The Future for Home Heating – life without fossil fuels

Guide

NHBC FOUNDATION
Housing research & guidance

NF87

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The NHBC Foundation

The **NHBC Foundation**, established in 2006, provides high-quality research and practical guidance to support the house-building industry as it addresses the challenges of delivering 21st-century new homes. To date, it has published more than 80 reports on a wide variety of topics, including the sustainability agenda, homeowner issues and risk management.

The NHBC Foundation is also involved in a programme of positive engagement with the government, academics and other key stakeholders, focusing on the current and pressing issues relevant to house building.

To find out more about the NHBC Foundation, please visit **www.nhbcfoundation.org**. If you have feedback or suggestions for new areas of research, please contact **info@nhbcfoundation.org**.

NHBC is the standard-setting body and leading warranty and insurance provider for new homes in the UK, providing risk management services to the house-building and wider construction industry. All profits are reinvested in research and work to improve the construction standard of new homes for the benefit of homeowners. NHBC is independent of the government and house builders. To find out more about the NHBC, please visit **www.nhbc.co.uk**.

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Foreword

Over half a century we have become used to the concept of the typical British home being connected to the national gas grid. Some rural areas have remained off grid, but the vast majority of new homes built since 1970 are heated by gas fuelled appliances.

In 2019 the Committee on Climate Change published two landmark reports which highlighted the contribution of our homes to UK carbon dioxide emissions and the opportunity to decarbonise our housing stock and for all new homes built from 2025 to be off the gas grid. The government responded with its announcement of the Future Homes Standard and an aspiration not to connect new homes built from 2025 to the gas grid.

This heralds a major change. Not just for the home-building sector, which will need to rethink and redesign its products, our homes, to meet this goal. We need to retrain its workforce and supply chain to produce and install new systems. It is a major change for homeowners, who will need to adapt their behaviour and lifestyles to using new heating technologies. It is also a challenge for those who advocate these changes to help to identify satisfactory solutions that are acceptable to consumers and to attract investment in delivering them.

This short publication begins to look at what the non-gas home of 2025 might look like. It considers the alternative heating solutions available to homebuilders; our need for hot water; and requirement for new homes to be energy efficient. It is a statement of the obvious, but the less energy a home needs to use, the lower the running costs, and the lower the demand for new generating and distribution capacity. And as our homes become more energy efficient, so the share of the energy bill for hot water increases. It looks at the potential role of heat pumps, solar heating and photovoltaic systems and the place of energy storage.

As we embark on this major re-evaluation of the way we design and deliver the most expensive item that many of us will ever buy, our home, this short review will help to begin that process of re-thinking. It is an important contribution to the process of moving the whole home-building industry into a new era of energy efficient low carbon homes. As homebuilders and the wider construction industry seek to restart after the past few months it is even more important to begin the process of reinvention of our homes for a low carbon future.

Hywel Davies
Technical Director of Chartered Institute of
Building Services Engineers and
NHBC Foundation Expert Panel Member

1 Introduction

Emissions of greenhouse gases due to human activities continue to increase, year after year. The Intergovernmental Panel on Climate Change (IPCC) has stated that our past and future greenhouse gas emissions make it highly likely that global temperatures will increase to 1.5-2.0°C above pre-industrial levels. The IPCC also suggests that in order to avoid the worst effects on the environment and our society this temperature rise actually needs to be limited to 1.5°C. This can be done, but it will require unprecedented levels of action starting immediately[1].

Whilst emissions from UK buildings overall have been falling and are now around 20% below 1990 levels, energy use in the UK's 29 million homes - which accounts for 14% of total UK emissions – actually increased between 2016 and 2017. There has been low uptake of energy efficiency measures and limited deployment of low-carbon heating options (eg. heat pumps) to date[2].

The Government has put in place a number of policies designed to meet its commitment to mitigate climate change. This publication discusses the implications for house builders, designers/architects and policy makers of one of the current key policy elements: that from 2025 no new homes should be heated by fossil fuels (which includes mains natural gas).

The publication explores the implications of designing and building low-energy homes without gas boilers, explains the key technical issues, and discusses the choices facing house builders and their designers/architects when specifying alternative heating systems.

2 The policy context

In 2006 the Government announced a planned Building Regulations trajectory to achieve zero-carbon newbuild housing by 2016 in England. Despite the encouraging progress that was made by house builders, designers and the supply chain over nine years, the policy was postponed by the Government in 2015 in response to the then-ongoing economic downturn.

In a 2019 report the UK's Committee on Climate Change (CCC) recommended that in order to play its part in limiting global warming to 1.5°C, the UK should meet a target of net-zero greenhouse gas emissions by 2050. The Committee stated that this is both necessary, feasible and cost-effective[3].

However, the scale of action required will have to include all sectors - electricity generation, industry, agriculture, transport and behavioural change - as well as energy reductions in buildings. The aspiration was enacted in law through an amendment to the Climate Change Act 2008[4].

At the time of writing, the Government is consulting on proposed changes to Building Regulations Parts L (heat and power) and F (ventilation) to come into force in England in 2020 and 2025[5]. The Government's preferred carbon emissions standard for newbuild homes in 2020 would be 31% better than the current (2013) standard, while the option to provide heating and hot water from a gas boiler would be retained at that time. The same consultation goes on to propose a 'Future Homes Standard' for 2025, whereby carbon emissions would be 75-80% lower than current levels[a].

The consultation indicates that low carbon heating systems, as well as enhanced fabric performance, will have to be specified to meet the 2025 standard. It also suggests that electric heat pumps will become the preferred mass-market solution, largely in response to the CCC's recommendation that new homes should not be connected to the gas grid from 2025.

Heat pumps are much more widely used in Scandinavian countries, for example, than in the UK. With little natural gas available, Sweden has 1.7 million heat pumps installed in its total stock of 10 million homes, and sales of heat pumps have doubled over the last 14 years. This is partly due to regulation (e.g. the banning of oil boilers), partly because the electricity supply grid has long been relatively low-carbon (including hydro, geothermal, wind and nuclear generation), and partly because consumers are demanding running costs lower than those of direct electric heating.

a Housing energy standards in Wales, Scotland and Northern Ireland are undergoing similar reviews at this time, some of which propose more stringent targets and/or timescales than in England.

3 The basics of a low-energy, low-emissions home

It is possible in principle to make a home 'low emissions' simply by switching the means of generating its heating and hot water to a fuel with lower carbon content. However, such a home would be vulnerable to future variations in the carbon content of that fuel (especially if it were grid electricity, which is changing rapidly).

A better approach is to design the home to use as little energy as is practically possible before relying on the fuel to make it a 'low-emissions' home. With this approach it would then be appropriate to refer to the home as 'low-energy' as well as low-emissions[b].

Regardless of the heating and hot water system used, a good low-energy home might have the following basic characteristics[c]:

- minimal space heating demand (e.g. floor, roof and wall U-values around 0.10 - 0.15 W/m^2K; triple-glazed windows; near-zero thermal bridges - which in practice means psi-values ≤ 0.01W/mK; air leakage ≤ 1.0m^3/m^2h @50Pa)
- mechanical ventilation with heat recovery (MVHR) with an efficiency of 85% or better
- good heating controls (ideally zoned and weather-compensated)[6]
- LED fixed lighting
- efficient electrical appliances (A+ or better), if provided by the builder

It is important to note that the energy section of the Building Regulations takes a holistic approach which allows many of these fundamental characteristics to be traded-off against each other.

This general specification can be achieved in principle using either lightweight or heavyweight construction, but either way the design detail must ensure a managed level of solar gain to avoid summertime overheating. Specific guidance on the interplay between energy consumption, daylighting and thermal comfort is available, including from the NHBC Foundation[7].

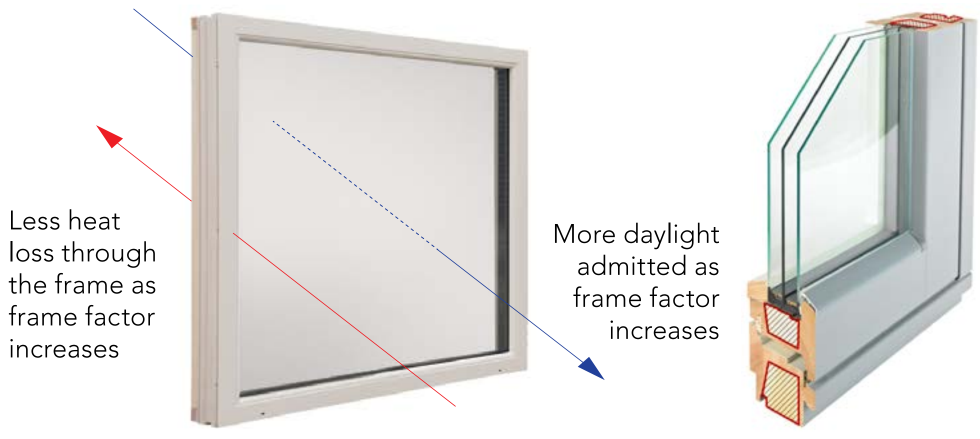

Figure 1 Some of the window characteristics that can affect overheating. (From 'Windows – making it clear', NF78.)

b This is also consistent with the currently proposed Part L 2020, which suggests that primary energy is likely to replace carbon dioxide as the principal performance metric.

c These characteristics are based loosely on the Passivhaus standard. See www.passivhaustrust.org.uk

Figure 2 Photovoltaic panels

The typical low-energy home is also likely to include photovoltaic panels to generate renewable electricity, possibly with a storage battery, which will further reduce its carbon emissions and running costs[8].

Depending on the available roof area, the home may also incorporate a solar hot water system. Hot water demand will be largely unaffected by the higher fabric specification of low energy homes; in fact as space heating demand falls, hot water will become an increasingly high proportion of a home's overall energy demand.

Figure 3 Solar thermal (hot water) tubes

Quality management processes are increasingly being recognised as key to reducing the 'performance gap' in new homes. It is even more important with low-energy homes to ensure that rigorous quality processes are in place during construction. For example, the Passivhaus certification process[9] requires that critical details such as construction junctions and product receipts are photographed and lodged at key stages, and that air leakage tests are carried out at several points as the build proceeds (not just at the end). This is designed to head off problems before it is too late to rectify them.

Figure 4 Examples of quality assurance processes during construction: photographically recorded key details (Top); air leakage testing (Bottom).

4 Electric heating systems in the 2025 home

4.1 Principles

As discussed, it is current Government intent that no new homes will be heated by fossil fuels (including natural gas) from 2025. Another key assumption is that the national electricity grid will be progressively decarbonised, ie. the proportion of generation from renewable sources will continue to increase over time[d]. This means that, subject to the considerations in chapter 6, the domestic heating systems of the future will almost exclusively be electric.

Carbon or energy as a metric – what is the difference ?

For many years the UK's chosen metric for gauging and regulating the intended performance of a home has been the design-stage annual carbon dioxide emissions (often referred to as just 'carbon emissions'). This has meant that a home's compliance with Building Regulations depended upon its calculated heat loss characteristics, the fuel used to heat it and the efficiency of the heating appliance. Compliance could be achieved by trading off these parameters to some extent.

It is now proposed by Government that a further metric will be used alongside carbon emissions: the home's primary energy consumption. Primary energy includes not only the energy content of the fuel used in the home but also the energy used before the fuel reaches the home. In the case of gas and oil, for example, this means the energy used to extract, refine and pump the fuel. In the case of renewably-generated electricity, primary energy includes both the electricity used in the home and the energy lost in transmitting it from the power station to the home.

Using a home's primary energy consumption as a compliance metric essentially means that its compliance with Building Regulations will not change as the grid (and other fuels) are progressively decarbonised, and the home will therefore comply on the basis of its design-stage energy efficiency (including that of the heating appliances).

Direct-acting electric heating (fan heaters, electric radiators and infrared heating) and electric storage heaters operate with 100% efficiency at the point of use – ie. the same amount of energy that they consume from the grid ends up as heat in the home. Heat pumps, on the other hand, can in practice operate with upwards of 200% efficiency, and often as high as 400%. In other words, they can provide up to four times as much heat to the home as the electricity that they consume from the grid. They do this by using a fluid compression/expansion process to move extra heat from a colder place to a warmer one – in this case from the outside environment to the interior of the home.

d It is interesting to note that the proportion of renewable electricity in the UK generation mix has already increased from 23% in 2009 to 48% in 2019.
See www.nationalgrid.com/britains-clean-energy-system-achieves-historic-milestone-2019.

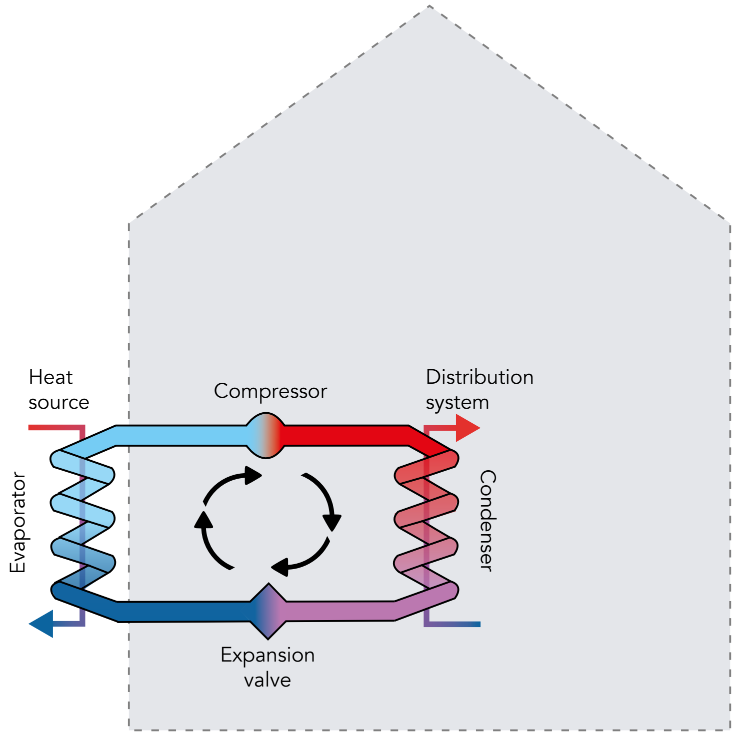

Figure 5 The fluid compression/expansion cycle of a heat pump

The high efficiency of heat pumps results in considerably lower emissions and greatly reduced running costs for the residents, and for this reason heat pumps are likely to be the electric heating solution of choice for the 2025 home. Importantly, electric heating systems other than heat pumps are also unlikely to comply with the proposed primary energy performance targets in future Building Regulations.

Efficiency, COP, SCOP or SPF – which performance indicator should we use?

The efficiency of a heating appliance is essentially defined as the heat energy delivered into the home divided by the energy content of the fuel that was used by or burnt in the appliance while providing that heat. The efficiency of a gas or oil boiler is denoted by a percentage figure, modern boilers having efficiencies of around 90-95% (meaning that 90-95% of the energy in the fuel burnt in the boiler heats the home, the other 5-10% being lost up the flue).

Because percentage figures greater than 100% are counterintuitive to many people, the efficiency of a heat pump is conventionally expressed as a Coefficient of Performance (COP) instead, where a COP of 1.0 is identical to an efficiency of 100%. Similarly, a COP of 2.0 corresponds to 200% efficiency, 3.0 is 300%, etc.

To ensure that different manufacturers account in a consistent way for the energy used in a heat pump's ancillary equipment such as its fans, and also the fact that a heat pump's COP varies from summer to winter, a worldwide industry-standard Seasonal Coefficient of Performance (SCOP) has been defined. The SCOP, or its variant the Seasonal Performance Factor (SPF), are the most comprehensive figures to use when comparing models.

It is not necessary for house builders to understand the detailed technical differences between all of these indicators, but it is essential that the claimed performance of different heat pumps is always compared on a like-for-like basis, ie. using the same indicator. Ideally this should be a seasonal indicator.

4.2 Types of heat pump

In practice, for most UK housing there is a choice of two basic types of heat pump:

- air-source heat pumps (ASHPs)
- ground-source heat pumps (GSHPs).

Air-source heat pumps take heat from the outside air via an external fan-coil unit. There has to be space outside the home to locate the fan-coil unit, for example an external wall that faces into a garden or private courtyard. Planning permission may be needed as a result. ASHPs tend to be less expensive than GSHPs but generally have lower heat outputs and may operate less efficiently, especially when it is particularly cold outside. This is discussed further in chapter 5.

Figure 6 The external unit of an air-source heat pump (ASHP)

A variant of the ASHP is the **exhaust air heat pump** (EAHP), where heat is taken from used ventilation air being mechanically extracted from the home rather than from the external air. EAHPs can operate at slightly higher efficiencies, and in the process recover heat that would otherwise be wasted. In some cases an EAHP may be installed as a second-stage heat recovery device on a conventional MVHR system.

In **ground-source heat pumps** (GSHPs) heat is extracted from the ground, and while GSHPs can provide greater heat output than ASHPs and can operate at higher efficiencies, they are generally more expensive. Part of the reason for the increased cost of GSHPs is that they obtain the heat using a liquid-filled loop located in a vertical borehole or, if external space is more plentiful, a shallower horizontal trench; both of these require excavation work to be carried out on site.

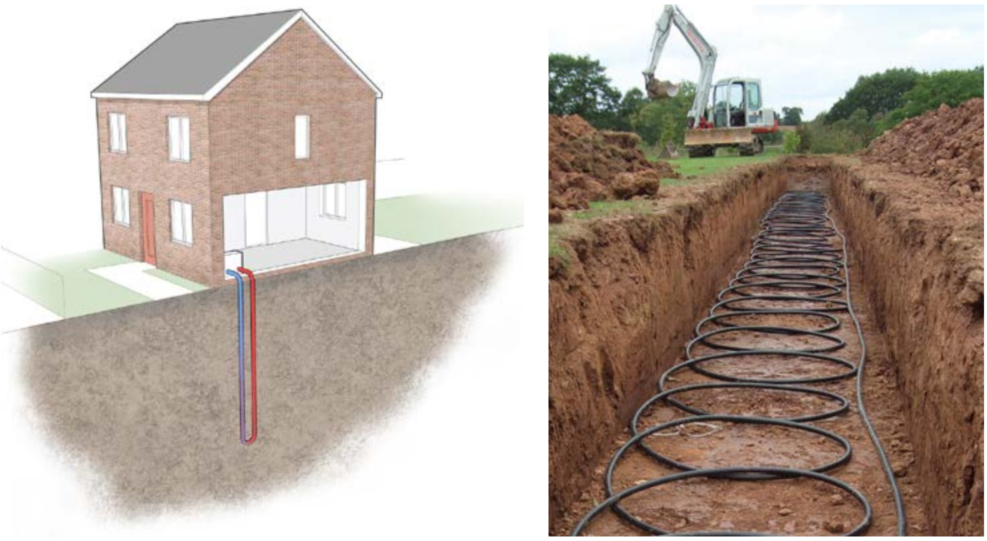

Figure 7 Ground loops: schematic of a vertical loop (L), and 'slinky' configuration horizontal loop (R)

Figure 8 The indoor unit of a ground-source heat pump

Given that the heating demand of the 2025 low-energy home will be very low, as discussed in chapter 3, the relatively low output of an ASHP is likely to be adequate for all but the largest individual homes.

> **IMPORTANT NOTE:** It is vital to consult a qualified heating system designer, in particular one who specialises in heat pumps, to ensure that the system is correctly sized and can provide the necessary comfort conditions for the residents. This is doubly important with ground-source heat pumps, where the design of the ground loop is in itself a specialist subject[10].

4.3 Heat emitters for heat pump systems

Irrespective of whether the heat pump is ground-source or air-source, there are essentially two ways in which the heat can be distributed around and emitted into the home:

- directly via the air, or
- using a wet circuit such as radiators or underfloor pipes.

These are discussed in the following sections.

Figure 9 An air-based heat distribution unit

4.4 Heat pumps in houses

Houses, which are conventionally heated by a mains gas boiler to wet radiators or underfloor pipework, can use either ASHPs or GSHPs. Due to their higher thermal output and somewhat higher cost, GSHPs would tend to be used in larger houses or in a small number of closely-grouped houses which can share a ground loop.

Air-based heat distribution is currently relatively uncommon in UK houses for various reasons. There are physiological reasons why human beings tend to feel 'less warm' in the absence of some proportion of radiant heat[11], and as a result warm-air heating systems became unpopular in the relatively poorly-insulated homes of the 1970s. House builders tend to find it easier to market homes with wet distribution systems.

There can also be physical challenges in distributing the required amount of heat using just air, especially in larger homes. Whilst it is more common, even in low-energy houses, to distribute the heat using a wet system such as a conventional radiator circuit and/or underfloor heating, air-based distribution systems may become more common in smaller types of future home.

IMPORTANT NOTE: As with the heat pump unit itself, it is vital to consult a qualified heating system designer to ensure that the heat emitters are correctly sized and can provide the necessary comfort conditions for the residents. See also chapter 5, 'Emitter sizing'.

Individual heat pump systems using wet distribution circuits in homes are, at the time of writing, eligible in principle for Government subsidy through the domestic Renewable Heat Incentive (RHI). It is, however, inadvisable to rely on such subsidies when making investment decisions[12].

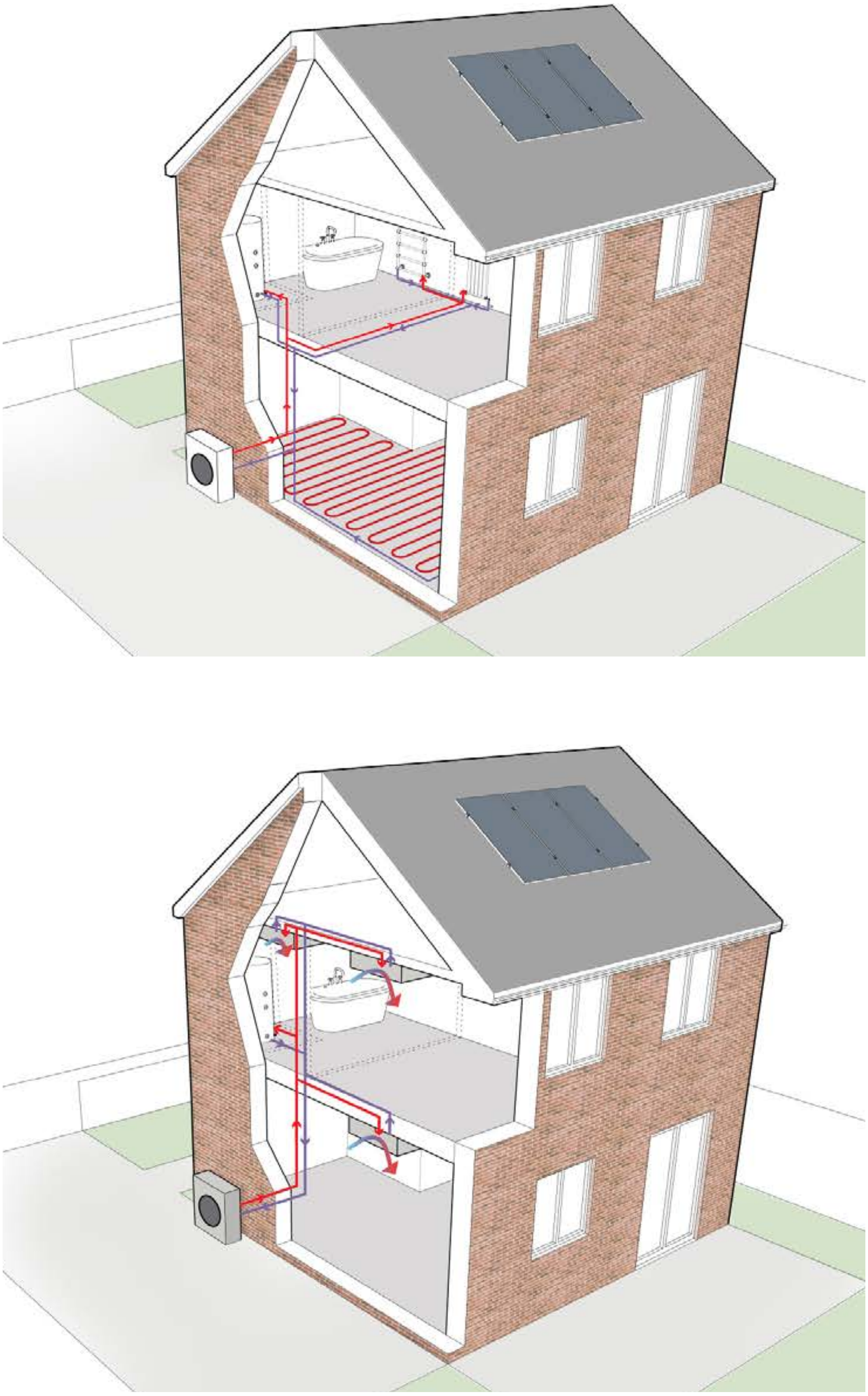

Figure 10 General schematics of a typical heat pump home: (a) with a wet distribution system, and (b) with an air-based distribution system

4.5 Heat pumps in apartments

Apartments are traditionally heated by electric storage heaters, direct-acting electric panel and fan heaters, or communal boiler systems (usually gas-fired). According to the current consultation the natural gas-fired solution will not be allowed from 2025, and the traditional electric systems are unlikely to comply with the proposed future primary energy targets discussed above. Heat pumps are therefore likely to be the preferred solution in the 2025 apartment as well as the 2025 house.

The capital cost of the heating system is particularly critical in smaller residences, and house builders need to take this into account if considering individual air-source heat pumps for apartments. Moreover, apartments may not have the necessary external wall area on which to affix individual air-source heat pumps. It is therefore more common to use some form of communal heating system in apartments.

In this communal scenario the traditional shared boiler may be replaced by one or more central heat pumps – either ground-source (sometimes located in a basement plant room) or air-source (often on the roof, as commonly seen in office developments). The heat produced by the central heat pump(s) is circulated around the building either via a high-temperature wet circuit and then through radiators in each apartment, as in traditional boiler-based communal systems, or through the building's ventilation system.

In this scenario, ideally the heat used is individually metered and billed for each apartment, which can add to the capital cost and complexity. Centralised systems of this nature can also lead to overheating of communal areas such as corridors and stairwells if the pipework is poorly designed and/or inadequately insulated.

An emerging solution is to omit the central heat pump(s) and simply route a shared-array ground loop around the building. Heat is extracted from the relatively cool shared loop by a very small[e] ground-source heat pump in each apartment. These systems are sometimes referred to as "shoebox-type" heat pumps due to their small size, even though they are rather larger than a real shoebox[13].

e Typically 500mm x 500mm x 400mm

Shoebox-type heat pump systems

Figure 11 A shared ground loop array for an apartment block

In such systems the loop fluid emerges from the ground at ambient temperature (which can vary between -5°C and +20°C, but is typically +10°C in the UK), and is distributed around the building at this temperature. This minimises distribution losses and prevents overheating of corridors etc. Heat is extracted from the ambient (or 'neutral') loop by each apartment's heat pump and is distributed within the apartment via a conventional wet radiator or underfloor system.

These heat pumps are engineered to be particularly quiet, and energy metering is extremely straightforward since each one is simply plugged into the apartment's normal electrical circuits. There is usually no need for a large central water pump for the shared loop, since it is driven by the small water pumps within the individual heat pumps.

Figure 12 A shoebox-type heat pump in situ

One area that requires particular attention is to ensure that the domestic hot water (DHW) cylinder in each apartment has a correctly sized coil for the heat pump being used. These coils will typically be larger than would be expected for a gas boiler system. Some systems boost the storage temperature of the DHW using electric immersion heaters, and accept the additional running costs. This is discussed further in chapter 5, and whichever solution is chosen the importance of employing a suitably experienced heating designer is again stressed.

Some communal heat pump systems are, at the time of writing, eligible in principle for Government subsidies through the non-domestic RHI scheme. It is, however, inadvisable to rely on such subsidies when making investment decisions[14].

5 Further issues to consider in the 2025 home

5.1 Water heating

Domestic hot water (DHW) loads are becoming an increasing percentage of a home's total energy demand. When a heat pump is providing DHW via a conventional indirect cylinder, the heat pump's flow temperature is often increased for short periods to typically 70°C rather than the optimal 45-55°C. This can lead to a lower efficiency while the heat pump is providing DHW[f], and there has been some concern in the past that this can lead to higher running costs.

Many of the historical issues were due to bad design, installation and/or commissioning, and as long as the calculated heating and hot water demand is properly matched to the heat pump's output characteristics and the cylinder design then there should be no problem[15].

Some heat pumps, notably certain models of exhaust-air heat pump, contain an integral DHW cylinder. In this instance it would be reasonable to assume that the integrated system is sized to work well as a whole, but the suitability of the system to the home still needs to be checked by a heating designer.

The DHW temperature might in certain systems be boosted by an electric immersion heater. In some installations the DHW may be entirely provided by a conventional electric dual-immersion system, although these only operate at 100% efficiency so may run into compliance issues in terms of running costs, carbon emissions and the proposed primary energy target.

In small homes where the hot water demand is low, DHW might be provided by instantaneous electric water heaters at each point of use. These are relatively cheap and incur no storage losses, but are likely to have the same compliance issues as electric immersion systems. A qualified on-construction domestic energy assessor (OCDEA) will be able to advise in both cases.

Larger homes with sufficient roof area may benefit from solar water heating, operating in conjunction with a heat pump or other electric water heating appliance. Solar hot water systems clearly reduce energy consumption, running costs and emissions, but there are trade-offs to be considered (e.g. is it actually cost-effective? Would it be better to dedicate any available roof area to photovoltaics?). Advice should be sought from an OCDEA and cost consultant.

IMPORTANT NOTE: As always, the importance of employing a suitably experienced heating designer cannot be emphasised enough. The designer should consider both the system sizing and any temperature cycling that may be required to avoid the risk of Legionella.

f Because it is an inherent characteristic of heat pumps that a higher flow temperature leads to a lower operating efficiency

5.2 Emitter sizing

In order for a wet-emitter heat pump to work at the highest efficiency, the flow temperature needs to be lower than that of a conventional gas boiler system – typically 45-55°C as opposed to 65-70°C.

One way to ensure that the home is warm enough with such a low flow temperature is to specify considerably larger radiators – perhaps as much as twice the normal size. Even though this is technically straightforward it is prudent to have the radiators sized by an experienced heating designer. Alternatively, compact low-temperature radiators are available which may have better aesthetic appeal than oversized ones. They are typically made of aluminium rather than steel, with highly efficient convection fins, low water content and sometimes incorporating a small electrical fan. Low-temperature radiators can be more expensive than traditional ones, but have a more normal 'wall footprint'.

Alternatively, a wet underfloor distribution system can be used. Underfloor systems work with lower flow temperatures than radiators as a matter of course, so are sometimes said to be inherently more suitable for heat pump installations. There can, however, be cost implications in installing underfloor systems rather than radiators.

Figure 13 A low-temperature radiator

Due to the lower flow temperatures of heat pumps, it is likely that residents will need to adjust certain elements of their behaviour. For example, to maintain adequate comfort conditions in mid-winter it may be necessary to leave the heating on constantly, rather than for the more usual two separate heating periods per day. Running costs will depend on the room temperature selected by the residents.

5.3 Running costs, carbon emissions and Energy Performance Certificates.

At the time of writing, the UK's national calculation methodology for Building Regulations compliance, SAP, is in the process of being revised[16]. Moreover, there is a proposal to change the main compliance metric as described in the box 'Carbon or energy as a metric – what is the difference?' in chapter 4. It is not, therefore, appropriate for this report to discuss specific SAP ratings, Dwelling Emission Rate (DER) calculations or Energy Performance Certificate (EPC) results.

However, it is generally recognised that the running costs and carbon emissions of a home heated by an electric heat pump can be comparable to those of the same home heated by a different system, depending on the type[17].

5.4 Midwinter performance

Between 2008 and 2012, research by University College London and the then Department of Energy and Climate Change (DECC) revealed that many heat pumps were performing considerably worse than predicted[18]. For example, the outdoor fan-coil unit of some ASHPs iced up during extended periods of very cold weather, which caused their output to fall and required them to switch into expensive and carbon-intensive defrost modes to restore full performance.

It has subsequently been concluded that many such issues were caused by bad design, installation and/or commissioning rather than by any inherent shortcomings in heat pump technology. As long as the heat pump is professionally sized for UK conditions and properly installed there should not be an issue[19].

5.5 Noise (internal and external), and other planning requirements

There have been cases where the external fan units of air source heat pumps have been found to be unacceptably noisy, especially when installed in a small garden or courtyard that the residents use socially. This can be exacerbated by the fact that the heat pump compressor can also be located in the external unit. Excessive noise is not inevitable however, and it is recommended that house builders ask their suppliers to demonstrate the proposed external fan/compressor unit in a real installation.

ASHPs can be classed as permitted developments as long as a series of requirements, including the Microgeneration Certification Scheme planning standards, MCS 020, are met[20]. However, at the time of writing ASHPs require a full Planning application to be made if they are sited within 1m of the property boundary or installed on a wall which is fronting a highway and is more than one storey high. In all cases the external noise of an ASHP must be less than 42 dB(A) when measured 1m from any habitable room in the next-door property.

Where air distribution is used within the home, the heat pump will have one or more indoor fan units. This should be designed by the manufacturer to be virtually silent, but again house builders should ask their suppliers to demonstrate the noise level in a real installation. Where heat is distributed by a wet system, the pump will be a conventional, near-silent, central heating pump.

The main unit of a GSHP is often located inside the home. Some GSHP manufacturers state that their indoor units are quieter than conventional gas boilers, but since the unit contains both the loop pump and the compressor it is prudent in this case to check that the noise level in a real installation is indeed satisfactory.

If the home contains a whole-house ducted ventilation system such as MVHR, it is essential with well-insulated buildings (which are already quieter) that the ventilation system runs quietly. Duct-generated noise can be reduced by using generally larger duct sizes, but ideally the acoustics of the system should be modelled by the designer or supplier. They should then specify correctly sized silencers (or 'attenuators') for each duct run, and the house builder should ensure that the specified silencers are actually installed on site.

Some ducted systems include both primary attenuators to reduce noise generated by the fans, and secondary 'cross talk' attenuators to reduce voice transmission between rooms.

5.6 Maintenance

Heat pumps are generally reliable, long-lasting and require relatively little maintenance. Most manufacturers recommend that their products are serviced annually, as is normally the case with gas boiler systems. A heat pump service includes a number of items that a gas boiler service does not, for example the cleaning of coils and fans, replacement of filters, checking refrigerant level/pressure and verifying compressor operation. For GSHPs the antifreeze concentration in the ground loop will be checked, along with the operation of the loop pump. For ASHPs the outside unit will be cleaned to ensure that airflow is not impeded by debris (leaves, dust etc).

The cost of a heat pump service is typically slightly more than that of a gas boiler.

Figure 14 Blocked ASHP outside unit

5.7 Cooling using heat pumps

It is technically possible to operate most heat pumps in cooling, as well as heating, mode. If this were to happen at a national scale it would increase the UK's energy consumption and carbon emissions by a significant amount. Government policy is therefore that new homes should mitigate summertime heating by passive design principles and simple ventilation measures rather than by using electrical cooling technologies. Notably, the permitted development rules discussed in section 5.5 only allow heat pumps which can be used solely for heating purposes.

In this light, house builders should carefully consider whether to market their new homes on the basis that they include cooling.

5.8 Direct electric heaters in apartments

Where a smaller apartment is used as a weekend holiday home or occasional commuting residence, the residents may choose to run the heating just for short periods. In this instance it may be more effective to heat the apartment using direct electric heaters (e.g. fan heaters, electric radiators or infrared heaters) than with a heat pump. In this instance the higher daily running cost of the direct electric system might be offset by its lower capital cost.

It is interesting to note that there are an increasing number of infrared (IR) heaters appearing on the market at present, which work in a slightly different way to other direct electrical heaters. Infrared energy is radiated from the panel face in multiple directions and directly heats objects in the environment. This means that IR heaters must be located in a place where they are unobstructed and can provide direct heat transfer to the room, and for this reason many infrared panels are installed on ceilings. This also helps to overcome the fact that some models reach high temperatures. With this in mind, manufacturers' installation guidelines should be followed to ensure that health and safety concerns, as well as resident comfort, are properly considered.

The manufacturers' premise is that IR heaters use less energy to heat a home than convector heaters (which also heat the air). It should be noted, however, that the Building Regulations compliance tool, SAP, does not currently recognise any such energy benefit of IR heaters over other direct electric systems.

Figure 15 An infrared heating panel

For any home heated by direct electric appliances, a qualified energy assessor should be asked to carry out the relevant calculations to confirm that the home still complies with the primary energy target of the proposed Building Regulations.

Note: traditional electric storage heaters would not normally be considered appropriate for an intermittently-heated home, due to their slow response to changes in heating demand.

5.9 Cooking

Clearly the 2025 home will not have natural gas cooking, since it will not be connected to the gas main. Because consumer preference has traditionally been for gas hobs and electric ovens, house builders may face a challenge of marketing all-electric cooking.

Modern electric hobs fall into four categories: sealed plate, ceramic, halogen and induction. In a householder survey carried out in 2011, respondents with ceramic and sealed plate hobs disliked the lack of control over the exact cooking temperature, the time taken to heat up and cool down, and the appearance. Those with halogen hobs particularly liked the appearance, ease of cleaning and quality of heat distribution across the base of pans.

Most importantly, house builders can be reassured that there are electric hobs available that consumers will happily accept. Moreover, energy modelling has shown that the most advanced electric hobs can achieve levels of energy consumption akin to gas hobs.

Full details can be found in the NHBC Foundation report 'Low carbon cooking appliances', NF33[21].

Figure 16 Electric cooking hobs: ceramic (L); induction (R)

5.10 Electrical supply capacity

Assuming that the principles of the proposed 2025 non-mains gas newbuild standard are progressively rolled out to the existing housing stock too, the national electricity infrastructure will face significant challenges. The move to electric vehicles will also magnify the scale of the effect. There are serious implications at the level of the individual home, the development, the local distribution network, the national transmission network and the UK's power stations. It is possible that peak national electricity demand could be 40% higher in 2050 than it is today[22].

A detailed discussion of the problem and its solutions is beyond the scope of this report. Government and the energy industry recognise the scale of the challenge and are working on the issues. It is likely that more power stations will have to be built (running on renewable energy), the physical capacity of the distribution and transmission networks will have to be increased, new specifications for individual consumer units will be needed, and a combination of new energy management techniques, both supply-side and demand-side, will have to be used.

These will include grid-scale and small local battery storage, vehicle-to-grid services, domestic demand-side reduction services, peer-to-peer energy trading and other techniques yet to be invented. For a more detailed discussion of these technologies and services see the NHBC Foundation guide 'Watts in store? Introduction to energy storage batteries for homes', NF83 [8].

It is interesting to note that the UK's current smart meter rollout programme was put in place as much to support these techniques and services as to enable the energy suppliers to provide more accurate bills[23].

5.11 Skills shortages

The current consultation on the Future Homes Standard recognises that a major move from gas to electric heating may cause skills shortages. The Government states in the consultation that it is currently engaging with the supply chain to ascertain the scale of the challenge and determine the crucial roles for Government and industry to address the problem.

5.12 The performance gap

There have been many studies of the as-built performance of UK homes compared to their design performance, for example by the Zero Carbon Hub during the 2010s[24]. As heating systems are progressively down-sized to match the heating demand of modern low-energy homes, it becomes increasingly important that there is no performance gap, in order to ensure that the homes are as warm in practice as they are designed to be. The Government's aspiration is that the proposed amendments to Part L can help to address this via an increased focus on build quality and compliance checking.

6 Non-electric heating in the 2025 home

There are few scenarios under which the future non-gas home might be heated by a fuel other than electricity.

6.1 Heat networks and combined heat and power (CHP)

New wide-area heat networks (also known as district heating) can give rise to capital cost savings as well as reduced running costs and carbon emissions. They can give some flexibility for centrally-generated heat to be provided by waste heat or by the combustion of renewable fuels such as biomass. However, most existing heat networks are fuelled by natural gas.

At the time of writing there is some uncertainty as to whether the Government will view the connection of a new home to an existing gas-fired heat network as connecting it "to the gas grid". If new connections to existing gas-fired networks were to be prohibited in this way, it could cause problems for networks whose economics were planned around a phased build-out of connected homes over a number of years.

There are further carbon benefits if electricity generation is added to a heat network (which would then be known as a 'combined heat and power', CHP, scheme). However, if such a system were fuelled by natural gas there would be the same doubt about whether it would comply with the Future Homes Standard.

6.2 Hydrogen

The proposal to prohibit new homes connecting to the gas grid arises because mains natural gas is methane, a damaging greenhouse gas in itself as well as a source of carbon dioxide when burnt. It is therefore likely that the composition of mains gas (still available to existing homes after 2025) will be changed over time to include an increasing proportion of biogas and/or hydrogen. There have also been UK initiatives to heat homes using pure hydrogen delivered to and stored on the plot in cylinders.

Hydrogen can be produced by 'reforming' natural gas, an industrial process during which the carbon component of the methane is captured and locked away permanently (a technique known as 'carbon capture and storage', CCS). Hydrogen can also be produced by electrolysing water, and as long as the electricity used for this is renewably generated (e.g. by wind turbines or photovoltaics) then the hydrogen can be said to be carbon-free.

There are safety issues relating to pure hydrogen gas, since it can explode at dispersion levels at which methane cannot. If it is stored and transported in cylinders then there are additional issues of transportation cost (heavy cylinders) and its low density (so hydrogen requires larger storage facilities than, say, propane).

Some boiler manufacturers are developing hydrogen boilers, and a major Government-sponsored project is underway to explore the many issues[25]. It is nevertheless considered unlikely that pure hydrogen heating will become mainstream in the newbuild sector in the near future.

6.3 Biofuels

Individual homes can also be heated by biogas or liquid biofuels, which are produced from sewage, solid waste or crops grown for the purpose. These, too, have issues of transportation and storage. Biofuels in general are also likely to be in great demand by the transport sector, leading to competition for the limited land resource in the UK that is needed to produce the fuels.

A number of low-energy new homes have been built over the years with biomass boilers (e.g. wood, wood pellets or straw). However, the relatively high output of solid fuel heating appliances does not lend itself to the very low heat demand of such homes. Moreover, the growing policy intent by Government to improve air quality is likely to restrict solid fuel combustion significantly in future[26].

Figure 17 A farm-based biogas facility

7 Summary and conclusions

- Policy announcements and the revisions to Building Regulations proposed at the time of writing suggest that new homes built from 2025 will not be allowed to be heated by fossil fuels (including mains natural gas).
- The same proposals indicate that electric heat pumps will then become the predominant method of heating homes, although there are alternatives.
- In order to meet the proposed carbon and primary energy targets, the 2025 home must be designed and built to have minimal energy demand in the first place. This will require most or all of the following:
  - minimal heat losses via the building fabric and air infiltration
  - a high-efficiency heat recovery ventilation system
  - good heating controls
  - LED fixed lighting
  - A+ rated (or better) electrical appliances, where provided
  - photovoltaic panels, battery storage and/or solar hot water systems.
- Two types of electric heat pumps are available: ground source and air source. Both types can in principle distribute the heat around the home via the ventilation air or a wet radiator/underfloor system.
- The choice of which type of heat pump and distribution system to install depends on the built form, size, tenure and physical location of the home.
- In order to ensure that the home is warm enough, and that the provision of domestic hot water is adequate, it is vital that specialist advice is sought from a suitably qualified and experienced heating designer. There have been examples of heat pumps being undersized, unreliable or too noisy through lack of such advice.
- House builders will need to consider how best to market homes that have a heat pump and do not have a gas cooker.
- It is possible that there will be a shortage of skilled designers and installers of heat pumps, at least initially, as the policy comes into force.
- House builders should consider the benefits arising from heat networks (or ‘district heating’ schemes) where a network already exists or it is technically and economically possible to install one from scratch.
- House builders will need to consider how future home owners and occupiers are made aware of how to operate and maintain non-fossil fuelled homes.

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