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Decarbonisation of heat across the
food and drink manufacturing sector



Decarbonisation of heat
across the food and drink
manufacturing sector

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1.0 EXECUTIVE SUMMARY

Background

In 2015, the Government published a decarbonisation and energy efficiency roadmap for the Food and Drink sector¹. The roadmap presented potential decarbonisation paths to 2050 through actions to reduce emissions from electricity and heat use. In 2012, the food and drink industry emitted approximately 9.5 million tonnes of CO₂ and the roadmap concluded that the sector could reduce its emissions by 60-80% compared to 2012 if projects were implemented beyond what is considered as business as normal². The report did not look to evaluate the potential for decarbonisation of gas, the introduction of green gas, or using hydrogen to generate heat.

Since 2015, the Government has changed its national commitments around greenhouse gas emissions from an 80% reduction by 2050 to 'net zero' and projects have been established to look at hydrogen generation and distribution. The UK is committed to net zero emissions by 2050 but the pathway to achieve net zero is currently unclear; the Government has not updated the Food and Drink sector road map to understand how the transition could be achieved for the sector.

Decarbonising the electricity used by the sector is largely dependent on how the national electricity grid decarbonises together with increasing use of on-site renewables to generate electricity, whereas decarbonising emissions from heat use will be much more dependent on the actions taken by the sector and the decarbonised energy sources available.

Objectives of this report

This report has been produced as a collaboration between the Food and Drink Federation (FDF) and SLR Consulting. The objectives of this paper are to:

- Understand how the food and drink manufacturing sector can decarbonise its heat generation towards net zero, and
- Identify what actions are needed by all stakeholders to enable the transition.

Changes to heat demand across the sector (i.e. due to energy efficiency, heat recovery, or decreased heat use) have not been evaluated in this paper as our focus has been on where significant step changes and hence investment are needed.

Business as usual

A business as usual (BAU) emissions trajectory to 2050 has been established to understand what the emissions from heat are likely to be under normal circumstances.

We have focussed on the emissions from FDF members in EU ETS and all the emissions in the FDF's food and drink manufacturing Climate Change Agreement (CCA).

¹In the roadmap sub-sectors of food and drink manufacturing included dairy, brewery, distilling, sugar, confectionery, bakery, rendering, meat processing, fish and seafood, poultry, malting, soft drinks, animal feed, oil and fat, glucose, canned food, ice cream, and pet food.

² Industrial Decarbonisation & Energy Efficiency Road maps to 2050: Food and Drink, Department for Energy & Climate Change, 2015

1.0 EXECUTIVE SUMMARY

Companies in the membership and CCA cover sub-sectors such as sugar, baking, chilled foods, confectionary, ice cream, cereals, milling, canned foods, oil and fat, glucose and pet foods. This population has been identified as the 'FDF sub-sector'. The emissions from heat from the 'FDF sub-sector' were approximately 3.5 million tonnes CO₂e in 2012³; approximately 37% of the total sector's emissions. Of these emissions, just under 97% come from the use of natural gas.

We have used the BAU forecast applied in the 2015 road map where the sector is assumed to grow 1% per annum and emissions reduction would continue but without additional interventions. The BAU forecast has been adapted to incorporate the expected decarbonisation of the natural gas grid through addition of biomass and hydrogen by up to 20% by 2035.

Options to decarbonise and the maximum potential

We have used research undertaken by FDF in 2012 and 2020 to identify the equipment and processes that generate and use heat across the 'FDF sub-sector'. Boilers and direct fired ovens use over 80% of the energy used to provide heat to the manufacturing processes.

Table 1 1 Implementation of decarbonisation themes

	2020	2025	2030	2035	2040	2045	2050
Boilers	Low carbon fuels, Renewables, Electrification (boilers or indirect heat users)			Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification (boilers or indirect heat users)			
Direct Fired Ovens	Electrification		Renewables, Electrification	Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification			
Other Direct Fired	Electrification		Renewables, Electrification	Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification			
CHP ⁵	Renewables, Electrification (indirect heat users)			Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables			
Other	Electrification		Renewables, Electrification	Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification			

Table 1 2 Generic barriers to implementation

Timeframe	Reasoning
2020-2030	<ul style="list-style-type: none"> Cost of alternatives not yet competitive enough and like for like replacements made. Lack of knowledge or confidence in electrification of some processes. Availability of renewable sources. Uncertainty about future energy sources.
2030-2040	<ul style="list-style-type: none"> Cost of alternatives not yet competitive enough and replacement cycles are delayed. Supply of decarbonised gas or hydrogen not yet established. Availability of renewable sources. Lack of knowledge or confidence in new technologies. Product quality compromised with alternatives.
2040-2050	<ul style="list-style-type: none"> Cost of alternatives not yet competitive enough and replacement cycles are delayed. Supply of decarbonised gas or hydrogen not yet established in less populated areas. Product quality compromised with alternatives.

There are a number of technological options for decarbonising heat use. In Section 4 of this report, Tables 4-1, 4-2 and 4-3 identify the technologies currently available and likely to exist in the future to reduce the emissions from the different heat using technologies. Decarbonisation options mainly arise from the common themes of using a decarbonised gas, hydrogen, renewables, or electrifying processes which use decarbonised grid electricity. The potential decarbonisation options have been mapped against the major energy users as shown in Table 1-1.

Barriers and enablers

Through a PESTLE⁴ analysis, we have identified the barriers that will exist to the implementation of the different major decarbonisation technologies: renewables, decarbonised gas or hydrogen, and electrification (Tables 5-1, 5-2 and 5-3). Table 1-2 presents a summary of the common themes identified during the decades to 2050.

Building on the PESTLE analysis, we grouped common barriers and identified potential enablers which could help overcome the barriers (Table 6-1).

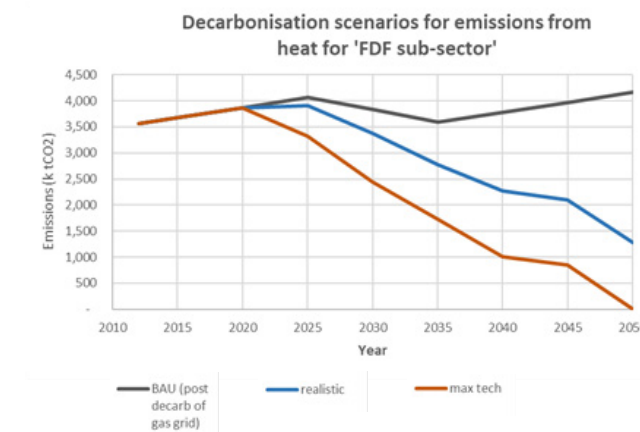
Decarbonisation potential

The maximum technical ('maxtech') decarbonisation potential of the 'FDF sub-sector' assumes that when any equipment is at the end of its life it is replaced with a lower carbon solution.

The realistic decarbonisation potential has been derived using the barriers identified whereby only a proportion of equipment at the end of its life is replaced with a lower carbon solution.

Figure 1 shows the maxtech and realistic scenarios against the BAU forecast.

Figure 1 - Decarbonisation potential of the 'FDF sub-sector'



Conclusions

It should be technically possible to fully decarbonise the emissions from heat from the 'FDF sub-sector' by 2050 if the electricity grid fully decarbonises and there is sufficient access to decarbonised gas, mainly via hydrogen. In reality, there are a number of barriers that exist and they will impede the maximum technical potential from being achieved. Realistically, it is likely the 'FDF sub-sector' could reduce emissions from heat by approximately 64% versus 2012 actual emissions without additional interventions.

The greatest contribution to the decarbonisation of heat is likely to come from changes to boilers; either switching to low carbon fuels or electrifying the processes that the boilers provide heat to.

The scale of change required means that coordinated step changes are required and not just independent nudges. The food and drink sector needs to work closely with Government and other stakeholders to implement these actions to achieve zero carbon emissions from heat by 2050.

Recommendations

a) Collaboration

i. A food-and-drink industry taskforce is required to facilitate knowledge share across the sector on technology innovations and implementation, policy development with Government and to spearhead the transition to net zero for the sector.

ii. A biofuels taskforce should be established to bring together industry, electricity generators, BEIS, DEFRA, HMT and DCLG to ensure objective alignment around the use of biomass.

b) Policy Development

i. Government needs to understand actual investment cycles in industry to help guide policy making and support measures.

ii. In the forthcoming Energy White Paper, Government should provide the clear direction needed on the long-term future of carbon pricing and mechanisms to ensure domestic industry competitiveness and encourage the move from high to low carbon energy solutions.

iii. Each Local Enterprise Partnership⁶ needs to bring together key stakeholders to address local area planning challenges for example in electricity and gas networks investments, as well as to promote wider opportunities for example in developing heat networks.

c) Finance

i. Government should establish a bottom-up approach to a new financial support scheme for industrial decarbonisation both in the near term to 2030, and beyond for funding of key demonstration projects on step-change technologies, particularly around options to electrify heat or for processes which avoid heat generation.

ii. The Government should extend the non-domestic Renewable Heat Incentive (RHI) (currently due to finish in March 2021) to be in parity with the domestic RHI.

iii. Government should implement a third phase of Climate Change Agreements which builds on previous successes and shift focus to carbon reductions.

About Food and Drink Federation

The Food and Drink Federation (FDF) is the voice of the UK food and drink industry, the largest manufacturing sector in the country. The UK food and drink industry accounts for 20% of the total manufacturing sector by turnover and employs over 430,000 people in the UK across 7,400 businesses. We are an incredibly diverse sector, speaking on behalf of global brands and thriving small businesses.

FDF helps its members operate in an appropriately regulated marketplace to maximise their competitiveness. FDF communicates industry values and concerns to Government, regulators, consumers and the media. FDF also work in partnership with key players in the food chain to ensure our food is safe and that consumers can have trust in it.

About SLR Consulting

SLR Consulting is an international consulting firm that provides global environmental and advisory solutions from a network of offices in Europe, North America, Asia-Pacific and Africa.

SLR delivers advice and support on a wide range of strategic and project-specific issues across the full spectrum of environmental, social and governance factors to a diverse and growing base of business, regulatory and government clients. We specialise in the oil and gas, mining and minerals, infrastructure, built environment, financial, power, and industry sectors.

3. CCA and EU ETS data for 2012/2013 4. PESTLE: Political, Economic, Social, Technological, Legal, Environmental

5. CHP: Combined Heat and Power 6. www.lepnetwork.net

2.0 INTRODUCTION

In 2015, the UK Government published a decarbonisation and energy efficiency road map for the Food and Drink sector⁷. This was alongside road maps for seven other industrial sectors⁸. The road map presented potential decarbonisation paths to 2050 and an action plan to deliver them. The scope of the road maps was restricted to CO₂e emissions from energy use only (i.e. no CO₂e emissions from F-Gases).

The road map was developed through collaboration between the UK government, industrial companies, representative sector associations, academia and technology and service providers. Food and Drink Federation (FDF) was a key stakeholder during the project.

The report identified the following key technology groups that would have the largest influence on enabling the sector to decarbonise:

- Electricity grid decarbonisation.
- Electrification of heat to move to lower carbon electricity.
- Increasing use of biomass as a fuel to generate heat and/or electricity.
- Energy efficiency improvements to reduce heat and electricity use.
- Recovery of heat to minimise heat generation.

Other technologies discussed in the report included carbon capture and storage and clustering (i.e. sharing of energy generation or capture and re-use amongst a cluster of sites). The report did not look to evaluate the potential for decarbonisation of gas, green gas or using hydrogen to generate heat.

Since 2015, the Government has changed its national commitments around greenhouse gas emissions from an 80% reduction by 2050 to 'net zero'⁹. The Government has not updated the Food and Drink sector road map to understand how the transition could be achieved.

To address some of the barriers to implementation identified in the road maps, the Government has since introduced and consulted upon new funding schemes to help companies implement the decarbonisation measures identified in the road maps. For example, the Industrial Heat Recovery Support (IHRS) Programme started in 2018, and the new Industrial Energy Transformation Fund (IETF); aimed at larger scale energy efficiency and decarbonisation projects.

The pathway to net zero is currently unclear for the Food and Drink manufacturing sector, as are the policy needs to help achieve it. FDF would like to understand if it is possible for companies to achieve net zero and what support is needed to enable certain technology transitions.

2.1 Building on the 2015 road map

FDF want to build upon the 2015 road map and produce a paper to identify how the sector can strive for net-zero. Through understanding this, FDF can also identify where support is needed to facilitate the low carbon transition in the sector.

The data analysis in this report focuses on FDF's food and drink manufacturing CCA and emissions from members in the EU ETS. This

means that the data itself does not cover some sectors that were also included in the 2015 road map; i.e. dairy, brewing, distilling, rendering red meat and poultry processing, maltings and animal feed. Companies in the CCA cover sub-sectors such as sugar, baking, chilled foods, confectionary, ice cream, cereals, milling, canned foods, oil and fat, glucose and pet foods. This population will be known as the 'FDF sub-sector'¹⁰.

2.1.1 Excluding electricity

As described in the 2015 road map, decarbonising the electricity used by the sector is largely dependent on how the national electricity grid decarbonises plus an increase in the use of on-site renewables to generate electricity. As decarbonisation pathways for electricity use are well understood and have been significantly modelled by Government, this paper will not address a specific 'FDF sub-sector' decarbonisation pathway for electricity use.

2.1.2 Heat use

Heat is used within the FDF sub-sector by many processes, i.e. cookers, ovens, evaporators, pasteurisers, spray driers, kettles, fryers, cleaning systems. Heat is generated either through direct combustion of a fuel (mainly natural gas) into the process, or, by indirect combustion where a heat exchanger is used to supply heated water, air, oil or steam to the process. Indirect heat is most often generated through a boiler but can also be from a Combined Heat and Power (CHP) plant or via heat exchangers. There are also a number of applications addressed where electricity already provides the heat source including resistance heating, induction, microwave and radio frequency. The paper will specifically focus on the potential for decarbonising heat use across the 'FDF sub-sector'.

2.1.3 Excluding energy efficiency and demand changes

Potential savings from energy efficiency were also modelled extensively in the 2015 road map. The focus of this paper has been around decarbonising heat generation sources because that is where significant step changes are needed. Changes to heat demand across the sector have also not been evaluated in this paper as our focus has been restricted to the significant decarbonisation investments required. The objective of this paper has not been to quantify absolute carbon emissions but rather to identify if it is technically possible to decarbonise the heat raising technologies, and then what is realistically achievable given the likely barriers facing us.

2.2 Objectives of this paper

The objectives of this paper are to:

- Understand how the food and drink manufacturing sector can decarbonise its heat generation towards net zero, and
- Identify what actions are needed by all stakeholders to enable the transition.

3.0 BASELINE AND BUSINESS AS USUAL FORECAST

3.1 Baseline

The baseline in the 2015 road maps was 2012. We have used the same baseline in this paper to enable comparability.

The 2012 heat emissions baseline for the 'FDF sub-sector' population has been constructed using data from the FDF's Climate Change Agreement and from the EU Emissions Trading System's (EU ETS) Union Registry Transaction Log¹⁰. The emissions for 2012 were 3,568 kt CO₂. A map plotting the heat emissions from the different sites in the 'FDF sub-sector' is shown in Figure 2 below.

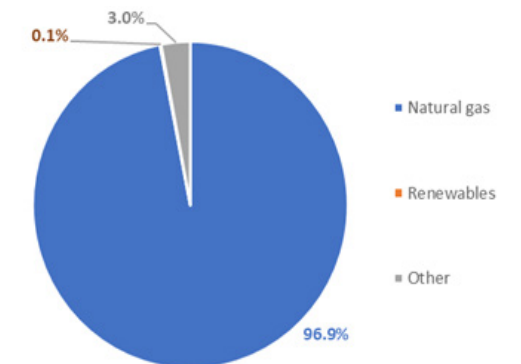
Figure 2 - 2012 emissions from heat from the 'FDF sub-sector'



As demonstrated in Figure 2, the distribution of food and drink manufacturing sites in the 'FDF sub-sector' is very disperse with no high concentration of sites in local level geographies.

In Figure 3 below, we show the breakdown of the energy use behind the 2012 emissions by energy source. This demonstrates how natural gas dominates the energy use of the sector.

Figure 3 - Breakdown of 2012 energy use by fuel source



3.1.1 Direct versus indirect heat users

It is important to also split the 2012 emissions into types of heat user:

- Indirect heat users: use a fuel source to heat another energy medium, and that energy medium is used to provide heat to the process.
 - Examples: boilers, combined heat and power, anaerobic digesters.
 - The 'medium' could be steam, hot water, hot air, hot oil, electricity.
 - The users of the heat medium could be blanchers, fryers, cookers, ovens, pasteurisers, etc.

Decarbonisation opportunities will include both the heat generation equipment and the indirect heat users, but focusing mainly on the heat generation equipment (i.e. boilers) rather than the indirect heat users (e.g. blanchers).

- Direct heat users: the heat generated by combusted fuel is directly used by the process.
 - The fuel could be gas, LPG, electricity etc.
 - Examples: fryers, ovens, bar markers, space heaters, grills, kettles.

Decarbonisation opportunities will be focused on these technologies; production speeds and product quality will be key factors in determining low carbon alternatives.

7. In the road map sub-sectors of food and drink manufacturing included dairy, brewery, distilling, sugar, confectionery, bakery, rendering, meat processing, fish and seafood, poultry, malting, soft drinks, animal feed, oil and fat, glucose, canned food, ice cream, and pet food.

8. Iron and Steel, Oil Refineries, Chemicals, Cement, Paper and Pulp, Glass and Ceramics

9. <https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law>

10. <https://ec.europa.eu/clima/ets/welcome.do>

Figure 4 shows the breakdown of major heat users. The breakdown was obtained via a survey undertaken in 2012 by FDF of CCA participating companies where approximately 50% of CCA sites (approximately 840) responded to the questionnaire, plus, estimations of energy use for EU ETS sites that are not in a CCA.

Figure 4 - Breakdown of heat use

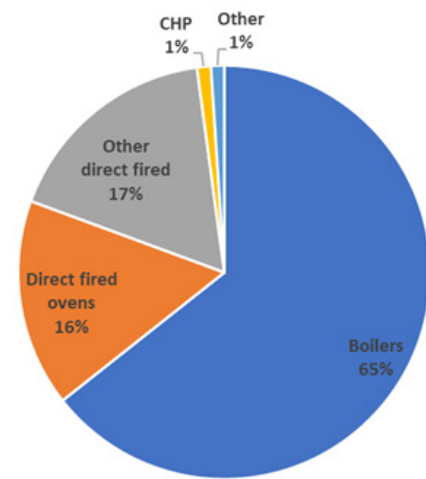


Figure 4 shows that the majority of energy sources (i.e. natural gas etc) are used in boilers to generate heat for the processes. Most of the remaining heat is used by direct fired equipment where ovens dominate.

3.2 Methodology for establishing the Business As Usual forecast

In the 2015 road maps, the emissions for the Food and Drink Sector were estimated by examining how the sector may grow or contract, and what changes are likely to happen under normal circumstances. This led to a 'Business As Usual' (BAU) forecast being developed. The BAU forecast in the roadmap included:

- A 1% growth rate per annum for the sector¹¹, and
- Emissions reductions that would be achieved without new developments, but being achieved through improvements in process design (20% by 2050), adoption of renewables (10% by 2050), improvements in steam use (25% by 2050), and decarbonisation of the electricity grid.

In this paper we have also sought to establish a BAU forecast so the impacts of the different heat decarbonisation technologies can be modelled and understood. As this paper is only focussing on heat, we cannot use the same BAU forecast as was used in the roadmap as that included electricity.

Therefore, in this paper we have generated a BAU forecast by applying a 1% growth per annum to the 2012 base line emissions, and have modelled how conservative decarbonisation of the natural gas grid will naturally reduce emissions.

3.2.1 Decarbonisation of the natural gas grid

The UK Government has not issued a forecast of how the natural gas grid may decarbonise, similar to the graphs published for electricity grid decarbonisation. Reports from different stakeholders including National Grid¹², Parliamentary Office of Science and Technology¹³ and Energy Stakeholders Networks Association¹⁴, conclude that biogas and hydrogen can be added to the existing gas grid, with hydrogen up to 20% of the volume. This could be achieved by mid 2030s and should not require changes to be implemented by gas users.

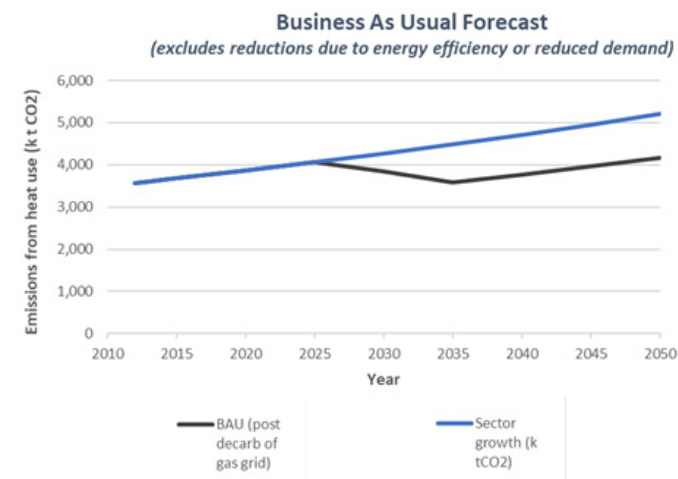
The gas grid could decarbonise further through combined increases in biogas and the introduction of green hydrogen. It could eventually switch to 100% hydrogen (if the volume of low carbon hydrogen was available) but such a change would require significant investment in the networks and by all industrial, commercial and domestic gas users to adapt from burning natural gas to hydrogen.

For this study, we have modelled a linear decarbonisation in the gas grid to 2035 of 20% with no further savings thereafter due to the investment required. Switching to 100% hydrogen supplies is discussed as a potential decarbonisation measure in Section 4 of this paper.

3.3 Business as Usual (BAU) forecast

Using the baseline data, methodology and forecast as described in this Section, Figure 5 below shows the BAU forecast for emissions from heat use for the 'FDF sub-sector' from 2012 to 2050.

Figure 5 - Business As Usual forecast for the 'FDF sub-sector' 4.0



4.0 DECARBONISATION OPTIONS AND 'MAXTECH' POTENTIAL

There are a number of technological options for decarbonisation for both direct fired and indirect fired heat sources. The following section details the options for each of the main identified heat using unit operations and then models what is the maximum technical (maxtech) decarbonisation potential of the 'FDF sub-sector'.

4.1 Methodology

The objective is to identify alternative technologies and techniques for creating heating which will allow for decarbonisation of heat. The maximum technical decarbonisation potential, 'maxtech', will be calculated, in which it is assumed that the maximum impact of alternative technologies is achieved. In reality, the rate of adoption of low carbon technologies will depend on economics, political and market forces, standards and legislation.

As described in Section 3 of this paper, a survey of FDF members has identified the main heat users and related equipment, and the heat sources used. The equipment has been categorised as direct fires and indirect fired. In addition, there is equipment where electricity is used to supply the heat or there are other sources of heat not directly related to combustion processes. A separate section describes these technologies.

For each technology a literature survey has been performed to determine what alternative heat sources are already commercially available and where equipment suppliers have already developed commercially available equipment. The impact of equipment and production development has then been considered to estimate what may be developed and when. Simply having a technology available does not make it widely applicable. A commentary on the likely development and applicability has also been made.

There are common decarbonisation technologies which can be applied to both direct and indirect fired equipment and processes. These will be described separately.

4.2 Direct Fired users of heat

Common direct fired equipment used within the food and drink manufacturing processes include:

- Bar markers¹⁵
- Building space heating (radiant tube heaters, fired convection heaters)
- Cookers
- Fryers direct fired
- Grill gas
- Kettle gas fired
- Ovens

Table 4-1 summarises the decarbonisation options - see page 12.

4.3 Indirect fired equipment and the generators of their heat

Indirect fired equipment has a separate heat generator (e.g. boiler) which supplies hot water, steam, hot oil, hot air, etc, to the process depending on the

application. In all cases it is possible to either decarbonise the energy source of the heat generator (i.e. change the boiler to run on a low carbon fuel rather than natural gas), or, to switch to an alternative arrangement (i.e. electrify the process, use heat pumps, etc).

4.3.1 Options to decarbonise the generators of heat for indirect fired equipment

The advantage of indirect fired equipment is that change a change to the generator of the heat does not require modification of the food processing equipment or production line. As shown in Section 3 of this paper, the major generator of heat to indirect fired heat users is the boiler. CHP plants are an alternative that is used by some sites across the 'FDF sub-sector'.

Table 4-2 (page 13) presents the different decarbonisation options for the equipment that provides heat to indirect fired heat users.

4.3.2 Options to change the source of heat for indirect fired equipment

Existing indirect heated equipment at end of life could benefit from inclusion of more energy efficient and low carbon technologies such as microwave or radio frequency. Replacing at end of life would enable alternative technologies which cannot readily be retrofitted to be adopted.

Table 4-3 (page 14) presents the different decarbonisation options for such equipment.

11. BEIS Industrial Decarbonisation and Energy Efficiency Road maps to 2050 – Food and Drink, March 2015, Page 65

12. National Grid: "Enabling the Gas Markets Plan 2019/2020"

13. Parliamentary Office of Science and Technology: PostNote 565, "Decarbonising the Gas Network", Nov 2017

14. ESNA: "Pathways to Net-Zero: Decarbonising the Gas Networks in Great Britain", Oct 2019

15. Bar markers are used to give a flame grilled or griddled effect to some foods

Table 4-1 Direct fired equipment decarbonisation options

Direct fired user	Current status	Available technology	Future scenario
Bar Marker	Most direct fired bar markers are gas or LPG fired.	<p>Install separate ingredients cooking and bar marker.</p> <p>Some manufactures have produced electric bar markers. (https://www.gsitalia.com/grigliatori)</p> <p>The potential for laser bar marking has been demonstrated but is not yet commercially available. (https://www.laserphotonics.com/laser-grilled-chicken)</p> <p>Existing gas fired bar markers are already capable of using biogas and are likely capable to run on 20% hydrogen/gas mixture.</p> <p>Higher levels of hydrogen would require modified burners and may not be possible.</p>	<p>On replacement of plant could:</p> <ul style="list-style-type: none"> Select electric bar marker. Purchase unit/burners compatible with higher levels of hydrogen.
Buildings	<p>Space heating supplied by direct fired heaters (radiant tube and convection heaters).</p> <p>Hot water provided by on demand fired water heaters.</p>	<p>Electric heating systems are available in the form of immersion heaters, induction heaters and electric resistance heaters.</p> <p>Heat pumps are readily available now (ground source, air source, heat source). Ground source heat pumps are unlikely to be retrofitted, but air source or water source especially from waste heat streams are readily available.</p> <p>Where ducted air handling systems are used, heat recovery from exhaust air with a heat pump to resupply as heating to the incoming air may be possible, dependent on layout.</p>	<p>Electrification of low-grade heat for space heating and hot water is most likely, combined with maximising heat recovery.</p> <p>Heat pumps for both hot water and specie heating are viable though can be expensive to run.</p>
Cookers	Many cookers are supplied with indirect steam heating or direct water heating. Electrical water heaters are readily available. For higher temperature cookers there may be hot oil heated or direct gas fired. Alternatives of electrically heated are readily available.	Gas, steam and electric cookers readily available. Increased humidity may be required for steam cooking, though this could be achieved through water injection to an electrically heated cooker.	<p>Decarbonisation of steam through alternative heat sources.</p> <p>Gradual conversion to electric heating. Alternative electric ovens include Microwave and RF.</p>
Fryer (direct fired)	All currently gas fired or LPG	<p>Existing units are already capable of using biogas and are likely capable to run on 20% hydrogen.</p> <p>Higher levels of hydrogen would require modified burners and may not be possible.</p>	Would expect continued firing with gas, so would rely on decarbonisation of gas grid
Grill	Generally, use gas fired grills, though electric grills are readily available.	<p>Existing units are already capable of using biogas and are likely capable to run on 20% hydrogen.</p> <p>Higher levels of hydrogen would require modified burners and may not be possible.</p> <p>Electric grills are available.</p>	<p>Would expect continued firing with gas, so would rely on decarbonisation of gas grid.</p> <p>Electric grills available and possible.</p>
Kettles	Generally, use gas fired grills, though electric grills are readily available.	Electric heating systems are available in the form of immersion heaters, induction heaters and electric resistance heaters.	<p>Decarbonisation of steam through alternative heat sources.</p> <p>Gradual conversion to electric heating.</p>
Ovens (direct fired)	Direct fired either with natural gas or LPG.	<p>Existing units are already capable of using biogas and are likely capable to run on 20% hydrogen.</p> <p>Higher levels of hydrogen would require modified burners and may not be possible.</p>	<p>Would expect continued firing with gas, so would rely on decarbonisation of gas grid.</p> <p>Electric heating modules are available for many ovens.</p>

Table 4-2 Decarbonisation options for the generators of heat to indirect fired equipment

Direct fired user	Current status	Available technology	Future scenario
Boiler	<p>The majority of boilers are natural gas or LPG fired, with a small number of oil-fired boilers.</p> <p>Where biogas is available, this may also be used.</p>	<p>To use the existing boiler plant the main option would be to decarbonise the gas supply using biogas from anaerobic digestion, gasification/pyrolysis of waste or green tariff gas (renewable gas produced by a third party). Most boilers could also run on up to 20% hydrogen blend in natural gas.</p> <p>Biomass boilers using wood pellets or other solid biomass are also on the market, although biomass supply may become an issue.</p> <p>Electric steam generators are available, mostly for very low steam flowrates of up to 150 kg/hr. A small number of manufacturers have larger units for up to 20 t/hr. (http://www.industrial-steamboiler.com/sale-10422648-heating-electric-steam-boiler-with-natural-circulation-500-kg-h-steam-capacity.html, https://www.stong-boiler.com/products/electric-heating-boiler/ldr-wdr-electric-steam-boiler.html)</p> <p>Hydrogen boilers are being developed (https://www.hydrogentechnologiesinc.com/#!), but the rate of development would depend on availability of hydrogen and demand.</p>	<p>Connection of boilers to renewable gas supplies would be the preferred option.</p> <p>The electric boiler market may expand, but the expansion would be limited by the high relative cost of electricity, typically 4-5 times more expensive than gas.</p> <p>Hydrogen boilers will be developed but have yet to be proven. It may be possible that hydrogen burners will be developed to use on existing boiler plant</p> <p>(https://h2-nrg.co.uk/, https://www.zantingh.com/en/news/varigas-the-industrial-natural-gashydrogen-burner-system/).</p> <p>A reliable supply of hydrogen would also be needed.</p> <p>It would be possible to combine the production of green hydrogen on site through electrolysis (https://www.hydrogenics.com/hydrogen-products-solutions/industrial-hydrogen-generators-by-electrolysis/outdoor-installation/, https://hydrogeneurope.eu/about-us-2)</p>
CHP	The majority of CHP are natural gas or biogas fired.	<p>All CHPs run on gaseous or liquid fuels. Technology is readily available to use biogas from anaerobic digestion, gasification/ pyrolysis of waste or green tariff gas (renewable gas produced by a third party) or liquid biofuels.</p> <p>Existing gas engines should be able to run on up to 20% hydrogen/natural gas blends. Claims are that existing gas engines can be converted to run on hydrogen</p> <p>(https://pureenergycentre.com/hydrogen-engine/).</p> <p>Trials so far on using hydrogen on industrial gas turbines has shown existing turbine designs are very limited in capability to use hydrogen mixes and are mostly limited to 15-20% under trial conditions. Development is ongoing, but for high hydrogen content would require new plant specifically designed for hydrogen as fuel (https://www.hydrogenics.com/hydrogen-products-solutions/fuel-cell-power-systems/stationary-stand-by-power/fuel-cell-megawatt-power-generation-platform/).</p> <p>An alternative more likely to be available at scale would be fuel cell technology to oxidise hydrogen and to produce heat for steam raising. These are available now and are being developed further.</p>	<p>Connection of CHP to renewable gas supplies would be the preferred option.</p> <p>It may be possible to convert existing gas engines to run on hydrogen, though gas turbines would need to be replaced. Fuel cells are available but are very expensive.</p> <p>A reliable supply of hydrogen would also be needed. It would be possible to combine the production of green hydrogen on site through electrolysis (https://www.hydrogenics.com/hydrogen-products-solutions/industrial-hydrogen-generators-by-electrolysis/outdoor-installation/, https://hydrogeneurope.eu/about-us-2).</p> <p>A reliable supply of hydrogen would also be needed.</p>

Table 4-3 Indirect fired equipment decarbonisation options

User	Current status	Available technology	Future scenario
Blanchers	Generally supplied with steam heating either as direct steam or hot water (see decarbonisation of steam boilers).	Decarbonisation of the steam supply is the most likely solution, either through electric steam generation or alternative fuel boilers (biomass, biogas, hydrogen). Microwave is thought to remain as a specialist application and will not penetrate the bulk market (https://www.fediol.eu/data/fediol_EU_DOCS_1205.pdf).	Decarbonisation of steam, hot water or hot oil through alternative heat sources.
Buildings	Space heating and domestic hot water supplied through cascade heating of hot water by steam or waste heat.	Electric water heating using induction and resistance heating is available. Most sites using thermal processing will have low grade waste heat that can be recovered through heat exchange or upgraded through heat pumps. Heat can be recovered from exhaust air discharges from process plant and wastewater heat recovery, or simply by exchange between inlet and outlet air on air changes. Heat pumps are readily available now (ground source, air source, heat source) to provide low grade space heating or to recover and upgrade recovered heat. Ground source heat pumps are unlikely to be retrofitted, but air source or water source especially from waste heat streams are readily available. For the commercial building sector there is a lot of development in heat pump technology for space heating, which will improve the performance and reduce the costs.	Electrification of low-grade heat for space heating and hot water is most likely, combined with maximising heat recovery.
CIP and wet rooms	Generally supplied with steam heating either as direct steam or hot water (see decarbonisation of steam boilers)	Decarbonisation of the steam supply is the most likely solution, either through electric steam generation or alternative fuel boilers (biomass, biogas, hydrogen). Electric water heaters are also readily available. Heat can be recovered through from wastewater heat recovery. For closed circuit CIP sets in which the discharged hot water can be collected, heat recovery could minimise this heat demand.	Heat pumps for space heating and hot water will become an economic alternative.
Coaters/ enrobers		Decarbonisation of the steam supply is the most likely solution, either through electric steam generation or alternative fuel boilers (biomass, biogas, hydrogen). Electric heaters for melters are also readily available and often used.	Decarbonisation of steam through alternative heat sources.

User	Current status	Available technology	Future scenario
Evaporator/ concentrators	Evaporators/concentrators: Generally, steam heated.	Heat supplied by steam. Decarbonisation of the steam supply is the most likely solution, either through electric steam generation or alternative fuel boilers (biomass, biogas, hydrogen). Electrical steam generators or electrical immersion heaters available. Can introduce more multiple effect evaporators, using vacuum to reduce the heat load.	Decarbonisation of steam through alternative heat sources. Where possible use multiple effect evaporators and vacuum to reduce the heat load.
Fryer	Either use external gas firing or high-pressure steam..	Existing units are already capable of using biogas and are likely capable to run on 20% hydrogen. Higher levels of hydrogen would require modified burners and may not be possible. Electric heating elements are available.	Would expect continued firing with gas, so would rely on decarbonisation of gas grid. Electric heating likely to be very expensive.
Kettles	Many kettles are supplied from steam heating or direct water heating.	Gas, steam and electric cookers readily available. Increased humidity may be required for steam cooking. Electrical water heaters are readily available.	Decarbonisation of steam through alternative heat sources. Gradual conversion to electric heating
Melters	Require low-grade heat to melt coatings. Typically, these are heated with hot water produced by cascade heating from steam. Electric heaters for melters are also readily available and in common use.	Decarbonisation of the steam supply is the most likely solution, either through electric steam generation or alternative fuel boilers (biomass, biogas, hydrogen). Electric water heaters are also readily available.	Decarbonisation of steam through alternative heat sources. Wider use of electric heaters for coatings.
Mixers	Often not heated but in some cases may be jacketed supplied from steam heating or direct water heating.	Decarbonisation of the steam supply is the most likely solution, either through electric steam generation or alternative fuel boilers (biomass, biogas, hydrogen). Electric water heaters are also readily available.	Decarbonisation of steam through alternative heat sources. Wider use of electric heaters for coatings.
Ovens (indirect fired)	Many ovens are supplied from steam heating or direct water heating. Indirect heating with electric elements readily available.	Decarbonisation of the steam supply is the most likely solution, either through electric steam generation or alternative fuel boilers (biomass, biogas, hydrogen). Electric water heaters are also readily available.	Decarbonisation of steam through alternative heat sources.

Table 4-3 Indirect fired equipment decarbonisation options (continued)

User	Current status	Available technology	Future scenario
Packing lines	(Shrink wrap, thermoforming, packaging machines): Heat seals and glue are electrical heat already. Heat tunnels could be steam heated or electrically heated, in general electric heating.	Continue with electric heating and decarbonise electric supply. Where steam is used, see boilers. Further development of stretch wrap or alternative packaging which would avoid heat load.	Decarbonisation of electric supply. Decarbonise steam supply. Alternative techniques not involving heat.
Pasteuriser	Requires hot water or steam. High levels of heat integration are possible through heat recovery, therefore heat load can be minimised.	Heat pumps to upgrade heat may allow the process to run without additional external heat sources. RF and microwave pasteurisers have also been developed, though currently have limited application.	Decarbonisation of steam through alternative heat sources. Higher efficiency heat recovery. Investigate future use of RF or microwave pasteurisers.
Retorts	Many retorts are supplied from steam heating or direct water heating.	Gas, steam and electric water heaters readily available. Increased humidity may be required for steam cooking.	Decarbonisation of steam through alternative heat sources. Gradual conversion to electric heating.
Storage	Requires hot water or steam. Could have electrical steam generator but currently either gas/LPG. Some lines electrical tracing already.	Gas, steam and electric water heaters readily available.	Decarbonisation of steam through alternative heat sources. Gradual conversion to electric heating.
Waste and effluent plants	Some heat is needed for aerobic and anaerobic digestion. For anaerobic created biogas can be used for heating, can be self-sufficient.	Anaerobic digestion to produce biogas. Wastewater heat recovery. Gasification/pyrolysis of solid waste	Extensive anaerobic digestion and gasification/pyrolysis of solid waste

4.4 Decarbonising energy supplies

In the previous section we discussed the technologies using or generating heat and their decarbonisation options. In this section we look in more detail at the energy sources which the technologies could use.

4.4.1 Decarbonising fuel supplies

On combustion natural gas creates CO₂. There are several options for decarbonising the existing supply of natural gas via the gas grid network. These are being pursued but it is early days in decarbonisation, and there needs to be more detailed proof of concept.

Decarbonising the gas grid

Hydrogen blending into natural gas

Introduction of up to 20% hydrogen into the existing natural gas grid is being

trialled in the UK and elsewhere¹⁶. Trials have shown that up to 20% hydrogen in natural gas does not cause any problems with domestic appliances¹⁷, but trials would be needed to check the impact on industrial heating. The Fuel/air ratio would need to be changed and due to the lower calorific value for hydrogen the thermal capacity would change. A change in thermal capacity may result in de-rating the plant capacity or the requirement for new burners to maintain the existing thermal capacity. Burning of hydrogen would also increase the humidity of the combustion gases for the same temperature, which may then adversely impact product quality if direct fired. Some changes to combustion set ups would be needed.

Above 20% hydrogen some modification to burners is likely to be required. Three trials are in hand in the UK, feeding both domestic, commercial and industrial premises¹⁸. These trials are currently small scale and are due to complete in 2025.

Larger scale trials would then be needed to determine the practicality of introducing hydrogen across the national network¹⁹. These larger scale trials are unlikely to yield widespread change until at least 2035. Some scenarios suggest we could have decarbonised gas: 70% hydrogen/30% biogas blend, by 2050, however this would require large scale technology development and change of virtually all industrial, commercial and domestic heating devices^{20,21,22}.

For this to result in decarbonising the hydrogen production would need to be decarbonised. This would either be by:

- Carbon Capture, Utilisation and Storage (CCSU) with large scale steam reforming of methane,
- Use excess renewable energy for electrolysis using renewable electricity.

Biogas blending into natural gas

Centralised and distributed biogas injection²³ into the national gas grid is expected to decarbonise the gas grid by 30% by 2050²⁴, assuming that the grid demand decreases.

Currently, only 2.5% of the estimated available organic farm waste in the UK is used to create green gas, making biomethane a promising component in our future low carbon gas mix.

An additional potential source of biogas could be created at site level from pyrolysis and gasification of renewable organic waste. The technology to produce the gas is already available and is used on waste-water treatment plants for disposal of sewage sludge. Further details on waste production and locations would be needed to fully evaluate the sector uptake for bio waste gasification.

Hydrogen

Research is underway to develop processes and equipment that could burn 100% hydrogen²⁵. Initial research and development are concentrated on power generation^{26,27}. Most existing gas turbines can only cope with 15-20% hydrogen in gas without significant modifications. Larger turbines used in power stations can more easily be converted to run on pure hydrogen. Aero derived engines used in industrial CHP are the least capable of handling hydrogen. Replacement of the turbines would be required in order to use hydrogen as a fuel. This would be aided by the maintenance cycle of gas turbines, in that complete rebuilds are required every few years. With ongoing equipment development this may be possible within 20 years²⁸. Dedicated networks for 100% hydrogen are being researched on a small scale²⁹.

There is the potential to have site-based hydrogen generation through electrolysis, but to decarbonise this would need a significant supply of renewable electricity. Plant is available for production of green hydrogen on site through electrolysis and there are many development programmes around the world.

<https://www.hydrogenics.com/hydrogen-products-solutions/industrial-hydrogen-generators-by-electrolysis/outdoor-installation/>
<https://hydrogeneurope.eu/about-us-2>

Alternative heat sources including renewables

Development of distributed heat sources would be possible. Technology already exists but this would need to be invested in and potentially further developed.

- Heat networks from renewable sources. Trials are already in place with renewable power stations distributing waste heat to local business and housing. This however is generally low-grade heat at 60 °C or less.
- On site waste digestion and pyrolysis/gasification. Gasification of sewage sludge and other wastes is already available though would undergo considerable development. The gas produced could be used in a biogas CHP or could be used to provide process heat.
- Biomass boilers would enable low carbon steam to be produced. If low carbon steam can be produced any process using steam for heat would be effectively decarbonised.
- Energy from waste does not count as renewable but the energy produced by energy from waste facilities replaces that generated by other fuels such as coal, oil and natural gas.
- Where indirect heating is used, biodiesel (from waste cooking oil) or other bio liquid fuels could be used.
- Geothermal energy may be applicable in very limited areas. Demonstration projects using deep mine geothermal or heat recovery from disused flooded mine workings for district heating may be applicable for low grade heat requirements in a limited area.
- Solar thermal may also be considered however, the thermal capacity is relatively low in the UK. It may be applicable for domestic hot water in office blocks and amenity areas.

16. Hydrogen trial at Keele could dramatically cut UK's carbon emissions, <https://www.keele.ac.uk/discover/news/2019/september/hydrogen-trial-at-keele-could-dramatically-cut-uks-carbon-emissions/hydrogen-trial-keele.php>

17. HyDeploy Project Second Project Progress Report (PPR), December 2018, https://hydeploy.co.uk/app/uploads/2018/12/15055_HD_PP2_PROJECT_REPORT_v2.pdf

18. <https://hydeploy.co.uk/>

19. Commercial Scale Feasibility of Clean Hydrogen, Ahn, H 2017, European Zero Emission Technology and Innovation Platform, European Commission

20. <http://www.northerngasnetworks.co.uk/wp-content/uploads/2016/07/H21-Report-Interactive-PDF-July-2016.pdf>

21. Conversion of Industrial Heating Equipment to Hydrogen, Final Report, BEIS and Hy4Heat, November 2019

22. Hy4Heat WP6, Conversion of Industrial Heating Equipment to Hydrogen, BEIS, November 2019, <https://static1.squarespace.com/static/5b8eae45cfd799896c80314/r/se287d78dc5c61ct1609e3d/157971903964/WP6+Industrial+Heating+Equipment.pdf>

23. Biomethane – A Producers Handbook, <https://biomethane.northerngasnetworks.co.uk/wp-content/uploads/2015/11/NGN-Biomethane-Full-document-low-res.pdf>

24. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597387/Biomass_leadstock_availability_final_report_for_publication.pdf

25. Conversion of Industrial Heating Equipment to Hydrogen, Final Report, BEIS and Hy4Heat, November 2019

26. <https://www.ge.com/power/gas/fuel-capability/hydrogen-fueled-gas-turbines>, https://www.solarturbines.com/en_US/solutions/fuel-flexibility/hydrogen.html, <https://new.siemens.com/global/en/company/stories/energy/hydrogen-capable-gas-turbine.html>, <https://www.turbomachinerymag.com/the-hydrogen-turbine/>, <https://gasturbineworld.com/working-toward-100-percent-hydrogen/>

27. Hydrogen as a Fuel for Gas Turbines, Andy Brown AFIChemE and Mike Welch, The Chemical Engineer, 2 March 2020.

28. <https://climatenewsnetwork.net/hydrogen-can-replace-natural-gas-by-2050/>, <https://www.northerngasnetworks.co.uk/2017/04/27/northern-gas-networks-hydrogen-project-takes-step-forward-as-25-million-fund-announced-for-hydrogen-in-homes/>

29. <https://www.sgn.co.uk/about-us/future-of-gas/hydrogen/hydrogen-100>, <https://www.iea.org/reports/tracking-energy-integration/hydrogen>

4.4.2 Decarbonising heat using electricity

For most users of heat electricity is an option for providing the source in the future, however this will only be a benefit if the electricity source is decarbonised. This decarbonisation will be achieved through grid decarbonisation, B2B green tariff electricity and through renewables. Each of these are discussed below.

Use of electricity for process heat will decarbonise the heat at least 99.98% by 2035, based on grid electricity alone. The rate of decarbonisation may be accelerated through green tariff electricity purchases and from renewables.

Electricity technology for process heat

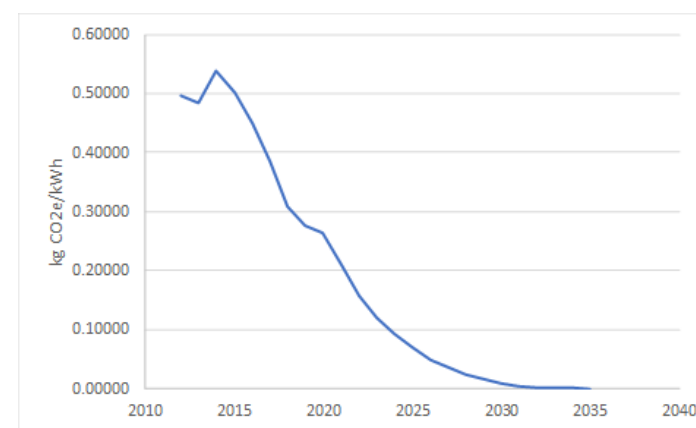
Heat can be supplied using electricity through several technologies, each of which may have a different time line and technical implications:

- Indirect heat generation from electricity is currently available through the use of resistance (immersion) and induction heating. These technologies can be used to heat water/oil, air or to generate steam. Indirect heat generation using electricity is proven technology. This will involve replacing existing boilers and heaters with electric heaters.
- Direct heating can be provided again through resistance and induction heating. These technologies are readily available, and it may be possible to retrofit on existing plant.
- On certain application other more efficient direct heating electrical technologies can be used such as infra-red, microwave and RF. Due to the technology and safety, these can only be applied on purpose-built equipment. As the heating process is different this may impact product quality and characteristics and would therefore necessitate extensive product development. Both microwave and RF heat from the inside of the product, whereas conventional convective heating will rely on conduction of heat through the product.
- Where there is a small temperature difference between the exhaust/reject heat and the supply, heat pumps driven by electricity can be employed. Typically, a heat pump can upgrade the temperature by 30-40 °C. Two stage heat pumps may be used to achieve a higher temperature increase. Heat pumps have a limited temperature range and must be designed and specified for a specific opportunity and application. They are therefore suitable for single product lines or where the temperatures are kept within a narrow band. Heat pumps will be less effective for heat recovery on multi-product lines where the process temperatures vary from product to product. A heat pump will yield 50-70% savings compared to conventional heating, simply due to the coefficient of performance (<http://industrialheatpumps.nl/en/applications/>). Project examples have shown that for high utilisation processes where low temperature rise is required a payback of around two years may be possible. A hybrid heat pump uses the principles of operation of both a mechanical and an absorption heat pump. Temperatures as high as 130 °C can be reached with relatively low system pressure. Therefore, standard components can be used. A hybrid heat pump would typically be used for hot water and space heating³⁰.

Grid electricity

Grid electricity is gradually being decarbonised through the increasing application of renewable sources. The grid electricity carbon intensity is reducing year on year, therefore simply changing to grid electricity for process heating will decarbonise any heat source to a great extent. The achieved and forecast grid decarbonisation is shown in Figure 6³¹. This shows that the forecast by 2035 is that the grid will be 99.98% decarbonised compared with a 2012 baseline. Other projections of grid decarbonisation give differing trajectories. The target is then to fully decarbonise grid electricity by 2050. This may not be achieved but will be very close – grid supply from distributed generation and CHP may not be fully decarbonised, although any existing CHP may not be operational by 2050. In some instances, emergency generators are currently used for frequency response to supply grid peak loads and this supply is unlikely to be decarbonised.

Figure 6 – Grid electricity emission factor forecast



Green Tariff Electricity

It is available now to specify green electricity, whereby renewable generated electricity can be allocated to a user. This will guarantee decarbonisation but at elevated costs.

Typical existing contractual agreements with electricity suppliers would be for 2-5 years. It may be necessary to wait until contract re-negotiation in order to change to a green tariff, but this means that by 2025 it would be possible for any site to change its tariff.

Care is needed when selecting a green tariff, as not all are genuinely green or can guarantee renewable sources. All electricity customers already contribute to the costs of increasing generation of electricity from renewables and reducing carbon emissions – to the tune of 8-10% of domestic gas and electricity bills. Some green tariffs are simply a re-packaging of these existing customer subsidies, although many do provide additional environmental

benefits. Under the guidelines the tariffs must provide benefits to the environment above and beyond what the current subsidies are delivering to be accredited under the independent accreditation scheme and thus marketed as 'green'. This could, for example, involve a supplier investing on behalf of customers in demand management, renewable heat, or properly accredited carbon offsets³².

Embedded electricity generation from renewable sources

Individual sites or cluster can invest in wind, solar PV or biomass CHP. Individual site investment in embedded renewables to generate green electricity on site is increasing, however in general it is expected that this would be a slow process and would only contribute a small percentage of site electricity on average.

Solar PV is in general unlikely to contribute more than 5%, in that it would be installed on building roofs and thus have limited surface area. In a few cases sites may have more space available and own more land. An Energy Services Company installation of photovoltaics accompanied with a power purchase agreement would ensure a higher proportion of green electricity could be supplied at a lower cost than a green tariff with the existing electricity supplier, however it would not ensure any higher decarbonisation.

4.4.3 Carbon Capture Storage and Use (CCSU)

For carbon capture to be viable, there needs to be a significant emissions source that has a financial value (for example through a trading scheme like EU ETS) to drive investment in CCSU, and there needs to have a viable storage facility or use available.

CCSU was not considered a viable option for the food and drink sector during the 2015 road maps because the emissions are not significant enough to warrant investment in a CCSU plant on site. The roadmap for the food and drink sector did not model any reductions in emissions due to CCSU.

It is likely that any CCSU plants in operation in the UK by 2050 will be located around a cluster of significant emitters including power stations and steel or cement plants. The location of these plants is currently unclear as is the viability of a food and drink manufacturing site connecting to it by 2050.

There have been no major developments in CCSU since 2015 that would justify changing the view that CCSU is unlikely to be applicable to the food and drink sector by 2050.

4.5 Reduction of heat load

Whereas this paper is primarily concerned with decarbonisation of heat, it is important to mention that existing and new processes to reduce the heat demand should continue and be a priority in the short term. Replacement of existing plant or changes in fuel sources are unlikely to have a large impact before 2030 and many heat load reduction opportunities have much shorter pay backs, in that they will provide a return on capital and provide additional financial and carbon benefit prior to any major changes.

4.5.1 Energy efficiency

Energy efficiency measures should still be a priority in the short term. Experience has shown these can typically yield a 3 – 10% reduction in heat load in the short term, with simple payback of less than 3 years. Typically, this may include:

- Insulation
- Combustion control
- Heat exchange improvement
- Refrigeration heat recovery
- Heat recovery and storage

4.5.2 Heat integration

Heat integration has not been optimised on most food and drink sites. Heat integration is supported by pinch analysis. Pinch analysis is a thermodynamic analysis method that can be applied to both batch and continuous processes and is designed to develop a practical optimum for heat exchange, heat recovery and heat storage. This method is applied in order to minimise the external heat load to be provided by combustion or other heat input.

4.6 Alternative Process Technology to Minimise Heat Requirement

A number of alternative process technologies and procedures have been developed both in the food and drink sector and in other industrial sectors such as chemical, pharmaceutical and oil and gas. Depending on market forces further new technologies may also be developed. These may either minimise or eliminate the need for heat.

Process and technology development may be needed to be able to apply the technologies to the food and drink sector and to ensure they comply with food safety and hygiene regulations. Cross sector symbiosis is also important for uncovering these process alternatives: what may be a well-known and established process or procedure in one industrial sector may not have been considered or have any penetration in food and drink.

Examples of potential alternative processes can be found on the following page, though this is not an exhaustive list.

30. Hybrid Heat Pumps, final report, BEIS, December 2017 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700572/Hybrid_heat_pumps_Final_report.pdf

31. Updated Energy and Emissions Projections 2018, BEIS, April 2019 <https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2018>

32. Ofgem clears up green tariff confusion, 16th July 2008 https://www.ofgem.gov.uk/sites/default/files/docs/2008/07/ofgem26-16072008_1.pdf

Table 4 4 Examples of alternative process technology

User	Current status	Available technology
Clean in Place (CIP) and cleaning	Generally supplied with steam heating either as direct steam or hot water.	<p>Chemical cleaning without the application of heat:</p> <ul style="list-style-type: none"> Flushing in order to eliminate residues Alkaline cleaning operation: alkaline detergents dissolve fat and proteins, and cleaning where harder deposits have occurred Intermediate water rinse Acidic cleaning operation: for neutralising the caustic remaining on the surfaces of the plant. The acidic detergents remove mineral deposits in the equipment Final water rinse: Cold water purges out the residual acid solution <p>Ultrasonic CIP</p> <ul style="list-style-type: none"> High-intensity ultrasonic to minimise fouling. Used on small scale
Pasteurisation/sterilisation	Often apply heat to hold product stream above target temperature for minimum period	<p>UV pasteuriser</p> <ul style="list-style-type: none"> These are commercially available, widely used on water and beverages. Can be used in combination with reduced heat load. Microwave sterilisation These are commercially available. Would require replacement of existing plant. <p>Ultrasonics and sono-chemistry</p> <ul style="list-style-type: none"> High-intensity ultrasonic pasteurization of foods and drink is an emerging technique that permits achieving the required levels of microbial inactivation at much lower temperatures (about 40 °C), which does not deteriorate the quality of the products. <p>Ionising radiation</p> <ul style="list-style-type: none"> Food processing by radiation (cold pasteurization) is a physical, nonthermal mode of food preservation. Irradiation causes minimal modification in the flavour, colour, nutrients, taste, and other quality attributes of food Safety considerations important <p>High pressure processing</p> <ul style="list-style-type: none"> High Pressure Processing is a cold pasteurization technique by which products, already sealed in its final package, are introduced into a vessel and subjected to a high pressure <p>Pulsed light sterilisation</p> <ul style="list-style-type: none"> Typically used for sterilisation of packaging (bottles, tins etc Widely in use, proven technology
Separation and concentration	Thermal evaporation using steam is most common	<p>Absorption/desorption processes</p> <ul style="list-style-type: none"> Commonly used in chemical and pharmaceutical processes for purification and concentration Uses physical absorbents, chemical and immobilised enzymes and bacteria <p>Membrane processes</p> <ul style="list-style-type: none"> Reverse osmosis for concentration is common and widely used Pervaporation is a membrane assisted selective evaporation process that can remove water, solvents or other selected components. Claimed to save 50% energy compared with thermal process. Has been used for alcohol removal from beer.

User	Current status	Available technology
Separation and concentration	Thermal evaporation using steam is most common	<p>Membrane processes (continued)</p> <ul style="list-style-type: none"> Diafiltration is a selective ultrafiltration, currently used in biotech and medical applications. Pulsed electric field Has been applied to fruit juice extraction and to cell disruption to speed up drying, and to reduce frying times of vegetables and potatoes
Heating	Thermal processes most often use steam or gas direct or indirect heating	<p>Microwave</p> <ul style="list-style-type: none"> Available for heating of water in products Commercially available from numerous suppliers. <p>Ohmic heating</p> <ul style="list-style-type: none"> Ohmic heating generates heat by passage of electrical current through food which resists the flow of electricity. Heat is generated rapidly and uniformly in the liquid matrix as well as in particulates, producing a higher quality sterile product that is suitable for aseptic processing. Application for fruit/vegetable slurry/mixture Limited suppliers but commercially available <p>Radio frequency (RF)</p> <ul style="list-style-type: none"> Low energy heating technology for food products thanks to its rapidity that is associated to the large penetration depth and the uniform heating behaviour. It has been successfully applied for many food needs like baking, drying and thawing and even for pasteurization and sterilization. Has been applied to baking, thawing, pasteurisation, sterilisation. Has included white bread baking ovens

4.7 Maximum technical potential by 2050

The potential decarbonisation options have been mapped against the major energy users as shown in Figure 4 (boilers, direct fired ovens, other direct fired equipment, CHP and other). This allows us to estimate the decarbonisation potential of the FDF sub-sector. Table 4 45 shows the implementation of the different decarbonisation themes applicable to each major energy user by 2050.

The maximum technical potential scenario assumes that when any equipment at the end of its life it is replaced with a lower carbon alternative as described in Table 4 5, i.e. the uptake of the decarbonisation measures is 100%. This scenario does not consider the barriers that may exist; i.e. availability of renewable fuels, cost to convert, etc. Such barriers are discussed in Section 5 of this paper and a 'realistic' scenario has been developed.

Table 4 5 Implementation of decarbonisation themes

	2020	2025	2030	2035	2040	2045	2050
Boilers	Low carbon fuels, Renewables, Electrification (boilers or indirect heat users)			Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification (boilers or indirect heat users)			
Direct Fired Ovens	Electrification		Renewables, Electrification	Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification			
Other Direct Fired	Electrification		Renewables, Electrification	Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification			
CHP	Renewables, Electrification (indirect heat users)			Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification			
Other	Electrification		Renewables, Electrification	Low carbon fuels, Fully decarbonised gas, Hydrogen, Renewables, Electrification			

To understand the maximum technical potential, it is important to understand when equipment is likely to be replaced and hence what is the lifecycle of the major energy using equipment identified.

Table 4.6 Lifetime of major energy users

Energy User	Expected Lifecycle (Years)
Boilers	30
Direct Fired Ovens	30
Other Direct Fired	20
CHP	20
Other	20

Based on these lifecycles, it is expected that all major energy users will require replacing before 2050. It is likely that equipment will not be replaced when due and instead the lifetime will be extended, this is discussed in Section 5.

Using the baseline and BAU forecast from Section 3, with the decarbonisation options and replacement lifecycles described above, Figure 7 shows the maximum decarbonisation potential of the sector.

Figure 7 - Maxtech decarbonisation potential of the FDF sub-sector

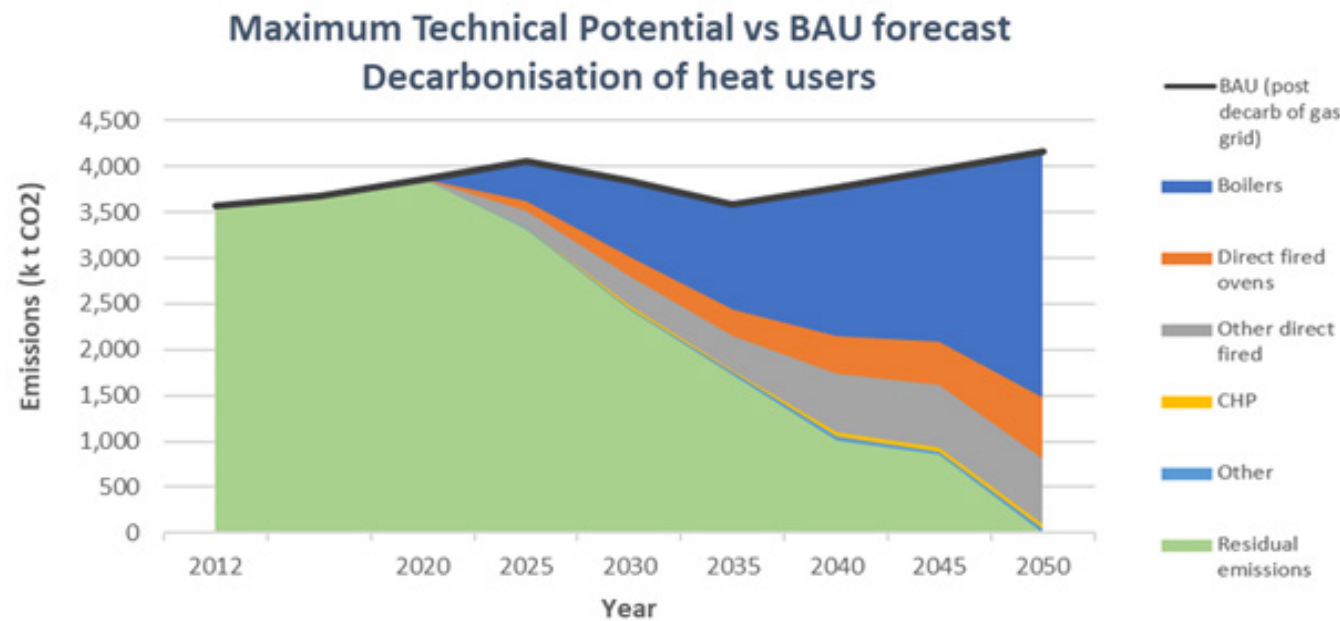


Figure 7 shows that it could be technically possible for the FDF sub-sector to reach zero emissions by 2050. We have not separated which decarbonisation options would be adopted for each energy user as at this stage it is simply unclear what options would suit different sites, we have simply modelled that a decarbonisation measure would be implemented and hence the action would reduce emissions.

The cost of achieving such decarbonisation is also unclear. The capital cost to fully decarbonise heat, assuming that the national infrastructure is available to provide both decarbonised electricity and decarbonised gas/hydrogen would be excessive and without financial support or cross border caption adjustments would likely make the sector uncompetitive versus products imported from countries not yet making such changes. The relative cost of electrically heated equipment is higher than for the equivalent gas fired, but it should not change. The cost of gas fired plant is likely to increase in the short term as it adapts to alternative fuels, but from 2030 to 2050 the costs of gas fired plant should be equivalent to now. Therefore, if heat sources are replaced at end of life the relative cost of investments will increase as more electrification of heat is implemented. The ongoing maintenance of existing plant will be much cheaper than investing in new plant, up to the point when the existing plant would need significant changes/modifications to cope with changing fuel composition.

5.0 BARRIERS TO IMPLEMENTATION

Heat generation with hydrogen rich gas tends to create much higher NOx levels than for conventional gas, therefore in order to comply with the Medium Combustion Plant Directive it may then be necessary to include NOx abatement, which would increase new plant costs. This impact is unknown at the moment as there are very few hydrogen burning plants on which to verify this impact.

The ongoing expansion of renewable wind development, proposed carbon capture and storage on existing gas-based power generation and proposed gas to wire (electricity generation from natural gas at source combined with carbon capture and storage will make electricity availability secure and decarbonised. However, the price will be higher. The UK is well placed with capacity for CCUS and renewable energy, so although prices will be higher, we should be competitive with neighbouring countries.

Estimates for the cost of decarbonised gas/hydrogen by 2050 are to be the same order of magnitude as current natural gas costs, but in the interim could easily double or triple in costs. While technology to produce hydrogen is still expensive in Western markets, there are encouraging signs. The cost of alkaline electrolyzers made in North America and Europe fell 40% between 2014 and 2019, and Chinese made systems are already up to 80% cheaper than those made in the west. If electrolyzer manufacturing can scale up, and costs continue to fall, then calculations suggest renewable green hydrogen could be produced at price competitive with natural gas prices in Brazil, China, India, Germany and Scandinavia on an energy-equivalent basis³³.

The biggest cost however for the hydrogen economy would be storage and distribution. It has been suggested that depleted gas fields could be used to store bulk hydrogen as well as smaller salt and rock caverns, however this has yet to be tested and the economics are not known.

5.0 BARRIERS TO IMPLEMENTATION AND 'REALISTIC' POTENTIAL

In this section we consider the barriers that will exist between now and 2050 and which will impede implementation of the different decarbonisation options and use this to identify what the 'realistic' potential of the sector is.

In March 2020, FDF and SLR undertook a survey of companies in the FDF CCA to understand the barriers that companies believed impeded their adoption of low carbon solutions. The results from this survey have been used to identify barriers. In the same survey we also sought to understand how prepared companies are for the significant transition ahead, Figure 8 presents the findings.

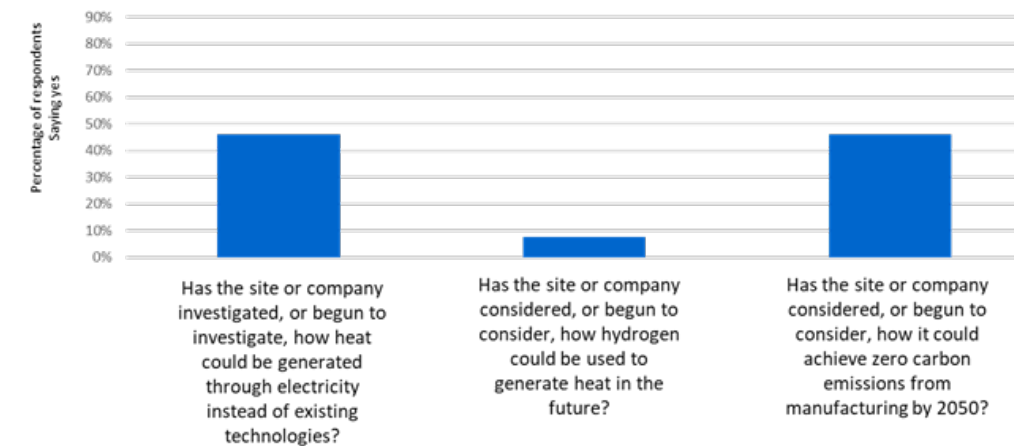
Figure 8 reveals that over half the companies surveyed have not considered how heat could be generated through electric solutions, or begun to think about how they could achieve net zero carbon emissions by 2050. Less than 10% of companies surveyed have begun to consider how hydrogen may be used in the future to generate heat. These results help us to understand what barriers are likely to exist across the sector.

5.1 Barriers

We have undertaken a 'PESTLE' analysis (political, economic, social, technological, legal, environmental) to identify the barriers that are likely to exist which will prevent the maximum technical potential from being achieved. We have identified the different barriers against the decarbonisation themes identified in Table 4.4.

The tables on the following pages describe the barriers of the different decarbonisation themes.

Figure 8 - 2020 FDF/SLR survey of companies in the FDF CCA



33. Hydrogen Economy Outlook, key messages, BloombergNEF, March 30 2020

Table 5-1 Barriers to the implementation of renewables

Barriers originating from	Barriers to update of renewables
Political	Stability and longevity of renewable incentive schemes have been vulnerable to political change and undermine confidence in making investments.
Economic	Renewable fuels could be significantly more expensive than traditional energy sources if the demand increases. The cost of upgrading or replacing existing equipment or network connections could be much higher than maintaining existing old equipment or like for like replacements. Economic incentives may be needed to support the changeover. Reliability of receiving biomass feedstock volumes and being exposed to higher energy costs if supplies fail.
Social	Uncertainty over the availability of sufficient biomass supplies. Competing users of biomass and the social acceptability of potentially diverting biomass from agricultural uses (e.g. for animal feed). Acceptance of communities to more wind turbines or PV arrays. Knowledge of on-site engineering staff to manage a diverse range of energy generation equipment.
Technological	Matching the heat demands of the process to the heat profiles of the different renewable technologies that are appropriate for the site. Lack of technology demonstration, such as larger scale gasification/pyrolysis of waste at site level.
Legal	Constraints in locating or installing equipment due to planning regulations.

Table 5-2 Barriers to the implementation of decarbonised gas or hydrogen

Barriers originating from	Barriers to update of renewables
Political	Development of a decarbonised gas network (either running on 100% hydrogen, or 70/30 blend of hydrogen and biogas) requires significant national investment and political backing. Timing on the availability of such a network and the passed through costs is unclear making planning for significant change difficult. Undeveloped regulatory framework for large scale decarbonised gas/ hydrogen storage, distribution and use.
Economic	It is currently unclear what the price differential would be between decarbonised gas or 100% hydrogen versus the future main alternatives of electricity or renewables. The cost of upgrading or replacing existing equipment could be much higher than maintaining existing old equipment or like for like replacements hence adoption rates may be slower.

Barriers originating from	Barriers to update of renewables
Social	Uncertainty regarding the safety of hydrogen use at a food and drink manufacturing site. Knowledge of on-site engineering staff to procure and manage different equipment and use a different energy source.
Technological	Changes in energy source could affect product quality in some previously direct fired applications. Production speeds could be impeded due to technologies changes. Combustion of hydrogen can create higher NOx than with natural gas.
Legal	Compliance with the Medium Combustion Plant Directive by 2030 may bring forward some replacements and as decarbonised gas/hydrogen might not be widely available by then hence replacements could continue use natural gas and the switch to decarbonised would not be implemented for another investment cycle. Combustion of hydrogen can create higher NOx than with natural gas NOx abatement on new plant to meet MCPD requirements would make it more expensive.
Environmental	Only becomes a low carbon solution if the hydrogen production method involves electricity from renewable sources or a production process that has a CCSU plant. NOx generation and abatement from hydrogen combustion plant could impose new environmental constraints.

Table 5-3 Barriers to the implementation of electrification options

Barriers originating from	Barriers to update of renewables
Political	Only becomes a low carbon solution if the electricity grid continues to decarbonise and that is supported by Government.
Economic	Delay in adopting electrification options due to price differential between gas and electricity. Cost of switching to electric options increased because upgrades to grid connections are required and adoption is slowed. The cost of upgrading or replacing existing equipment could be much higher than maintaining existing old equipment or like for like replacements hence adoption rates may be slower.
Social	Knowledge of on-site engineering staff to procure and manage different equipment.
Technological	Changes in energy source could affect product quality in some previously direct fired applications. Production speeds could be impeded due to technologies changes.
Legal	
Environmental	The sustainability of the sources behind the low carbon electricity generation must be assured to avoid other negative impacts. Constraints in the physical footprints of a site to be able to accommodate different technological solutions.

5.2 Realistic potential by 2050

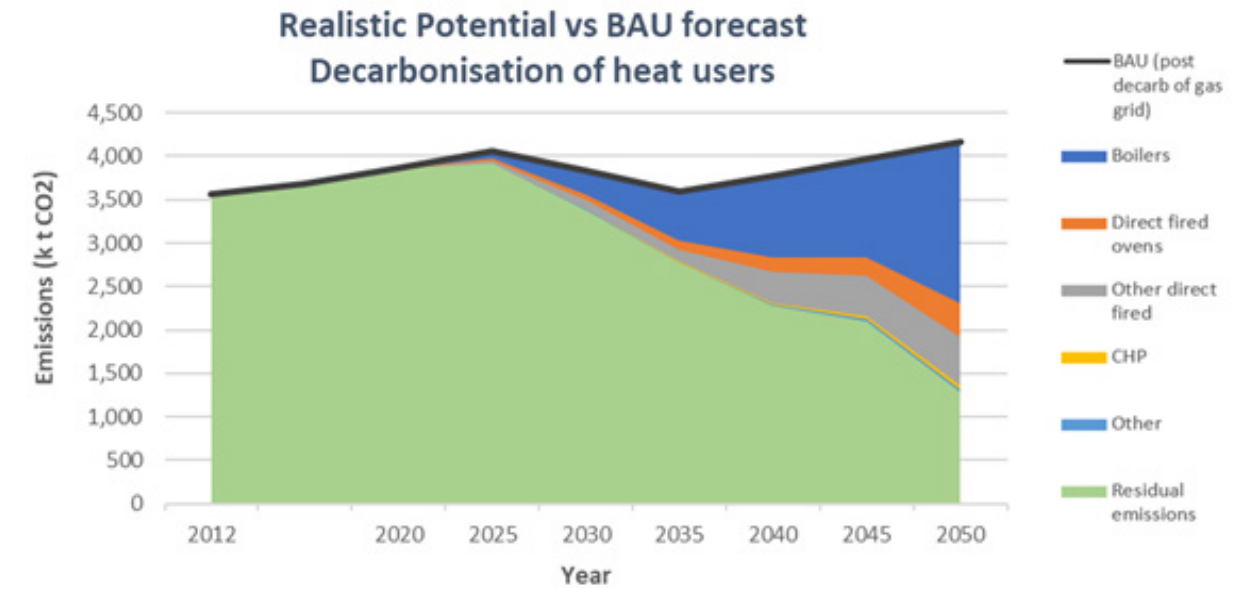
Using the barriers described in section 5.1, we have estimated what percentage of equipment being replaced before 2050 will be replaced with a decarbonised alternative. Table 5-4 states our estimate of the likely uptake of decarbonised solutions reflecting the barriers identified and why these are unlikely to be 100%. The estimates are based on our experience of the decision-making processes faced by companies when confidence in the emerging alternatives are low.

Table 5-4 Estimated percentage of replacements switching to decarbonised alternatives

Timeframe	Boilers	Direct Fired Ovens	Other Direct Fired	CHP	Other	Reasoning
2020-2025	20%	20%	20%	10%	20%	<ul style="list-style-type: none"> Cost of alternatives not yet competitive enough and like for like replacements made.
2025-2030	50%	40%	40%	20%	40%	<ul style="list-style-type: none"> Lack of knowledge or confidence in electrification of some processes. Availability of renewable sources. Uncertainty about future energy sources.
2030-2035	75%	50%	70%	70%	70%	<ul style="list-style-type: none"> Cost of alternatives not yet competitive enough and replacement cycles are delayed. Supply of decarbonised gas or hydrogen not yet established.
2035-2040	85%	60%	80%	80%	80%	<ul style="list-style-type: none"> Availability of renewable sources. Lack of knowledge or confidence in new technologies. Product quality compromised with alternatives.
2040-2045	90%	75%	85%	85%	85%	<ul style="list-style-type: none"> Cost of alternatives not yet competitive enough and replacement cycles are delayed.
2045-2050	93%	90%	90%	90%	90%	<ul style="list-style-type: none"> Supply of decarbonised gas or hydrogen not yet established in less populated areas. Product quality compromised with alternatives.

Using the percentage adoption of decarbonised solutions identified in Table 5-4, in Figure 9 we have modelled the 'realistic' decarbonisation potential for heat used by the 'FDF sub-sector' by 2050.

Figure 9 - Realistic decarbonisation potential of heat used by the 'FDF sub-sector'



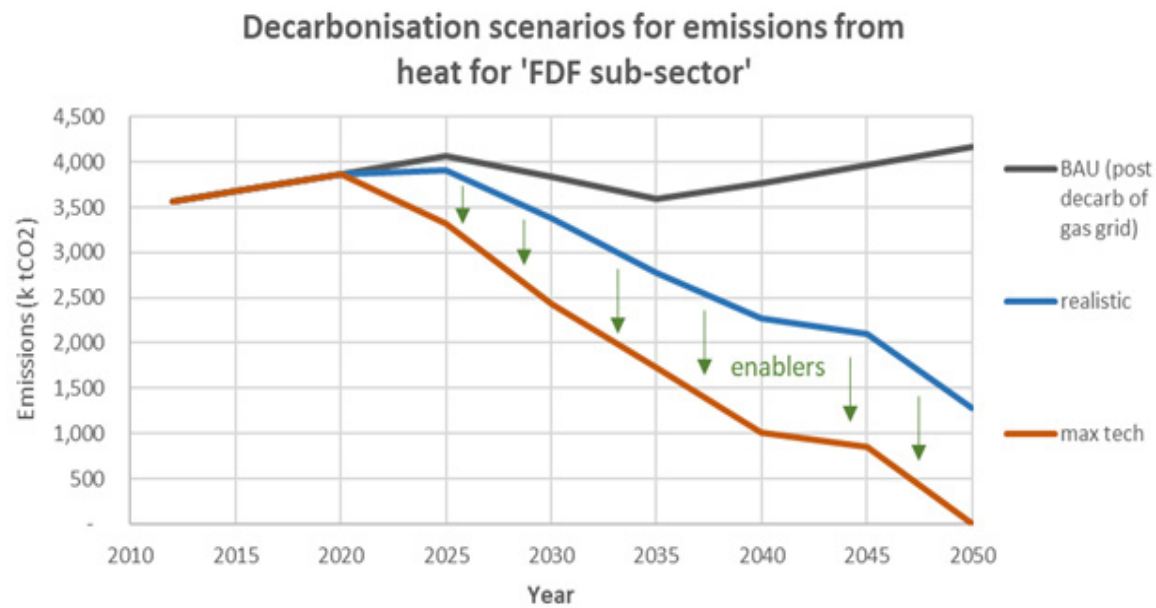
The 'residual emissions' shown in Figure 9 indicate that the 'FDF sub-sector' will not be able to reach zero emissions from heat use by 2050, instead reaching approximately a 64% reduction versus 2012 actual emissions, and 69% versus 2050 project BAU emissions.

The greatest contribution to the decarbonisation of heat is likely to come from changes to boilers; either switching to low carbon fuels or electrifying the processes that the boilers provide heat to. Decarbonisation savings increase markedly after 2035 when decarbonised gas and/or hydrogen should become available and the electricity grid has fully decarbonised.

6.0 ENABLERS TO INCREASE IMPLEMENTATION

Figure 10 presents a summary of the different scenarios modelled for the emissions from heat from the 'FDF sub-sector' so we can compare the 2050 emissions for each.

Figure 10 - Summary of decarbonisation scenarios



In this section, we look at what actions could enable the 'realistic' emissions reduction scenario to move towards the 'maxtech' scenario.

Table 6-1 presents a summary of the common barriers identified in section 5 and suggests potential enablers to overcome these barriers.

Table 6-1 Common barriers and potential enablers

Barriers originating from	Ref.	Common barriers identified	Suggested enablers
Political	1	Stability and predictability of the policy framework.	The Government needs to make clear commitment to long term policies and support programmes to give businesses the confidence they need to support investment decisions.
	2	Clarity as soon as possible on potential hydrogen/ decarbonised gas networks expected and timing.	The Government needs to provide advice to industry as soon as possible on what a future hydrogen/decarbonised gas might look like.

Barriers originating from	Ref.	Common barriers identified	Suggested enablers
Political	1	Stability and predictability of the policy framework.	The Government needs to make clear commitment to long term policies and support programmes to give businesses the confidence they need to support investment decisions.
	2	Clarity as soon as possible on potential hydrogen/ decarbonised gas networks expected and timing.	The Government needs to provide advice to industry as soon as possible on what a future hydrogen/decarbonised gas might look like.
Economic	3	Uncertainty regarding market for biomass.	A clear strategy from government is needed about how to prioritise the use of biomass.
	4	Uncertainty regarding financial support for renewables schemes.	As 1, the Government needs to make clear commitment to long term policies and support programmes to give businesses the confidence they need to support investment decisions.
	5	The cost of upgrading or replacing existing equipment could be much higher than maintaining existing old equipment or like for like replacements.	Support will be needed between now and 2050 from the Government to financially support the transition so higher cost, higher payback decarbonisation options can be implemented without damaging competitiveness.
	6	Price differential between gas and electricity high and deterring electrification of processes.	Government tax and levy policies need to address the different between gas and electricity prices to stimulate the transition away from natural gas.
	7	Cost to upgrade grid connections impeding electrification of processes.	As 5, support will be needed between now and 2050 from the Government to financially support the transition so higher cost, higher payback decarbonisation options can be implemented without damaging competitiveness.
Social	8	Uncertainty over the availability and best use of biomass supplies.	As 3, a clear strategy from government is needed about how to prioritise the use of biomass.
	9	Challenges to site developments from communities	Industry sectors and Government need to educate communities around the large developments needed to move to a decarbonised economy.
	10	Knowledge of on-site engineering staff to manage a diverse range of energy generation equipment.	The food and drink sector needs to upskill its staff to be aware of the future large scale decarbonisation options and understand the technologies involved.
	11	Uncertainty regarding the safety of hydrogen use at a food and drink manufacturing site.	Industry sectors and Government need to educate businesses around the safe use of decarbonised gas or hydrogen.

Barriers originating from	Ref.	Common barriers identified	Suggested enablers
Technological	12	Matching the heat demands of the process to the heat profiles of the different renewable technologies that are appropriate for the site.	The food and drink sector needs to upskill its staff to be aware of the range of decarbonisation options and how they could be used to meet differing heat demands across their sites.
	13	Changes in energy source or technology could affect product quality or production speeds.	The food and drink sector and Government need to run demonstration projects to prove concept and build confidence in using new technologies or solutions.
	14	Impact of fuel composition changes on equipment and combustion, in particular NOx emissions.	The government needs to encourage research and development on hydrogen combustion and in particular NOx minimisation.
Legal	15	Constraints in locating or installing equipment due to planning regulations.	Industry sectors and local Government need to work together to identify planning challenges and potential solutions.
	16	Compliance with MCPD may affect decarbonisation potential by 2050.	The food and drink sector needs to better understand the impacts from MCPD and how it may impact replacement cycles and uptake of decarbonisation measures.
Environmental	17	The sustainability of biomass feedstocks needs to be assured.	The food and drink sector needs to understand sources of biomass and how to ensure they are sustainable.
	18	Constraints in the physical footprints of a site to be able to accommodate renewable installations.	As 15, industry sectors and local Government need to work together to identify planning challenges and potential solutions.

7.0 CONCLUSIONS

7.1 Conclusions

a) It should be technically possible to fully decarbonise the emissions from heat from the 'FDF sub-sector' by 2050 if the electricity grid fully decarbonises and there is sufficient access to decarbonised gas, mainly via hydrogen. The maximum technical potential of the 'FDF sub-sector' to decarbonise is 100% versus 2012 emissions.

b) In reality, there are a number of barriers that exist and they will impede the maximum technical potential from being achieved. The barriers arise from limited knowledge in the sector around some of the decarbonisation options, the financial burden of switching to low carbon energy sources or technologies, and the lack of confidence in switching to new technologies without compromising product quality or production efficiencies. It is likely the 'FDF sub-sector' will reduce emissions from heat by approximately 64% versus 2012 actual emissions, and 69% versus 2050 business as usual emissions without additional interventions.

c) The greatest contribution to the decarbonisation of heat is likely to come from changes to boilers; either switching to low carbon fuels or electrifying the processes that the boilers provide heat to. Decarbonisation savings should increase markedly after 2035 once decarbonised gas and/or hydrogen should become available and the electricity grid has fully decarbonised. We support the work of the Industrial Clusters Mission³⁴ to look at the role of hydrogen and how the regulatory framework could develop to take account of commercial and operational issues.

d) Actions need to be undertaken by different stakeholders (i.e. food and drink sector, appliance manufacturers, energy providers) to enable the transition from a realistic prediction of a 64% reduction versus 2012 emissions towards the maximum technical potential of a 100% reduction. The scale of change required means that co-ordinated step changes are required and not just independent nudges. We hope the forthcoming Energy White Paper will provide that strategy.

CONCLUSIONS AND RECOMMENDATIONS

e) The UK food and drink industry is the largest manufacturing sector in the country and accounts for 19% of the total manufacturing sector by turnover, employing over 430,000 across 7,400 businesses in the UK. The food and drink sector needs to work closely with Government to implement these actions to achieve zero carbon emissions from heat by 2050. Dedicated policy support as received by other sectors to assist with decarbonisation is required, particularly in light of international competition and Brexit.

f) The stability and longevity of support mechanisms are key to investor confidence and promoting more investment:

i. In the March 11th Budget, the introduction of a green gas levy to support biomethane production to increase the proportion of green gas in the grid was very welcome. However, this is insufficient to cover the gap that is left once the non-domestic RHI scheme finishes in March 2021.

ii. The soon-to-be-launched Industrial Energy Transformation Fund, will be welcome in providing some funding. But given the expanse of sectors covered, limited funds, requirements for match funding particularly post COVID-19, this does not cover the gap once the non-domestic RHI closes in March 2021. It is also unclear whether this really will lead to the demonstration projects that companies need to assess impact on product quality and other key parameters of new technologies.

g) As the economy starts to recover post-COVID, this provides an opportunity to establish a solid foundation for green growth. This may also include the scope for upskilling the workforce, a key requirement for the transition to net zero.

8.0 RECOMMENDATIONS

The recommendations below reflect the actions that can be initiated now to address the suggested enablers identified in section 6. They do not reflect all the potential enablers as some will not be able to be addressed for some years (e.g. likely future costs of hydrogen or investment in the gas and electricity networks).

a) Collaboration

i. A food-and-drink industry taskforce is required to facilitate knowledge share across the sector on technology innovations and implementation, policy development with Government and to spearhead the transition to net zero for the sector. This will help companies including industrial appliance manufacturers to understand the potential role that hydrogen and electrification will play and how prepare for their implementation.

ii. A biofuels taskforce should be established to bring together industry, electricity generators, BEIS, DEFRA, HMT and DCLG to ensure objective alignment around the use of biomass. This would help further growth and

deployment through supporting sustainability, avoiding competing uses whilst maximising efficiency, engender greater local engagement and a more streamlined planning process.

b) Policy Development

i. Government needs to understand actual investment cycles in industry to help guide policy making and support measures. If policies and investment cycles are miss-matched, the ability to meet the 2050 net zero target will be increasingly difficult and costs will rise, as investments will be locked in. Investment policy will be key over the next decade.

ii. In the forthcoming Energy White Paper, Government should provide the clear direction needed on the long-term future of carbon pricing and mechanisms to ensure domestic industry competitiveness and encourage the move from high to low carbon energy solutions.

iii. Each Local Enterprise Partnership³⁵ needs to bring together key stakeholders to address local area planning challenges for example in electricity and gas networks investments, as well as to promote wider opportunities for example in developing district heating networks.

c) Finance

i. Government should establish a bottom-up approach to a new financial support scheme for industrial decarbonisation both in the near term to 2030, and beyond for funding of key demonstration projects on step-change technologies, particularly around options to electrify heat or for processes which avoid heat generation.

ii. The Government should extend the non-domestic RHI (currently due to finish in March 2021) to be in parity with the domestic RHI. As announced in the 11th March 2020 Budget, an equivalent scheme to the future Clean Heat Grant needs to be developed for industry.

iii. Climate Change Agreements are one of the more successful schemes for engaging industry. Post 2025, the Government should implement a third phase of CCAs, which builds on its success by moving to a focus on carbon reduction. The future scheme must incentivise the adoption of renewable technologies and 'deep decarbonisation' in addition to measures on energy efficiency. A third phase of CCAs must be at least ten years long to provide a stable and predictable policy environment.

34. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803086/industrial-clusters-mission-infographic-2019.pdf

35. www.lepnetwork.net

Appendix 1 Decarbonisation options – further information

Bar (Grill) marker

Bar markers currently on the market are either direct gas fired or electric. Whereas a direct fired unit may cook and bar mark in one piece of equipment, an electric bar marker will more often bar mark raw ingredients or ingredients cooked in a separate oven.

The decarbonisation options for a direct fired bar marker are:

- Utilise low or zero carbon fuel on the existing direct fired equipment. Alternatives would be to: use biogas from anaerobic digestion, gasification or pyrolysis; burn hydrogen/gas blends or eventually to be able to combust pure hydrogen. Whereas biogas and up to 20-30% hydrogen may be usable in existing equipment, any higher hydrogen content would need a change of burner or more likely completely new plant.
- The simpler alternative would be to change to electric bar marking on refit or end of life of existing equipment. Some technologies such as laser bar marking is being developed which would use far less electricity, but these have not yet reached commercialisation

Buildings

Space heating is provided often by a number of direct and indirect fired technologies. Direct fired space heating is supplied by radiant tube heaters and direct fired convection heaters.

These would typically be natural gas or LPG fired. Decarbonisation of the gas supply as mentioned above may be possible, but more than 20% hydrogen blends would not be feasible.

Electric space heating systems are available in the form of electric resistance heaters. Heat pumps are readily available now (ground source, air source, heat source). Ground source heat pumps are unlikely to be retrofitted, but air source or water source especially from waste heat streams are readily available.

Hot water for process and wash points is most commonly supplied by indirect heating or local electric water heaters, but local fired heaters are still common. Decarbonisation of the gas supply as mentioned above may be possible, but more than 20% hydrogen blends would not be feasible. Electric water heaters are daily available now. And heat pumps may also be used. Hot water generation energy consumption may be reduced using wastewater heat recovery systems. With a heat pump wastewater heat recovery system for specific applications it may be possible to avoid any other energy source other than the heat pump itself. Electric induction heating for direct hot is also readily available and can be used for on demand hot water.

Cookers

Most cookers are heated indirectly using steam or using electric resistance or induction heaters. For higher temperature cookers there may be hot oil heated or direct gas fired cookers. Electric cookers are readily available, or indirect heating could be used from a decarbonised heat source.

On installing electric cookers, a number of heating mechanisms could be considered: resistance, induction, microwave, radio frequency. Resistance and induction heating elements for cookers are readily available and could be applied to existing cookers as well as being used in new installations.

- Microwave and microwave assisted cooking is available from a very limited number of suppliers. Microwave cooking will not brown and may have limited applications. Maintenance and safety are also very important considerations. Further equipment development and innovation would be needed.
- Radio frequency (RF) cooking has been available for many years but has had limited market penetration. Its main use is for defrosting and tempering. It may also be used for low temperature cooking of meat products such as sausages (<http://www.rffoodsystems.com/en/applications-en>, <https://www.worldfoodinnovations.com/innovation/radio-frequency-cooking>) or for white crust bread baking and post bake drying (<https://www.stalam.com/eng/product/food/applications-for-industrial-bakeries/oven-for-white-crust-bread-wavebake>, <http://www.strayfield.co.uk/food.htm>). Further equipment development and innovation would be needed.

Grill

Both gas fired and electric grills are readily available. As with other technologies it would be possible to use decarbonised gas supply or a limited hydrogen blend.

Kettle

Many kettles have heat supplied from steam heating or direct water heating. Electrical water heaters are readily available with the heat supplied by immersion elements or induction heating. Electrically heated equipment is readily available.

Ovens

Direct fired continuous or batch ovens are the most common use of direct fired equipment. Decarbonisation of the gas supply is possible but would be limited by availability and capacity of supply.

Batch ovens with electric heating are already available and in many cases electric heating could be retrofitted on the existing oven. Continuous baking and cooking ovens with electric heating are available using infra-red, induction, resistance or convection heating. It may be possible to convert existing gas fired ovens.

Appendix 2 Glossary of terms

BAU	Business As Usual
BEIS	(Department for) Business Energy and Industrial Strategy
CCA	Climate Change Agreement
CCSU	Carbon Capture Storage and Use
CHP	Combined Heat and Power
CIP	Cleaning In Place
CO2	Carbon Dioxide
DCLG	Department for Communities and Local Government
DEFRA	Department for Environment, Food and Rural Affairs
EU ETS	EU Emissions Trading System
EWP	Energy White Paper
FDF	Food and Drink Federation
F-Gases	Fluorinated Gases
HMT	Her Majesty's Treasury
IETF	Industrial Energy Transformation Fund
IHRS	Industrial Heat Recovery Scheme
LPG	Liquified Petroleum Gas
NOx	Nitrogen Oxide
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
RF	Radio Frequency
RHI	Renewable Heat Incentive
UV	Ultra Violet

FOOD AND DRINK FEDERATION

The Food and Drink Federation (FDF) is the voice of the UK food and drink industry, the largest manufacturing sector in the country. The UK food and drink industry accounts for 20% of the total manufacturing sector by turnover and employs over 430,000 people in the UK across 7,400 businesses. We are an incredibly diverse sector, speaking on behalf of global brands and thriving small businesses.

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SLR CONSULTING

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