Fuelling the future

Working hand in hand with the government to decarbonise home heating.

CONTENTS

Executive summary

As a market leader, we have had the privilege of inputting both directly and with the industry to assist in the practical adoption of the Government's 'Net Zero' carbon target by 2050.

We think it is essential that as an industry we need to roll up our sleeves and start putting plans into action, which is why our own experts have been appraising all of the various technologies that can contribute towards a net-zero future.

One example is the hydrogen-ready boiler, currently being developed at our Worcester head office and research facilities, which is undergoing both laboratory and now field trials. As a manufacturer of all heating technologies, we are also very aware that there is unlikely to be one singular answer for all applications and consequently, we have been investigating how best certain heat generating sources may be more suited to certain property types over others.

It is clear that a wholesale change, such as replacing the current single boiler the majority of us use today, with say a multi-household district heating solution, could be a huge cost both in infrastructure and deployment, and this will undoubtedly have an impact on UK consumers. So, we are aiming in our advice to be as practical as we can while being agnostic on the technology chosen.

With this paper, we aim to give an honest, impartial and technology agnostic view on the benefits, advantages and suitable applications for the UK's future domestic heating requirements. The heating industry has some very strong opinions and voices on the most suitable heating source and does not always present an aligned position to Government.

We hope you find the information within useful and that it helps you form an opinion on the best technology, for advising customers, for a practicable Net Zero future.

Carl Arntzen
CEO of Worcester Bosch

TECHNOLOGY #1

100% Hydrogen

What is a hydrogen-ready boiler?

A hydrogen-ready boiler is a gas-fired heating boiler which is capable of burning either natural gas or pure (100%) hydrogen.

Hydrogen-ready boilers are the key to enabling conversion of the existing gas distribution networks from natural gas (which is mostly methane) to hydrogen. Hydrogen is a carbon-free energy carrier and combustion of hydrogen produces no carbon dioxide or carbon monoxide at the point of use. Hydrogen can be manufactured from water using electricity as a renewable energy source, or from natural gas accompanied by carbon capture and storage. Recent work, such as the H21 Leeds City Gate study, has shown that conversion of UK gas distribution networks is feasible and could help to decarbonise the heating of buildings. A hydrogen-ready boiler is intended to provide a like-for-like replacement for an existing natural gas boiler, allowing the appliance to be replaced with a hydrogen-ready variant when it reaches the end of its natural life. A hydrogen-ready boiler can be quickly and easily converted to burn hydrogen at the time when the local network switches over.

Hydrogen also offers **benefits for the energy system** as a whole.

What are the advantages and disadvantages of a hydrogen-ready boiler?

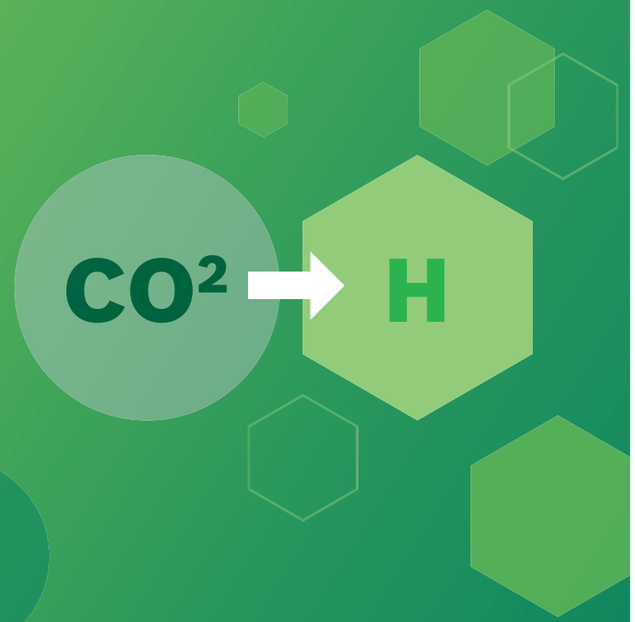
Many existing homes, despite energy efficiency improvements, still have relatively poor insulation and high rates of air exchange with the outdoors. A lot of existing hydronic heating systems are designed to operate at high temperatures and are hard to hydraulically balance. While these issues can be addressed, in many cases the associated costs would be very high. A hydrogen-ready boiler is capable of accommodating an existing high temperature heating system in a hard-to-heat building. Where costs are highly constrained, a hydrogen-ready boiler (and conversion of the local gas network) provides an accessible way to deeply decarbonise heat.

Heat users have high expectations of system control; to respond quickly to heat demands providing rapid warm-up of the building, or to deliver heat reliably in extreme weather events or times of unexpected building occupancy. Compared to other technologies, boilers offer very resilient and flexible heat delivery and provide consistent performance in a wide range of operating conditions. From an end-user point of view, a hydrogen-ready boiler does not require any behaviour change and will provide the same delivery of comfort as an existing appliance.

Hydrogen also offers benefits for the energy system as a whole. In order to use a high proportion of renewable energy generation, electricity systems need large quantities of flexible energy storage. Hydrogen offers one of the most attractive means of providing very large-scale energy storage and can integrate the energy systems through electrolysers and hydrogen-fuelled electrical generation. Heat is a very large energy demand which varies very rapidly at key points in the day. Currently, this demand is satisfied by the distributed energy storage intrinsic to the gas networks; the continuous use of a form of gas for heating will relieve stress on future electricity systems, as well as offering overall energy flexibility and resilience.

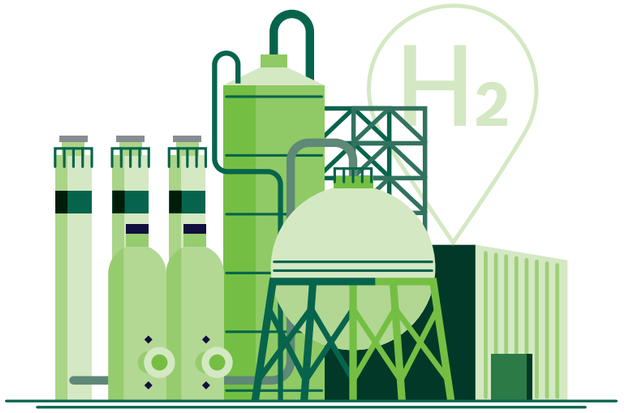
Creating a national hydrogen infrastructure may also open the door to more wide-scale use of hydrogen for transport. Hydrogen fuel cells are seen as an attractive technology for commercial transport applications.

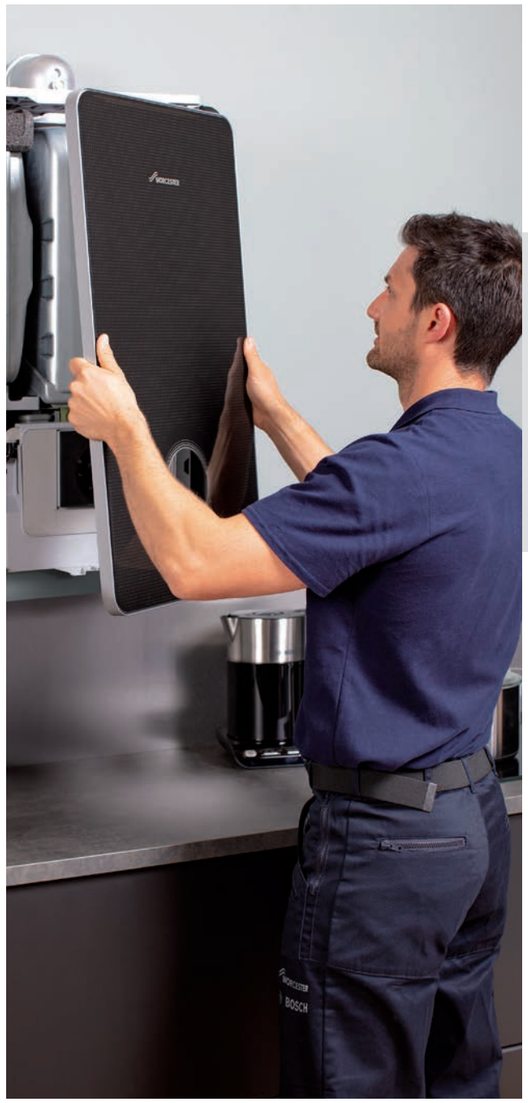
Hydrogen-ready boilers are the **key to enabling conversion** of the existing gas distribution networks from natural gas to hydrogen.



How does a hydrogen-ready boiler work?

A hydrogen-ready boiler is very similar to its natural gas predecessors; it is constructed and functions in much the same way that an existing condensing boiler does. While some components are distinct, such as the air-gas mixer and flame detector, most are identical to those used in natural gas boilers today. Converting a hydrogen-ready boiler from natural gas to hydrogen will take around an hour and involve changing a couple of components such as the burner. It is envisaged that Gas Safe engineers will be trained to work with hydrogen by a qualification scheme similar to that available today for LPG.





A hydrogen-ready boiler **functions in much the same way** as an existing condensing boiler.

How much does it cost to install a hydrogen-ready boiler?

The cost of a hydrogen-ready boiler installation will be very similar to that for a condensing boiler today. The ancillary components, accessories and controls will be identical to those for natural gas boilers. The property will at some stage require a hydrogen-ready gas meter to be fitted ready for network conversion, however, this could be installed on a later date than the boiler. Initially, hydrogen-ready boilers might form a niche market, but a regulatory change mandating their installation would make them a high volume technology. There is no reason why, at a similar scale, hydrogen-ready boilers should not reach a similar cost to natural gas boilers today.

TECHNOLOGY #2

Heat pumps

What are the basic workings of a heat pump?

A heat pump is a relatively new technology in the UK although they are widely used in Scandinavia and many parts of Europe where there is an abundance of renewably sourced electricity.

A heat pump takes energy from outside and transfers it into heat to be circulated around a heating and hot water system. A heat pump uses electricity to run the components of a heat pump, principally a fan, compressor and circulating pumps to transfer the energy from the heat source into the heat sink or heating system.

What type of heat pumps are available?

For use in a domestic heating system application, there are basically two forms of heat pump; Ground Source or Air Source.

A Ground Source heat pump has a collection pipe filled with a Heat Transference fluid and collects heat from the ground. The collection pipework is normally a continuous, unjointed length of pipe buried in the ground either horizontally or vertically in a borehole. For an average sized domestic property, if the collection system was sited horizontally, it would require the pipe to be buried around one metre in depth and would occupy an area of ground similar in size to a tennis court. If the collection system is to be sited vertically then either one or more boreholes equivalent to around 150 metres deep would be needed.

An Air Source heat pump takes the outside air as its heat source and is consequently easier and less expensive to install as there is no collection pipework to install into the ground. The outside unit contains a fan that draws into the unit outside air and transfers this into the refrigerant circuit which is then compressed to a high temperature and then transferred into the water within the heating system via a heat exchanger.

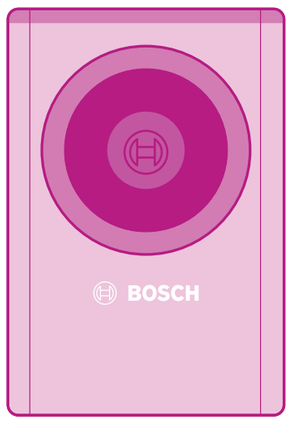
What are the advantages and disadvantages of the different types of heat pumps?

There are debates over which system is the most efficient however, an air source heat pump is reliant on the outside air temperature which can be a lot cooler than the ground temperature which by comparison is relatively stable. Consequently, a ground source heat pump tends to be more efficient in all outside temperature situations however, they are significantly more expensive to install and are therefore less popular than an air source heat pump.

A heat pump **takes energy from outside and transfers it into heat** to be circulated around a heating and hot water system.

How does the operation of a heat pump differ from a boiler?

A heat pump is at its best when it is circulating low temperature water around the heating system in a “steady state” mode. The heat pump is best run from a weather compensation system and allowed to run at all times as dictated by the external weather temperature and the internal room temperature. Because of the low temperature of the heating system water it is not best suited to be operated intermittently like a boiler. A boiler is typically turned on for a couple of hours in the morning, switched off all day and then turned back on at night for 5 or 6 hours. The high temperatures that a boiler can generate result in it heating the house more quickly than a heat pump can hence the need to run the heat pump in a “steady state” mode and avoid the need to heat the house quickly and from a low base temperature.



What are the servicing requirements of a heat pump?

The servicing requirements of a heat pump are not as onerous as a boiler however, there are disagreements as to whether the homeowner can undertake this or a service engineer is required.

With a Ground Source heat pump the requirements are more of a check than an activity, the closed loop collection system needs to be checked for the correct levels and efficacy as the fluid also serves as an anti-freeze. The heating system water pressure needs to be maintained and, if the installation has a mains pressure unvented hot water storage cylinder, the servicing requirements of that needs to be considered.

An Air Source heat pump requires the external unit to be kept free of leaves and debris, any filters within also need cleaning or replacing as specified by the manufacturer. And similar to a Ground Source heat pump, any unvented, mains water pressure cylinder needs to be serviced to the manufacturer’s instructions.

A heat pump is at its best when it is **circulating low temperature water** around the heating system in a **“steady state”** mode.

What are the annual running costs of a heat pump system?

The running costs of a heat pump will vary from house type to house type. A well-insulated house built to new building regulation standards will generally be less expensive to run than a gas or oil fired boiler system providing the heating system flow temperatures are kept relatively low, ideally around 40ºC. A heat pump will be less efficient and more costly to run when generating higher temperatures, either because the house isn’t well insulated, the radiators are insufficiently sized for the lower temperatures or when generating higher temperatures to produce hot water.

A heat pump **can be connected** to an existing heating system.

(Dependant on certain conditions being met)

Can I connect a heat pump to an existing heating system?

A heat pump can be connected to an existing heating system however, there are several conditions that will need to be checked otherwise there could be issues with customer satisfaction and running costs;

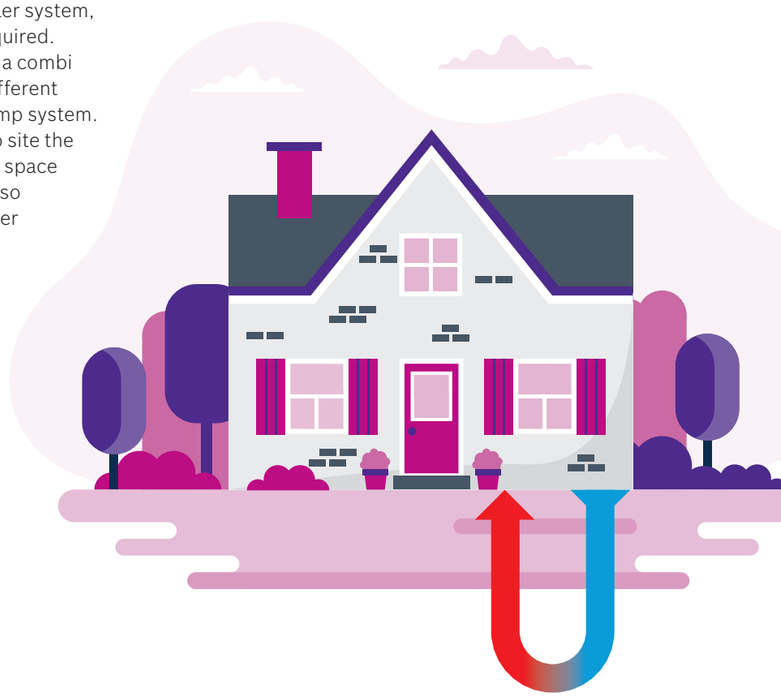
- A heat loss calculation of the property needs to be undertaken to ascertain the correct radiator or heat emitter sizes required. If the original system was sized on the presumption that a boiler running at relatively high temperatures, i.e. 70-75ºC flow, then unless the house has since then had additional insulation measures undertaken such as cavity wall, double glazing etc. then the radiators and distribution pipework may not be large enough to heat the rooms when operating at a heat pump temperature of around 40-45ºC. There have been instances where this has not been correctly undertaken and the heat pump is then turned up to operate at a higher flow temperature which results in the heat pump running at a lower efficiency or even the back-up immersion heaters operating.
- If the homeowner is used to operating a boiler system intermittently, they need to be instructed as to how differently a heat pump system needs to operate. Many of the customer complaints about the suitability of a heat pump result from their expectations of how the two systems operate differently. They will need to be informed that the radiators will not be as hot as they have been used to and that they need to be more attentive to the actual air temperature in the room rather than the surface temperature of the radiator.
- If the existing heating system is a combi boiler system, then a hot water storage cylinder will be required. There are around 17m homes in the UK with a combi boiler installed so there are considerably different aspects between this system and a heat pump system. There needs to be space within the house to site the newly required cylinder which could involve space being lost from a bedroom or landing and also education to the homeowner that the cylinder now needs to heat up before hot water is available rather than instantly heated when a hot water tap is opened.

How much does it cost to install a heat pump?

The installation cost of a heat pump will differ from house to house and from size and type of heat pump chosen. As a rule of thumb, an air to water heat pump will cost around £8k to install and a ground source heat pump could be anything up to and around £20k. This though is very dependent on the site and as to whether the existing heating system can be used and the position of the equipment etc. There are grants available to assist in the investment, sometimes locally and regionally, as well as the Renewable Heat Incentive (due to end March 2022) which will pay an annual sum to the purchaser of the system for 7 years.

Are heat pumps noisy?

An air source heat pump has an outdoor unit that contains a fan to induce the external air into the unit and consequently, they are noisier than a ground source heat pump. Generally, there are few complaints about the noise from a heat pump and when compared with the normal ambient external noise are quite acceptable.



TECHNOLOGY #3

Hybrid systems

What is a hybrid system?

A hybrid heating and hot water system is a combination of two or more technologies generating heat to provide heating and hot water to the home or building.

These are typically a gas or oil-fired boiler in combination with a heat pump, or a set of solar panels or even another, smaller heating source such as a log fired heater. For the purpose of this document, we are concentrating on a hybrid system comprising of a gas or oil-fired boiler and an air source heat pump.

For a heat pump to work most efficiently the temperature of water being generated should be kept as low as possible, ideally around 40-45ºC maximum. Over 80% of UK homes were built before 1960 and are generally not that efficient with relatively poor fabric insulation and glazing. There are obvious exceptions to this with most homes now with double glazed windows however, not so many homes without cavity wall insulation have had it retrofitted and even fewer have had floor insulation improvements made.

A major advantage of a hybrid system is **the reduced alterations needed** to an existing heating and hot water system and the property itself.

What are the advantages and disadvantages of a hybrid system?

Most existing heating systems which are heated by a gas or oil-fired boiler, (circa 24m), have radiators installed that were sized on the basis that the water temperature within was around 75ºC and an external air temperature of -3ºC. They were also sized on the basis that the boiler would be operated intermittently, perhaps for one or two hours in the morning and 4 or 5 hours at night. Outside of these times, the heating system would be switched off with a small number of systems having controls that allowed the air temperature in the house to drop to a set-back temperature 4 or 5ºC lower than the comfort temperature (which is typically 21-22ºC). If the setback temperature is reached then the boiler will fire and keep the house at this set-back temperature until the next demand for the higher comfort temperature.

Consequently, there are many occasions where only putting air-source heat pump water temperatures, (40-45ºC) into radiators sized for temperatures more like 75ºC will result in lower room air temperatures being experienced and discomfort and perhaps secondary heating devices needing to be used with more carbon being emitted.

Conversely, there will be moments in the year when the outside air temperature is higher than the design temperature basis and the required room temperatures will be achieved by the lower flow temperatures of a heat pump, with no noticeable drop in heat pump efficiency. Typically with anything over around 7ºC external air temperatures, it is likely that the heat pump will be suitable for the existing radiators to achieve the desired room temperatures and therefore with the lowering carbon intensity of electricity generation, a worthy consideration for carbon reduction measures.

A major advantage of a hybrid system is the reduced alterations needed to an existing heating and hot water system and the property itself. To substitute a gas or oil-fired boiler totally with a heat pump is likely to require improvements to the fabric of the house to reduce the heat loss and also make the existing radiators and pipework suitably sized for the lower water temperatures. Also and perhaps more significantly there are around 17 million homes with combi or combination boilers installed and therefore no hot water storage cylinder. To remove a combi and replace it with a heat pump would require a hot water storage cylinder to be installed and a location for it found, and in most cases this will mean taking a portion of the landing or one of the bedrooms and constructional work to facilitate this. As you can imagine there will be very few people happy to accept this requirement.

Using a hybrid heat pump system would allow the heat pump to be sited externally and no or very few remedial changes are required to the heating and hot water system or the property. The boiler would heat the house during the colder periods and, when the weather isn't quite so cold, yet heating is still required, a combi can provide hot water whilst the heat pump warms the property.

How does the control of a hybrid system work?

There are quite a few different control methodologies that are available for a hybrid system, from a quite basic control that simply allows the heat pump to heat the system whilst the external air temperature is higher than 7ºC, to a control system that takes into consideration the cost of the fuels, the amount of over or under generation of grid electricity and numerous other factors. The major consideration of the designers and manufacturers of a hybrid system is to reduce the amount of complexity for a householder as this is when heat pumps have experienced issues with inefficiency and comfort issues. Ideally, the householder should be able to programme the heating system times and temperature requirements and the control systems will orchestrate what technology actually generates the heat required, not dissimilar to a hybrid car where the driver simply drives as normal without any knowledge as to whether it's the combustion engine or the battery that is propelling the vehicle.

A modern hybrid control system ensures the most appropriate heat source is being used, whilst also allowing the heat pump and boiler to operate in parallel where the heat pump takes the lead while the boiler tops up the difference between what the heat pump is able to deliver and what the property demands. It is, therefore, cost effective and efficient to choose a heat pump with an output below the maximum heat demand of the building – this ensures that the heat pump is delivering its maximum potential.

A typical system will have an internal room temperature controller and an external weather sensor, or an internal room temperature controller that accesses the external temperature via the internet. This arrangement delivers the most efficient and carbon-reducing way of heating the system. The more complex systems also provide other inputs into the technology being used, by taking account of the fuel tariffs on offer, the amount of electricity available in the grid, the amount of solar PV being generated on the house, and whether an electric vehicle is charging or fully charged etc.

How much does it cost to install a hybrid?

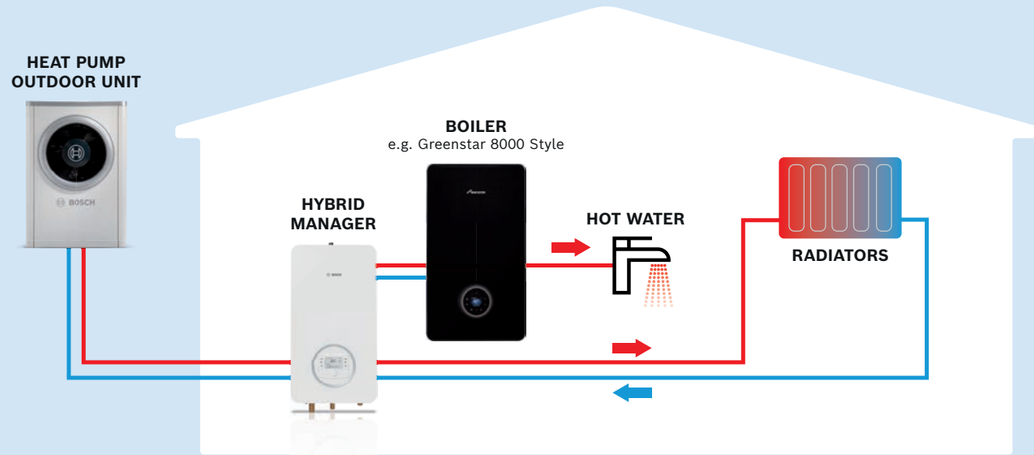
The cost of a hybrid heat pump installation will vary significantly on a number of factors;

- Is the installation both a new boiler and a new heat pump?
- If the existing boiler is retained and it's just a heat pump that is the new addition
- The proximity between the heat pump and the boiler
- Is the hybrid system going to be with a Regular boiler system or a combi boiler system
- Is the heat pump a split or monoblock

Generally, a heat pump of around 6kW output is the size of the majority of hybrid installations and can therefore provide the heating requirements for around 70% of the time. The heat pump, excluding installation cost, would be around £4k and a boiler, such as a 30kW gas-fired combi, would be around £1k. The controls and installation will again vary from site to site but the installation of the component parts onto an existing system, with labour and other materials, could be anything up to and around £8k-£10k.

System operation (demand for high/low temperature)

A system will bring on either the heat pump or boiler depending on the system and demand conditions. With a weather compensation control, the system can work at the most efficient setting depending on the target temperature.



You can’t force change, but you can encourage it

There is no silver bullet when it comes to tackling decarbonisation. Many say that everything should be electric, but to generate enough for that demand we would have to use sources that produce carbon.

We are confident that hydrogen gas, with the by-product when burned only being water, could be the closest silver bullet we have.

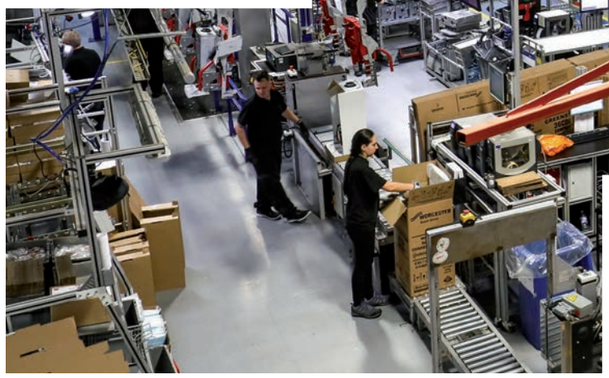
But even so, we believe that the best chance we have of hitting our net-zero target is by using integrated technologies, all working together with the same goal.

As you will have seen from this paper, various technology solutions can effectively heat UK homes without always needing to disrupt homeowners. We need consumers’ buy-in for this to work and the best way to do that is to give choice, not force change.

It is also by being aware of the end-cost to the consumer, who will bear the brunt of wholesale change.

It is going to be a long road to Net Zero Carbon 2050. It may seem a long way off, but if the country doesn’t start making clear decisions and outline the right paths now, you can be sure that we won’t hit that target.

When the Government sets a policy, the industry must work together to find practical solutions that will benefit consumers while we achieve the goals that we have for the future of the planet.



Meet the team

Worcester Bosch’s R&D team have a history of developing innovative technology and products.

From combi boilers to heat pumps, district heating to hybrids, the team have explored multiple avenues to decarbonise the heat in our homes.

In 2016, the H21 Leeds City Gate project delivered a report showing that the conversion of our gas networks to carbon-free hydrogen is feasible. Such a direct path to deep decarbonisation of heat had not been proposed before, and the potential was clear.

However, it was clear at that point that although we know hydrogen works through various applications such as hydrogen cars, we had no clear evidence in the UK heating market that a hydrogen boiler could work.

The R&D team at Worcester Bosch took up the challenge and in December 2017 our hydrogen laboratory demonstrated a working prototype, practical evidence that switching to hydrogen was feasible for the whole of the country. In 2018 we joined the UK government’s Hy4Heat project to develop hydrogen-ready appliances.

Since then, our committed team of engineers have developed innovative heating solutions, from heat pumps to hybrid systems, which will be transferable to the UK domestic market, helping reduce carbon emissions and making a real difference to the environment.

From humble beginnings in a spare space within the R&D department, the team now occupies a state-of-the-art, purpose-built hydrogen lab and continues to grow as Worcester Bosch prepares to support pilot demonstration trials in the UK.

The team pride themselves on their technical approach, using cutting-edge simulation tools and extensive testing to develop and validate technical solutions. Worcester Bosch quality runs deep, and the team engineer it in from the very start.

The core team of engineers are supported by many areas of the wider business. From the trainers beginning to introduce low carbon training to installers, to marketing and communications ensuring that the correct facts are given to policy makers, the heating industry and the general public.

All of us at Worcester Bosch are pushing hard to ensure that the country has the right information, technology and choice as we move forward towards a net-zero future.

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