EMS717U/EMS717P
Renewable Energy Resources

Building Energy Efficiency (2)

Prof. HuaSheng Wang

Content

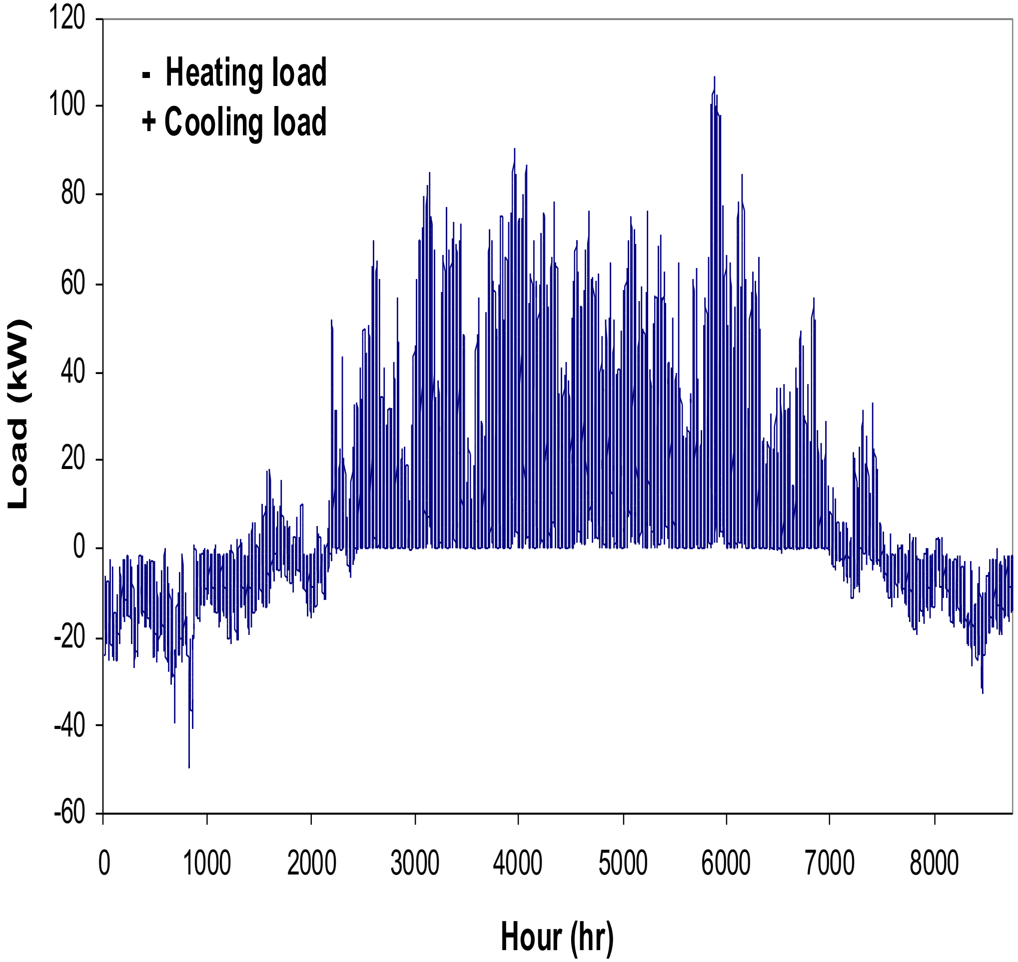
- Sizing of the system based on heating & cooling loads
- Domestic and non-domestic heating systems,
- Air conditioning systems and their applications.
- Combined cooling, heat and power (CCHP).
- Heat pumps.
- Building energy efficiency assessment and EPC.
- Ways to improve building energy efficiency.
- Net zero building.

Sizing of Systems (Design Load)

(Boiler and Chiller)

- 100% X peak load
- 70~90% X peak load
- 150% X peak load

- Design load = peak load
- If undersized, cool storage to meet peak load—ice made at night
- If oversized, more initial investment capital, high running and maintenance cost



System Efficiency (Boilers)

Design load will never meet the actual building load profile

- Load profile is binned into 15%, 30%,100% of full load demand.
  Seasonal Boiler Efficiency =
  $$0.5*(Eff_{15\%}) + 0.20*(Eff_{30\%}) + 0.30(Eff_{100\%})$$
- For example, a boiler with efficiencies of 96% full load, 98% at 30% load, 96% at 15% of full load
  Seasonal efficiency of example boiler = 0.5*96 + 0.2*98 + 0.3*96 = 96.4%

System Efficiency (Chillers)

- Load profile is binned into 25%, 50%, 75%, 100% of full load demand.
  Seasonal Energy Efficiency Ratio (SEER)
  $SEER = a*(EER_{25}) + b*(EER_{50}) + c*(EER_{75}) + d*(EER_{100})$

- EER (Energy Efficiency Ratio) is that measured at the defined part load conditions of 100%, 75%, 50% and 25%, and a, b, c, and d are the binned load profile weighting factors.

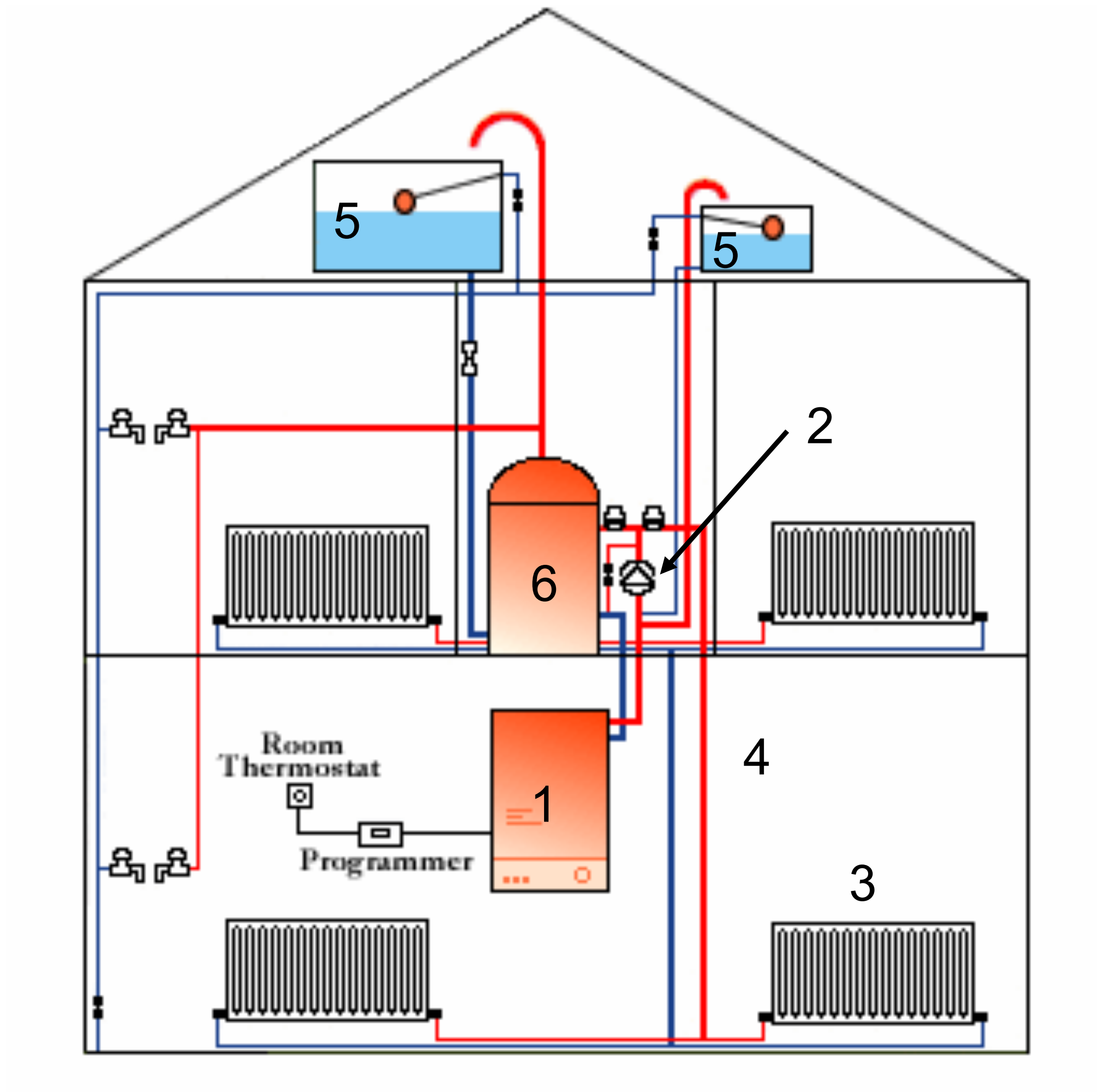
- The weighting factors values that most closely represent the typical UK office type building are 0.55, 0.33, 0.1, 0.02.

  For example, a chiller with: EER_{100} 4.89, EER_{75} 4.42, EER_{50}3.93, EER_{25} 2.59.
  $SEER = (0.55*2.59 + 0.33*3.93 + 0.1*4.42 + 0.02*4.89) = 3.26$

Building Heating Systems

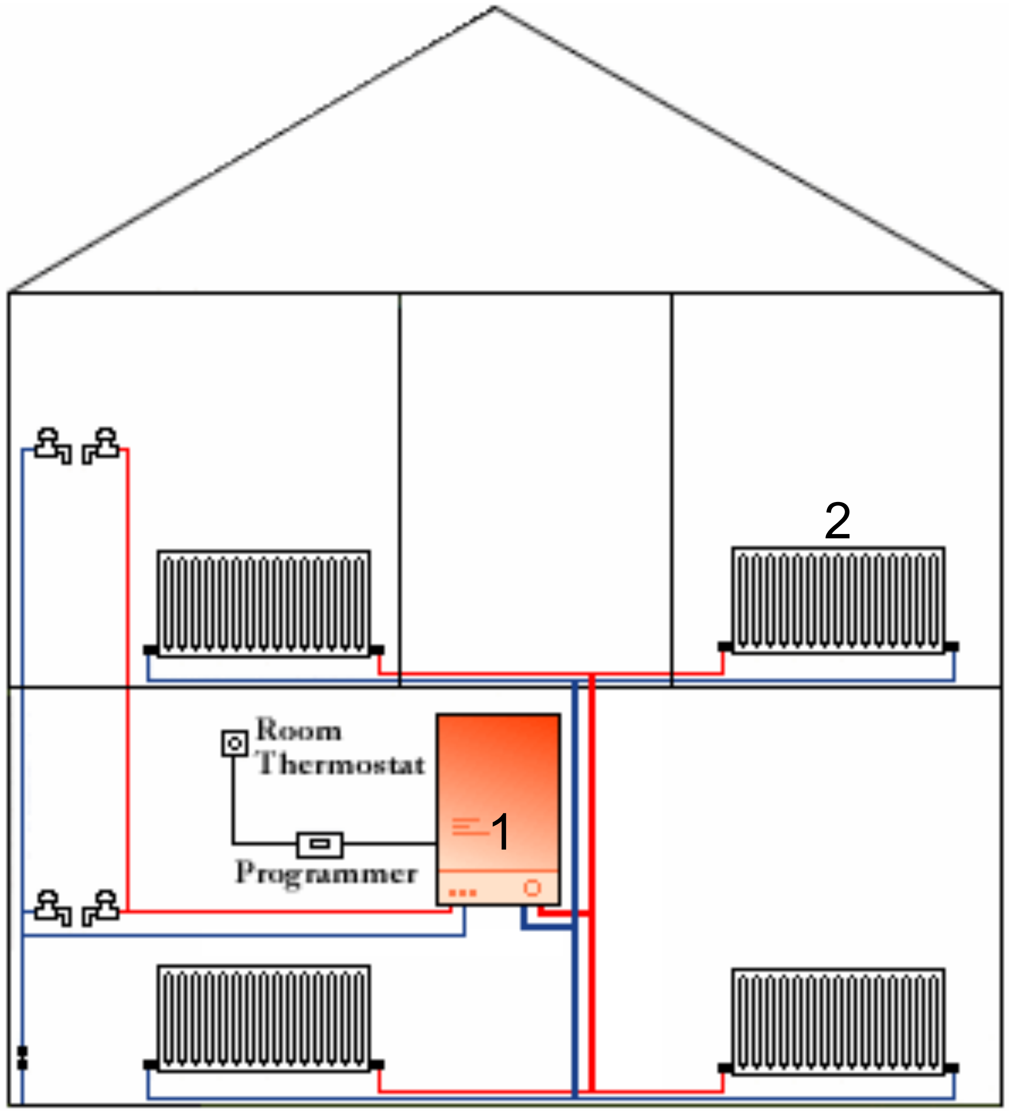
- Domestic boiler central heating system
- Non-domestic district heating system

Domestic Boiler Central Heating System



1. Conventional boiler (flue T≈150^{o}C)
2. Pump
3. Radiators
4. Connecting Pipe
5. Expansion and feed tank
6. Hot water storage tank

Domestic Boiler Central Heating System



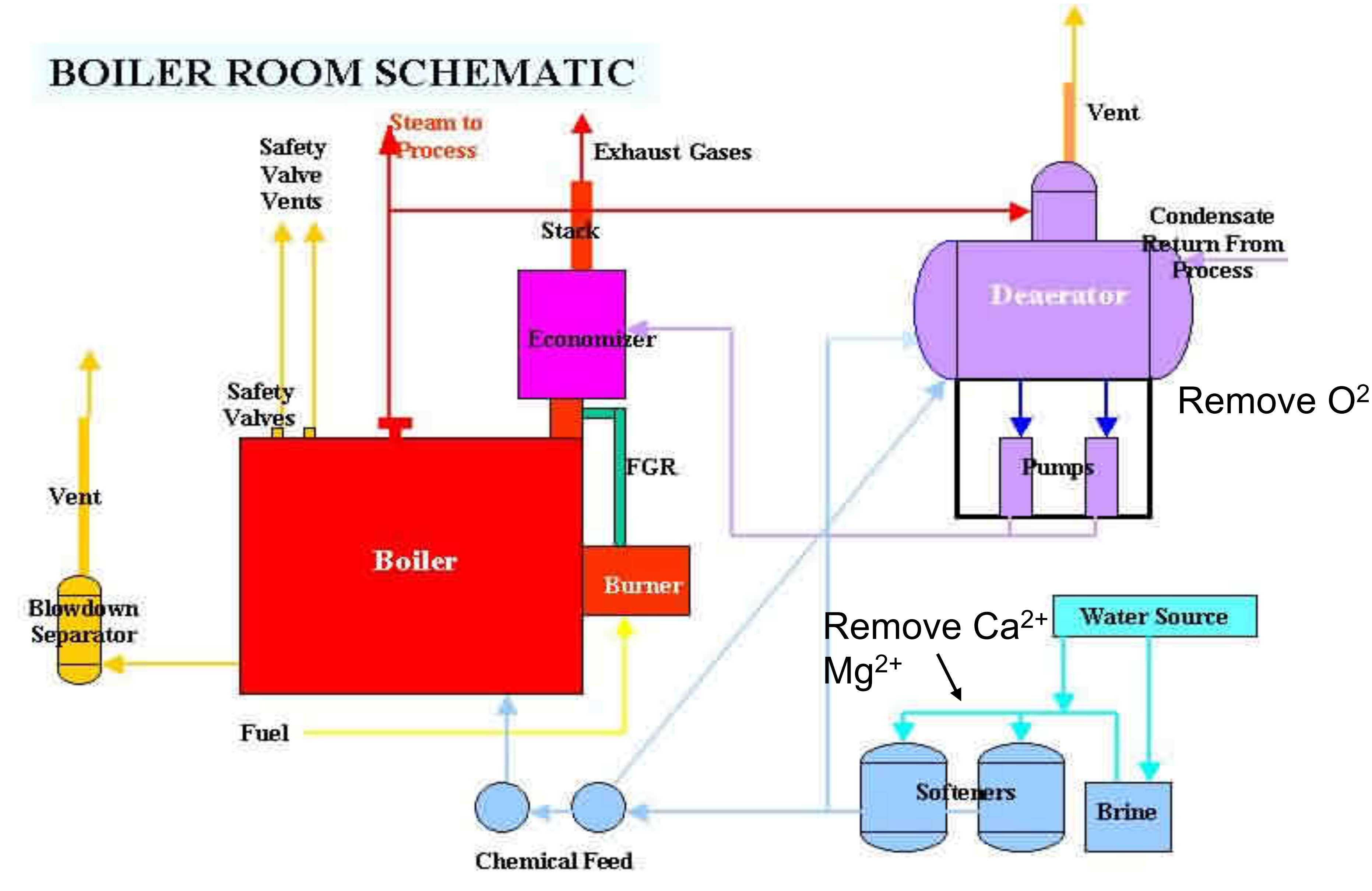
1. Combi boiler (high efficiency, heat recovery, flue T≈50^{o}C)

2. Radiators

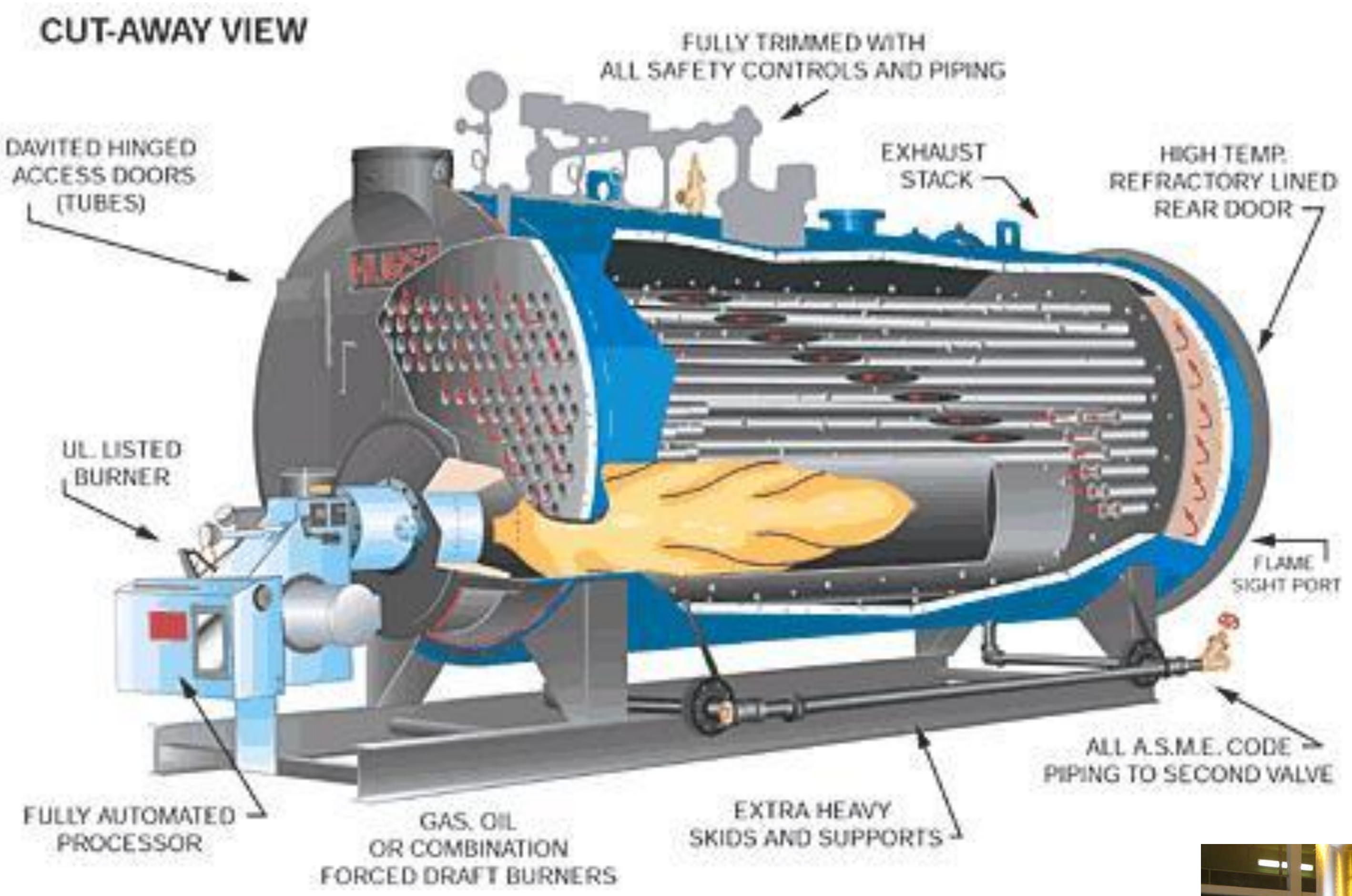
No pump, expansion and feed tank, hot water storage & less connecting Pipe (less)

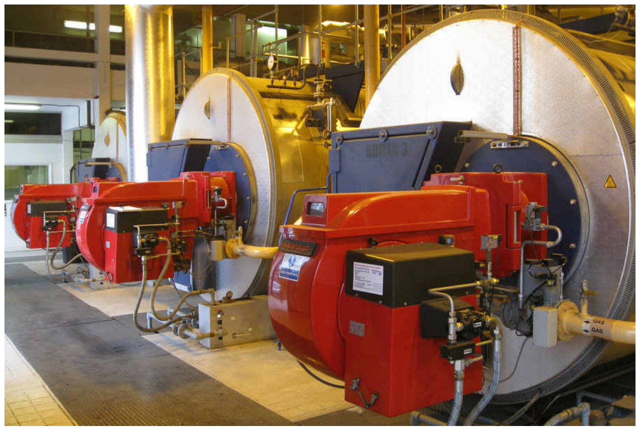
Main water pressure (~2 bars)

Non-domestic District Heating System

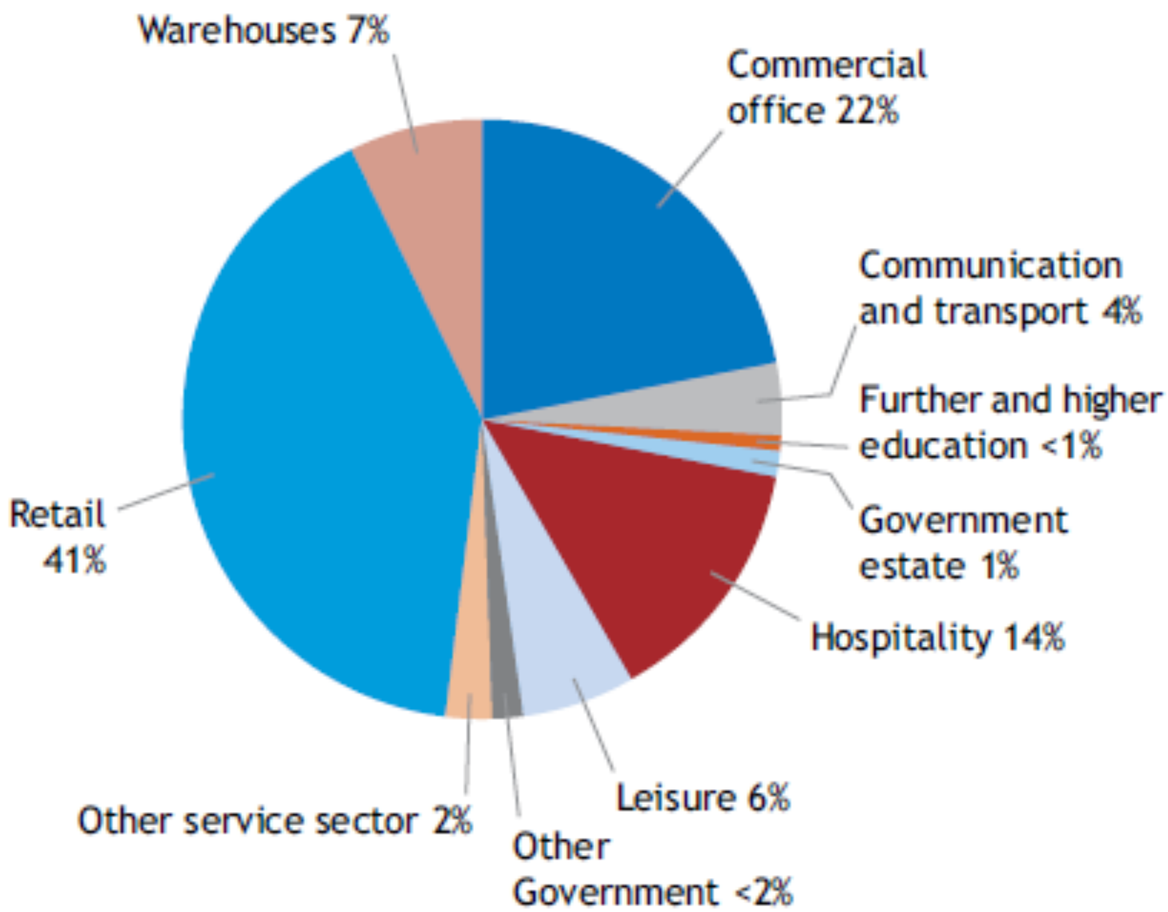


Inside view of boiler and installation in plant room





Air conditioning energy use by UK sector



Note: Agriculture, health and school sectors each had less than a 1% share.

Types of air conditioning systems

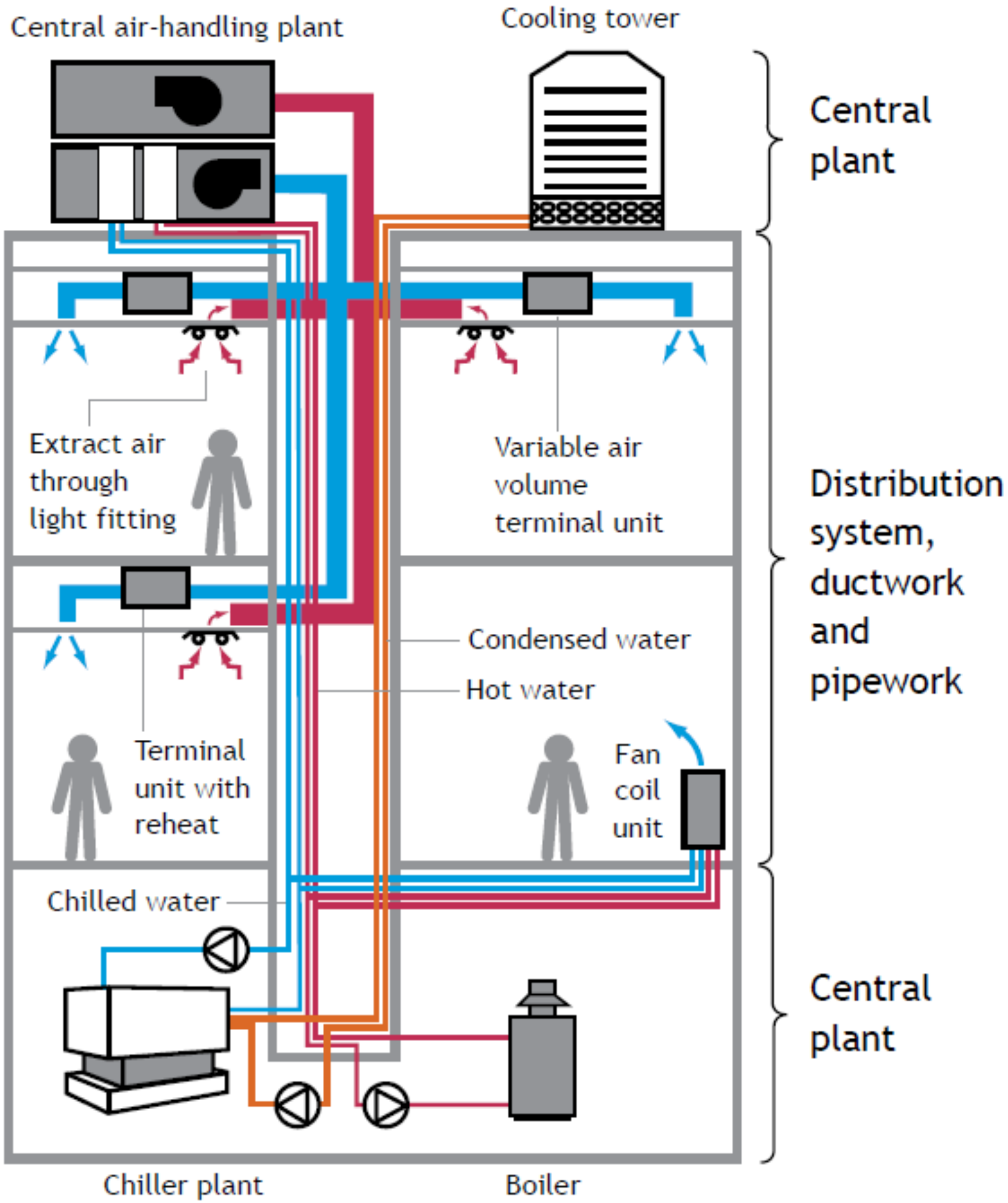
- There are three generic types of air conditioning system, each with many variations:

- Centralised air systems, where all the heating and cooling is carried out in a central plant room and conveyed to the rooms by ductwork.

- Partially centralised air/water systems, where centrally cooled and heated air is further heated or cooled at entry to the rooms.

- Local systems, where all operations are performed locally.

Centralised air/water systems

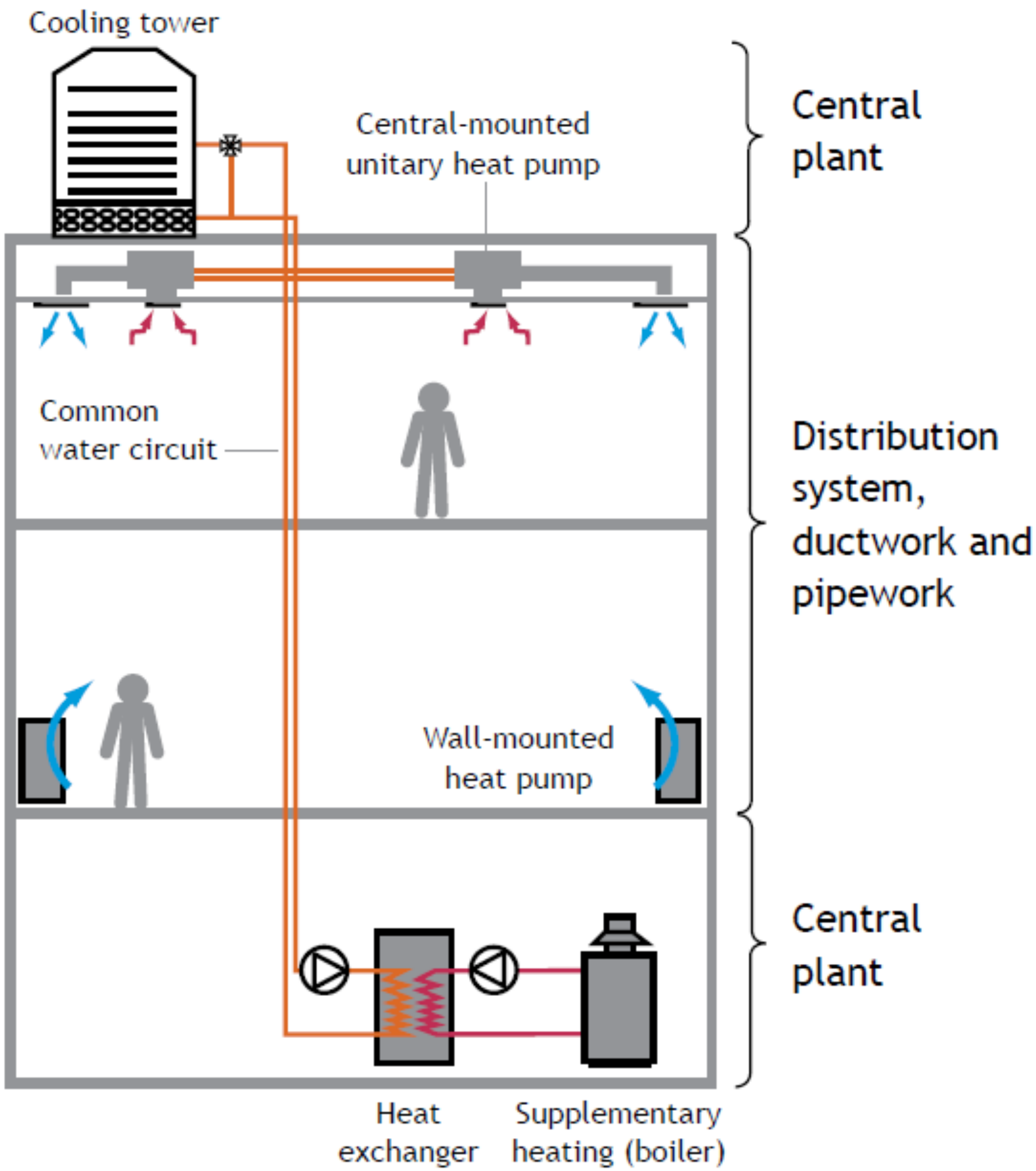


- Centralised air systems, where all the heating and cooling is carried out in a central plant room and conveyed to the rooms by ductwork.

- Centralised water systems, where water at 7 ºC, supplied by a chiller in the plant room, is circulated to fan coil units in rooms, and returns to the chiller at 12 ºC.

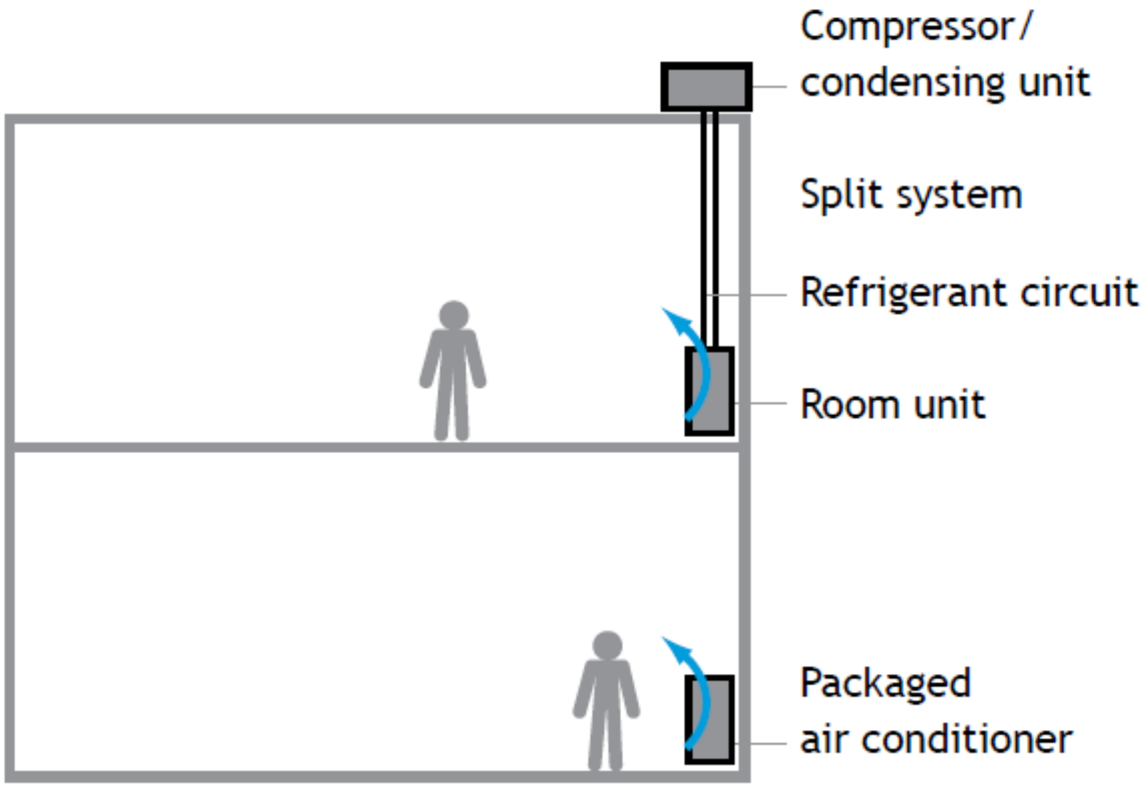
- Compare their difference.

Partially centralised air/water systems



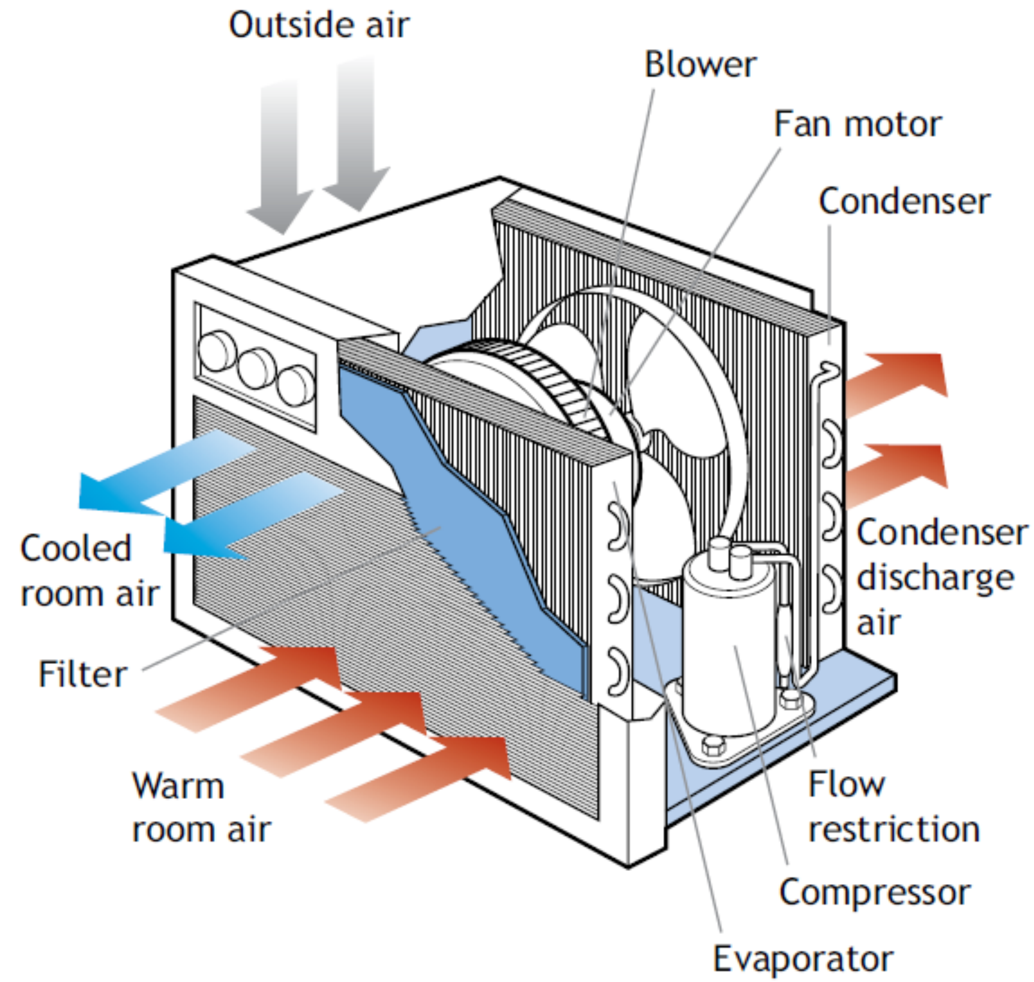
- Partially centralised air/water systems, where centrally cooled and heated air is further heated or cooled at entry to the rooms.
- Part of the rooms are air conditioned by a central air/water system.
- Part of the rooms are air conditioned locally.

Localised air conditioning system



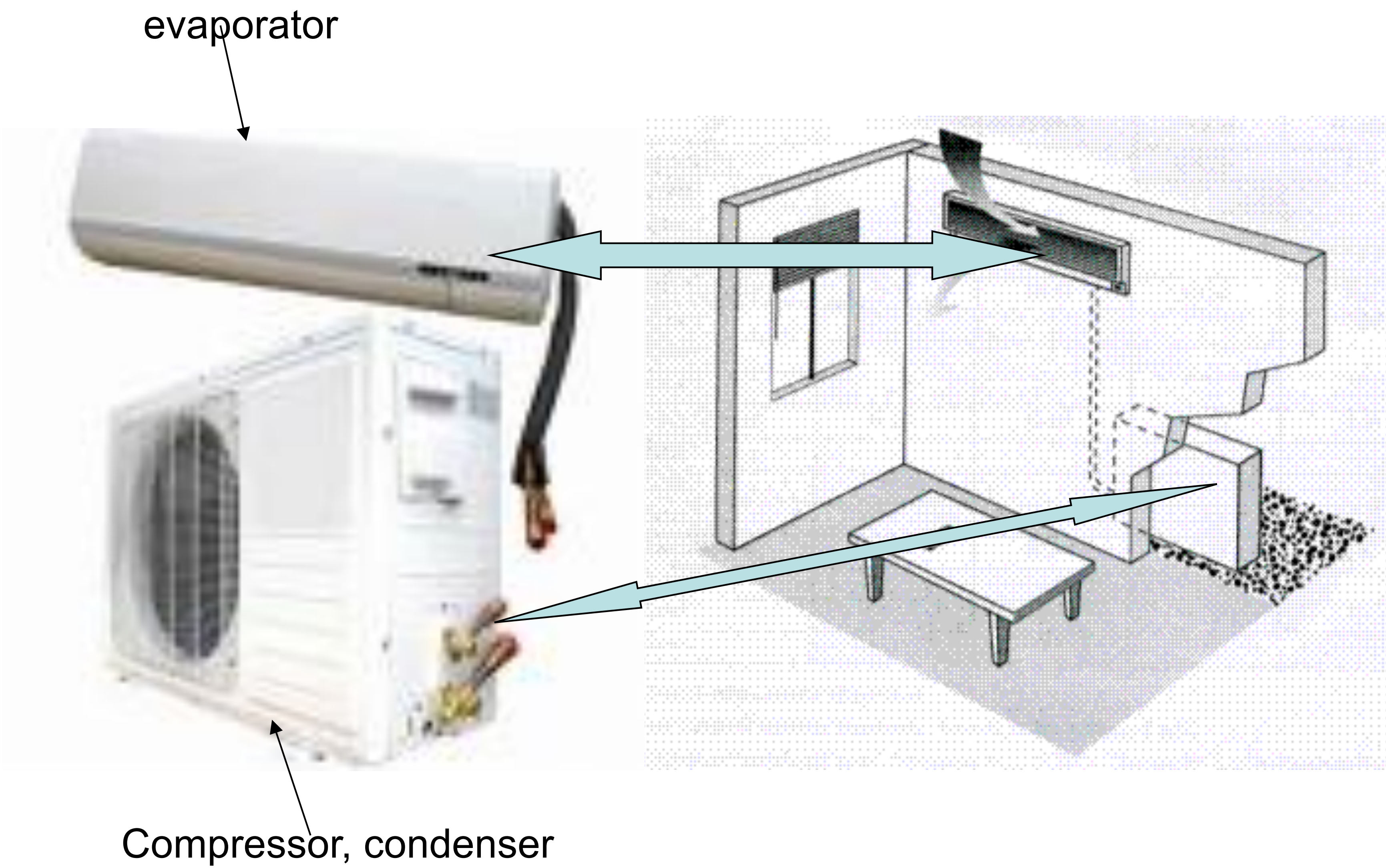
- Local systems, where all operations are performed locally.
- Split air conditioner.
- Packaged air conditioner.
- Only some specific rooms require air conditioning.

Components of an air conditioning unit

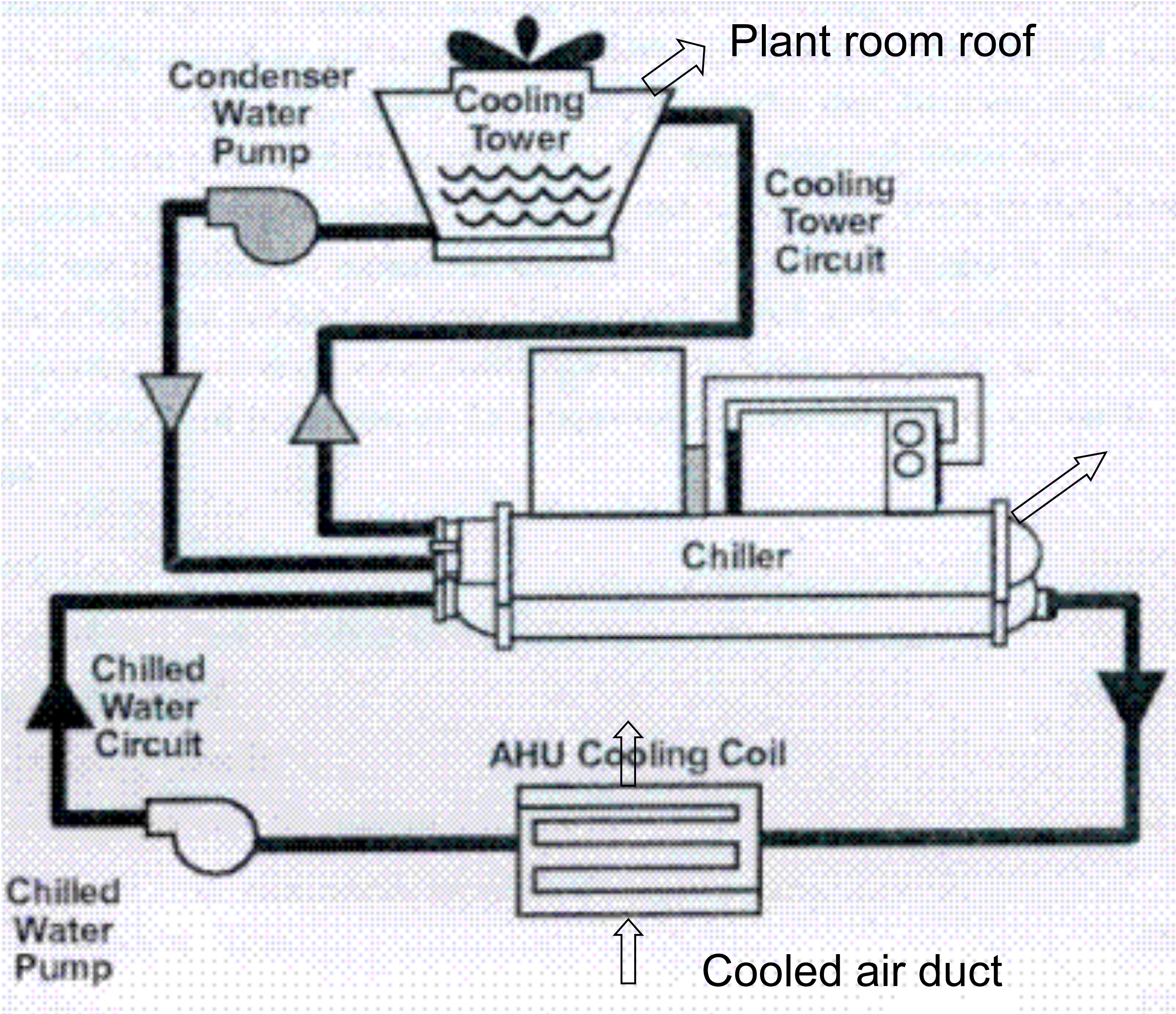


This diagram shows the major components of an air conditioning unit in a packaged system. Most air conditioning systems have these components; however, they will be arranged differently in every application. Packaged systems are discussed further on page 9.

Split air conditioner



Non-domestic Chiller Central Cooling System



Compressor chiller:
Centrifugal, Scroll,
Reciprocal

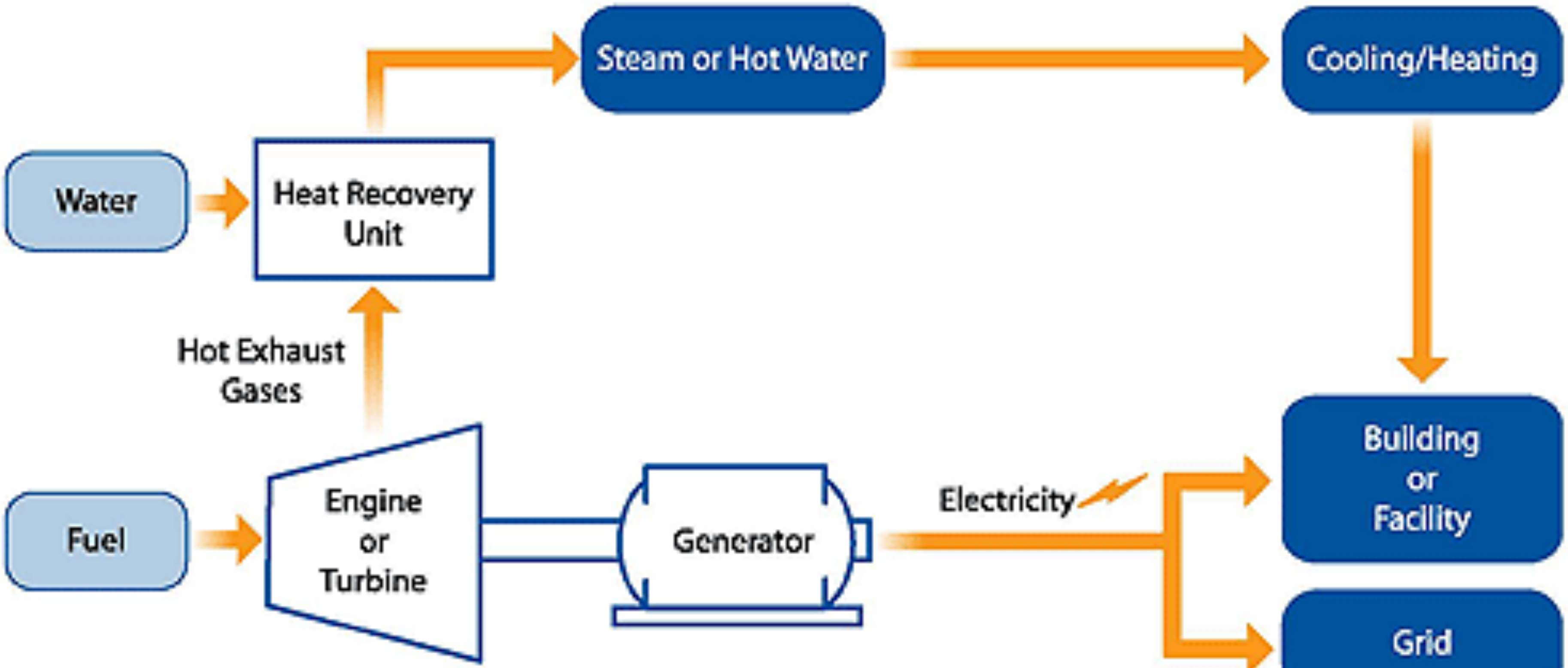
Non-electricity chiller:
LiBr absorption

Building Heating and Cooling Systems

- Combined cooling, heat and power (CCHP) systems
- Heat pump systems

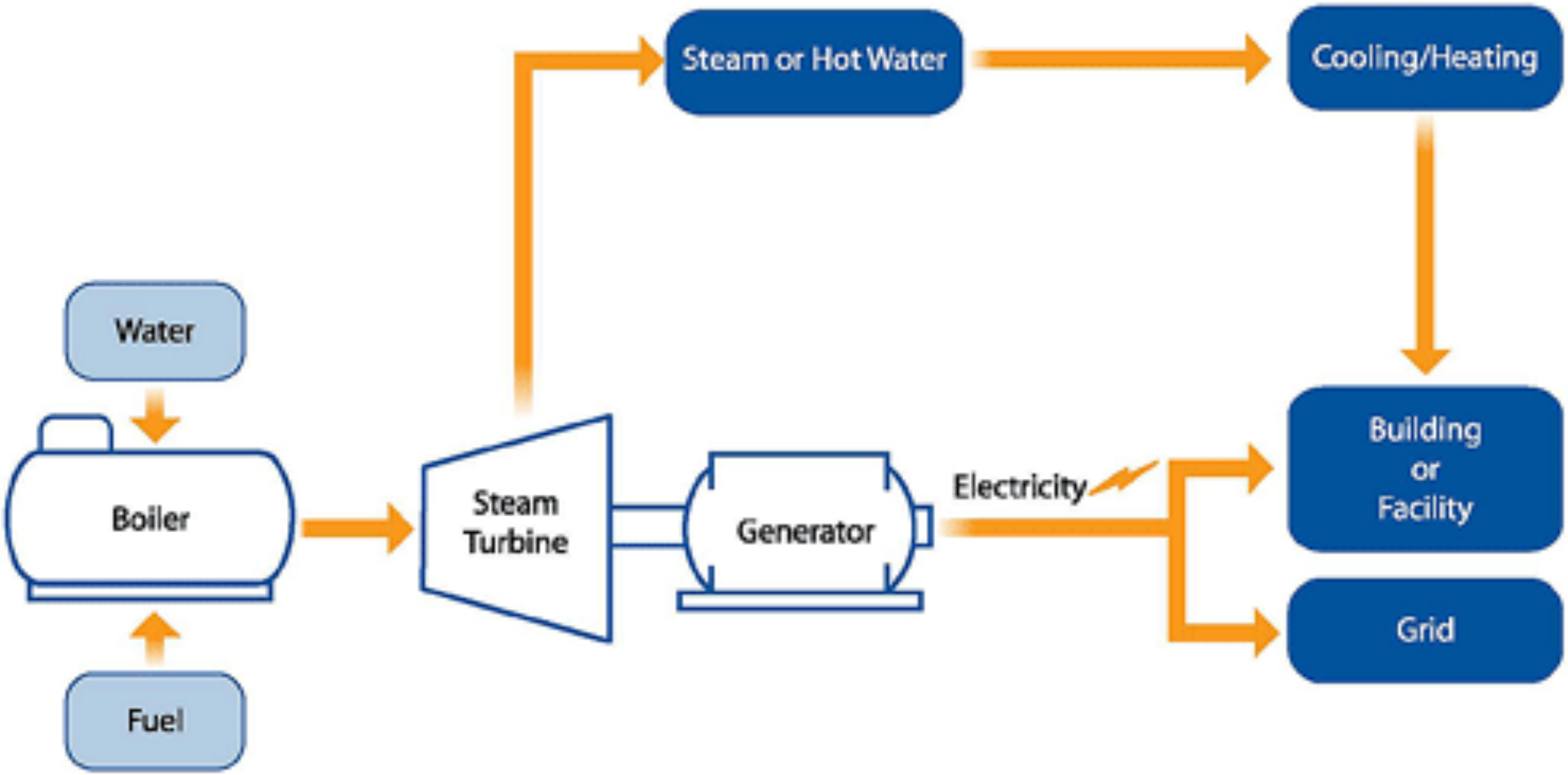
Combine Cooling, Heat and Power System

Gas engine with heat recovery

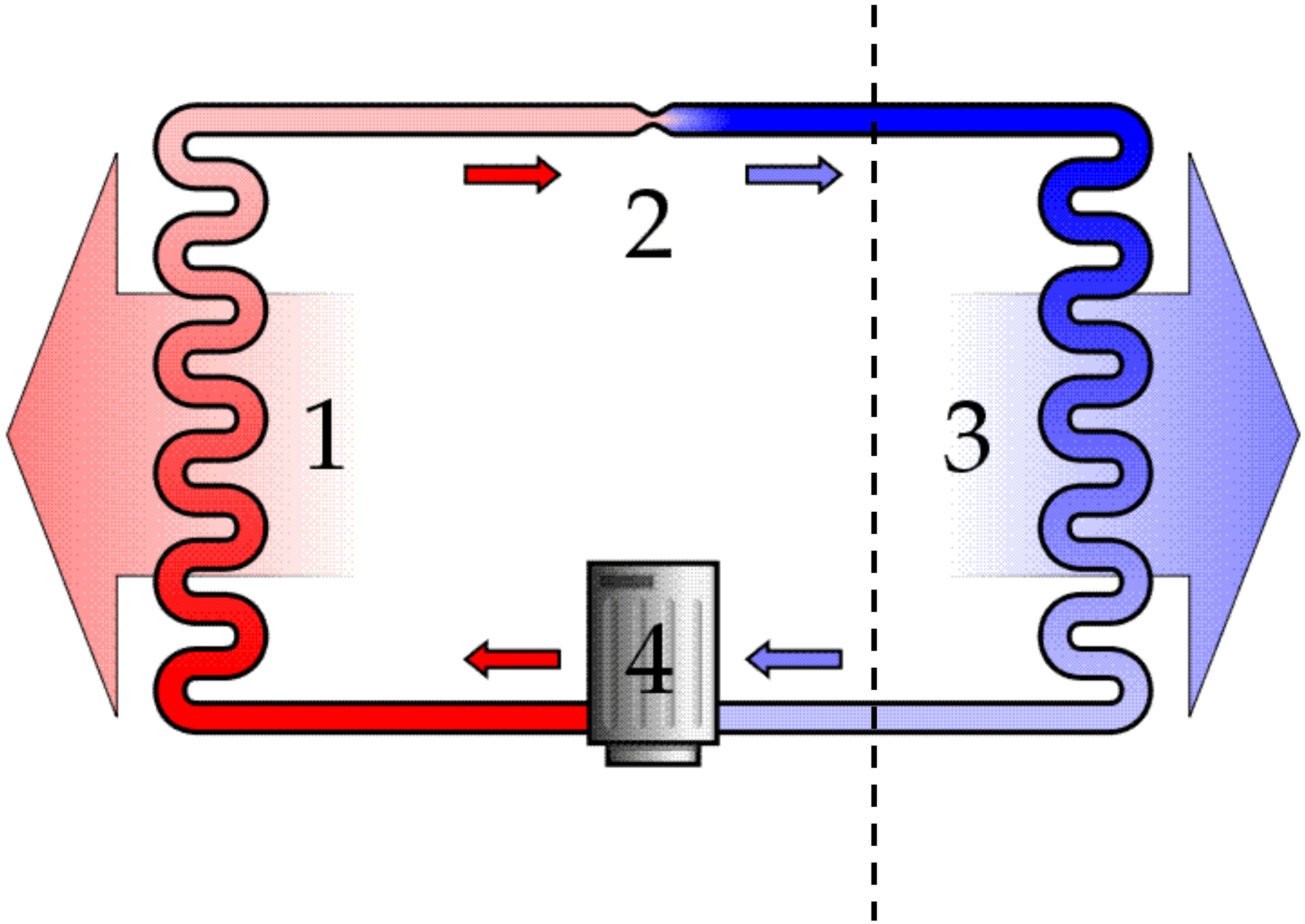


Combine Cooling, Heat and Power System

Steam boiler with steam turbine



Heat Pump System

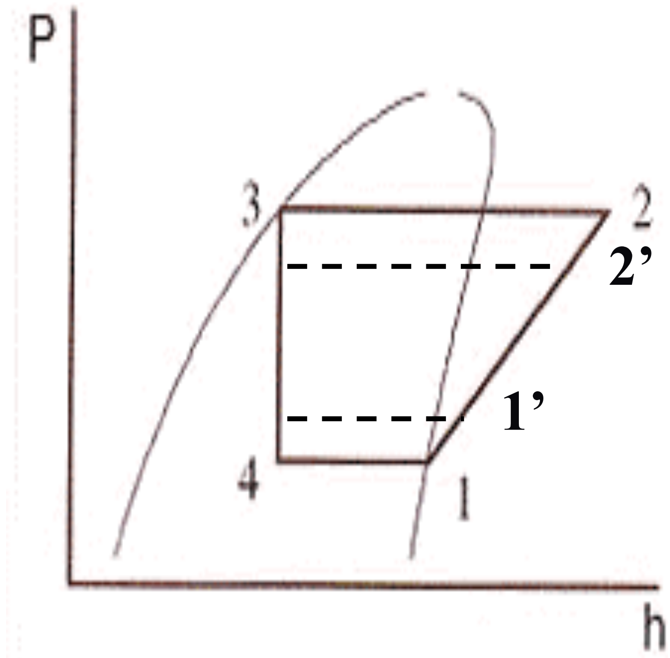


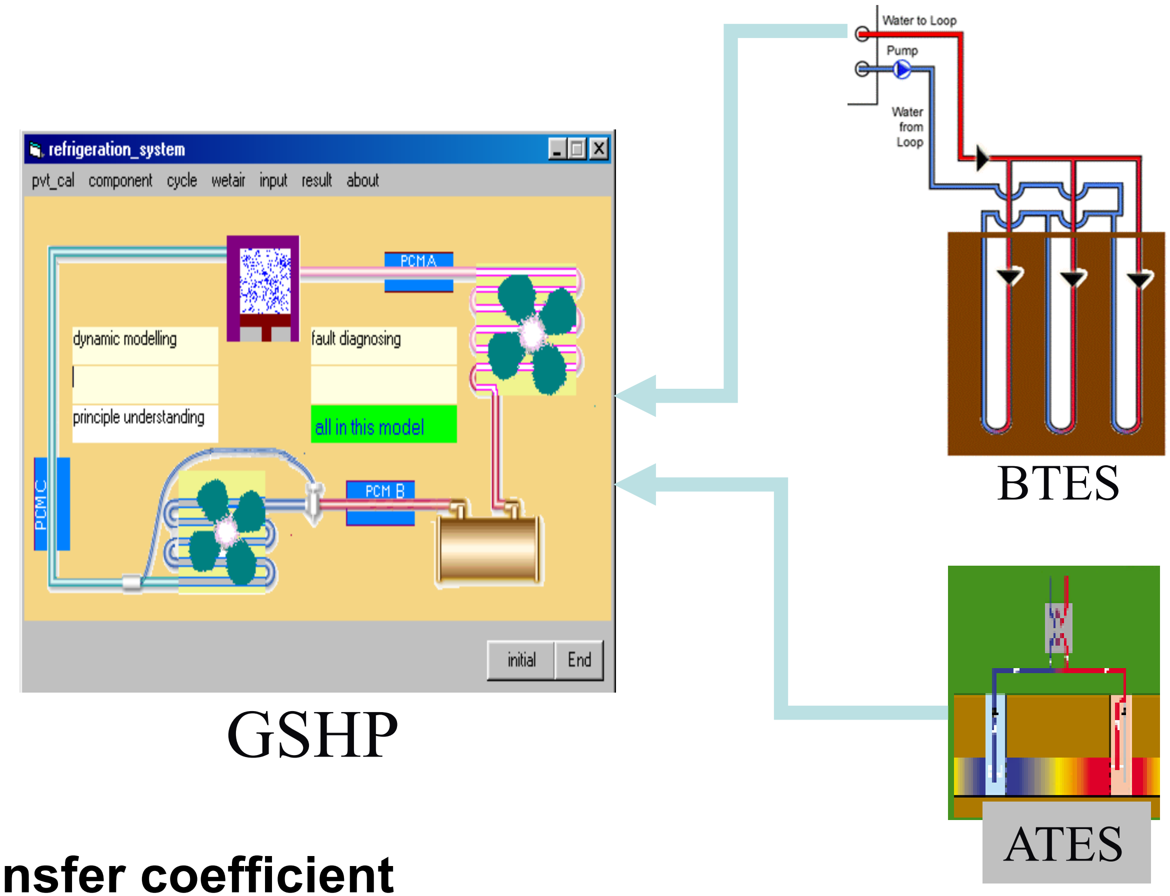
1 Condenser
2 Expansion valve
3 Evaporator
4 Compressor

Inside

- An air conditioner in cooling mode, EER or SEER
- Reverse cycle for heating, COP
- Air source, water source

ASHP *vs* GSHP





1. **Air side convective heat transfer coefficient always lower than water side**
2. **Ground water temperature always lower than air temperature in summer, higher than the air temp. in winter**

COP
GSHP > ASHP

Initial investment:
GSHP > ASHP

Building energy efficiency assessment

	Design Building Building Emission Rate (BER)	**Notion Building** Target Emission Rate (TER)
Size, Shape, Zone	As designed	As designed
Weather	CIBSE TRY	CIBSE TRY
U-values of fabric	As designed	NCM
Lighting control	As designed	As designed
Internal gains	NCM	NCM
Schedule	NCM	NCM
HVAC type	As designed	As designed
Plant room type	As designed	As designed

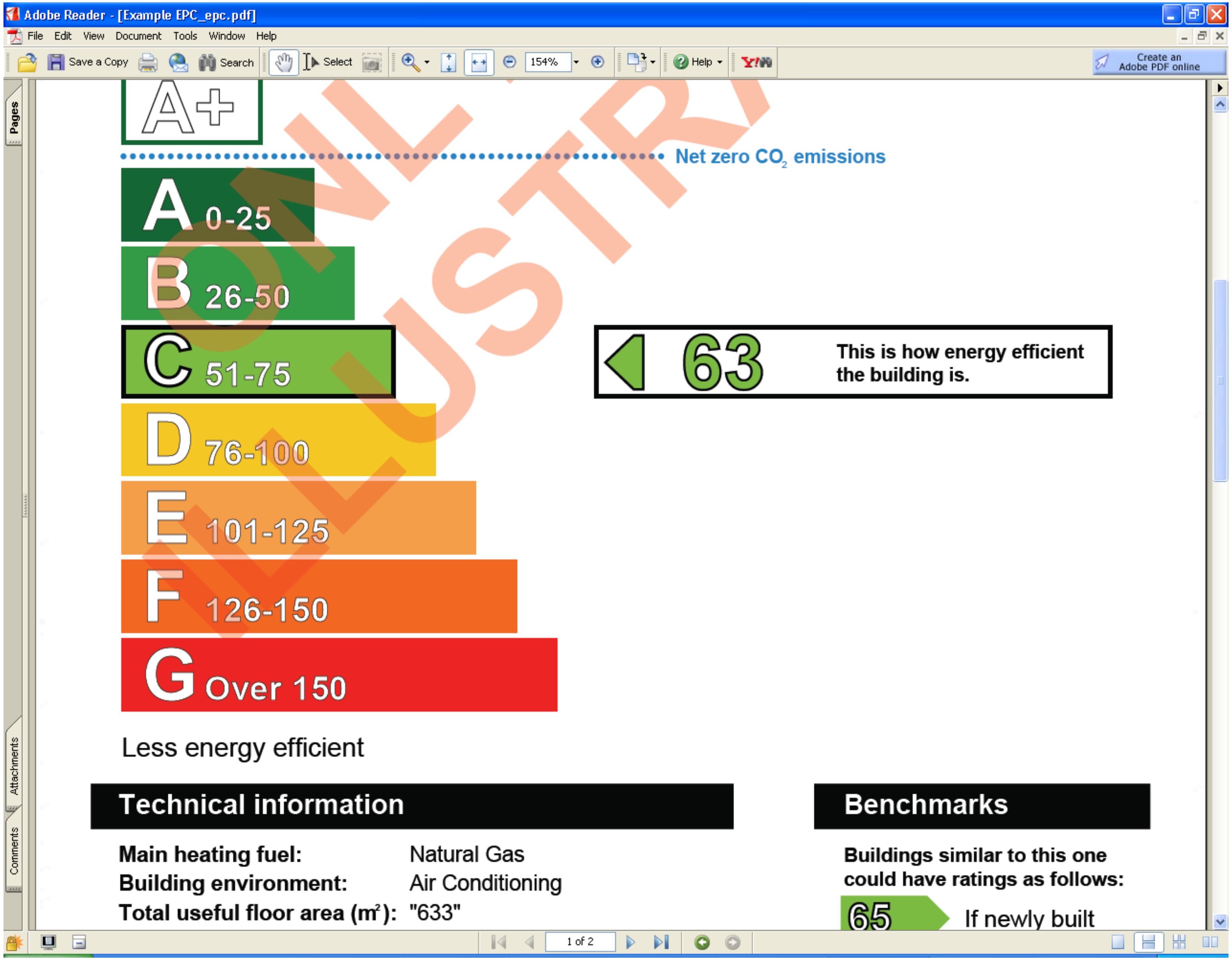
Building energy efficiency assessment

The National Calculation Method (NCM) for the EPBD (Energy Performance of Buildings Directive) is defined by the department for Communities and Local Government (CLG).

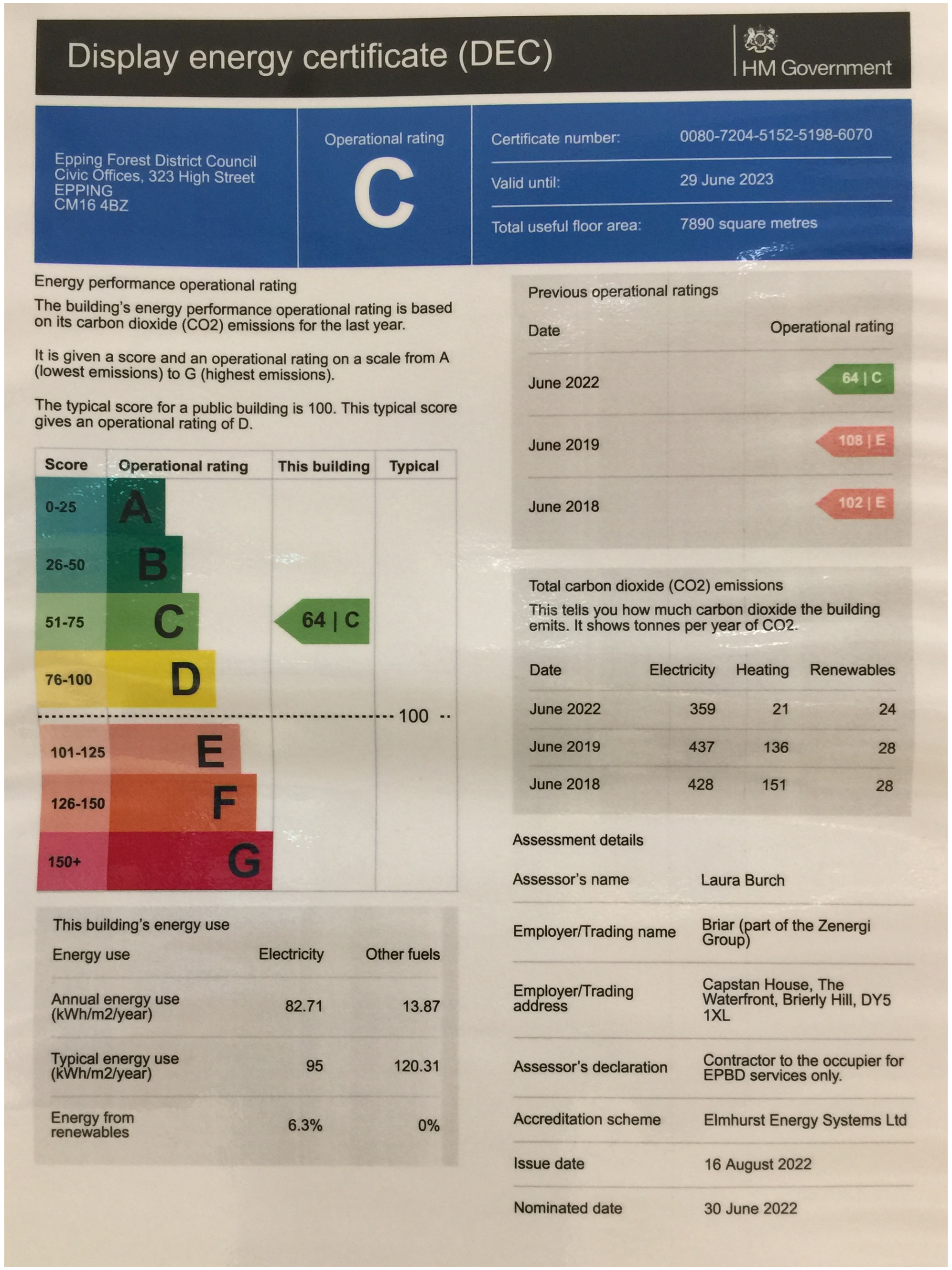
The procedure for demonstrating compliance with the Building Regulations for buildings is by calculating the annual energy use for a proposed building and comparing it with the energy use of a comparable 'notional' building.

Both calculations make use of standard sets of data for different activity areas and call on common databases of construction and service elements.

EPC Ratings


Adobe Reader - [Example EPC_epc.pdf]
File Edit View Document Tools Window Help
Save a Copy
Search
Select
154%
Help
Create an Adobe PDF online
A+
Net zero CO_2 emissions
A 0-25
B 26-50
C 51-75
D 76-100
E 101-125
F 126-150
G Over 150
63
This is how energy efficient the building is.
Less energy efficient
Technical information
Main heating fuel: Natural Gas
Building environment: Air Conditioning
Total useful floor area (m²): "633"
Benchmarks
Buildings similar to this one could have ratings as follows:
65 If newly built
1 of 2
Pages
Attachments
Comments

EPC Ratings



Display energy certificate (DEC)

HM Government

Epping Forest District Council Civic Offices, 323 High Street EPPING CM16 4BZ	Operational rating **C**
Certificate number:	0080-7204-5152-5198-6070
Valid until:	29 June 2023
Total useful floor area:	7890 square metres

Energy performance operational rating

The building's energy performance operational rating is based on its carbon dioxide (CO2) emissions for the last year.

It is given a score and an operational rating on a scale from A (lowest emissions) to G (highest emissions).

The typical score for a public building is 100. This typical score gives an operational rating of D.

Score	Operational rating	This building	Typical
0-25	A		
26-50	B		
51-75	C	64 | C	
76-100	D		100
101-125	E		
126-150	F		
150+	G		

This building's energy use

Energy use	Electricity	Other fuels
Annual energy use (kWh/m2/year)	82.71	13.87
Typical energy use (kWh/m2/year)	95	120.31
Energy from renewables	6.3%	0%

Previous operational ratings

Date	Operational rating
June 2022	64 | C
June 2019	108 | E
June 2018	102 | E

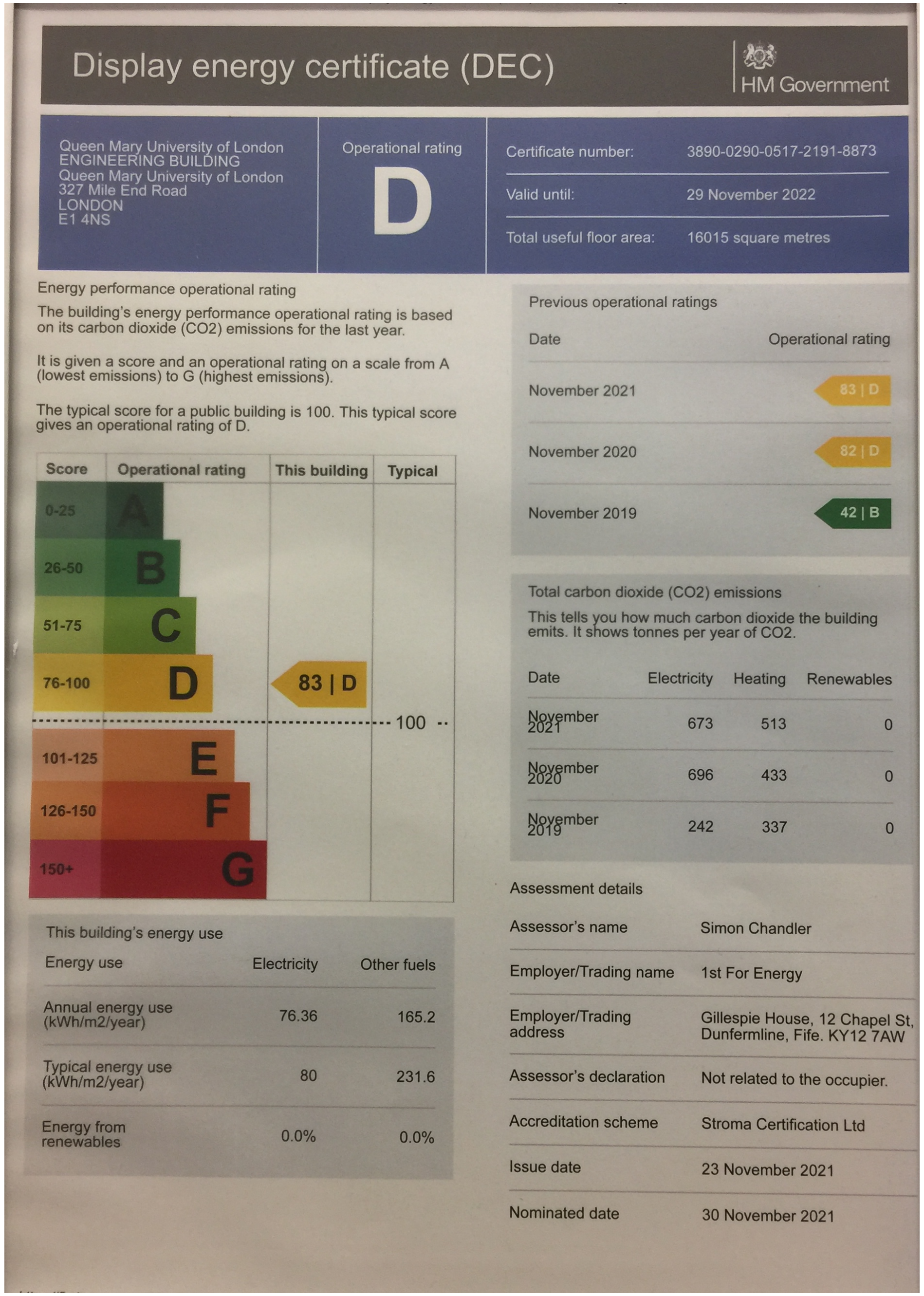
Total carbon dioxide (CO2) emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO2.

Date	Electricity	Heating	Renewables
June 2022	359	21	24
June 2019	437	136	28
June 2018	428	151	28

Assessment details

Assessor's name	Laura Burch
Employer/Trading name	Briar (part of the Zenergi Group)
Employer/Trading address	Capstan House, The Waterfront, Brierly Hill, DY5 1XL
Assessor's declaration	Contractor to the occupier for EPBD services only.
Accreditation scheme	Elmhurst Energy Systems Ltd
Issue date	16 August 2022
Nominated date	30 June 2022



Display energy certificate (DEC)

HM Government

Queen Mary University of London ENGINEERING BUILDING Queen Mary University of London 327 Mile End Road LONDON E1 4NS	Operational rating **D**
Certificate number:	3890-0290-0517-2191-8873
Valid until:	29 November 2022
Total useful floor area:	16015 square metres

Energy performance operational rating

The building's energy performance operational rating is based on its carbon dioxide (CO2) emissions for the last year.

It is given a score and an operational rating on a scale from A (lowest emissions) to G (highest emissions).

The typical score for a public building is 100. This typical score gives an operational rating of D.

Score	Operational rating	This building	Typical
0-25	A		
26-50	B		
51-75	C		
76-100	D	83 | D	100
101-125	E		
126-150	F		
150+	G		

This building's energy use

Energy use	Electricity	Other fuels
Annual energy use (kWh/m2/year)	76.36	165.2
Typical energy use (kWh/m2/year)	80	231.6
Energy from renewables	0.0%	0.0%

Previous operational ratings

Date	Operational rating
November 2021	83 | D
November 2020	82 | D
November 2019	42 | B

Total carbon dioxide (CO2) emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO2.

Date	Electricity	Heating	Renewables
November 2021	673	513	0
November 2020	696	433	0
November 2019	242	337	0

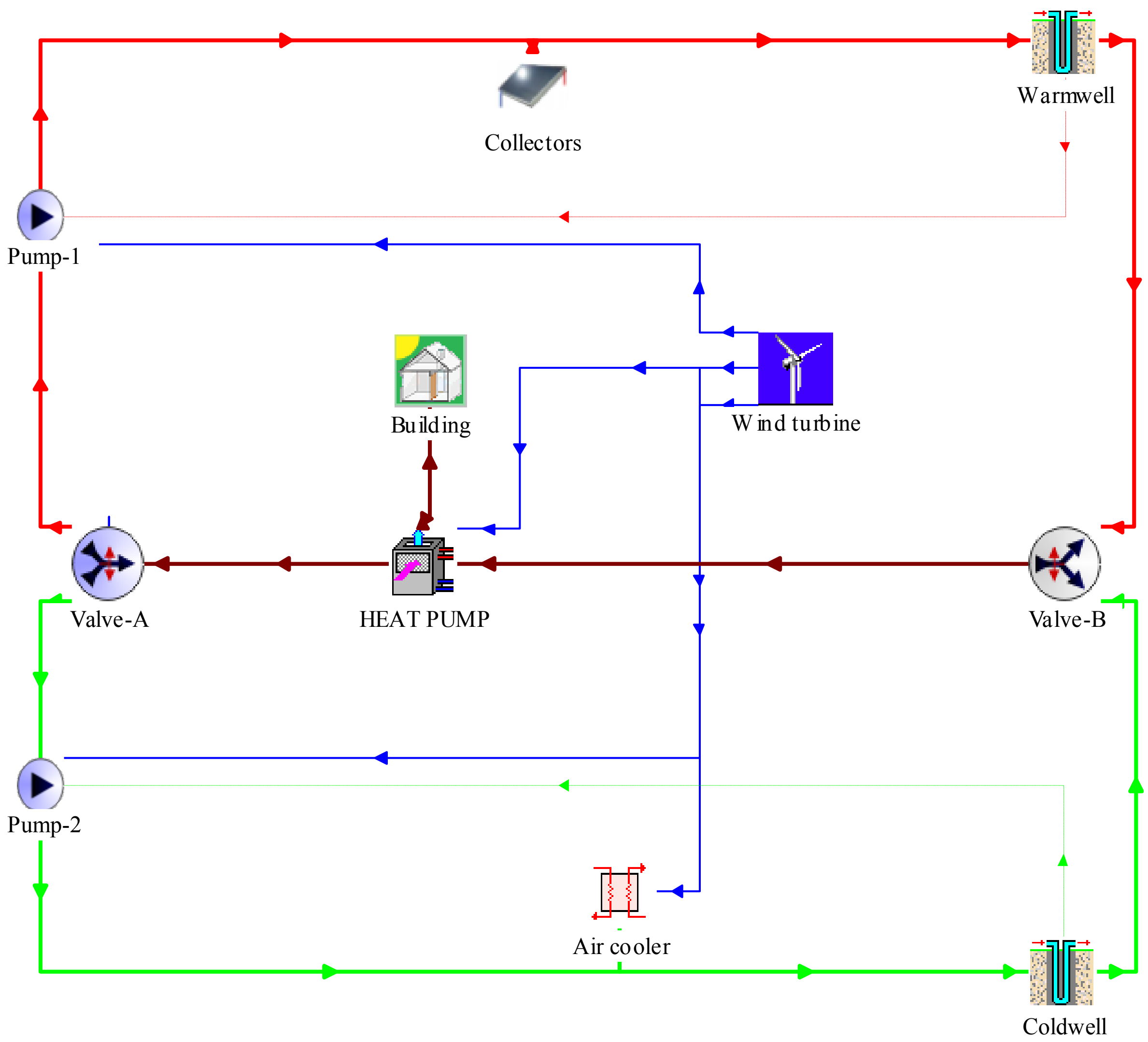
Assessment details

Assessor's name	Simon Chandler
Employer/Trading name	1st For Energy
Employer/Trading address	Gillespie House, 12 Chapel St, Dunfermline, Fife. KY12 7AW
Assessor's declaration	Not related to the occupier.
Accreditation scheme	Stroma Certification Ltd
Issue date	23 November 2021
Nominated date	30 November 2021

Improving Building Energy Efficiency

1. Energy consumption of the building envelope
- Low U-value of building exterior fabric
- Energy efficient building internal & external lighting
2. Efficiency of service systems
- Right-sizing heating and cooling systems
- Efficient building service system components
- Ground source heat pump systems
- Combined cooling, heat and power systems
- Radiant heating and cooling
- Cool storage
- Evaporation cooling (adiabatic cooling)
- Non-electric cooling (LiBr absorption)
3. Operation cost of the systems
- Variable speed drive (VSD) pumps, fans working at part load conditions
4. Use of renewable energy sources

Net zero Building



Heating mode:
Pump-1__Coll. __WW __Heatpump __ Pump-1

Charging mode:
Pump-2__Cooler __CW __Pump-2

Cooling mode:
Pump-2__Cooler __CW __ Heatpump __Pump-2

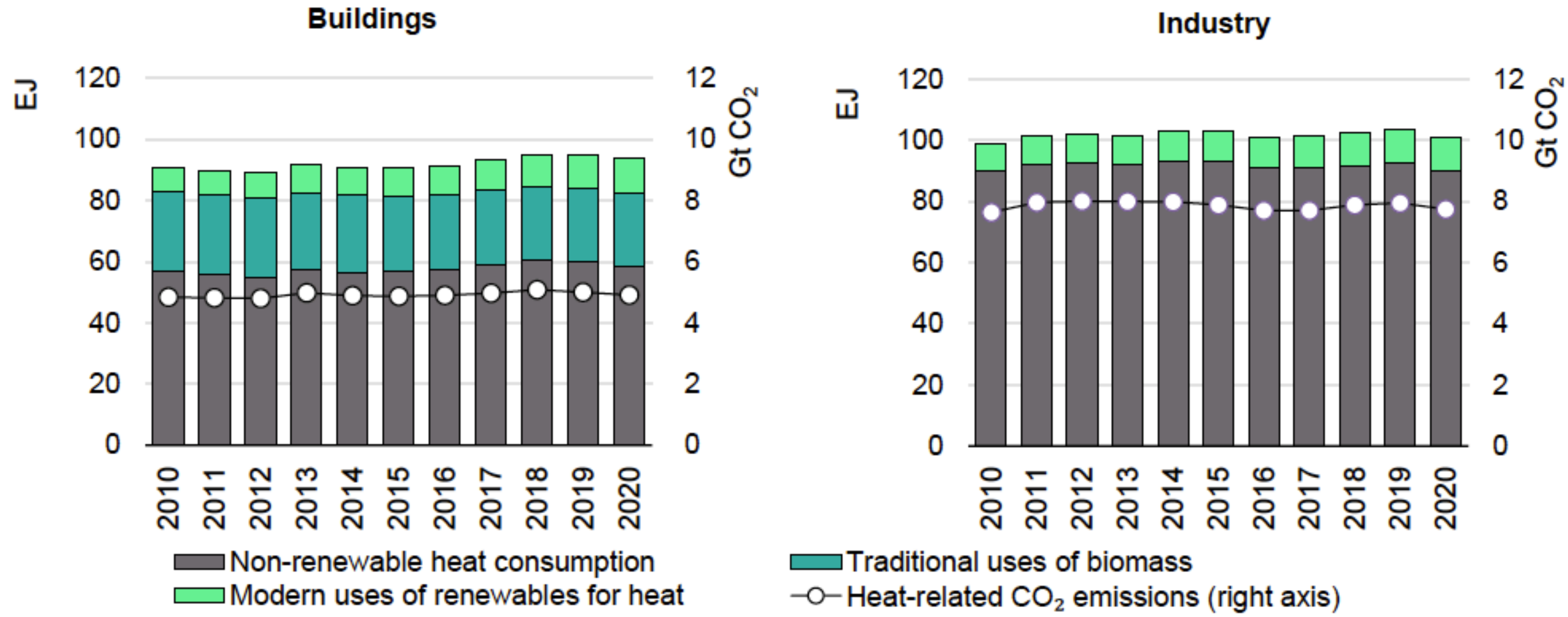
Charging mode:
Pump-1__Coll. __WW __ Pump-1

Renewables 2021

Analysis and forecast to 2026

Global progress on conversion to renewable heat has been limited

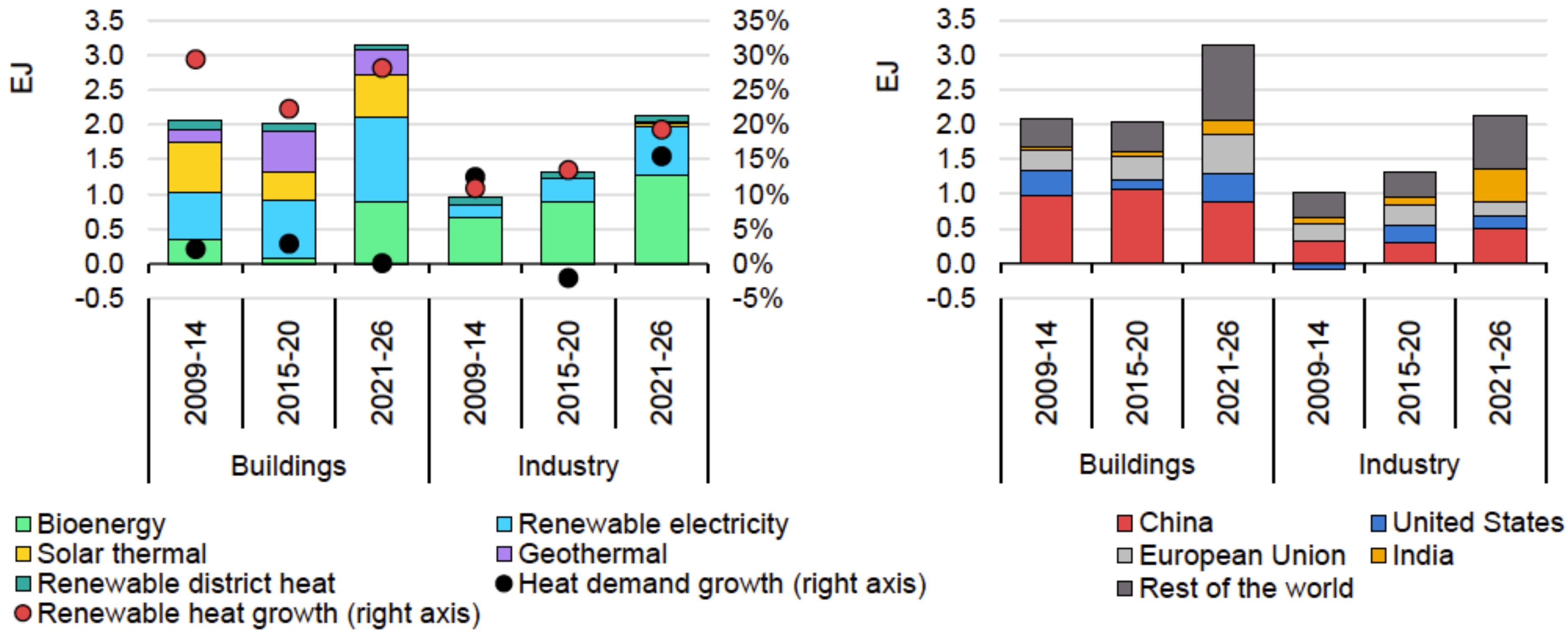
Figure 3.1 **Renewable and non-renewable heat consumption and heat-related CO_2 emissions in buildings and industry, world, 2010-2020**



Note: This figure does not account for ambient heat harnessed by heat pumps.

Sources: IEA (2021c), World Energy Statistics and Balances 2021 (database); IEA (2021b), World Energy Outlook 2021.

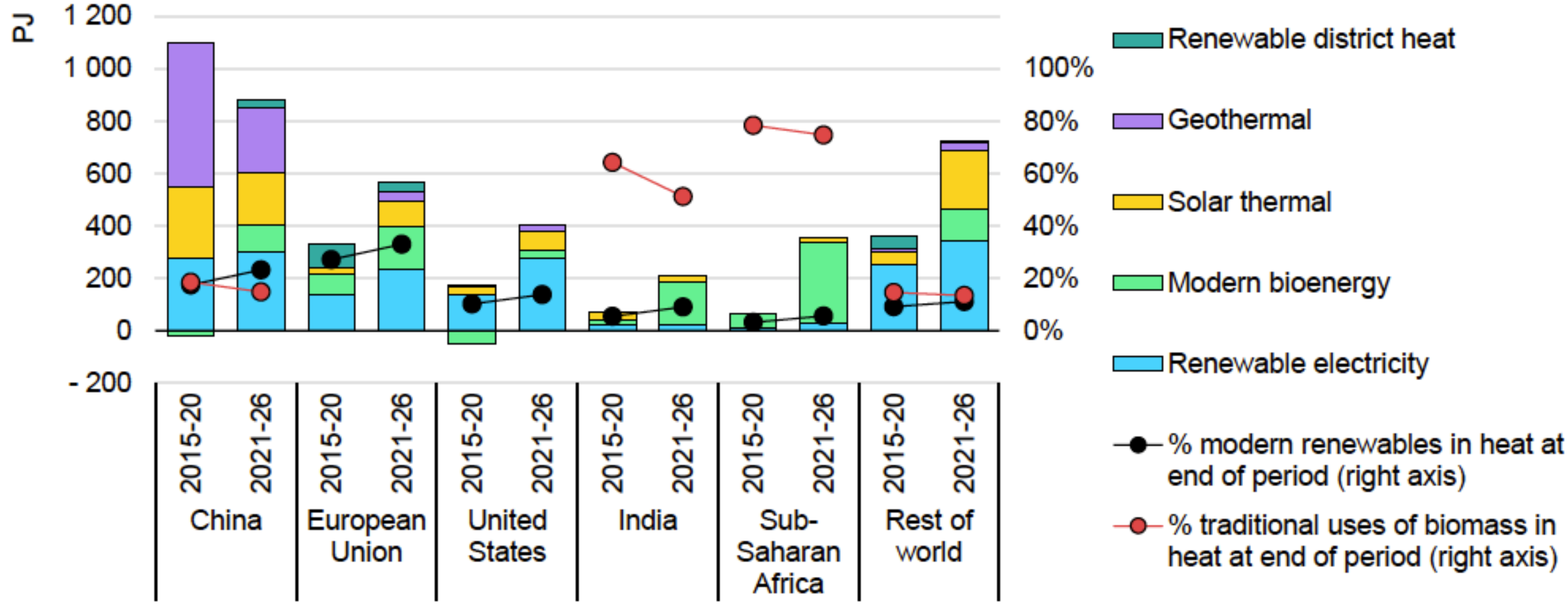
Figure 3.2 Increase in renewable heat consumption by energy source (left) and country/region (right), 2009-2026



Note: This figure does not account for ambient heat harnessed by heat pumps.

Sources: IEA (2021c), World Energy Statistics and Balances 2021 (database); IEA (2021b), World Energy Outlook 2021.

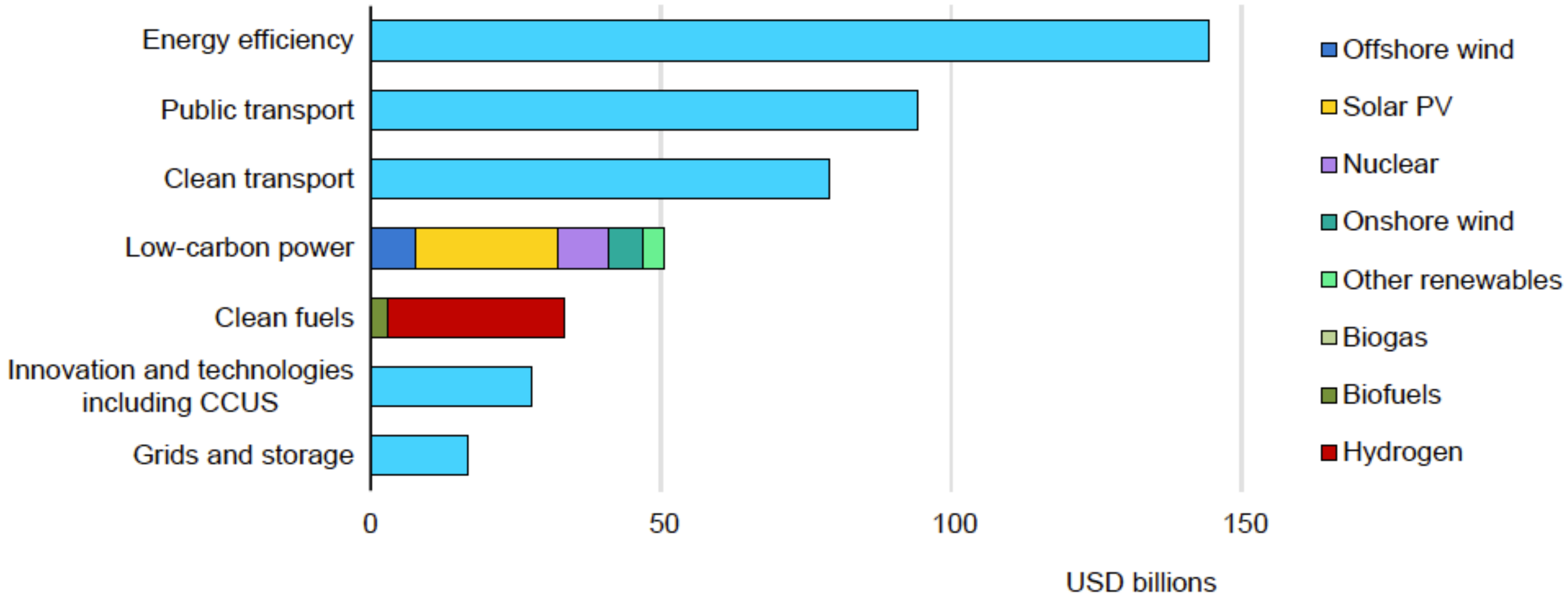
Figure 3.4 Increase in renewable heat consumption in buildings, and share of modern renewables and traditional uses of biomass in buildings heat demand, selected regions, 2015-2026



Note: This figure does not account for ambient heat harnessed by heat pumps.
Sources: IEA (2021c), World Energy Statistics and Balances 2021 (database); IEA (2021b), World Energy Outlook 2021.

How much will renewable energy benefit from global stimulus packages?

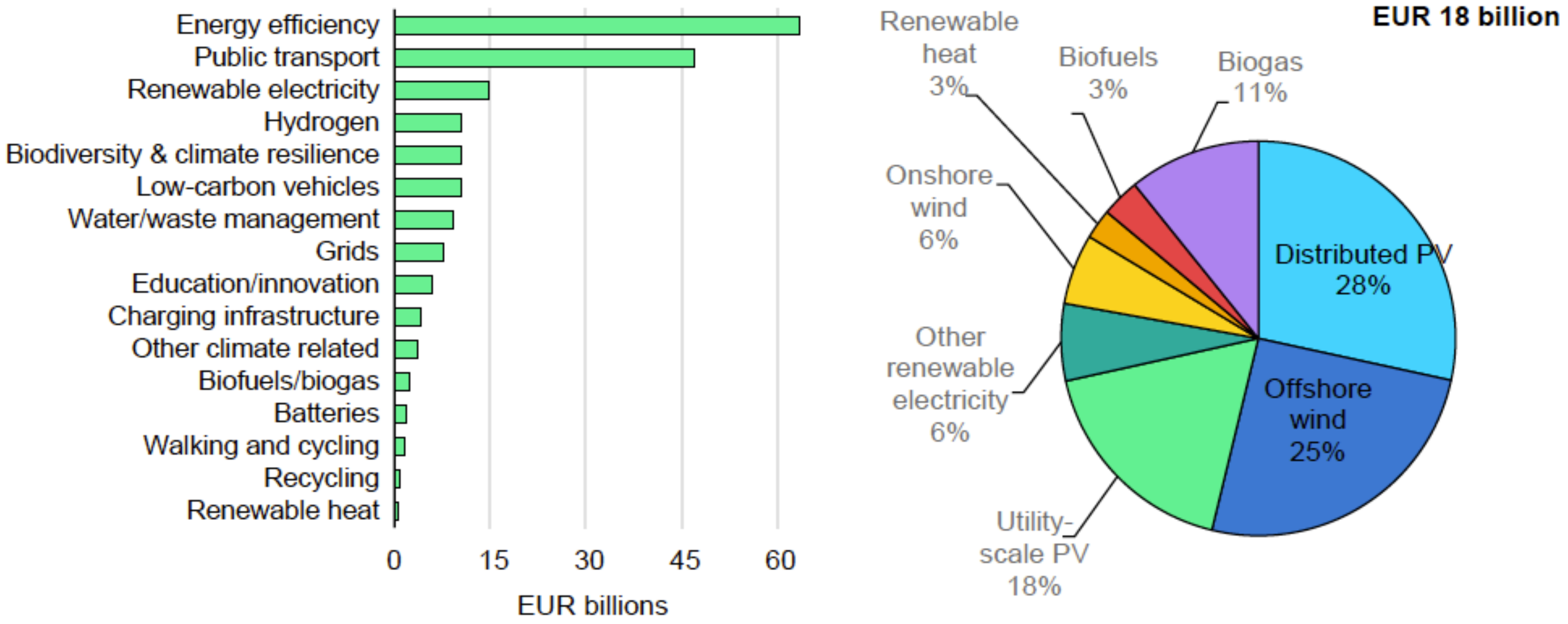
Figure 4.9 Global government clean energy spending by sector and technology, allocated up to October 2021



Source: Based on IEA (2021h), Sustainable Recovery Tracker.

How much will renewable energy benefit from global stimulus packages?

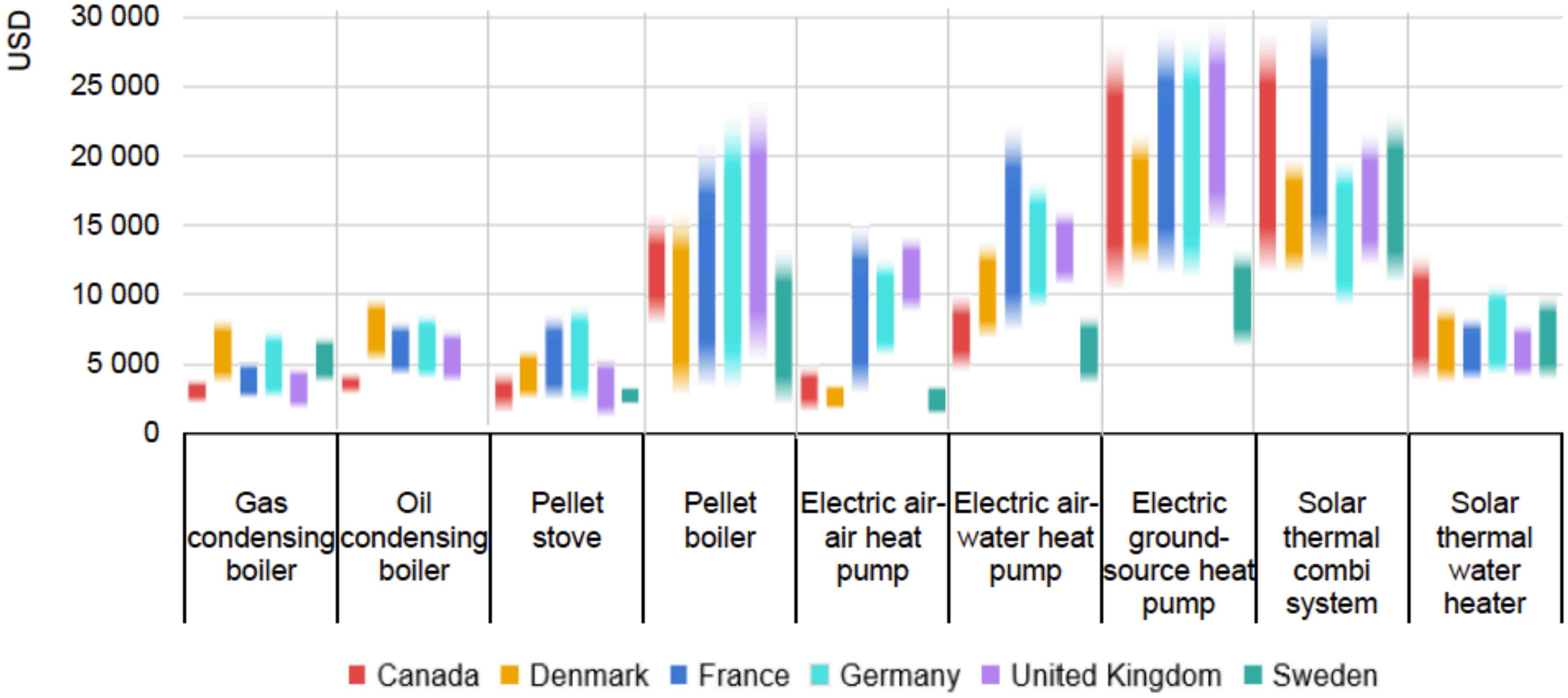
Figure 4.13 EU RFF fund allocation by sector and between renewables



Source: European Commission (2021f).

Are renewable heating options cost-competitive with fossil fuels in the residential sector?

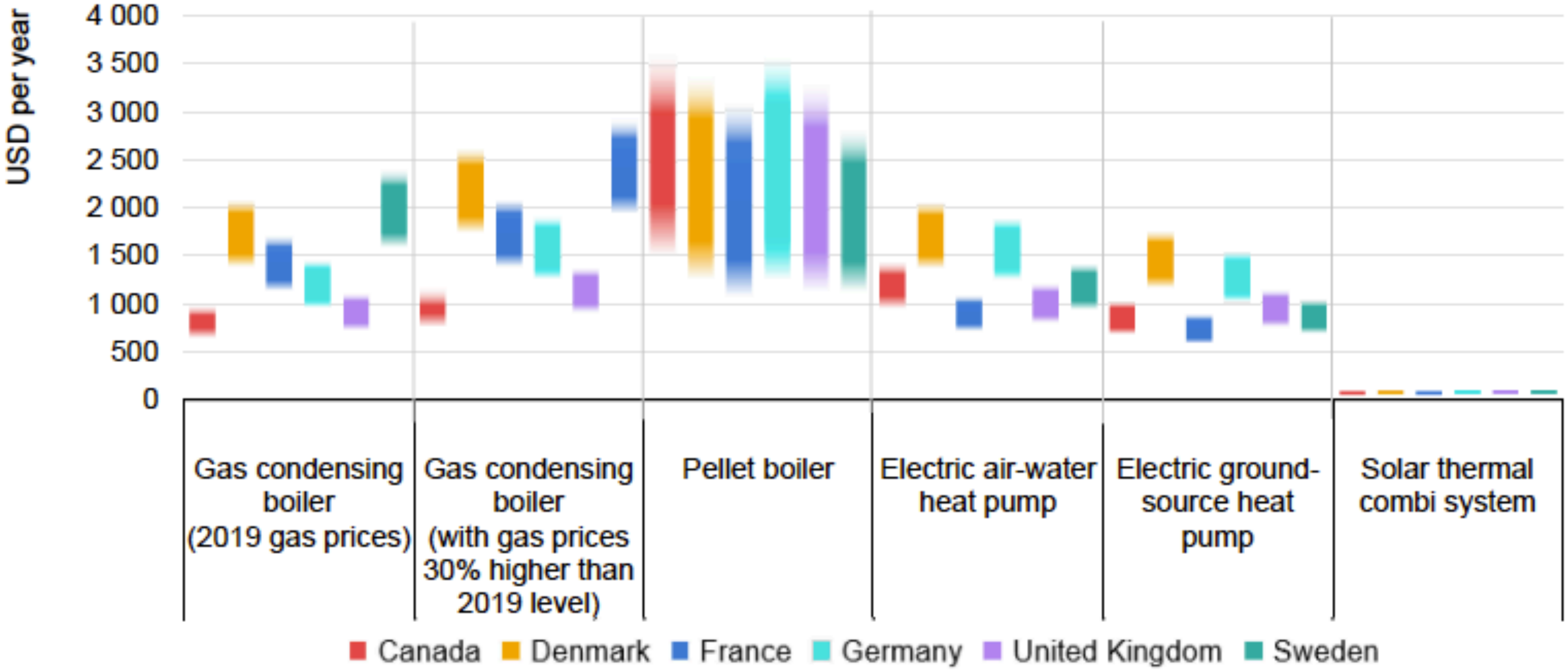
Figure 4.23 Investment cost range for selected residential space and water heating technologies and regions



Notes: Investment costs shown in this figure include unit purchase and installation costs, including value added tax (VAT), for an average single-family house. They exclude ancillary costs (e.g. distribution system) and do not account for policy support.

Are renewable heating options cost-competitive with fossil fuels in the residential sector?

Figure 4.24 Average annual operating cost range for selected space and water heating technologies and regions

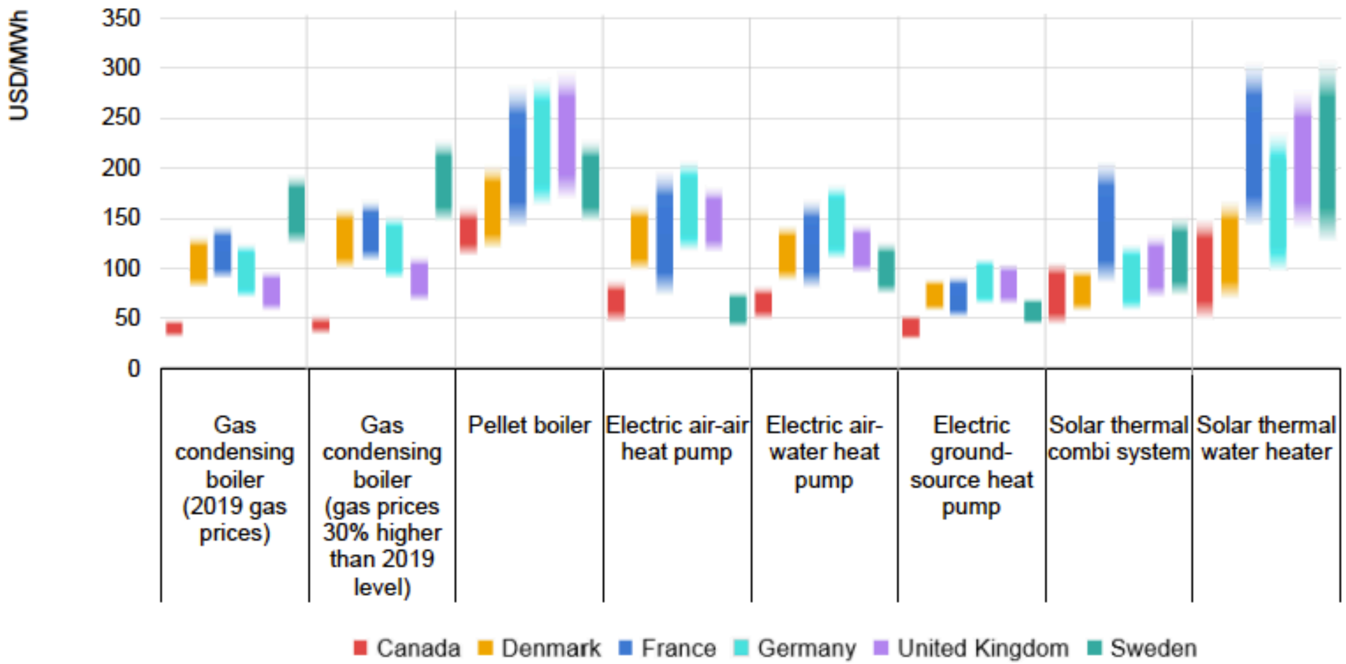


Note: Operating costs shown in this figure are calculated based on national average dwelling heat demand, technology efficiency, fixed operation and maintenance costs and 2019 end-user fuel cost for each country.

Are renewable heating options cost-competitive with fossil fuels in the residential sector?

Overall cost-competitiveness of heating technologies

Figure 4.25 Levelised cost of heating for consumers, for selected space and water heating technologies and countries



Notes: The levelised cost of heating ranges shown here are simplified estimates provided for information. The calculation includes investment costs (including VAT., excluding ancillary costs and policy support), maintenance costs and fuel costs over the lifetime of the technology. It does not account for the cooling potentially supplied by reversible heat pumps. For ground-source heat pumps, we considered the lifetime of the borehole (assumed to last 60 years), with replacement of the compressor unit every 20 years. The calculation assumes constant average dwelling space and water heat demand for each country, constant average national end-user fuel prices at 2019 values (unless specified) and a 2% discount rate. In practice, parameters such as heat demand, total investment costs, technology lifetime and efficiency vary significantly across the building fleet, making each installation a specific case.

The Six Carbon Budget (Dec 2020)

The UK’s path to Net Zero

Table 2.3
Phase-out dates of high-carbon activities under the Balanced Pathway

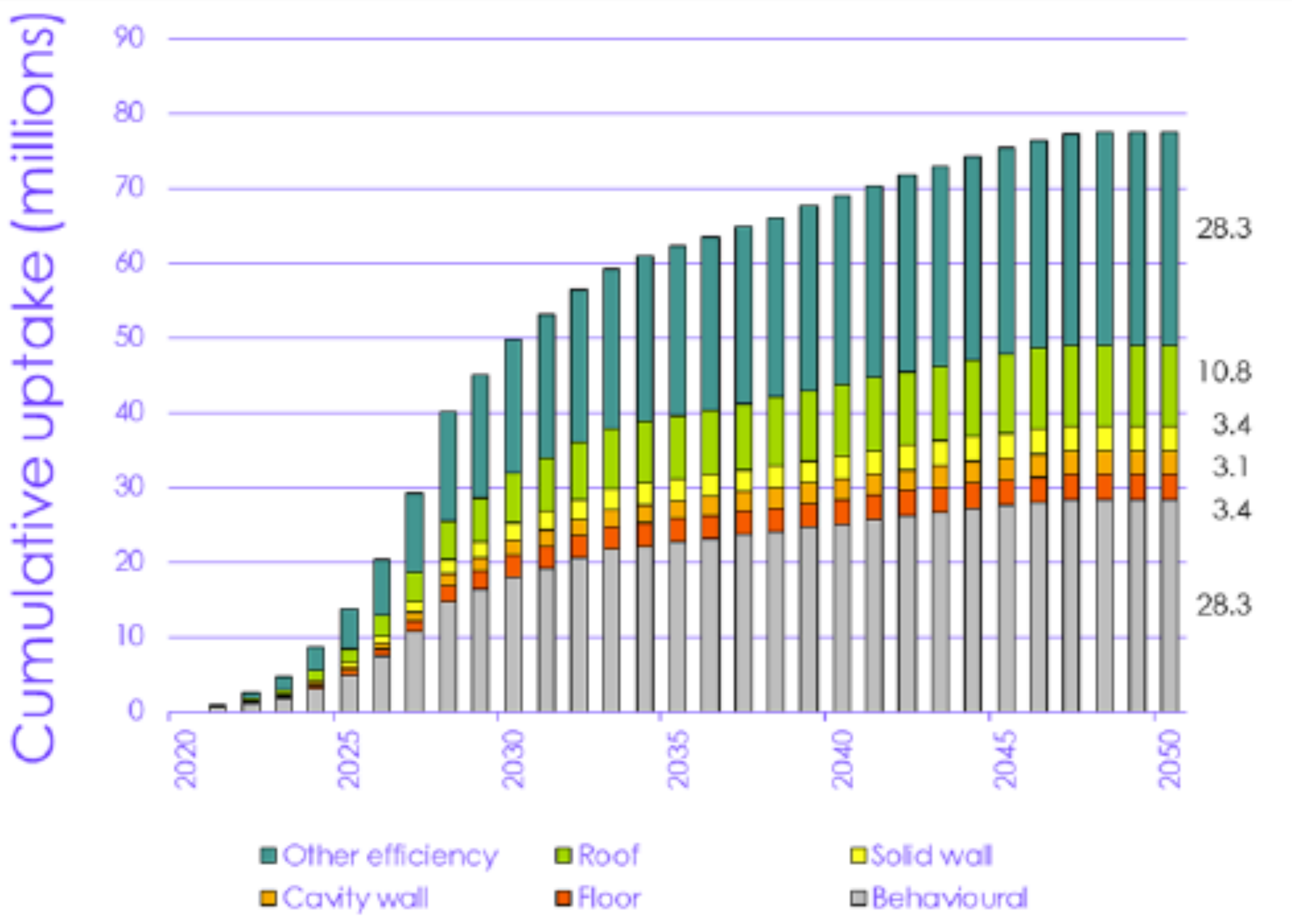
Technology/behaviour	Phase-out date (new sales)	Backstop date (operation)
New fossil-fuelled cars and vans	2032 (including plug-in hybrids)	2050
Gas boilers	2033 (in residential homes) 2030-33 (in commercial properties)	2050
Oil boilers	2028 (in residential homes) 2025-26 (in commercial properties)	2050
Gas power generation (unabated)	2030 (no new build of unabated gas plants from this date)	2035
HGVs	2040 (<1% of sales by 2040)	Beyond 2050
Biodegradable waste sent to landfill	N/A	2025 ban on all municipal & non-municipal biodegradable waste going to landfill
Unabated energy-from-waste plants	From today, new plants and extensions should be built with CCS or CCS ready	2050

Table 3.2.a
Implications in the Balanced Pathway for buildings

	Balanced Net Zero Pathway date	Scenario implications
Efficiency		
All new buildings are zero-carbon	2025 at the latest	100% of buildings built with high-levels of energy efficiency and low-carbon heating (e.g. heat pumps or low-carbon heat networks).
Rented homes achieve EPC C	2028	Rented homes to achieve EPC C by 2028, such that all practicable lofts and cavities are insulated alongside other low-regret measures, with solid wall insulation deployed where this supports low-carbon heat and wider benefits.
Standards for lenders targeting EPC C across the housing portfolio	2025 - 2033	Homes with mortgages achieve EPC C by 2033, such that all practicable lofts and cavities are insulated alongside other low-regret measures, with solid wall insulation deployed where this supports low-carbon heat and wider benefits. This covers just under half of all owner-occupied homes.
All homes for sale EPC C	2028	No dwellings can be sold unless they meet the minimum standard. At the current housing turnover of once every ten years for mortgagors and once every 24 years for outright owners, regulations at point of sale would be expected to result in a further 15% of owner occupied homes meeting the required standard by 2035 (with further upgrades driven by the standards on lenders, totalling at least 60% of owner-occupiers overall).

All commercial efficiency renovations completed	2030	All energy efficiency improvements are made by 2030 to meet the Government's target of reducing business and industrial energy consumption by 20%.
Heating		
All boilers are hydrogen-ready	2025	By 2025 at the latest, all new gas boilers are hydrogen-ready.
Oil and coal phase out (outside of any zones designated for low-carbon district heat)	2028	100% of heating system sales off the gas grid are low-carbon from 2028, with exemptions for any buildings in zones designated for low-carbon district heat. Earlier dates may be possible in public and commercial buildings.
Natural gas phase out (outside of zones designated for low-carbon district heat or hydrogen-conversion)	2033	100% of heating system sales are low-carbon from 2033, with exemptions for any buildings in zones designated for low-carbon district heat or hydrogen-conversion. We assume an earlier date of 2030 in public buildings so as to achieve the Clean Growth Strategy target of 50% emission reduction by 2032.
CHP phase out for low-carbon district heat	2025	Currently, around 93% of district heat networks use a fossil fuel-based primary fuel source. We assume that all new district heat network connections from 2025 are low-carbon. All heat networks supplied by legacy CHP schemes convert to low-carbon heat sources by 2040.
Notes: The fossil phase-out dates drive uptake of building-scale low-carbon heating – predominantly heat pumps, with some flexible resistive electric heating such as storage heating and panels.		

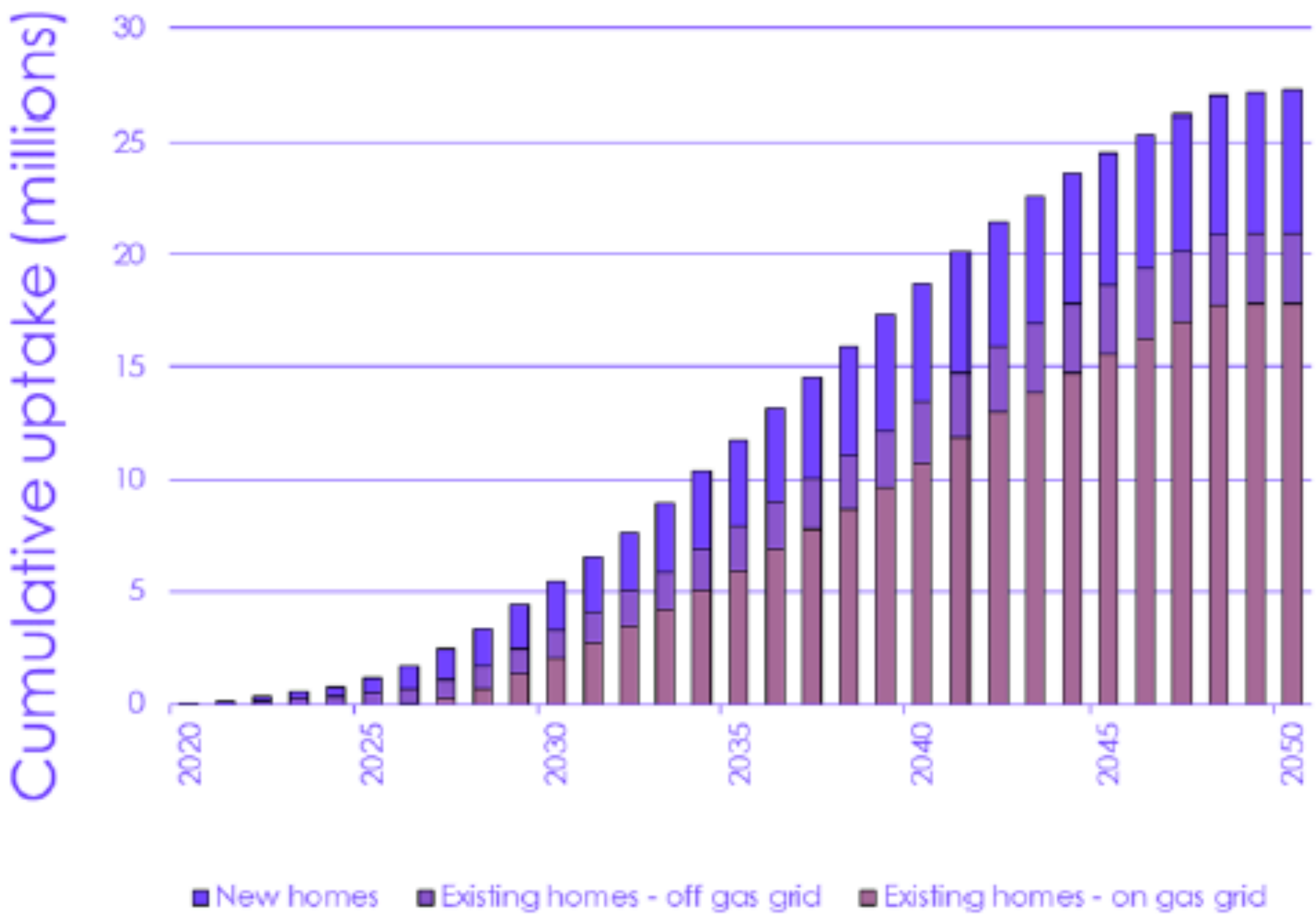
Figure 3.2.b Uptake of heating efficiency measures in existing homes



Source: Element Energy for the CCC (2020) *Development of trajectories for residential heat decarbonisation to inform the sixth carbon budget.*

Notes: This does not include measures which save other electrical demand such as LEDs, wet and cold appliances. Behavioural measures include multi-zonal heating controls and pre-heating (i.e. turning heating on early, off-peak).

Figure 3.2.c Uptake of heat pumps in residential buildings



Source: Element Energy for the CCC (2020) *Development of trajectories for residential heat decarbonisation to inform the sixth carbon budget.*

Our Balanced Net Zero Pathway implies that by 2030, low-carbon heat installations in homes could represent up to around 80% of sales.* Of these low-carbon heat installations, 75% are heat pumps (including hydrogen hybrids), 19% are low-carbon heat networks, and 5% are other flexible electric heating with space heat storage or solar thermal.

- By 2030, heat pump sales reach just over 1 million per year in new and existing homes of a total market of 1.8 million boiler installations currently. There are a total of 5.5 million heat pumps installed in homes by 2030, of which 2.2 million are in new homes (Figure 3.2.c).
- Hydrogen trials are scaled up rapidly in the 2020s to enable rapid grid conversion from 2030 onwards (as detailed in the separate Policy report).
- Low-carbon heat networks are built through 2020-2050, with scaling up through to 2028, from which point around 0.5% of total heating demand is converted per year. By 2050, around a fifth of heat is distributed through heat networks.

By 2030 37% of public and commercial heat demand is met by low-carbon sources. Of this low-carbon heat demand 65% is met by heat pumps, 32% district heating and 3% biomass. By 2050 all heat demand is met by low-carbon sources of which 52% is heat pumps, 42% is district heat, 5% is hydrogen boilers and around 1%