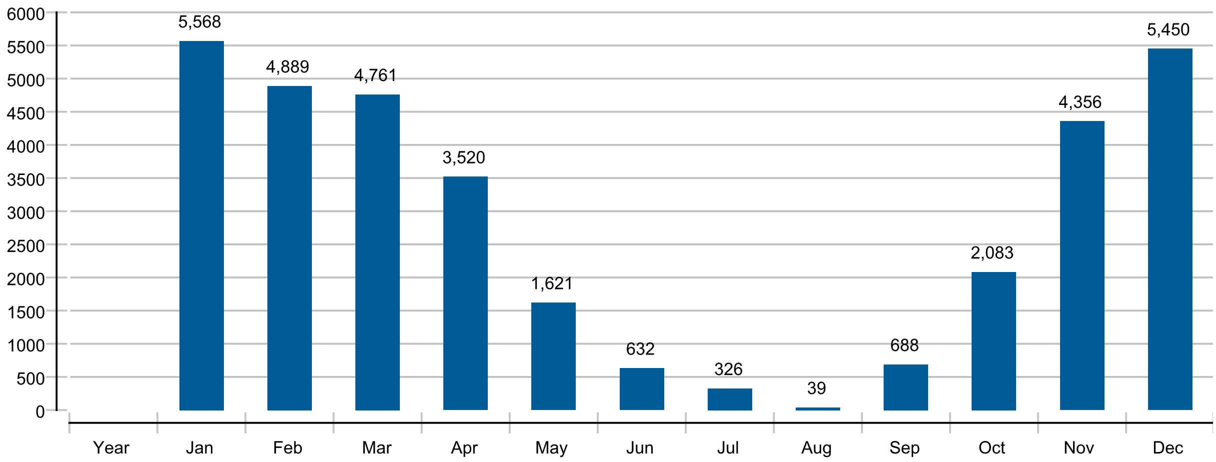
Total fuel and/or electricity consumption of the system [Etot]

kWh

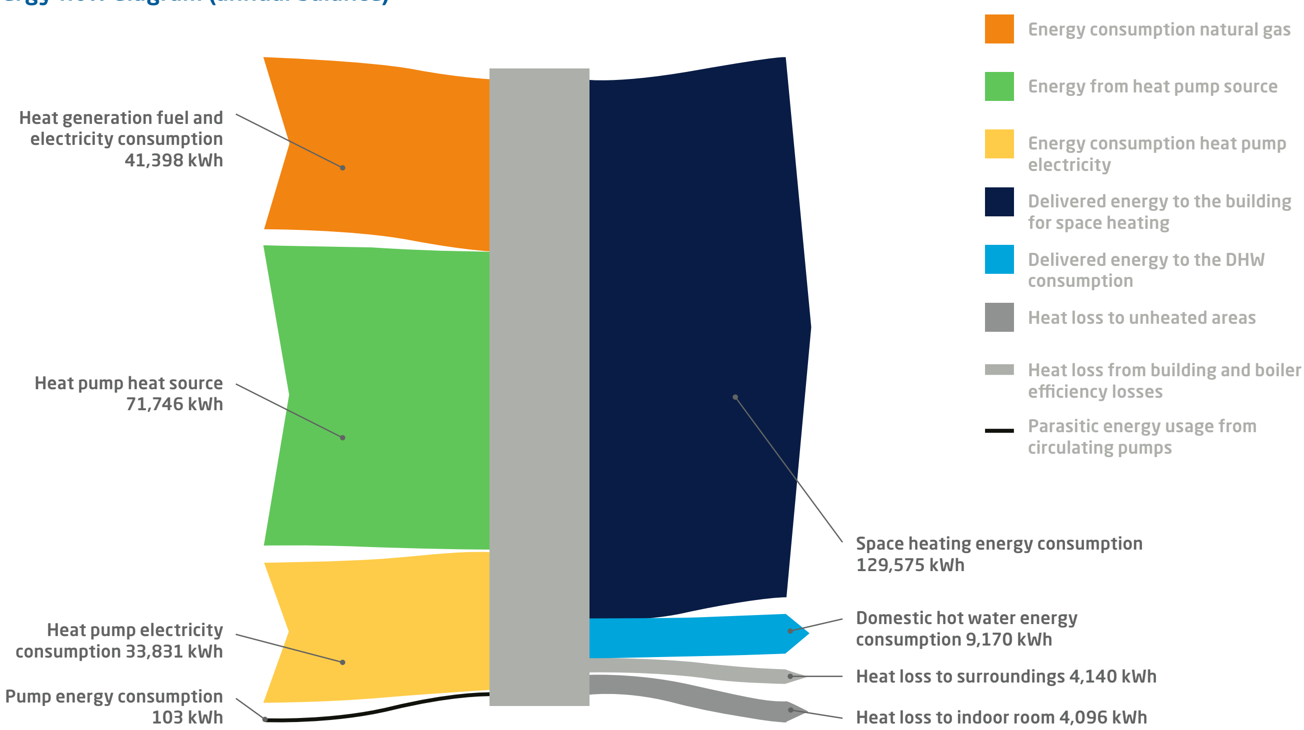


Total electricity consumption [Ecs]

kWh

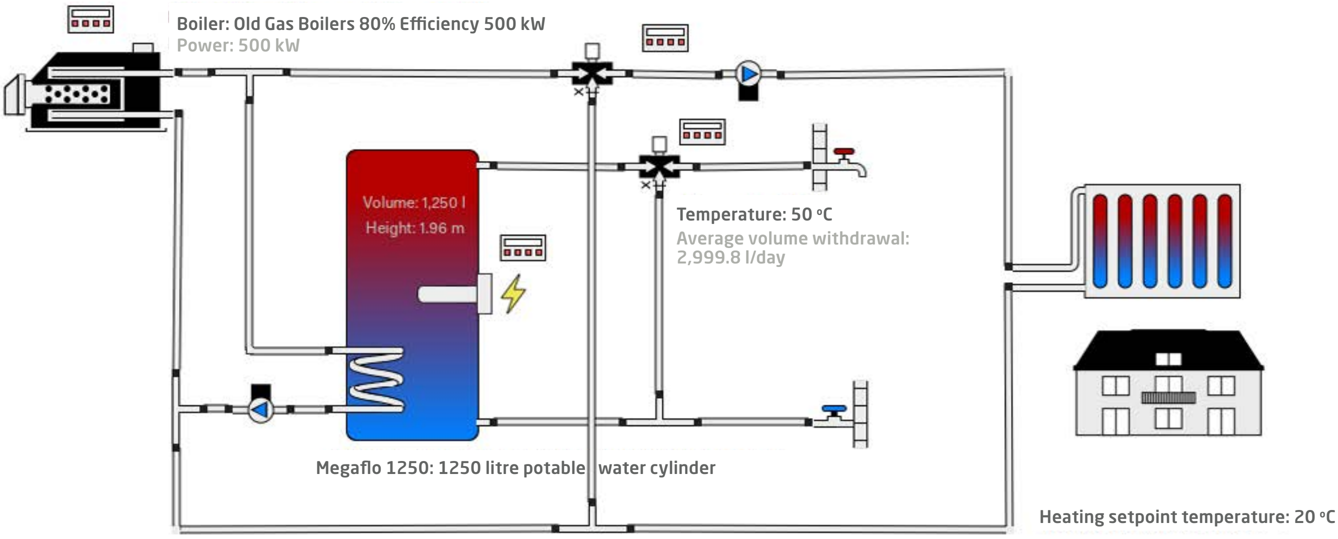


Energy flow diagram (annual balance)



[4] Today – Non-condensing boiler

Secondary school (pressure jet gas boiler, high/low operation)



Location of the system

United Kingdom
Wokingham
Longitude: -0.83 °
Latitude: 51.42 °
Elevation: 52 m

System overview (annual values)	
Total fuel and/or electricity consumption of the system [Etot]	1,081,994 kWh
Total electricity consumption [Ecs]	122 kWh
Total gas consumption [Egas]	1,081,871 kWh
Total energy consumption [Quse]	855,113 kWh
System performance [(Quse+Einv) / (Eaux+Epar)]	0.79
Primary energy factor	1.39
Comfort demand	Energy demand covered

Meteorological data – overview	
Average outdoor temperature	10.8 °C
Global irradiation, annual sum	985 kWh/m^2
Diffuse irradiation, annual sum	533 kWh/m^2

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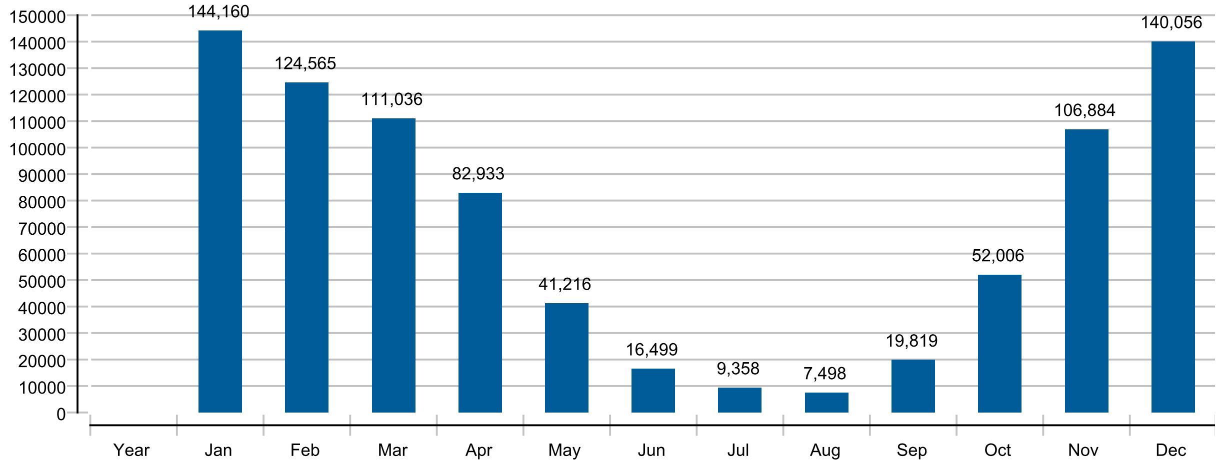
Professional report

Component overview (annual values)		
Boiler	**Old gas boilers 80% efficiency 500kW**	
Power	kW	500
Total efficiency	%	79.1
Energy from/to the system [Qaux]	kWh	856,030
Fuel and electricity consumption [Eaux]	kWh	1,081,871
Fuel consumption of the back-up boiler [Baux]	m^3(gas)	103,035
Exhaust fumes losses [Qex]	kWh	216,374
Building	**-**	
Heating setpoint temperature	°C	20
Heating energy demand excluding DHW [Qdem]	kWh	840,000
Useful heat gain	kWh	1,679,998
Total energy losses	kWh	2,519,998
Heating/cooling element	**82-71C radiator system**	
Power per heating/cooling element under standard conditions	W	1,000
Nominal inlet temperature	°C	82
Nominal return temperature	°C	71
Net energy from/to heating/cooling modules	kWh	801,400
Hot water demand	**Daily peaks**	
Volume withdrawal/daily consumption	l/d	3,000
Temperature setting	°C	50
Energy demand [Qdem]	kWh	49,865
Pump heat source	**Eco, small**	
Circuit pressure drop	bar	3.829
Flow rate	l/h	1,390
Fuel and electricity consumption [Epar]	kWh	9
Pump heating loop	**Eco, medium**	
Circuit pressure drop	bar	30.849
Flow rate	l/h	49,608
Fuel and electricity consumption [Epar]	kWh	113
Storage tank potable water tank	**Megaflo Indirect 1250 litre potable water cylinder**	
Volume	l	1,250
Height	m	1.96
Material		Stainless steel
Insulation		Rigid PU foam
Thickness of insulation	mm	100
Heat loss [Qhl]	kWh	374
Connection losses	kWh	64.7

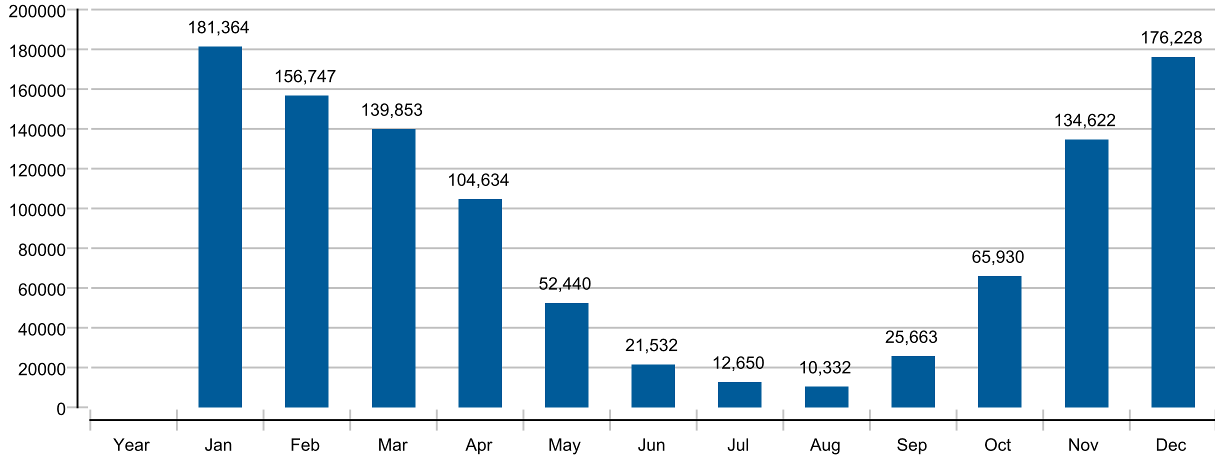
Heat generator energy to the system (solar thermal energy not included) [Qaux]

kWh



Total fuel and/or electricity consumption of the system [Etot]

kWh



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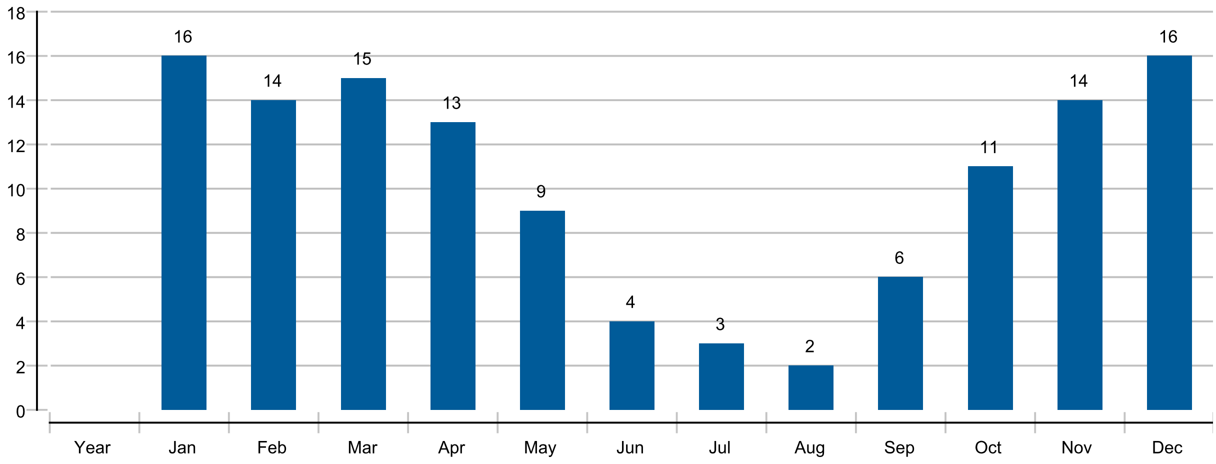
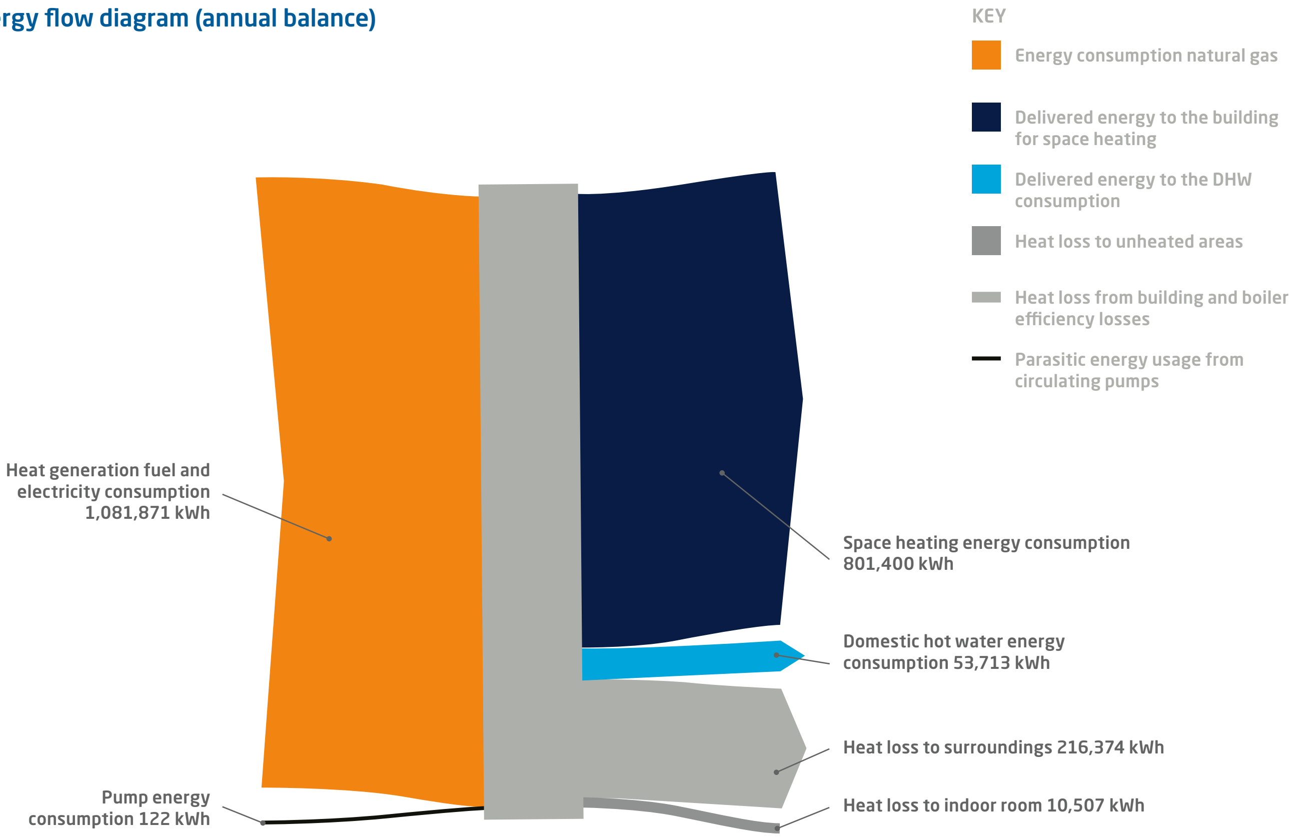
Total electricity consumption [Ecs]

kWh



Energy flow diagram (annual balance)



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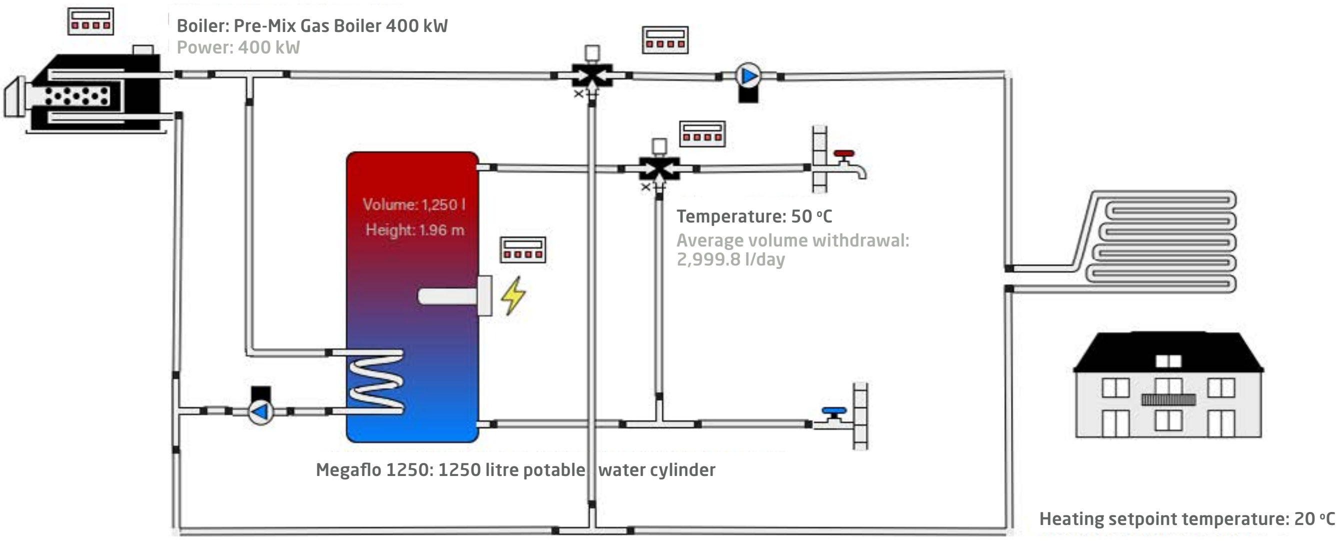
5 Phase One – Fabric first improvements, high efficiency replacement condensing boilers

Secondary school fabric first (modern pre-mix gas boiler, modulating operation)



Location of the system

United Kingdom
Wokingham
Longitude: -0.83 °
Latitude: 51.42 °
Elevation: 52 m

System overview (annual values)	
Total fuel and/or electricity consumption of the system [Etot]	682,380 kWh
Total electricity consumption [Ecs]	129 kWh
Total gas consumption [Egas]	682,251 kWh
Total energy consumption [Quse]	605,066 kWh
System performance [(Quse+Einv) / (Eaux+Epar)]	0.89
Primary energy factor	1.24
Comfort demand	Energy demand covered

Meteorological data – overview	
Average outdoor temperature	10.8 °C
Global irradiation, annual sum	985 kWh/m^2
Diffuse irradiation, annual sum	533 kWh/m^2

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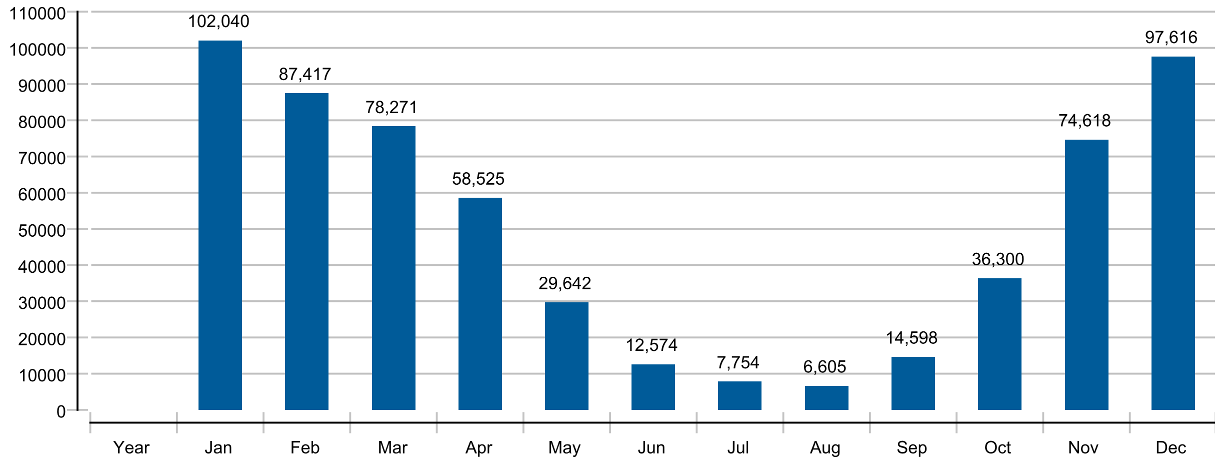
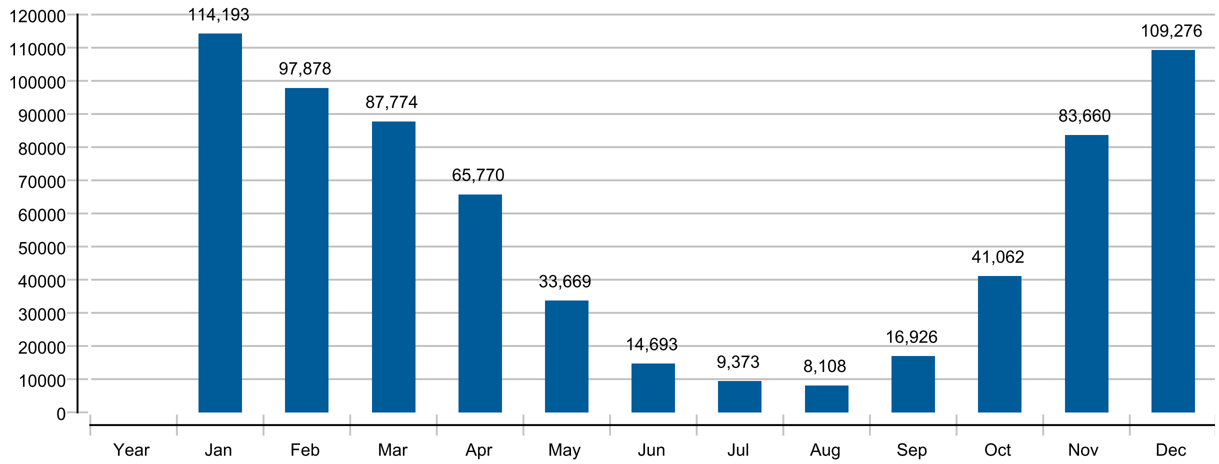
Professional report

Component overview (annual values)		
Boiler	**Pre-mix gas boiler 400kW**	
Power	kW	400
Total efficiency	%	88.8
Energy from/to the system [Qaux]	kWh	605,960
Fuel and electricity consumption [Eaux]	kWh	682,250
Fuel consumption of the back-up boiler [Baux]	m^3(gas)	64,976
Exhaust fumes losses [Qex]	kWh	68,225
Building	-	
Heating setpoint temperature	°C	20
Heating energy demand excluding DHW [Qdem]	kWh	630,000
Useful heat gain	kWh	1,259,999
Total energy losses	kWh	1,889,999
Heating/cooling element	**Floor heating**	
Power per heating/cooling element under standard conditions	W	1,000
Nominal inlet temperature	°C	50
Nominal return temperature	°C	40
Net energy from/to heating/cooling modules	kWh	550,262
Hot water demand	**Daily peaks**	
Volume withdrawal/daily consumption	l/d	3,000
Temperature setting	°C	50
Energy demand [Qdem]	kWh	49,866
Pump heat source	**Eco, small**	
Circuit pressure drop	bar	0.214
Flow rate	l/h	1,390
Fuel and electricity consumption [Epar]	kWh	16.3
Pump heating loop	**Eco, medium**	
Circuit pressure drop	bar	21.548
Flow rate	l/h	41,022
Fuel and electricity consumption [Epar]	kWh	113
Storage tank potable water tank	**Megaflo Indirect 1250 litre potable water cylinder**	
Volume	l	1,250
Height	m	1.96
Material		Stainless steel
Insulation		Rigid PU foam
Thickness of insulation	mm	100
Heat loss [Qhl]	kWh	394
Connection losses	kWh	74.9

Heat generator energy to the system (solar thermal energy not included) [Qaux] kWh



Total fuel and/or electricity consumption of the system [Etot] kWh



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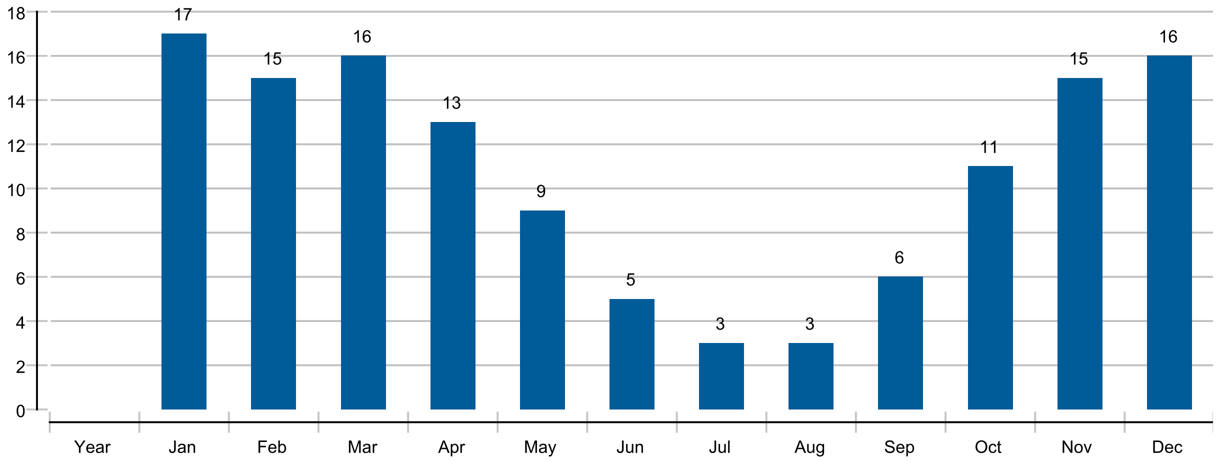
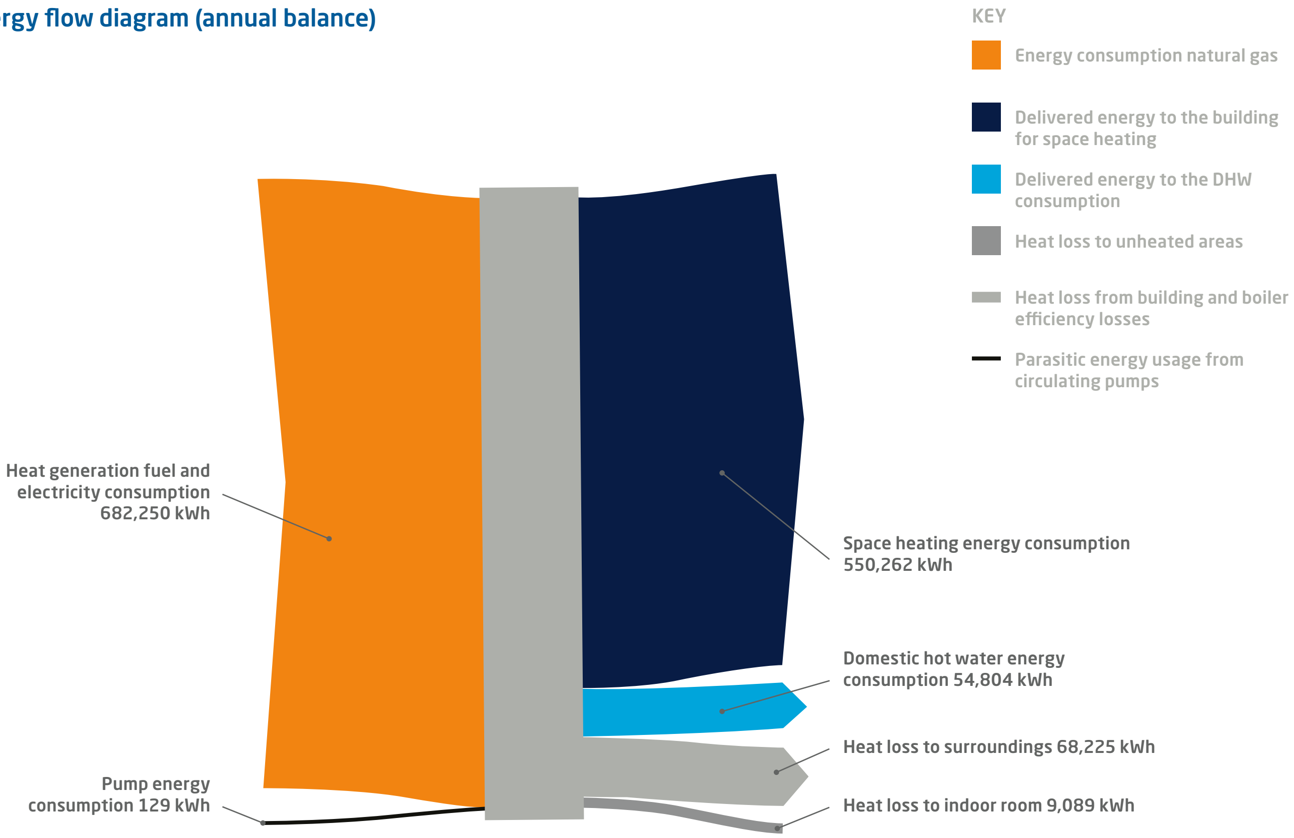
Total electricity consumption [Ecs]

kWh

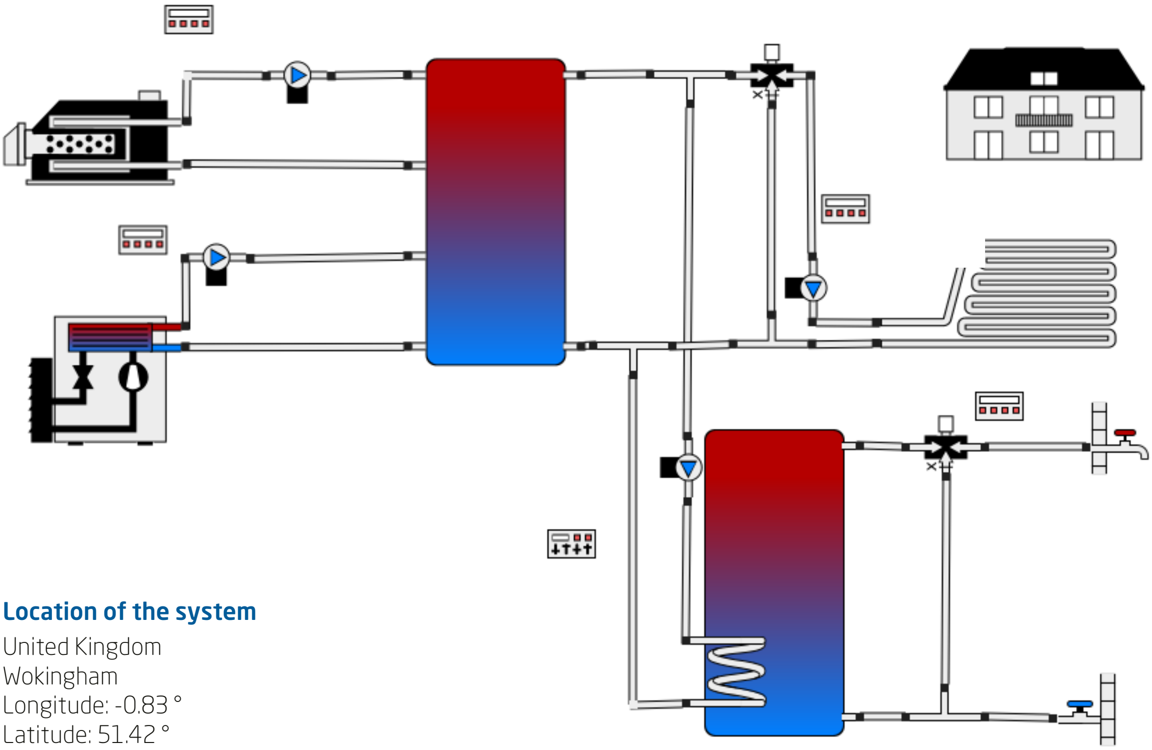


Energy flow diagram (annual balance)



6 Phase Two - Fabric first improvements, multivalent heat pump system

Secondary school (fabric first, multivalent system)



Location of the system

United Kingdom
Wokingham
Longitude: -0.83 °
Latitude: 51.42 °
Elevation: 52 m

System overview (annual values)	
Total fuel and/or electricity consumption of the system [Etot]	561,318 kWh
Total electricity consumption [Ecs]	54,105 kWh
Total gas consumption [Egas]	507,213 kWh
Total energy consumption [Quse]	627,702 kWh
Seasonal performance factor (SPF-SHP)	1.1
Primary energy factor	1.04
Comfort demand	Energy demand covered

Overview heat pump (annual values)	
Seasonal performance factor for air-to-water heat pump	3.5
Total electricity consumption when heating [Eaux]	53,889 kWh
Total energy savings	133,724 kWh
Total reduction in CO_2 emissions	71,729 kg

Meteorological data - overview	
Average outdoor temperature	10.8 °C
Global irradiation, annual sum	985 kWh/m^2
Diffuse irradiation, annual sum	533 kWh/m^2

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Professional report

Component overview (annual values)		
Boiler electricity	**Pre-mix gas boiler 400kW**	
Power	kW	400
Total efficiency	%	87.6
Energy from/to the system [Qaux]	kWh	444,111
Fuel and electricity consumption [Eaux]	kWh	507,213
Fuel consumption of the back-up boiler [Baux]	m^3(gas)	48,306
Exhaust fumes losses [Qex]	kWh	50,721
Heat pump	**E-HP AW 44**	
Heating power at A2/W35	kW	30.4
Electrical power at A2/W35	kW	7.7
COP at A2/W35		3.9
Delta T at A7/W35	K	5
Performance factor		3.48
Energy from/to the system [Qaux]	kWh	187,612
Fuel and electricity consumption [Eaux]	kWh	53,889
Energy savings heat pump	kWh	133,724
CO_2 savings heat pump	kg	71,729
Building 2	**-**	
Heating setpoint temperature	°C	17
Heating energy demand excluding DHW [Qdem]	kWh	630,000
Useful heat gain	kWh	1,259,999
Total energy losses	kWh	1,890,000
Heating/cooling element	**2 Floor heating**	
Power per heating/cooling element under standard conditions	W	1,000
Nominal inlet temperature	°C	40
Nominal return temperature	°C	35
Net energy from/to heating/cooling modules	kWh	577,812
Hot water demand	**Daily peaks**	
Volume withdrawal/daily consumption	l/d	3,000
Temperature setting	°C	50
Energy demand [Qdem]	kWh	49,866
Pump 5	**Eco, small**	
Circuit pressure drop	bar	0.12
Flow rate	l/h	3,600
Fuel and electricity consumption [Epar]	kWh	7.6
Pump heating	**Eco, small**	
Circuit pressure drop	bar	106.086
Flow rate	l/h	105,780
Fuel and electricity consumption [Epar]	kWh	29.4

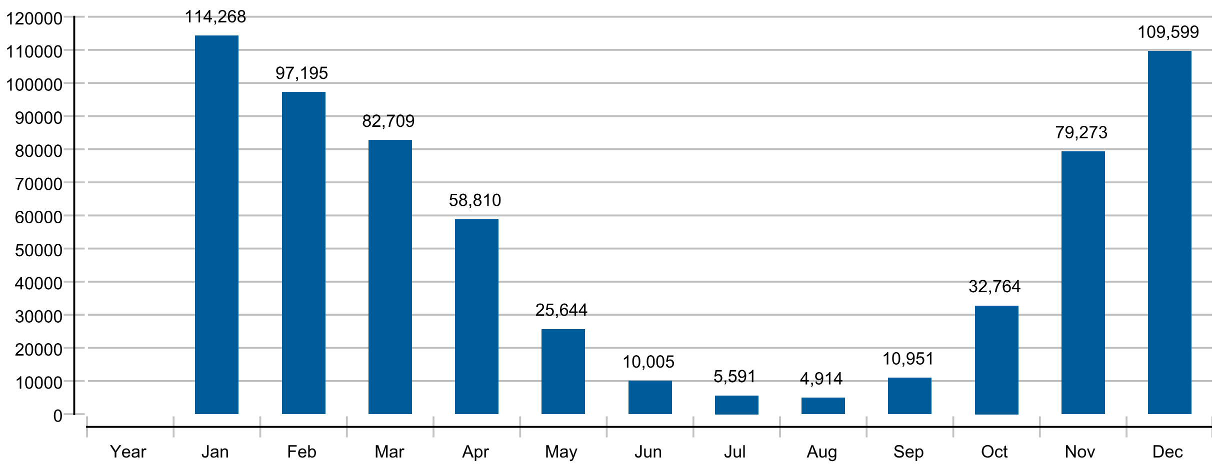
Pump heat pump loop	Eco, medium	
Circuit pressure drop	bar	0.705
Flow rate	l/h	7,540
Fuel and electricity consumption [Epar]	kWh	175

Pump 8	Eco, small	
Circuit pressure drop	bar	0.334
Flow rate	l/h	1,393
Fuel and electricity consumption [Epar]	kWh	4.1

Storage tank buffer	3000l Speicher	
Volume	l	3,000
Height	m	2
Material		Steel
Insulation		Rigid PU foam
Thickness of insulation	mm	100
Heat loss [Qhl]	kWh	1,236
Connection losses	kWh	171

Storage tank 17	Megaflo Indirect 1250 litre potable water cylinder	
Volume	l	1,250
Height	m	1.96
Material		Stainless steel
Insulation		Rigid PU foam
Thickness of insulation	mm	100
Heat loss [Qhl]	kWh	449
Connection losses	kWh	95.6

Heat generator energy to the system (solar thermal energy not included) [Qaux] **kWh**



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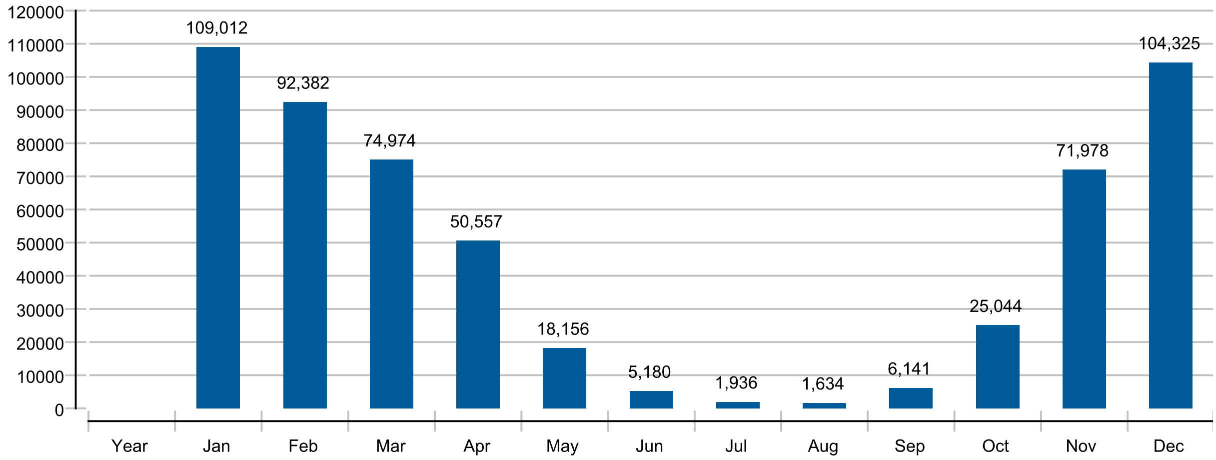
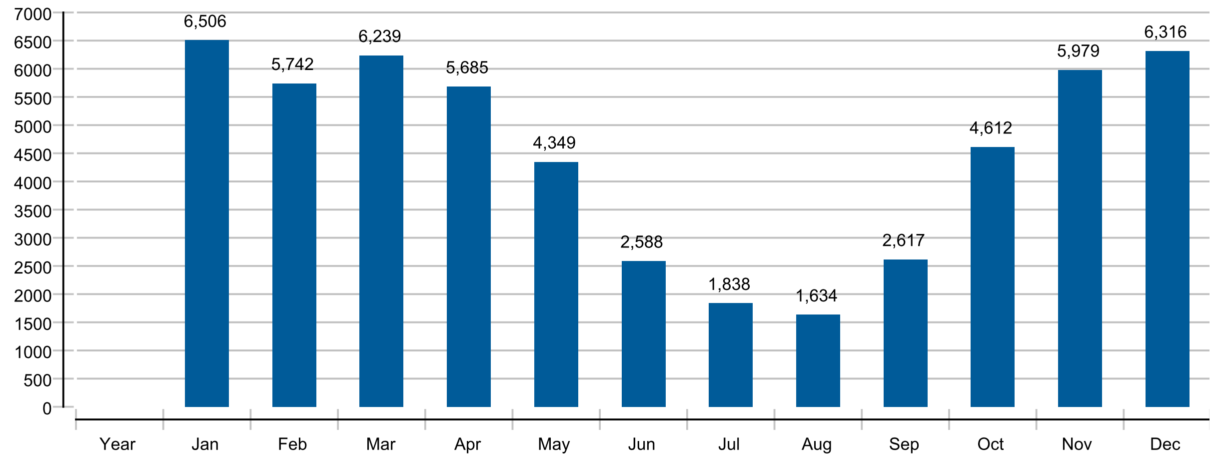
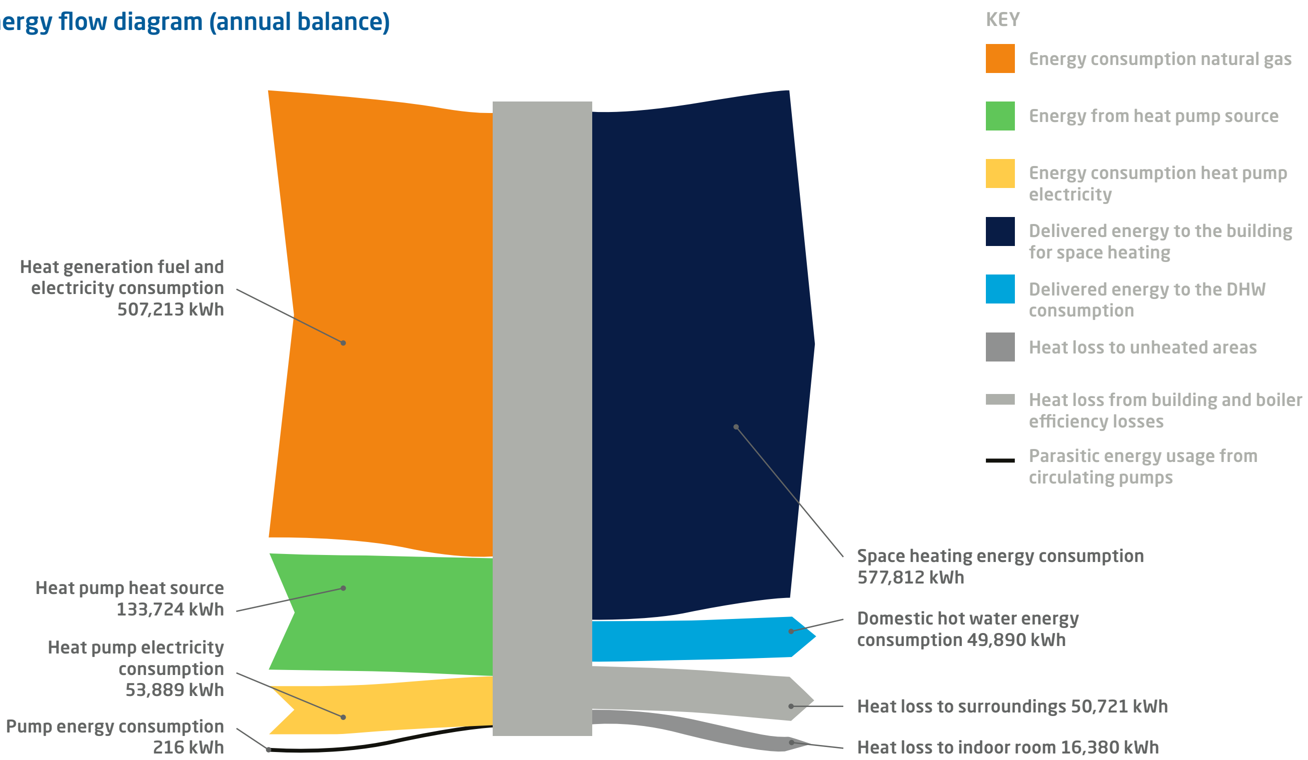
Total fuel and/or electricity consumption of the system [Etot]



Total electricity consumption [Ecs]



Energy flow diagram (annual balance)



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