House building: a century of innovation

Technical advances in conventional construction

Guide

NHBC FOUNDATION

Housing research & guidance

NF85

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Foreword

Two fundamental and related challenges for house builders are how to increase the output of new homes while at the same time ensuring that we continue to drive up standards. In this context much attention has been focused on modern methods of construction (MMC) and the contribution they can make to expanding volume and enhancing quality. In the debate about the advantages of MMC an unfavourable comparison is often made with 'traditional construction' – laying bricks in mortar and laboriously cutting timbers on site being characterised as dated and inferior to modular panels manufactured in a controlled factory environment. However, this oversimplifies the argument, ignoring the extent to which new homes supposedly built in a 'traditional' way actually incorporate new systems and technology, very different from what would have been used in the 'traditional' housing of the past.

The purpose of this latest NHBC Foundation report prepared by Studio Partington is to describe typical (non-MMC) construction used for new homes and contrast it with 'traditional' methods that have been used in the preceding 100 years or so. It makes clear that what lies beneath the skin of new homes is quite different from what has gone before.

Of particular note is the improved robustness of new homes and their inherent resistance to ground movement and the ingress of rainwater. Other advances include the improved efficiency in the use of materials that comes with components such as timber trussed rafters and engineered floor joists. Added to this are the enhanced comfort and lower fuel bills which flow from the higher energy performance standards of modern homes, setting them apart from previous generations of housing.

The report reminds us that all forms of construction may once have been considered to be MMC. A case in point is timber frame, which was introduced into the UK in the 1960s and currently accounts for nearly a fifth of overall output. According to NHBC statistics, about 75% of homes currently being built are using cavity masonry construction and 16% are timber framed. Based on these figures it appears that 'traditional' construction will continue to play a strong role, even if its components continue to evolve, reflecting advances in technology. Against this background it is important for us to have a proper understanding of what it actually is.

Rt. Hon. Nick Raynsford
Chairman, NHBC Foundation

1. Building envelope

Introduction

Despite changing fashions, regulations and taxes, the appearance of domestic architecture and the techniques used in its building have remained essentially unaltered for centuries. Homes were built from solid, often masonry, walls with small openings and pitched roofs formed from rafters supported on purlins and covered with small format coverings of tile or slate.

It was not until the introduction of the cavity wall in the mid-19th century that any significant change in building techniques occurred. Cavity construction became the norm and was standard for the great house-building boom of the 1930s, continuing throughout the 20th century, with the assurance of construction standards pioneered by NHBC.[1]

A brief period of experimentation with factory production led to a host of new materials and construction methods being introduced after the Second World War to make use of the existing manufacturing capacity and find alternatives in a period of scarcity of traditional materials.[2] These innovations helped meet the immediate and temporary housing need, but the traditionally built home prevailed in the following decades.

It was not until the 1980s that a series of successive legislative and consumer led changes saw a rapid change in domestic construction with substantial improvements in fire-safety, acoustics, energy conservation and general comfort.

This section looks at the technology and materials incorporated in the construction of a modern home and compares the performance achieved in relatively recent times with the advancements of the last two decades. Product and component suppliers began to provide standardised building elements to help improve quality and reduce the labour time on site. By the end of the century most roof trusses were delivered pre-assembled and many of the lintels, cavity closers, membranes and trays that provide support and defence against water ingress could be pre-formed accurately in the factory to complex shapes and profiles.

[1] The National House-Builders Registration Council (forerunner of the NHBC) published the first 'Model Specification' for new homes in the 1940s. NHBC's Standards are continually revised and are now republished annually.

[2] Timber stocks had greatly been diminished during the war, mainly for use in pit supports for the mining industry, and forest re-planting schemes were yet to deliver new supplies.

Components

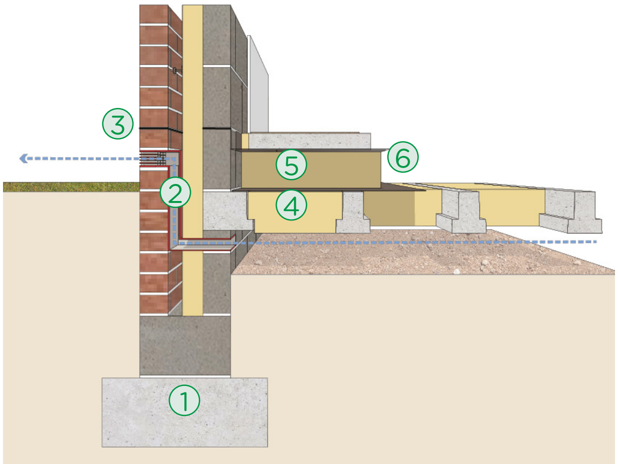
Outwardly the modern home can follow many different styles of design but the fabric of all new homes (the 'building envelope') must meet the same standards for insulation, acoustics, weather-tightness, fire protection and structural stability. Within the thickness of the wall and the depth of the roof and floors there are multiple layers of high-performing materials and many innovations that, although hidden, contribute to the overall performance of the home.

Figure 1 The building envelope

1 Concrete strip foundation
2 Ground floor – precast concrete beams with thermal insulation blocks
3 PVC-U windows with double-glazing and built-in ventilators
4 Multi-layered masonry external walls including thermal insulation
5 Engineered timber floor joists with voids for services
6 Deep loft insulation
7 Prefabricated timber trussed rafters
8 Waterproof and breathable underlay to the roof tiles and battens

1.1 Foundations and ground floors

Today’s foundations provide a solid base, resisting ground movement, subsidence and structural damage; ground floors are now free from draughts and insulated to keep the heat in.



1 Concrete strip foundation
2 Telescopic ventilator
3 Damp proof course (DPC)
4 Thermally insulated floor block
5 Ground floor insulation
6 Damp proof membrane (DPM)

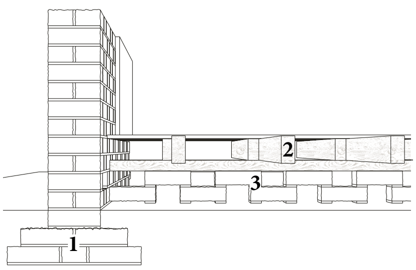
Figure 2 2019 typical foundation/ground floor

Now Concrete strip foundations in accordance with current Building Regulations are stable and resistant to ground movement. On clay soils where there are trees, deeper strip and trench fill foundations or engineered foundations (such as piling) are used, designed to NHBC’s Standards.

Ground floors are typically constructed using precast concrete beams with insulation blocks fitted between them and a sand and cement screed on top. This provides a stable, well-insulated floor that is free from draughts and is not at risk of timber decay. Membranes can also be incorporated to control ground gases such as radon where they are present.

Then Foundations were minimal – just a couple of courses of corbelled brickwork. Being shallow, they were susceptible to ground movement, at risk of subsidence and structural damage – a particular problem for homes built on clay soils close to trees.

Ground floors were typically constructed using timber floor joists supported on the external brickwork and intermediate sleeper walls with timber floorboards. Key issues were the risk of timber rot if the walls became damp as well as draughts through gaps between floorboards.



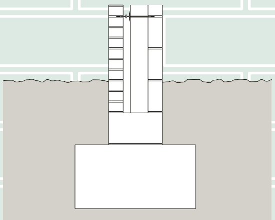
1 Stepped brick footing
2 2 x 8 inch timber floor joists
3 Sleeper wall

Model Specification
NHBC, 1946

Clause 73. Ground Floor Space

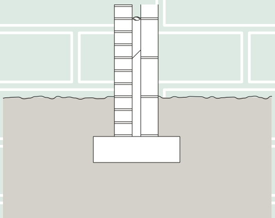
Before the ground floor boards are laid the space between the over-site concrete and the floor is to be entirely cleared

Figure 3 19th century typical foundation/ground floor



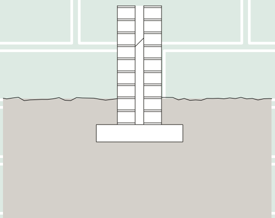
2019

Building Regulations require minimum width and thickness of plain concrete strip footings depending on type of ground



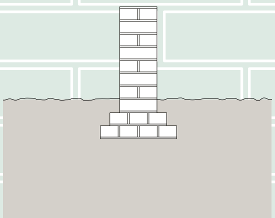
Post 1945

Mostly strip footings but raft foundations also popular, particularly under non-traditional houses



1939

Model Byelaws required a concrete foundation a minimum of twice the wall width and depth not less than the projection of the footing beyond the wall

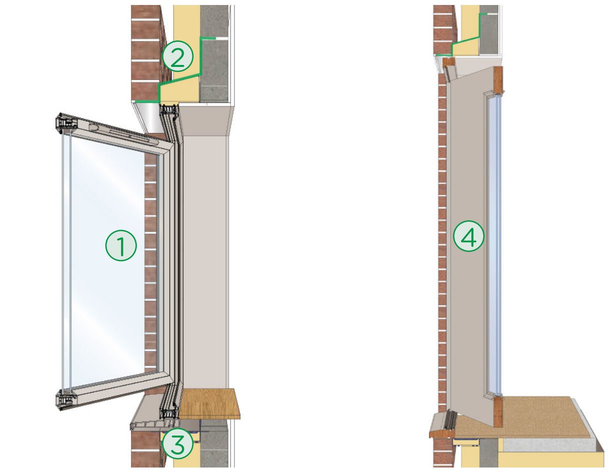


1878–1930

Shallow, stepped brick footings. Model Byelaws suggest footings twice the wall width but adoption was slow

1.2 Windows and external doors

Modern, high-performance windows are made from durable and maintenance-free PVC-U frames with double-glazing. Composite external doors offer improved security.

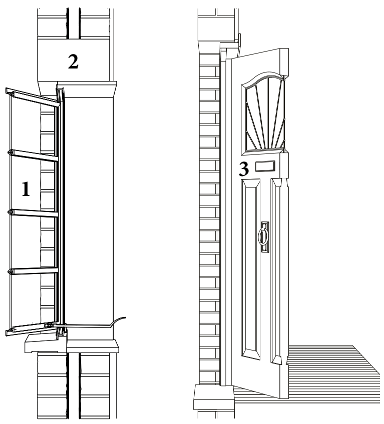


1 Double-glazed PVC-U window
2 Insulated lintel
3 Cavity closer
4 'Secured by Design' composite entrance door

Figure 4 2019 typical window and entrance door

Now Durable and low maintenance modern windows are usually prefabricated in a factory from PVC-U with double-glazing. Modern windows offer multiple opening modes to allow for safe cleaning and opening restrictors. Built-in ventilators provide background ventilation. Multiple layers of glass with proprietary seals, coatings to the glass and gas fill between panes eliminate draughts and reduce heat loss. Accredited external doorsets and windows, incorporating laminated and toughened safety glazing, offer enhanced security.

Then Period timber sash windows and external doors were constructed by skilled craftsmen from imported softwood with single glazing. In the Georgian era windows were made of several smaller square panes in a grid of thin glazing bars, as it was not yet possible to manufacture large panes of glass. Victorian sash and 1930s timber casement windows feature larger panes with fewer glazing bars and thicker frames. While stylish, period sash windows require regular maintenance and painting and are vulnerable to rot, swelling or rattling in the wind, due to shrinkage of the timber.



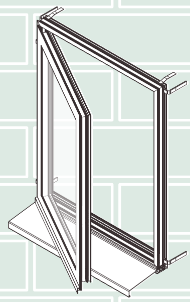
1 Single-glazed steel window
2 Masonry lintel
3 Solid timber door and frame

Model Specification NHBC, 1946

Clause 89. Front and Back Doors and Frames

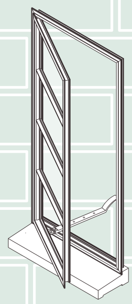
Front doors are to be framed out of 2 in. timber and back doors out of 1¾ in. timber

Figure 5 1930s typical window and entrance door



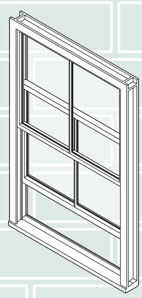
2019

Durable, high-performance, double-glazed PVC-U windows have followed on from the first double-glazed aluminium windows introduced in the 1970s. Trickle vents provide background ventilation



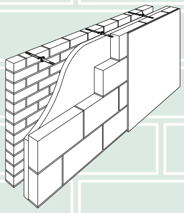
1930–70s

Single-glazed galvanised steel windows were common until the 1970s. Condensation on the cold inner face of the metal frames was an increasing problem as homes became better insulated and less well ventilated



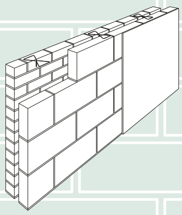
1700–1910

Handmade timber sash windows formed of small single-glazed panes because of the limitations of glass technology. Victorian improvements allowed larger panes



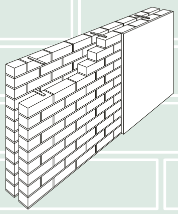
2019

Widened cavity allows for a thick layer of insulation. Combined with an inner leaf of aerated blockwork, thermal performance is dramatically improved



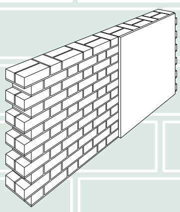
1930s–60s

Blockwork was commonly used for the inner leaf of cavity walls and fast setting, stronger cement mortar sped up construction



1920s

Hollow brick walls constructed as standard, improved weather protection. Two halves held together with galvanised steel wall ties

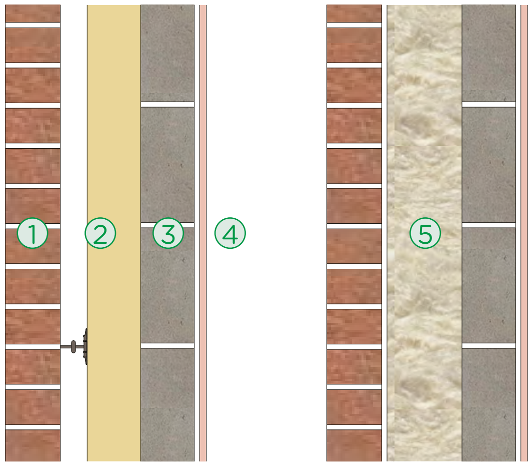


1800s

Solid brick walls, at least nine inches thick, bonded with lime mortar with solid plaster on the internal face

1.3 External masonry walls

Evolving from solid masonry to multi-layered construction, modern external walls provide a stable, weather-tight and heat-retaining enclosure.



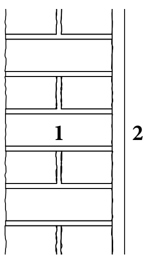
1 Brick external leaf
2 Rigid plastic insulation and 50mm cavity
3 Aircrete blockwork internal leaf
4 Plasterboard on dabs
5 Mineral wool insulation

Figure 6 2019 typical masonry external walls, partial-fill rigid insulation shown on left and full-fill insulation on right

Now Modern external masonry walls are designed to support the floors and roof and transfer loads to foundations safely. Multiple layers of construction including thermal insulation and increasingly sophisticated components, such as lintels and wall ties, are designed to be weatherproof, prevent heat transfer, control draughts, provide fire resistance and resist sound transmission.

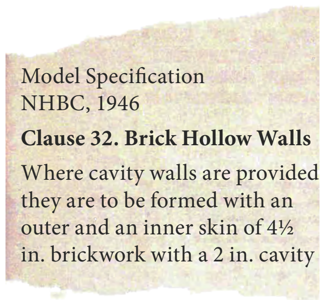
Then The Victorian nine-inch solid brick wall was predominant; walls simply held the building up and largely kept the rain out. It was not until the 1920s that cavity walls became standard to improve weather protection; the two halves were tied at regular intervals with galvanised steel wall ties.

From the 1930s to the 1960s blockwork became a common material for the inner leaf of cavity walls and faster setting, stronger cement mortar replaced lime mortar, speeding up construction.



1 9 inch solid brickwork external wall laid in Flemish bond
2 Solid plaster internal wall finish

Figure 7 19th century typical external wall

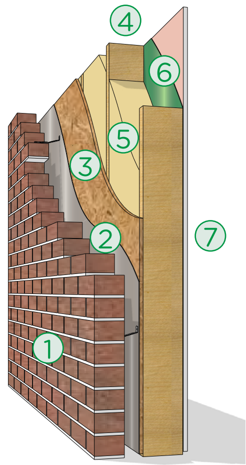

Model Specification
NHBC, 1946

Clause 32. Brick Hollow Walls

Where cavity walls are provided they are to be formed with an outer and an inner skin of 4½ in. brickwork with a 2 in. cavity

1.4 External timber frame walls

Almost one fifth of the UK's new homes are built using timber frame construction. Structural insulated panel systems (SIPs) and cross-laminated timber (CLT) are also currently increasing in popularity.



1 Brick external leaf
2 Water-resistant breather membrane
3 Plywood or wood-based board sheathing
4 140–190mm deep timber studs form floor-to-ceiling height panels
5 Mineral wool insulation between studs
6 Vapour control layer (VCL)
7 Plasterboard internal finish

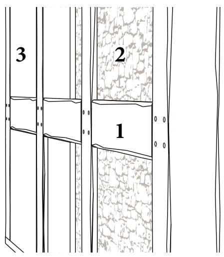
Figure 8 2019 typical timber frame external wall

Now The method generally used in the UK is known as platform timber frame: each storey is formed by floor-to-ceiling timber panels onto which is placed a floor deck from which the next floor is constructed. Because timber frame is usually factory-prefabricated, site work is reduced, allowing faster construction.

NHBC's Standards require careful design and construction to ensure that the timber is not at risk of decay – for instance a water-resistant breather membrane and a drained and vented cavity is provided to prevent rainwater from coming into contact with the timber. A thick layer of thermal insulation is provided between the structural timber studs to minimise heat loss.

Then For thousands of years UK-grown hardwood timber was the main source of structural material with various masonry or rubble being used to provide the infill between. During the 17th century timber frame declined as the UK urbanised, partly due to the risk of fire spread between more densely located homes.

'Balloon' timber frame, a construction method popular in the United States and Canada, was used to build some two and three storey houses until the mid-20th century. It used imported softwood with much longer vertical studs extending from the foundations to the rafters.



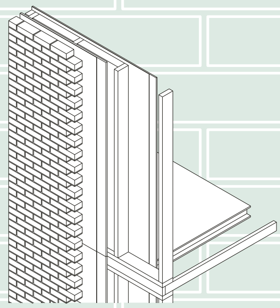
1 Hardwood timber frame
2 Various masonry or rubble materials used to infill frame
3 Lime render

Model Specification
NHBC, 1946

Clause 84. Framing

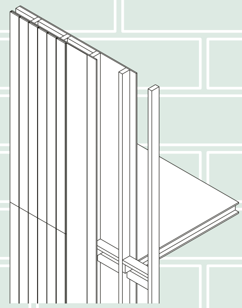
All framed work is to be put together with well-fitted mortice and tenon or properly dowelled and wedged up solid

Figure 9 Pre 19th century



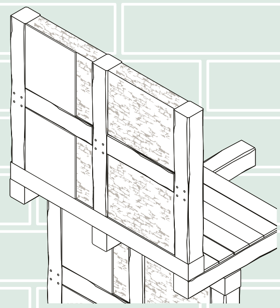
2019

Platform timber frame, each storey is formed by floor-to-ceiling timber panels and a floor deck, with firebreak between each floor. Can utilise factory assembled wall, floor and roof panels



1950s–1960s

Balloon timber frame for two-three storey homes, popular when long timbers were available. Studs extend from the foundations to the rafters

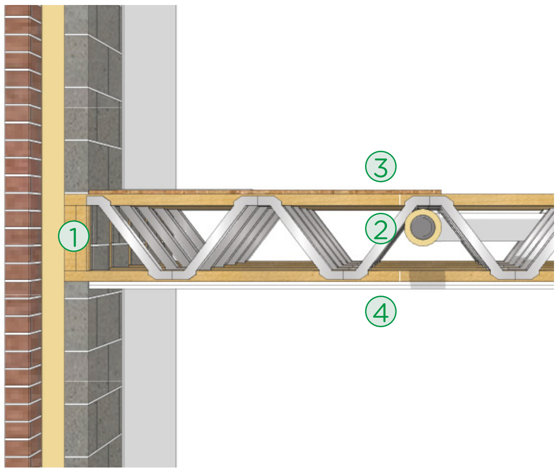


Vernacular

Timber frame construction in the UK dates back to medieval times. For thousands of years UK timber species provided the main source of structural material for building

1.5 Upper floors

Lightweight engineered timber joists incorporate voids for services, resist deflection and creaking and are sealed against draughts from the external walls.

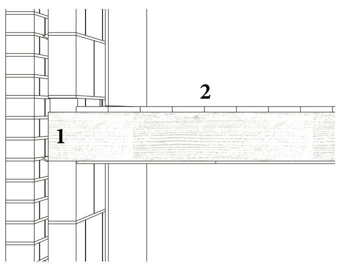


1 Engineered metal web timber floor joists built-into and strapped to blockwork internal leaf
2 Floor void for services
3 Tongue and groove chipboard deck
4 Plasterboard ceiling screwed to joists

Figure 10 2019 typical upper floor

Now Upper floor construction now uses lightweight engineered timber joists, either metal web or 'I' joists. These enable longer spans, make more efficient use of timber and help to eliminate creaking. They also incorporate voids within the structural depth of the floor for services and ventilation ductwork. The joists are built-into the inner blockwork leaf of the external cavity walls, creating a safe platform to work from as the walls are constructed. Metal straps are built in so that the floor provides structural restraint to the external walls. Wood-based board provides the floor surface and plasterboard ceilings are fixed to the underside of the joists.

Then Upper floors were typically constructed using 8 by 2-inch timber floor joists built into the external 9-inch thick solid brick walls. The floor joists were covered with square-edged softwood floorboards and a lath and lime plaster ceiling was installed below. Timber floor joists let in draughts where they were built into the external walls and were at risk of decay due to the moisture in the brickwork.



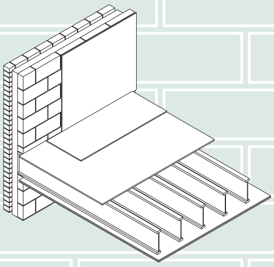
1 1½ x 7 inch timber floor joists built into the solid external walls
2 4½ inch wide tongue and groove timber floorboards

Model Specification
NHBC, 1946

Clause 98. Hair

A sufficiency of good, long, clean hair or other suitable fibre is to be employed in the first coat of plaster on lathing

Figure 11 1950s–60s typical upper floor



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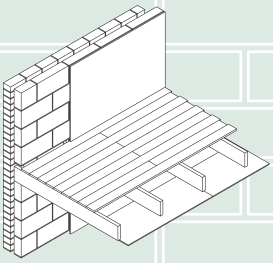
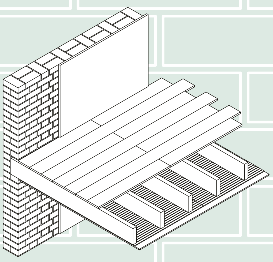
Engineered timber 'I' joists built into and strapped to external walls. Tongue and groove chipboard deck with weather-resistant surface. Plasterboard ceiling screwed to joists with joints taped and filled



1950s–60s

Timber upper floor with joist sizes reduced to save timber. Tongue and grooved softwood floor covering. Ceiling of small sheets of plasterboard nailed to joists with Artex surface coating or plaster skim

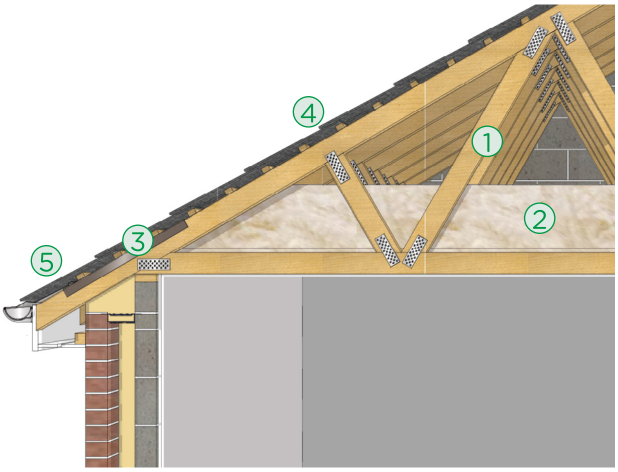


Victorian

2 x 8 inch timber floor joists built into the solid external walls. Wide square-edged timber floorboards. Ceiling formed by timber laths nailed to joists and three coats of lime plaster

1.6 Pitched roofs

Most new homes have prefabricated timber trussed rafters, which offer construction efficiencies and reduce the carpentry skills needed. Deep loft insulation minimises heat loss through the roof.



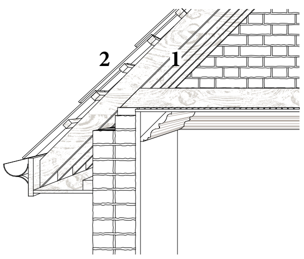
1. Timber trussed rafters with metal connector plates
2. Deep loft insulation
3. Advanced waterproof and breathable roof membrane
4. Slate roof tile on battens
5. Ventilated eaves and ridge

Figure 12 2019 typical pitched roof

Now Trussed rafters made from softwood with metal connector plates are craned into place. They are fixed together with a series of timber braces to ensure their structural stability. Some new roofs are constructed using structural insulated panels (SIPs), allowing the roof to be used as additional living space.

Current Building Regulations require very deep loft insulation to minimise heat loss through the roof. Advanced membranes are used to provide a waterproof underlay to the tiles and battens. These are generally breathable, allowing condensation to escape.

Then From 1700 to the mid-20th century the construction of roofs barely changed. Traditional 'cut' timber roofs were made from imported softwood assembled on site using skilled and time-consuming joinery techniques. Roofs comprised a series of sloping timber rafters fixed to a timber wall plate at the bottom and a timber ridge board at the top. Large roofs required additional purlin timbers to help support the rafters and brace the roof against wind loads, etc. Prefabricated trussed rafters were developed after the Second World War, in response to shortages of timber and skilled labour.



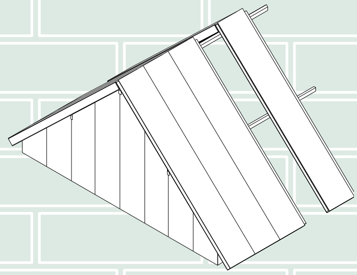
1. 'Cut roof' made up of timber rafters, ridge and wall plate
2. Natural slate or roof tile on battens

Model Specification
NHBC, 1946

Clause 79. Roofs

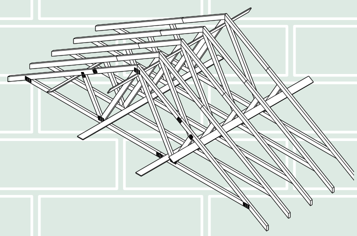
The rafters are to be notched and well spiked to the wall plates and purlins, and cut and well spiked to the ridges

Figure 13 19th century typical pitched roof



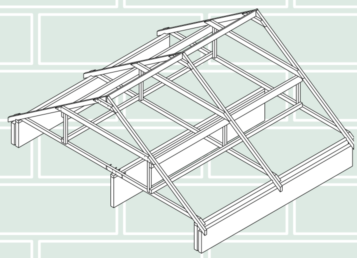
2019

Structural Insulated Panel (SIP) technology: high-performance rigid insulation core sandwiched between two timber boards, used to construct walls, intermediate floors and roofs



Mid 1960s

Most modern houses use prefabricated timber roof trusses, allowing smaller timber sizes to be used and reducing labour on site. Concrete tiles with felt and plastic guttering. Some insulation



1800s

Traditional cut timber roof, assembled on site using joinery techniques requiring labour and skill, with overhanging eaves, natural slate tiles and cast iron guttering. No felt or insulation

2. Building services

Introduction

In the 21st century we take the comfort and convenience of the modern home for granted but it was only two or three generations ago that everyday tasks, washing and drying clothes and even heating and lighting the home, were time consuming and arduous. The typical home was dimly lit, damp and draughty. Even as late as the Second World War, the majority of homes lacked an internal bathroom.[1] Central heating and labour-saving electrical appliances were rare and there was little privacy or convenience either with the trips to the 'privy' at the bottom of the garden or the weekly bath in a hand-filled galvanized tub in the kitchen scullery.

Although electric lighting was first introduced in homes and streets at the end of the 19th century,[2] it was not until the 1920s that the domestic use of electricity became widespread,[3] partly as a result of Government action to standardise power generation and distribution so that electrical goods (irons were the first) could be manufactured to use the same alternating current (AC).

Sanitation arrived earlier in the 19th century prompted by epidemics of cholera and dysentery, especially in urban areas where many households often shared what little sanitation existed, but the convention of keeping the WC outside persisted to the end of the century. One of the first housing schemes to propose having a lavatory in the bathroom at Bedford Park in west London, was roundly criticised.[4] However, by the 1920s a new home would have had running water, a separate internal WC and a kitchen, but the heating for the home and the hot water would have been by coal in fireplaces in each room and a solid fuel back boiler or combined stove and boiler for hot water. Central heating was not widely installed until North-Sea gas became available in the 1960s, although town gas had been piped to homes in towns and cities for lighting and for cooking.[5]

Nowadays we are so accustomed to and familiar with these commonplace conveniences that a certain amount of readjustment and learning for new householders has become necessary to master the sudden growth of new systems and technologies seeking to harness natural resources in a more sustainable way.[6] The modern home may now have solar panels on the roof, a heat pump for space heating, a charging point for an electric car and (very soon) a battery store to capture energy for us to use when the National Grid is stressed or renewable sources are depleted or not available (at night time for instance).

[1]A 1947 survey for the Ministry of Works found that only 46% of households in England had bathrooms https://uploads.guim.co.uk/2018/03/20/bathleader.jpeg

[2] Norman Shaw's Cragside was the first domestic installation of (hydro) electricity for lighting and appliances https://www.nationaltrust.org.uk/cragside/features/history-of-cragside

[3] The Electricity (Supply) Act 1922 (repealed 1989)

[4] The Bedford Park Society https://www.bedfordpark.org.uk/suburb/architecture/#godwin

[5] In 1892 George Livesey initiated a customer scheme whereby a gas supply with pre-payment meter, full lighting and a cooker were installed in homes without an existing supply at the South Metropolitan Gas Company's expense; the costs were recovered through a surcharge over succeeding years. Gasholder No.13, Old Kent Road https://historicengland.org.uk/listing/the-list/list-entry/1446329

[6] *NF68 Home Comforts* (NHBC Foundation, March 2016)

Components

In the modern home heating, lighting and ventilation are automatic and instantaneous, often 'running' quietly and efficiently in the background with very little conscious operation. The expectation that everything will work efficiently with little maintenance or adjustment applies equally to the safety features of the home, which have improved in every aspect.

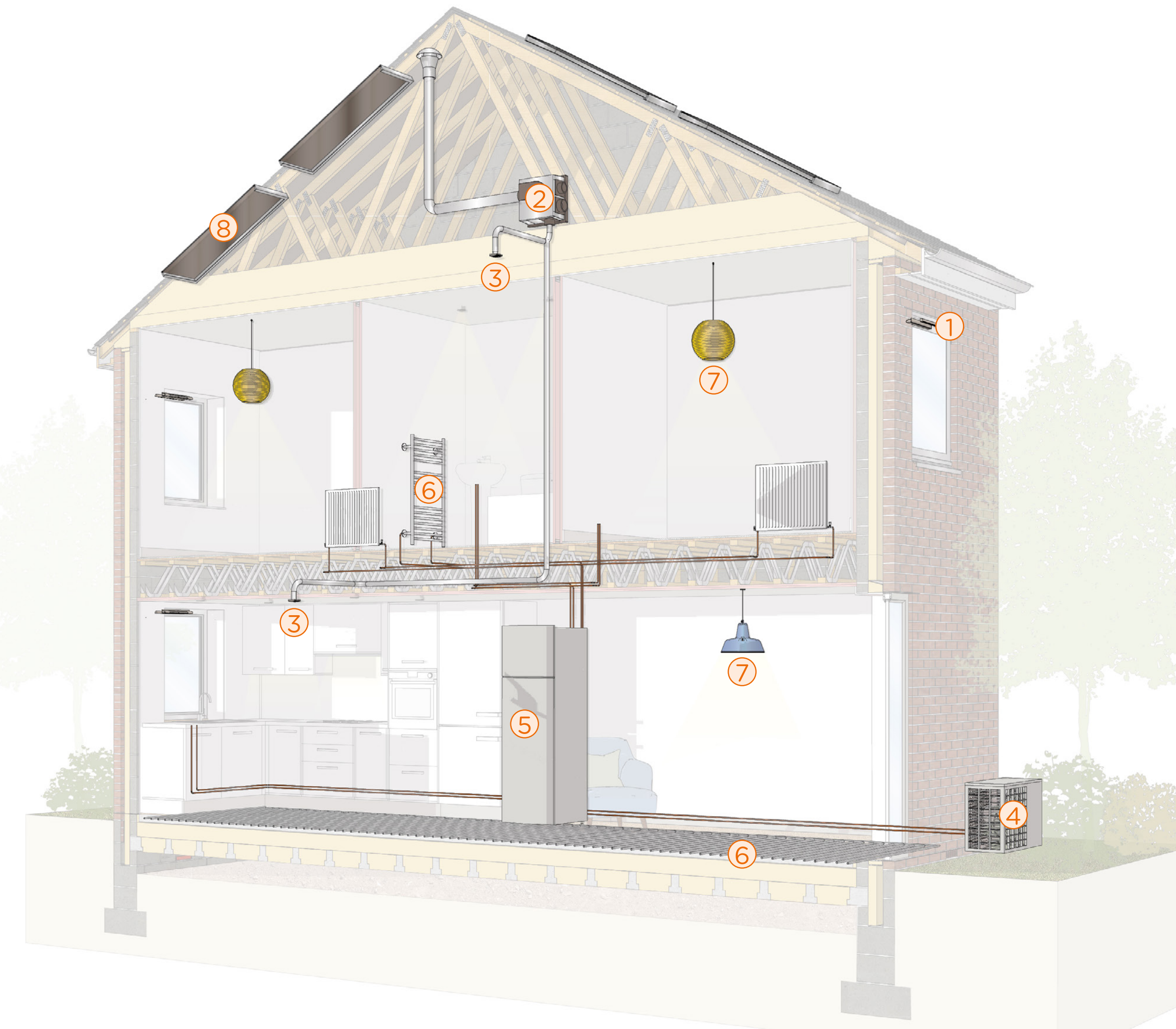
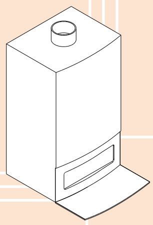


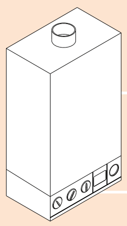
Figure 14 Building services glossary

1 Trickle vents in windows allow fresh air to enter the home
2 Mechanical extract ventilation (MEV) central extract fan provides simultaneous, low-level extraction from kitchens, bathrooms, shower rooms, utility rooms and toilets
3 System of ductwork and air extract grilles
4 Air source heat pump (ASHP) outdoor unit extracts heat from the air
5 ASHP indoor unit transfers heat to the home and stores hot water
6 Underfloor heating and towel rail
7 Efficient light-emitting diodes (LED) lamps
8 Roof-mounted solar photovoltaic (PV) panels or tiles



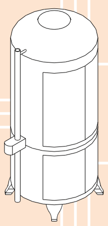
2019

Space-saving combination boilers heat water directly from the mains



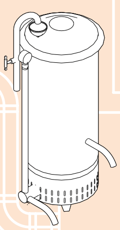
2007

All boilers installed in England and Wales are condensing boilers. Heat exchangers extract heat from the flue gases. 90% efficiency



1889

Invention of the automatic water storage tank, credited to Edwin Rudd

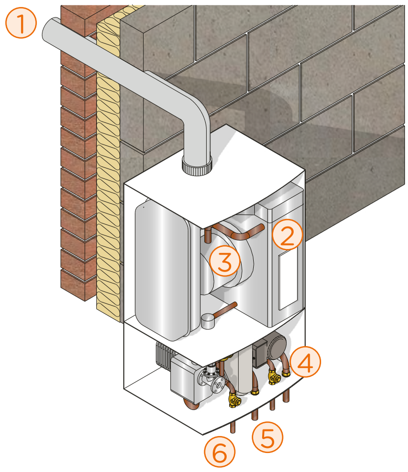


1868

'The Geyser' gas-fired instantaneous water heater invented. Dangerous and liable to explode as it did not have a flue or vent

2.1 Gas central heating

Central heating became common in the 1970s when North Sea gas was increasingly plentiful. Over the decades since, the efficiency of gas boilers has improved markedly.



1 Flue
2 Heat exchanger
3 Fan
4 Cold water in
5 Domestic hot water flow
6 Central heating flow

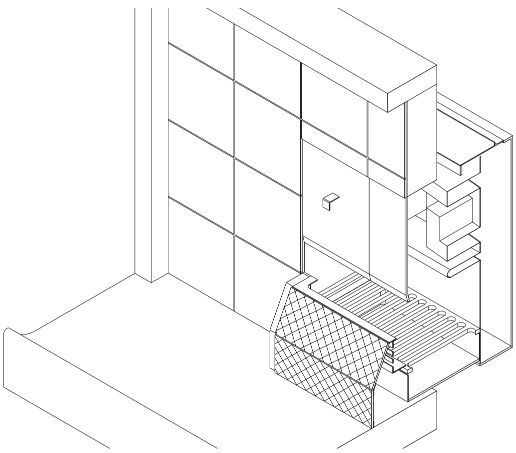
Figure 15 2019 typical combination boiler

Now Since 2007 all gas boilers installed in England and Wales must be condensing boilers. A condensing boiler is a modern, energy-efficient boiler that incorporates an extra heat exchanger so that heat from the hot exhaust gases is reused. They operate at efficiencies of 90% or better.

Combination or 'combi' boilers are used increasingly. They heat water directly from the mains with no need for a hot water storage cylinder or water tank in the roof space. Because a much smaller volume of hot water is stored with these systems, they can be very efficient and have the advantage of being able to provide an inexhaustible supply.

Then Regular boilers have existed for 100 years, heated by fuels including coal and firewood. Until the 1970s most boilers (wall mounted, freestanding and back boilers) had open flues to vent the combustion gases to the external air but bringing the risk of spillage of poisonous gases into the home.

Flue design has evolved to improve combustion and avoid the risk of flue gas spillage and carbon monoxide poisoning. With current room-sealed flue systems combustion supply air is drawn via ducts from the outside air and flue gases are discharged safely, without the risk of spillage.



Model Specification
NHBC, 1946

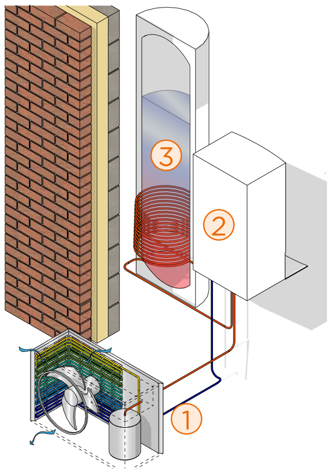
Clause 135. Boiler

The heating unit is to be (a) an independent boiler, or (b) a back boiler, heated direct by the kitchen range or other fire

Figure 16 1950s typical solid fuel 'back boiler'

2.2 Heat pumps

The carbon intensity of the National Grid is steadily decreasing as the use of renewable electricity generation increases. Heat pumps will play an important role in the low carbon, electric future.



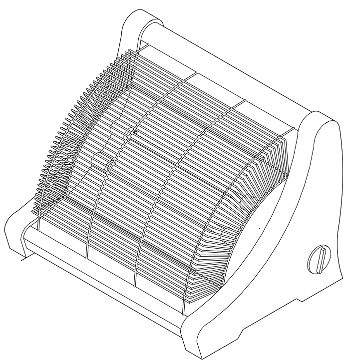
1. Air source heat pump (ASHP) outdoor unit extracts heat from the air
2. ASHP indoor unit transfers heat to the home
3. Stores hot water

Figure 17 2019 air source heat pump

Now Heat pumps extract heat from the outside air (even at sub-zero temperatures) or the ground using the same technology as is found in a domestic fridge. This can be used to heat radiators, underfloor heating systems and the domestic hot water supply. Although they do need electricity to run, a domestic air source heat pump typically generates two to three units of heat for every one unit of electricity.

Heating systems powered by heat pumps operate at a lower temperature than gas boiler systems and are suited to well-insulated new homes with substantially reduced demand. Underfloor heating is particularly well suited to heat pumps as it delivers heat over a large surface area.

Then Most of the UK's housing was built before the links between energy use and climate change were understood. It was also built when there were very different expectations of thermal comfort. Most families in 1970 lived in homes that would be uncomfortably cold by modern standards in winter – as cool as 12°C on average. In cold spells there may have been ice on the insides of the windows and nearly everyone accepted the need to wear thick clothes at home in winter. Few homes had central heating and many families used coal supplemented with electric fires for heating the single room that was occupied at any one time.

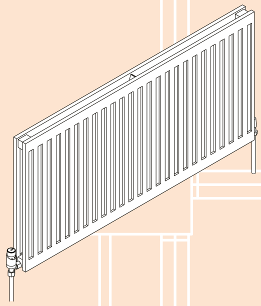


Model Specification
NHBC, 1946

Clause 133. Pipes

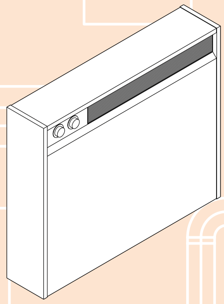
The pipes are to be (a) galvanised wrought-iron welded steam quality tubing, or (b) lead, or (c) copper

Figure 18 1950s typical electric fire or 'bar heater'



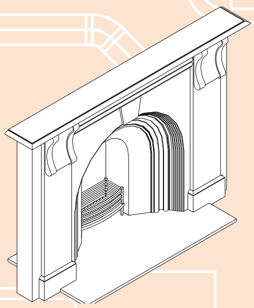
2019

Plumbed hot water central heating radiator with thermostatic radiator control valve (TRV) allowing the temperature to be controlled in each room. A lower setting uses less energy and will save money



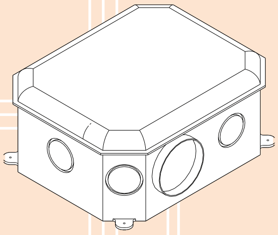
1970s

Electric storage heaters charge at night, when electricity is cheaper, then release heat the next day. Less efficient than gas central heating



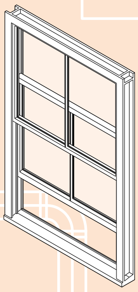
Victorian

Coal was the only significant fuel. Fireplaces in every room burnt coal and town gas (made from coal) provided artificial light. Cooking would be done on a range in the living room or the kitchen in large houses



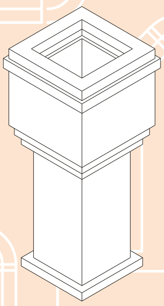
2019

Mechanical Extract Ventilation (MEV) reduces the risk of condensation and mould by removing humid air from the home. Helps to control the build-up of airborne pollutants



1700–1910

Sash windows were introduced in the late 17th century. They are operated by a counterweighted sliding mechanism

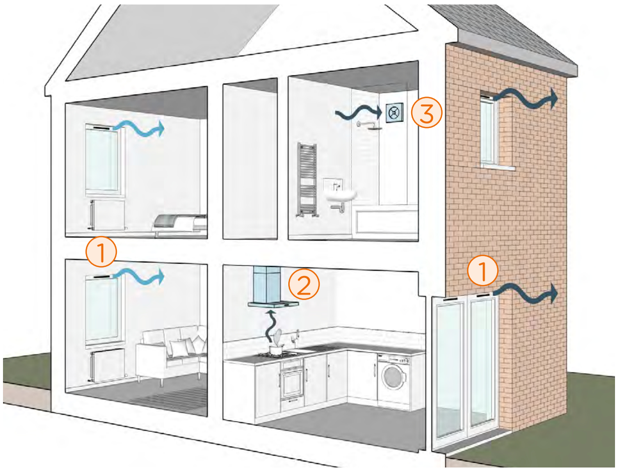


12–16th century

Chimneys and very small holes in the wall, protected by either bars or shutters for privacy and safety, provided ventilation until glass in windows was introduced in the 16th century

2.3 Background ventilation

Ventilation provides fresh air to the home for a healthy indoor environment. It also removes humid air that can lead to condensation and potential mould growth, and controls the build-up of airborne pollutants.



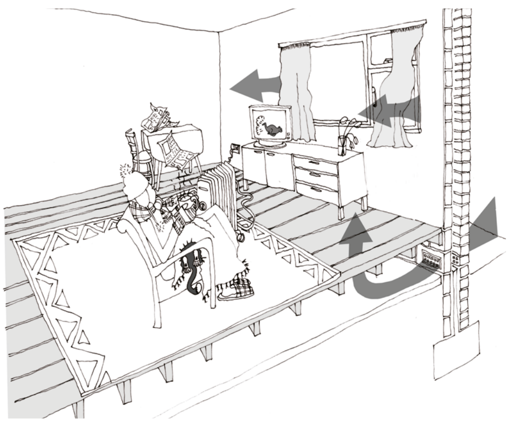
1. Trickle vents supplying fresh air and allowing stale air to escape
2. Cooker hood boosts the removal of humid air and cooking smells
3. Extract fan boosts the removal of humid air

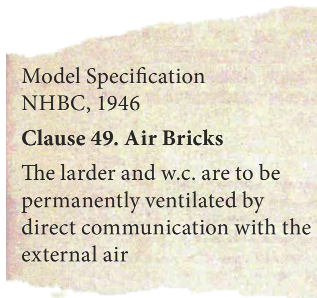
Figure 19 2019 natural ventilation

Now Natural ventilation is the most common ventilation system in modern homes. Trickle vents, usually in window frames, provide fresh air when windows are closed. Extract fans temporarily speed up the removal of humid or stale air from certain rooms, such as kitchens and bathrooms. In some kitchens the cooker hood provides air extraction.

Mechanical Extract Ventilation (MEV) reduces the risk of condensation and mould by removing humid air from the home. It also helps to control the build-up of airborne pollutants from everyday activity such as cooking and laundry. Fans run at a low level constantly to provide extraction from the kitchen, utility room, bathroom, shower room and WC to a central extract fan, typically located in the loft space, via a system of ductwork and grilles. Trickle vents supply fresh air.

Then Airbricks and gaps in the building envelope (around windows, through floorboards and under skirting boards) provided ample but uncontrollable background ventilation. Draughts were not only uncomfortable but also a sign that the home was leaking heat and energy.





Model Specification
NHBC, 1946

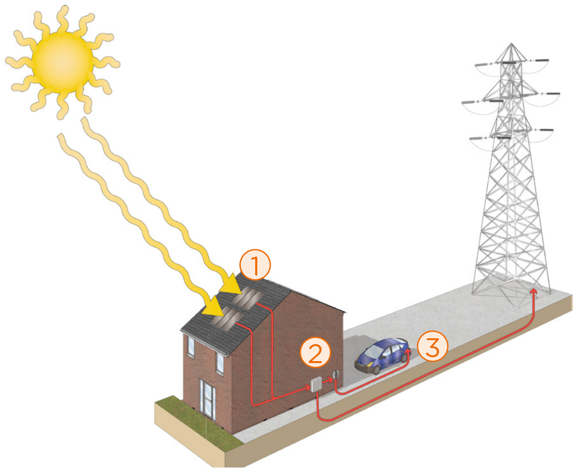
Clause 49. Air Bricks

The larder and w.c. are to be permanently ventilated by direct communication with the external air

Figure 20 1950s draughty room

2.4 Efficiency, safety and security improvements

In the face of climate change, fuel poverty and legally binding emission targets, the energy efficiency of homes is more important than ever. Since the 1980s the safety and security of homes has improved.



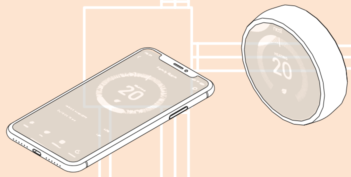
1 Photovoltaic panels collect solar energy and convert to electricity
2 Electricity stored in battery system
3 Vehicle charging by direct connector or induction

Figure 21 Low carbon electric future

Energy Efficiency The thermal performance of the building envelope (walls, roofs, floors, windows and doors) has been enhanced significantly and a range of low-carbon energy technologies, including solar photovoltaics, heat pumps and continuous extract ventilation, has been adopted increasingly on new housing developments, often incorporated almost seamlessly in traditional-appearing homes. Close attention to design and construction is essential in delivering homes that meet today's improved performance standards.

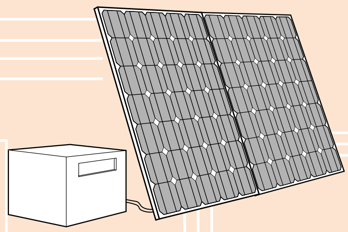
Safety and security improvements:

- Glass and window safety: laminated and toughened safety glass protects residents from fragile glass on low-level windows and doors and opening restrictors guard against falls
- Stair design: consistency in stair design as well as safe height, impact resistance and gaps for balustrades protect against falls
- Electrical safety: all circuits in new homes provide extra protection against electric shocks
- Fire safety: fire safety measures in new homes including interlinked mains-powered smoke alarms that provide early warning of potential fire have significantly reduced the risk to life
- Security: the Secured by Design scheme, established 30 years ago, has led the development of more robust windows, doors and locks resistant to attack and the planning of neighbourhoods to deter criminals. Since 2015 dwelling security has been included in the Building Regulations



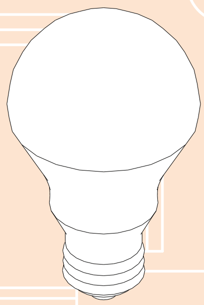
2019

Multi-zone heating with smart heating controls that are programmable, self-learning, sensor-driven, and Wi-Fi-enabled



2010–2019

Close to 750,000 homes install solar photovoltaic systems (PV) helped by the Feed in Tariff (FIT) subsidy, which closed in March 2019



2010

Homes begin to switch to LED bulbs that use very little energy and have a longer lifespan

3. Energy efficiency

Introduction

Regular revisions to the Building Regulations relating to the conservation of fuel and power in dwellings have led to significant improvements in heat loss through the building fabric. Figure 27 compares U-values for historic construction – pre-1900[1] and maximum values allowed in the 1995 Building Regulations – with U-values for current construction[2] showing the scale of improvements. Thermal transmittance, also known as U-value, is the rate of transfer of heat through a structure, divided by the difference in temperature across that structure (inside to the outside of a building). The units of measurement are W/m^2K. The lower the U-value, the slower the rate of heat transfers, therefore reducing heating demand.

A modern home also includes increasingly sophisticated, standardised components, such as lintels and wall ties, hidden within the multiple layers of construction. Composite materials are pre-formed accurately in the factory to complex shapes and profiles and designed to be variously weatherproof, insulate and prevent heat transfer, control draughts, provide fire resistance and resist sound transmission.

By the mid 1990s the Building Regulations required insulation to ground floors and suspended concrete floors became common with insulated floor blocks between the beams. Unlike construction in the past where solid concrete lintels spanned across the wall causing heat loss and condensation, insulating composite materials are increasingly used for lintels and wall ties. The contemporary window has a barrier to heat transfer within the frame. Durable advanced membranes are used to provide a waterproof and sometimes vapour permeable or 'breathable' layer under the roof tiles allowing condensation to escape.

[1] *SAP 2005 edition, revision 2* (BRE, 2008), p. 91 Appendix S: Reduced Data SAP for existing dwellings

[2] *Approved Document L1A: Conservation of fuel and power in new dwellings (2013 edition with 2016 amendments)* (HM Government, April 2016), p. 25 Table 4 Summary of concurrent notional dwelling specification

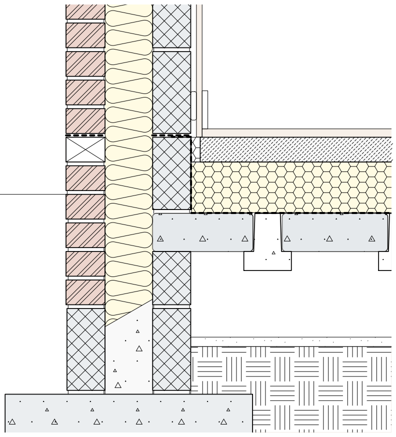


Figure 22 Ground floor insulation

Concrete beams combined with insulated floor blocks provide ground floor insulation.

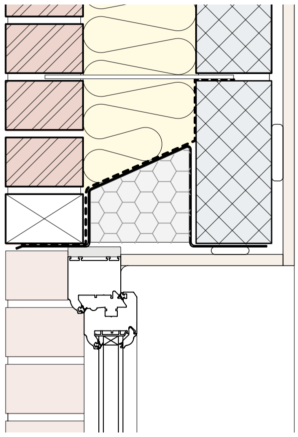


Figure 23 Thermally-efficient lintels

One-piece composite lintels (the horizontal supports across the top of a door or window) with pre-fitted insulation are designed to resist the passage of heat.

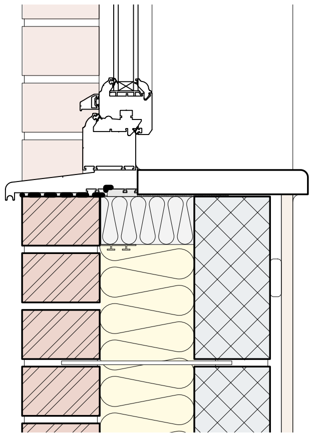


Figure 24 Insulated cavity closers

PVC-U extrusions with an insulation core provide a simple and efficient method of closing cavities around window and door openings in cavity walls.

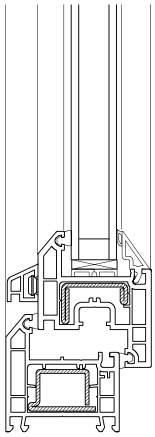


Figure 25 Energy-efficient windows

Double-glazed windows have two sheets of glass with a gap in between to create an insulating barrier that keeps heat in. Frames are designed to resist the passage of heat.

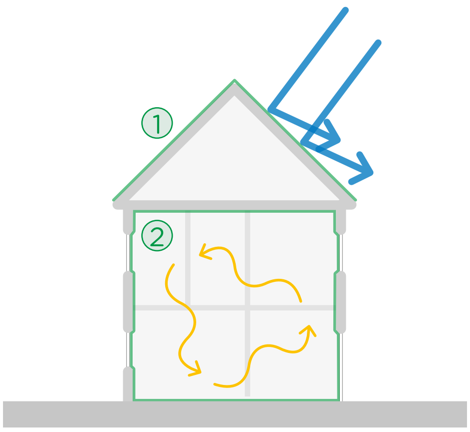
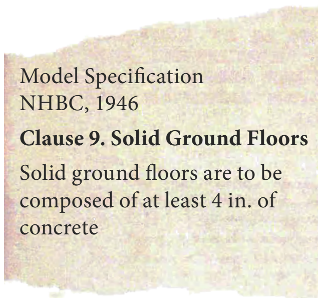


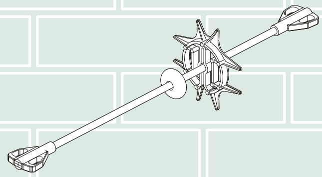
Figure 26 Advanced membranes

1 Waterproof roof underlay protects against external climatic conditions
2 Airtightness layer can reduce ventilation heat losses


Model Specification
NHBC, 1946

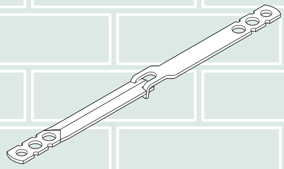
Clause 9. Solid Ground Floors

Solid ground floors are to be composed of at least 4 in. of concrete



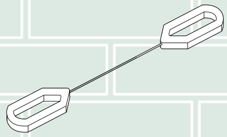
2019

Composite basalt fibre wall ties minimise heat crossing the insulated cavity



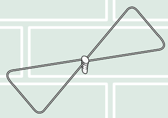
2003

Stainless steel split wall ties allow for increased insulation in cavities up to 300 mm wide



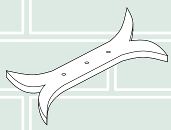
2000

Stainless steel wall ties with rounded safety ends for 75–100 mm wide insulated cavities



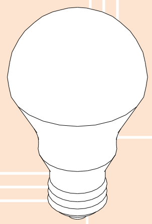
1984

Galvanised wire butterfly wall ties for 50 mm wide cavities, prone to corrosion



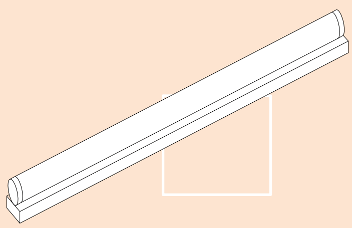
1920s–1978

Galvanised mild steel wall ties used to join the two leaves of a wall together, prone to corrosion



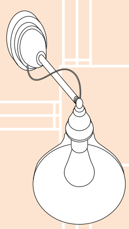
2010

LEDs (light emitting diodes) are very efficient and have very long lifetime expectancy (an LED could last for 30 years)



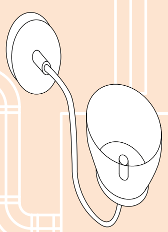
1960s

Efficient linear fluorescent lamps (LFLs) the familiar 'light tubes', have been in common use from the 1960s. They typically produce very bright light



1920s

After the First World War incandescent bulbs improved and the National Grid was established. We had the first clean, safe lighting



1840s

Gas mantles in homes began to catch on amongst the middle classes, but gas could be dirty and dangerous

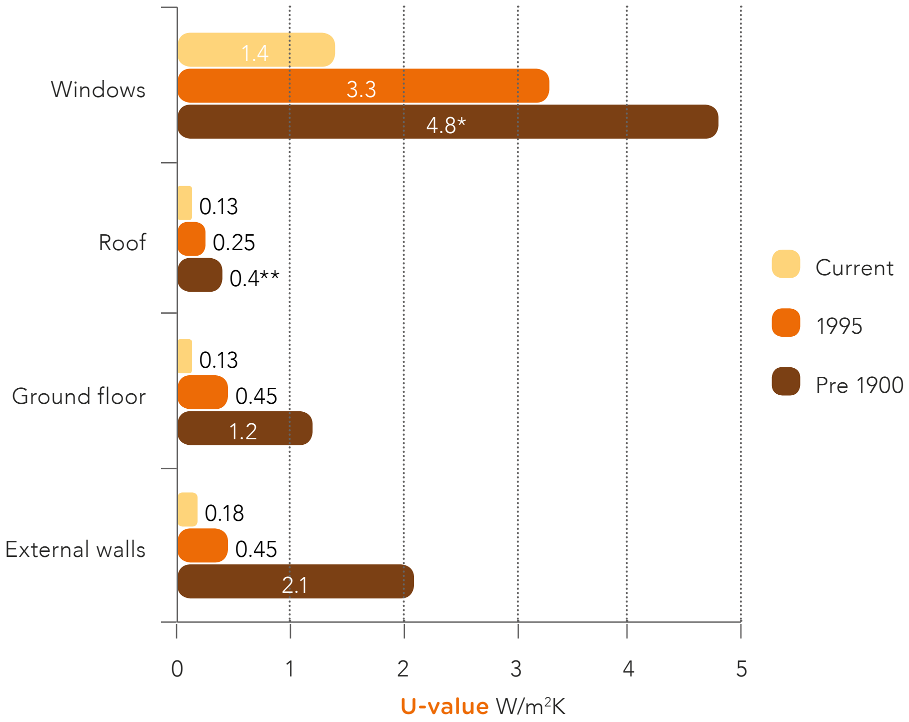


Figure 27 Comparison U-values

* Single-glazed windows
** 100 mm insulation at joists

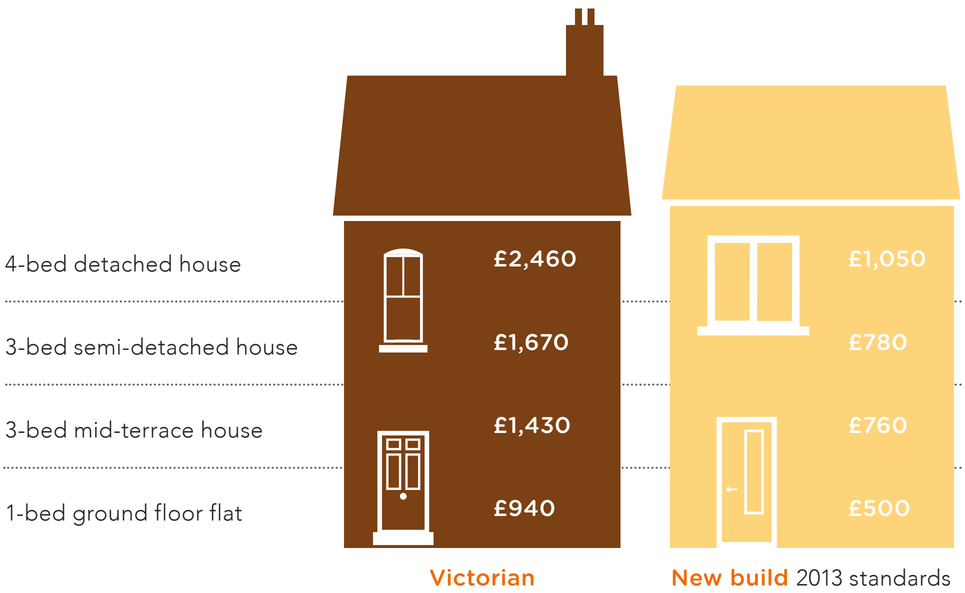


Figure 28 Annual household energy spend

A new home built to modern Building Regulations standards will cost approximately half as much to heat as a Victorian home.

Note: In this comparison, the Victorian home is the same size and has the same window area as the new home, but has uninsulated solid-brick walls, some single glazing and a gas central heating system.

Building Regulations vary throughout the UK and so the costs will be slightly different in Scotland, Wales and Northern Ireland.

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 85 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**.

House building: a century of innovation

Technical advances in conventional construction

The purpose of this latest NHBC Foundation report prepared by Studio Partington is to describe typical (non-MMC) construction used for new homes and contrast it with 'traditional' methods that have been used in the preceding 100 years or so. It makes clear that what lies beneath the skin of new homes is quite different from what has gone before.

Of particular note is the improved robustness of new homes and their inherent resistance to ground movement and the ingress of rainwater. Other advances include the improved efficiency in the use of materials that comes with components such as timber trussed rafters and engineered floor joists. Added to this are the enhanced comfort and lower fuel bills which flow from the higher energy performance standards of modern homes, setting them apart from previous generations of housing.

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