Department for Energy Security & Net Zero

Evaluation of the reformed Renewable Heat Incentive

Synthesis of findings from the evaluation of the non-domestic RHI

Findings report

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Executive Summary

Introduction

This report presents findings from the evaluation of the reformed non-domestic Renewable Heat Incentive (RHI). The evaluation was undertaken on behalf of the Department for Business, Energy and Industrial Strategy (BEIS) by CAG Consultants, in partnership with Winning Moves, Wavehill, Hatch, EREDA Consultants and UCL.

The non-domestic RHI scheme aimed to encourage the installation and use of renewable heat technologies (RHTs), and to support the development of a sustainable market for renewable heat that was less dependent on subsidy. The non-domestic scheme was open to applications from 28 November 2011 to 31 March 2021 and will continue to pay subsidies to accredited installations for 20 years from their accreditation date. The scheme supports the generation of heat from renewable energy sources, from commercial, public sector, voluntary and industrial installations, as well as domestic installations serving more than one property. It supports accredited installations in England, Scotland and Wales, providing payments for each unit of eligible heat produced over a 20-year period at a pre-specified tariff. Biomass boilers, biogas plants, combined heat and power (CHP) plants using biomass/biogas, biomethane plants, heat pumps, solar thermal and geothermal plants were all eligible for support under the scheme, subject to certain conditions.

Budgetary safeguards were built into the design of the scheme with the aim of ensuring that RHI payments provided value for money. An overall budget cap was set for the RHI, and mechanisms were put in place for RHI tariffs for new applications to be degressed (i.e. reduced) to reflect cost reductions for specific technologies, as indicated by increased take-up of those technologies.

A series of reforms were introduced to the non-domestic RHI scheme in stages between September 2017 and May 2018 to help the scheme better meet its objectives and to improve its cost-effectiveness. The effectiveness of these reforms is the primary focus of the current evaluation. The reforms included:

- the introduction of one level of support for biomass – replacing three tariff bands - to encourage investment in larger biomass plants which were expected to be more cost-effective than small and medium biomass installations
- the removal of most ‘drying’ uses from the list of heat uses eligible for the non-domestic RHI in order to improve the value for money and environmental sustainability of the scheme
- the requirement that waste-streams should comprise at least 50% of feedstocks for new biomethane and biogas plants, combined with a small uplift to biomethane and biogas tariffs, in order to reduce use of energy crops and divert biodegradable waste from landfill, thereby improving resource-efficiency and reducing methane emissions
- the introduction of ‘tariff guarantees’ to increase certainty for investors in larger and more complex installations which tend to have longer lead-times, thereby encouraging investment in larger plants that offer economies of scale

- the introduction of 'deeming' of heat demand for shared ground loop heat pump systems (see Glossary) to increase certainty of payments and remove the need to install separate meters for multiple properties served by shared ground loops

The evaluation focuses on the impact of these reforms. It has adopted a theory-based evaluation approach, seeking to develop, test and refine realist theories about the reformed non-domestic RHI throughout its lifetime.[1] This synthesis report draws on findings from multiple research activities, undertaken between 2017 and 2021. These include analysis of non-domestic RHI administrative data, applicant monitoring surveys, qualitive research with applicants and the renewable heat supply chain, and a range of other analytical exercises designed to understand market development and value for money (including a Sustainable Markets Assessment, Subsidy Cost-Effectiveness Assessment and Competition & Trade Assessment). Details of the methodology are set out in the main report and then in greater depth in the Technical Annex.

Key findings

What happened under the reformed non-domestic RHI scheme?

The non-domestic RHI was one of the first policies in the world to provide subsidies for generation of renewable heat. From the outset, it was designed as a 10-year policy that would make a significant contribution to the development of a sustainable market for renewable heat, providing subsidies over a 20-year period. The evidence presented in this report demonstrates that the policy was successful in stimulating take-up of renewable heat technologies. Qualitative research with applicants and supply chain stakeholders confirmed that long timeframes and policy certainty were important in supporting major investments in renewable heat.

A total of 22,421 valid full applications[2] were submitted to the non-domestic RHI scheme between the start of non-domestic RHI scheme in November 2011 and the end of October 2021[3]. The vast majority (85%) of all applications were made pre-reform. The total installed capacity of accredited full applications was 5,439 MW at end October 2021, excluding biomethane and tariff guarantee applications. This capacity figure will increase when tariff guarantee and non-tariff guarantee extension applications are included: an additional 350 applications for tariff guarantees and a further 609 non-tariff guarantee extension applications may convert to full applications before the commissioning deadline of 31 March 2023. Capacity may also increase owing to expansions of ground source heat pump capacity linked to shared ground loop systems.[4]

[1] A separate evaluation report on the domestic RHI can be found herehttps://www.gov.uk/government/publications/reforms-to-the-domestic-renewable-heat-incentive-evaluation.
[2] Duplicate, rejected, withdrawn and cancelled applications are not included in this number.
[3] The date on which analysis for this report commenced. There continue to be 'Full' applications beyond the closure of the scheme because relocated/replaced RHI plants get a new application and RHI number. In addition, non-tariff guarantee extension applications 'convert' to Full applications when they are commissioned. The commissioning deadline for non-domestic RHI installations has been extended to 31 March 2023.
[4] Rules allowing Modified Capacity for shared ground loop systems were introduced on 1st April 2021. These rules are designed to support installations looking to connect heat pumps in phases, primarily for multiple domestic dwellings. https://www.ofgem.gov.uk/publications/plans-modify-capacity-shared-ground-loops

Applications were dominated by biomass boilers which represented 70% of capacity accredited up to end October 2021. High levels of installations during the early years of the scheme (2014-2015) were driven by small and medium biomass boilers. The combined effects of the reforms and biomass tariff degressions led to much lower numbers of biomass applications post-reform, with a move away from small and medium biomass to larger biomass plants. Biomass applications were dominated by sectors where biomass waste streams or feedstocks were available (e.g. timber product businesses; paper/packaging manufacturers and food/drink manufacturers).

Other technologies represented in the scheme were biomethane (15% of capacity accredited up to end October 2021), biogas and biogas/biomass CHP (10% of capacity up to end October 2021) and heat pumps (5% of capacity up to end October 2021).[5] There was only one preliminary application for geothermal and minimal levels of solar thermal installations. These figures are not final because further applications, involving large installations, were not fully accredited at end October 2021.

How much carbon has been abated to date?

The non-domestic RHI scheme had paid for 68.6 TWh of renewable heat up to the end of October 2021. It has abated an estimated 16.1 million tonnes of CO2 equivalent (CO2e) to this date, compared to the alternative heating technologies that would have been used in the absence of the non-domestic RHI. This estimate of carbon abated takes into account the proportion of non-domestic applicants who would or would not have installed renewable heat technologies without the non-domestic RHI, based on analysis of applicant survey data. Estimates of heat generated and carbon abated will increase as the equipment supported by the non-domestic RHI continues to operate in future years.[6]

Has the reformed non-domestic RHI improved value for money?

The cumulative actual spend on the non-domestic RHI up to end October 2021 was £3.8 billion.[7] Participants who continue to meet scheme rules will keep receiving payments for a period of up to 20 years. The RHI reforms introduced between May 2017 and September 2018 were intended to improve value for money from subsidy of non-domestic installations. Comparison of pre-reform and post-reform figures shows that the mean annual subsidy cost per kW of installed capacity reduced considerably, from £244/kW pre-reform to £134/kW post-reform. Similarly, the subsidy cost per tonne of CO2e abated (up to end October 2021) reduced from £281/tonne CO2e to £248/tonne CO2e, while the subsidy cost per MWh of heat generated (up to end October 2021) reduced from £115/MW to £63/MWh.[8] These improvements in subsidy cost-effectiveness are likely to be due to a combination of reform effects plus automatic tariff degressions.

Post-reform, biomethane offered the lowest subsidy cost per tonne of CO2e abated (£105/tonne CO2e) and the lowest subsidy per MWh of renewable heat generated (£56/MWh) compared to other technologies (up to end October 2021). The Subsidy Cost-Effectiveness

[5] Capacity calculations are presented in Table 4 of the main report.
[6] The non-domestic RHI assumes that the lifespan of renewable heat technologies will be at least 20 years.
[7] BEIS payment data. Cumulative payments to end March 2021 were £3.31 billion, as presented in Ofgem (2021) Non-Domestic RHI Annual Report 2020-21.
[8] These figures are presented in Tables 9 and 10 of the main report. As cost-effectiveness is analysed in terms of subsidy paid per unit of benefit (e.g. per kW of installed capacity or per kWh of renewable heat generated), cost-effectiveness ratios would not be expected to change significantly over time. For example, both the cumulative subsidy and the cumulative heat generated will rise over time at a similar rate.

Assessment found that this was because of the economies of scale offered by biomethane plants coupled with carbon savings associated with diverting biodegradable waste streams from landfill. Significant degressions in the small and medium biomass tariff during the non-domestic RHI scheme, coupled with the impact of RHI reforms, contributed to biomass installations also offering relatively good subsidy cost-effectiveness for the taxpayer compared to other technologies in the scheme (i.e. relatively low subsidy across the three metrics of £/kW, £/tonne CO_2e and £/MWh in the post-reform period, up to end October 2021)[9]. Further depth, and details of subsidy cost-effectiveness for other technologies, are provided in the main report.

The Competition and Trade Assessment undertaken at the end of the scheme (covering both pre- and post-reform periods) found a low risk of over-compensation for biomethane installations and a low to medium risk of over-compensation for small-medium biomass installations. The risk of over-compensation for heat pump installations was found to be medium while the risk of over-compensation for large biomass installations was medium to high.

What impact has the non-domestic RHI had on the supply chain?

As part of its aim to support the development of a sustainable market for renewable heat, one of the RHI's objectives was to contribute to the development of the market for renewable heat technologies by stimulating demand. Supply chain stakeholders reported that a 'boom' in small and medium biomass markets during 2014/15, incentivised by the non-domestic RHI, was followed by a decline between 2016 and 2018. Qualitative research with applicants and installers suggest that the decline was caused by a combination of pre-reform RHI tariff degressions and the removal of drying uses as part of RHI reforms. During this period, many installers and some manufacturers struggled, either going out of business or diversifying to continue to operate. The market for biomass boilers stabilised at a lower level after 2018, with a final spike in activity being observed before the end of the scheme in March 2021.

While qualitative research with installers showed evidence of non-domestic RHI contributing to growth in the wider market for biomass fuels (for all purposes, including renewable heat), the number of suppliers of woody biomass registered on the Biomass Suppliers List fell significantly from 2018 to 2022. There may be a number of reasons for the decline in the number of woody biomass suppliers, including the introduction of higher quality standards for wood fuels as well as RHI tariff degressions for biomass installations.[10]

Qualitative research suggests that the supply chain for heat pumps developed more steadily, except for supply chain delays in 2020/21.[11] Qualitative research with anaerobic digestion (i.e. biogas and biomethane) stakeholders and manufacturers, suggests that the biomethane and biogas supply chain was largely dependent on support from the non-domestic RHI. Despite some growth in the UK market, supported by the non-domestic RHI, AD supply chain stakeholders reported in 2021 that there was insufficient growth to encourage further supply chain companies to set up UK bases.

[9] Subsidy cost-effectiveness calculations were inflated to 2021/22 prices using the GDP deflator. This means that the figures for earlier years were inflated, using an inflation index based on the GDP deflator, with 2021/22 as the base year.
[10] https://biomass-suppliers-list.service.gov.uk/home
[11] Qualitative evidence suggests that supply chain delays during 2020/21 were influenced by COVID, EU Exit, and a spike in heat pump demand during the final months of the non-domestic RHI scheme.

What difference did the reforms make?

The **restructuring of biomass tariffs** created a single tariff for all new biomass boilers rather than banded tariffs for small, medium and large boilers. Revised 'tiering' arrangements (based on heat load factor) were also introduced.[12] This reform reduced the tier 1 tariff for small and medium biomass boilers but increased the tier 1 tariff for large biomass. The reform was intended to encourage deployment of larger systems and remove incentives for installing multiple smaller boilers in place of one large one. This reform contributed to a dramatic reduction in the number of applications for small and medium sized biomass boilers: applications for small biomass boilers fell from 6,694 in 2014 to 153 in 2018, while those for medium biomass boilers fell from 1,268 in 2017 to 245 in 2018. However, qualitative research with applicants and installers suggested that these reductions were perhaps more influenced by pre-reform degressions in the small and medium biomass tariff and by the removal of drying uses (see below) than by tariff restructuring. The restructuring of tariffs contributed to the number of applications for large biomass boilers increasing from 18 in 2017 to 50 in 2018, representing a small number of large schemes, but qualitative research with applicants indicated that the introduction of tariff guarantees also played a role in this (see below). Qualitative research with applicants found that tariff maximisation[13] was not the only driver for some applicants choosing to install multiple small boilers in place of one large one: other drivers included allowing for future growth and improving operating efficiency. Further detail on boiler sizing is provided in the main report.

From May 2018 onwards, certain heat uses were no longer eligible for the RHI, including wood fuel drying, digestate drying and waste drying or processing. This reform was introduced to improve the cost-effectiveness and carbon-effectiveness of the scheme. The **removal of drying from heat uses eligible for the non-domestic RHI**, together with degression of biomass tariffs, contributed to a sharp reduction in biomass and CHP applications from the agriculture and forestry sectors post-reform. Qualitative research with applicants indicated that the removal of drying uses also contributed to the overall decline in small and medium biomass applications, alongside tariff degressions and restructuring of the biomass tariff. The applicant survey found that, within the biomass applicants submitting their applications during 2018, approximately one in ten specifically highlighted the impact of this reform on their installation decisions. Qualitative research with agriculture and forestry applicants and supply chain stakeholders during the post-reform period identified an active market for second hand pre-reform boilers, providing access to both drying uses and pre-reform tariffs. Higher prices quoted online for pre-reform boilers, compared to post-reform boilers, confirmed the relative attractiveness of pre-reform biomass boiler investments compared to post-reform.

The **50% waste requirement for biogas and biomethane** successfully increased the proportion of waste within feedstocks for post-reform anaerobic digestion (AD) plants. Qualitative research with pre- and post-reform biomethane applicants indicated that the types of waste feedstocks used included farm waste, sewage waste, manufacturing and industrial waste as well as municipal and commercial waste. Applicant survey findings, including a small sample of post-reform respondents, suggested that the reforms were successful in increasing the proportion of waste within feedstocks. The Subsidy Cost-Effectiveness Assessment found that the cost-effectiveness of biogas and biomethane improved post-reform, largely because of high tariffs in the early years of the scheme, but data on feedstock change was too limited to

[12] Under tiering, each installation was eligible to receive an initial higher 'tier 1' tariff for a given amount of heat use each year. Once this amount of heat has been generated, further heat use would receive a lower 'tier 2' tariff.
[13] Tariff maximisation means adjusting the details of the installation (e.g. boiler sizing) to maximise RHI tariff receipts.

be included in this analysis. The limited evidence available on feedstock change suggest that the improvement in post-reform cost-effectiveness would be greater if modelling of feedstock impacts had been possible. However, qualitative research with applicants indicated that the waste requirement may have undermined plant viability in some cases, despite the reforms including a slight reversal of previous degressions in the biomethane/biogas tariff.

Application data, combined with qualitative research, indicated that the **introduction of tariff guarantees** was successful in encouraging larger and more complex investments to come forward. Qualitative research with tariff guarantee applicants identified a number of factors that influenced the extent to which projects needed a tariff guarantee, including project scale and length of commissioning timescales, as well as tight business case margins, political risk associated with investment and the absence of wider drivers for renewable heat investments (such as carbon reduction and/or improvement of waste management processes). Biomethane was the dominant technology for tariff guarantees during 2018, in the early period of tariff guarantee availability, but the number of biomethane applications fell thereafter. From 2019 onwards, applications for large heat pumps (ground source and water source) were by far the most common technology for tariff guarantee applications. Large-scale biomass played a more minor role although tariff guarantee applications increased in the final months of the scheme.

Shared ground loops were defined as systems where an underground or underwater loop provided a heat source for multiple heat pumps in a range of properties. The **introduction of deemed heat demand for 'shared ground loop heat pumps'** (SGL) supported some growth in SGL schemes in the social landlord market. Deeming was intended to reduce barriers to deployment of SGLs by avoiding the need for meter reading and billing across multiple properties. Qualitative research with social landlords and other SGL applicants found that increased up-take of SGLs was enabled by innovations in the heat pump supply chain, involving the development of small heat pumps that could fit within small social housing properties. The reforms, supported by manufacturers and installers of these smaller heat pumps, enabled these systems to be installed without requiring individual heat metering and billing. Qualitative research with SGL applicants also found that deeming reduced uncertainty around the business case for investment, because future RHI payments were fixed in advance, rather than varying according to actual metered heat use. However, SGL applications qualifying for deemed heat demand remained a relatively small proportion of heat pump applications in the non-domestic scheme.

Administration of non-domestic RHI

Nearly half of applicants surveyed reported that they encountered no problems in completing their RHI application. And over 70% of applicants surveyed reported that they had no problems providing regular meter readings to Ofgem. Mixed views were expressed on the effectiveness and efficiency of the administration of the non-domestic RHI. Some applicants expressed considerable frustration because of delays experienced with the processing of applications and/or payments, particularly for high-value complex applications towards the end of the scheme. Such delays were reported to have led to serious cash-flow problems and investment delays for some businesses. However, some applicants did not report undue delays, and other aspects of scheme administration were viewed positively. The flexibility applied by Ofgem around the timing of the end of the scheme was welcomed by applicants.

Lessons for Future Renewable Heat Policy/Programmes

Qualitative research found that the long-term nature of the non-domestic RHI policy was important in supporting major investments in renewable heat. While the reforms, degressions and budget cap contributed to some uncertainty for applicants and supply chain stakeholders, these changes were effective in containing the scheme's costs and targeting support at larger scale and more carbon and cost-effective renewable heat technologies. Qualitative research with tariff guarantee applicants found that extensions to commissioning deadlines beyond the end of the scheme, and an additional round of tariff guarantees, helped to bring forward more capacity within the scheme.

The high level of non-domestic applicants who reported that they would not have installed renewable heat technologies without the non-domestic RHI (over 50% of those surveyed) suggests that a considerable proportion of demand has been supported by the non-domestic RHI. This provides an indication of the scale of the likely impact on demand from the loss of the RHI, in the absence of other forms of support.

The level of need for financial support beyond the end of the non-domestic RHI scheme varies between technologies and end uses. Qualitative research and analysis of applications suggest that there was progress towards a sustainable market in the following parts of the non-domestic space and water heating market during the post-reform period:

- social housing schemes that are off gas or are unsuitable for gas heating, where heat pumps (ASHP or GSHP) have become the preferred solution for social landlords, although qualitative research found that many SGL heat pump systems were still dependent on the non-domestic RHI
- large-scale commercial, horticultural and/or residential developments with low-cost access to renewable heat sources (for example water sources, sewage treatment works or deep boreholes) where large-scale heat pumps can be connected to a local heat network
- agricultural and forestry businesses with low-cost access to biomass fuel, where biomass boilers can readily be integrated into the business system
- new build commercial or residential premises, where heat pumps and high levels of insulation can be integrated into building design, driven largely by building regulations

In contrast, qualitative research found that non-domestic RHI support was critical to the business case for large-scale biomass installations (including use of renewable heat for process heating in industry) and most large-scale heat pumps. Similarly, both the applicant survey and qualitative research with biomethane applicants found that few biomethane investments were viable without subsidy (although this research was undertaken before the introduction of the Green Gas Support Scheme). Future support needs will be affected by perceived barriers and enabling factors in each market, as detailed in the main report.

Glossary

Accreditation	A system that has been the subject of an RHI application and which has gone through full checks by Ofgem to make sure that it complies with the relevant conditions.
Additionality	The extent to which observed outcomes are attributable to the intervention and would not have occurred in its absence.
Air quality damage cost	Valuation of the negative impacts of worsened air quality, based on HM Treasury Green Book guidance. The damage costs take into account understanding of health impacts, based on the latest advice from Public Health England and the Committee on the Medical Effects of Air Pollution.
Application effective date	The date from which an applicant can claim RHI payments for the renewable heat generated by their system.
Biogas	Biogas is a mixture of combustible gases produced by biological feedstock/fuel which are burnt to generate heat.
Biomass	Refers to any fuel derived from organic matter generally wood, but also includes straw, grass and organic waste.
Biomethane	Instead of burning biogas to generate heat on site, it can be processed to bring the calorific value of the gas to the same as that of natural gas and then injected into the gas network to be used elsewhere.
Capacity	The capacity of the system is the maximum power output. It depends on the installations size and technical capability.
Combined Heat and Power (CHP)	A system which generates electricity whilst also capturing usable heat generated in the process.
Commissioning date	Under the RHI, the commissioning date of the heating system is the date on which any final tests and procedures that amount to the usual industry practices for commissioning that type of system were completed. These tests will demonstrate that the heating system is operating correctly, generating heat, and that it complies with industry standards.
Counterfactual	The outcomes which would have been anticipated if an intervention had not been implemented.
Date of approval	The date on which Ofgem approved the application as eligible for RHI support and accredited the installation.
Date of first submission	When the application was first registered with Ofgem.
Deeming (deemed payments)	A process which was applied to domestic properties on shared ground loops in which RHI payments were made on the basis of deemed (or estimated) rather than metered usage. The Energy Performance Certificate (EPC) is used to calculate a space and water heating demand, based on the characteristics of the building. That value of heat is then paid for by Ofgem (with various regulations in place, e.g. for maximum demand and minimum energy efficiency levels).

Deep geothermal	Refers to the heat generated through radioactive decay below the surface of the earth.
EPC	Energy Performance Certificate.
Full application (non-domestic)	A completed application submitted to Ofgem with a relevant system already installed, in contrast to a Tariff Guarantee application.
Gate fee	A gate fee is the charge levied by a waste processing facility for a given quantity of waste that is received at the facility. The fee can be charged per load, per tonne or per item depending on the source and type of waste.
Heat pumps	A heat pump is a device that transfers thermal energy from a heat source to a heat sink (e.g. the ground to a house). There are many varieties of heat pump but for the purposes of the RHI they fall into 3 categories: air, ground and water source heat pumps. The first word in the title refers to the heat source from which the pump draws heat. The pumps run on electricity, however less energy is required for their operation than they generate in heat, hence their status as a renewable technology.
Low-grade heat	Definitions of low-grade heat vary but it is often referred to as low temperature heat that can be recovered and converted to higher temperatures. Heat pumps, for example, can convert the warmth from the ground, air and water into higher temperatures for use in space and water heating.
LPG	Liquefied petroleum gas is a fuel source used for heating homes. It is a mixture of flammable hydrocarbons compressed to liquid form and stored in canisters.
MW	MW stands for megawatt. A watt is a unit of power and a megawatt is a million watts.
MWh	MWh stands for a megawatt hour and is a unit of energy. It is equal to the amount of energy a system will generate in an hour whilst running at a megawatt power output.
Ofgem (Office of Gas and Electricity Markets)	Ofgem is the regulator of the gas and electricity industries in Great Britain. Ofgem Delivery and Schemes (formerly known as Ofgem E-serve) is Ofgem's delivery directorate that administers the RHI scheme.
Realist evaluation	A type of theory-based evaluation approach which involves exploring 'what works, for whom and in what circumstances' (or 'contexts').
Renewable heat	Heat energy that comes from a renewable source, such as biomass, the sun or the earth.
Renewable heat technology	A system which produces renewable heat.
Seasonal performance factor (SPF)	A seasonal performance factor (SPF) is a seasonally adjusted coefficient of performance (COP) used in the application of heat pumps. SPF is a measure of the operating performance of an electric heat pump heating system over a year. It is the ratio of the heat delivered to the total electrical energy supplied over the year. Therefore, a system with a COP of 2 will produce twice the amount of thermal energy than the electrical energy that it takes to run. It is a measure of how efficiently a heat pump is operating. The higher the SPF value the more energy efficient the heat pump system is.

Shared ground loop (SGL)	This technology involves a large underground or underwater loop providing low-grade (low temperature) heat to multiple heat pumps in individual properties. Although SGLs often serve domestic properties, applications were made under the non-domestic RHI because this technology serves multiple properties. See Appendix D in the Technical Annex for more detail.
Solar thermal	Panels which convert solar energy to thermal energy which can be used for heating.
Tariff band	The different rates paid per kWh of heat produced or bio-methane injected depending on the size and type of installation.
Tariff degressions	The means of controlling the budget for the non-domestic RHI. The tariffs which can be paid to new applicants are lowered as more renewable heating capacity is installed.
Tariff Guarantee	A tariff guarantee allowed applicants to the Non-Domestic Renewable Heat Incentive (NDRHI) to secure a tariff rate before their installation was commissioned and fully accredited on the RHI. The regulations for tariff guarantees were introduced on 22 May 2018.
Theory-based evaluation	An approach to evaluation which involves systematically testing and refining the assumed connections (i.e. the theory) between an intervention and the anticipated impacts.
Under review	An application that is currently being considered for accreditation.

Contents

Introduction

This report presents findings from the evaluation of the reformed Renewable Heat Incentive (RHI). It synthesises the evaluation's findings in relation to the non-domestic RHI, which closed to new applicants on 31 March 2021.

The evaluation is being undertaken for the Department for Business, Energy and Industrial Strategy (BEIS) by CAG Consultants, in partnership with Winning Moves, Wavehill, Hatch, EREDA Consultants and UCL. It aims to provide **a) an assessment of the impact of the scheme**, and **b) strategic learning to inform heat policy development focusing on the reforms**.

A separate report on the evaluation findings regarding the domestic RHI will be published alongside this report.

Policy Context

Non-domestic RHI overview

The non-domestic RHI scheme was designed to incentivise businesses, public sector bodies, non-profit organisations and district heating schemes[14] to install renewable heating systems. The scheme allowed applicants to apply for financial support for renewable heat installations over 20 years. Covering England, Scotland and Wales, the scheme went live on 28 November 2011.

The scheme was open to renewable heat installations that provided heat to buildings for purposes other than heating a single domestic property[15]. This included, for example, systems providing renewable heating to public buildings or commercial properties, for industrial or agricultural uses, or for heating a block of flats.

Heat technologies eligible under the scheme were: biomass; biogas; air, water and ground source heat pumps; solar thermal; combined heat and power (CHP) systems; and deep geothermal plants.

Each technology had a specific level of support, known as a 'tariff'. The tariff was the amount of support the owner of the system received in respect of each unit of heat produced and used for an eligible purpose or, in the case of biomethane, for each unit of biomethane produced and injected into the gas-grid.

With the exception of domestic properties with individual heat pumps connecting to a shared ground loop, where payments were deemed, accredited applicants[16] had to install meters to measure the amount of renewable heat generated that is used for eligible purposes or, in the

[14] Schemes in which a single heating system serves multiple buildings.
[15] Applications for installations heating a single domestic property were eligible for the domestic RHI scheme.
[16] An 'accredited applicant' is defined as an applicant to the non-domestic RHI who had had their application approved by Ofgem and was therefore eligible for RHI payments.

case of biomethane, the amount of biomethane injected. Eligible purposes include providing space- and water-heating in buildings and some types of drying and industrial processes.

Ofgem administers the scheme and makes payments to accredited applicants based on these measurements and the relevant tariff. Accredited RHI applicants receive quarterly payments for a period of 20 years, provided they continue to satisfy the eligibility criteria and ongoing obligations.

The scheme closed to new applicants on 31st March 2021, with a final cut-off date for payments being 31 March 2041.

Budget management

The scheme had two main mechanisms to manage spending levels:

- an RHI budget cap mechanism was introduced in April 2016 - it allowed the Government to close the scheme if there was a risk of overspending (additional budget caps also applied to Tariff Guarantee applications)
- reductions to the tariffs available (referred to as tariff 'degressions') occurred when spending reached pre-set levels - tariff degressions were designed to control spending on each technology, ensuring individual technologies did not dominate scheme spending, by reducing support levels as installation numbers grew and technologies began to take off

Scheme reforms

Reform objectives

The Government announced reforms to the non-domestic RHI in December 2016.[17] The reforms were designed to ensure the scheme:

- focused on **long-term decarbonisation**: promoting deployment of the 'right technologies for the right uses', while ensuring the RHI contributes to both the UK's decarbonisation and renewable energy targets
- offered **better value for money and protected consumers** by: improving how costs were controlled, giving consumers more confidence in the performance of particular technologies, addressing potential loopholes in the scheme, and significantly improving the scheme's subsidy cost-effectiveness
- supported **supply chain growth** and challenged the market to deliver: the reforms were designed to drive cost reductions and innovation to help build growing markets that provided quality to consumers and were sustainable without Government support in future

The principal reforms to the non-domestic RHI, introduced between September 2017 and May 2018, were:

[17] Department for Business, Energy and Industrial Strategy (2016), The Renewable Heat Incentive: A reformed scheme – Government response to consultation, 16 December 2016. Available at: https://www.gov.uk/government/consultations/the-renewable-heat-incentive-a-reformed-and-refocused-scheme [accessed: 24 May 2018].

- the introduction of one level of support for biomass – replacing three tariff bands - to encourage investment in larger biomass plants which were expected to be more cost-effective than small and medium biomass installations
- the removal of most 'drying' uses from the list of heat uses eligible for the non-domestic RHI in order to improve the value for money and environmental sustainability of the scheme[18]
- the introduction of 'tariff guarantees' to increase certainty for investors in larger and more complex installations which tend to have longer lead-times, thereby encouraging investment in larger plants that offer economies of scale
- the introduction of 'deeming' of heat demand for shared ground loop heat pump systems (see Glossary) to increase certainty of payments and remove the need to install separate meters for multiple properties served by shared ground loops
- a requirement that waste-streams should comprise at least 50% of feedstocks for new biomethane and biogas plants, combined with a small uplift to biomethane and biogas tariffs - the aim was to help divert waste from landfill and make use of available resources

Evaluation Background and Aims

The evaluation of reformed non-domestic RHI scheme began in February 2017 with the purpose of assessing the effectiveness of the reforms.

Aims

The aims of the evaluation were to:

A1: Provide an assessment of the impact of the scheme.

1. Assess the extent to which the RHI's expected aims have been achieved (including renewable heat generation, carbon abatement and development of a sustainable market).
2. Assess the extent to which the reform objectives have been met (including improving value for money).
3. Demonstrate the causal mechanisms through which the reformed RHI scheme has led to the achievement of the scheme objectives, and how these differ between different consumers and in different contexts.

A2: Provide strategic learning to inform heat policy development.

4. Identify the factors that are important in increasing the installation of renewable heat systems and the generation of renewable heat and how these differ across customer groups and/or technologies.

[18] This included the removal of: wood-fuel drying as eligible heat use other than where the renewable heat installation was replacing a fossil fuel heat source; and drying, cleaning or processing of waste as an eligible heat use.

5. Identify the factors that are important in supporting the development of a sustainable market for renewable heat and how these differ across customer groups and/or technologies.

Evaluation questions

To address the aims above, a set of detailed evaluation questions (EQs) were developed.

Five main EQs were agreed with BEIS:

1. How far have the renewable heat outcomes sought by the reformed RHI been achieved (for whom and in what contexts), and how has the reformed RHI contributed to these? (links to Aims A1.1 and A1.4)
2. How has design and implementation of the reformed RHI influenced these outcomes, in what respects and for whom? (links to Aims A1.4 and A2.5)
3. To what extent have the RHI reforms improved the cost-effectiveness of the RHI scheme, in terms of offering value for money to taxpayers and to different beneficiaries? (links to Aim A1.2)
4. How far has the reformed RHI contributed to the development of sustainable markets for renewable heat, and how does this differ across market segments or technologies? (links to Aim A2.6)
5. What lessons can be drawn by BEIS from the evaluation of the RHI regarding future renewable heat policy? (links to Aim A2)

A detailed set of sub-questions for each main EQ was also developed. These are set out in Appendix A in the Technical Annex. Further detail on evaluation design and methods is set out in chapter 2 and in Appendix B of the Technical Annex.

Report Structure

This report opens with a methodology chapter and then presents the findings, split into three main chapters, as set out in the table below.

Table 1: Report structure

Report chapter	Description	EQs addressed
Methodology	An overview of the methodology used to undertake the evaluation	n/a
What happened?	A presentation of key scheme outcomes as they relate to: decarbonisation, better subsidy cost-effectiveness, and supply chain development.	Parts of EQ1, EQ3 & EQ4
How did the RHI contribute to observed outcomes?	An exploration of the non-domestic RHI's role in supporting the installation of renewable heating technologies, focusing in particular on the impact of the scheme's reforms.	All of EQ2 Parts of EQ1, EQ3 and EQ4
Future lessons for policies and programmes on renewable heat	A summary of learning from the scheme for future policies and programmes on renewable heat.	EQ5

In addition, the Technical Annex, set out in a separate document, contains the following appendices:

- Appendix A: Evaluation questions – the full set of evaluation questions and sub-questions
- Appendix B: Technical methodology – an overview of the key methods employed for each of the evaluation workstreams that informed this synthesis report
- Appendix C: Tariff levels – a detailed table setting out the tariff levels for the different technologies in the scheme
- Appendix D: Shared ground loop systems – a brief explanation of the nature of these systems
- Appendix E: Data tables – setting out the data tables for figures cited in the report, where they are not already publicly available
- Appendix F: Theoretical framework – a summary of the theoretical framework for the evaluation

Methodology

This chapter sets out the methodological approach for the evaluation as a whole and for the research underpinning this synthesis report. It also outlines the process employed to synthesise the research findings from multiple evaluation workstreams.

Evaluation Design

The evaluation is theory-based and informed by the principles of realist evaluation.[19] This involves developing, testing, and refining 'realist' theory about the reformed RHI as the scheme proceeds.[20]

Evidence was collected across multiple workstreams, undertaken between 2017 and 2021. These included: analysis of RHI administrative data, detailed applicant monitoring, qualitive research with applicants and with the renewable heat supply chain, a Sustainable Markets Assessment, a Subsidy Cost-Effectiveness Assessment, and a Competition and Trade Assessment. Further detail on the methods for each workstream are set out in Appendix B.

Theoretical Framework

Overall theoretical framework for the evaluation

This evaluation followed a theory-based approach, employing realist evaluation principles. The use of theory-based evaluation is supported by HM Treasury guidance on evaluation.

A theoretical framework was developed to guide the research, featuring four layers:

- layer 1 - a high-level 'if, then, because' statement summarising the aims of the RHI reforms
- layer 2 – a high-level policy map setting out the causal linkages and feedback loops in the supply and demand system for renewable heat
- layer 3 – a set of realist 'Context-Mechanism-Outcome' (CMO) hypotheses focused on how the scheme impacted on demand, supply, usage, and fuel and feedstocks
- layer 4 - reform-specific CMO hypotheses for each wave of qualitative fieldwork conducted during the evaluation

Note that only layers 3 and 4 were purely realist, designed to frame the qualitative fieldwork in particular, while layers 1 and 2 were more general, non-realist, theories used to frame the

[19] R Pawson, R, and Tilley, N. (1997) *Realistic Evaluation*. London: SAGE Publications Ltd; and Pawson, R. (2006) *Evidence-Based Policy*. London: SAGE Publications Ltd.

[20] Realist Evaluation explicitly focuses on causal conjunctions rather than causal chains and relies on formal logic of causal mechanisms that are embedded in different contexts forming regular patterns or 'configurations' of context/mechanism/outcomes. Because realist approaches assume that the same mechanisms work differently in different contexts it is an approach well-suited to answer the question: 'what works for whom in different circumstances?' (referred to in EQs 1 & 2).

evaluation as whole across each of its six workstreams. The framework as whole was then used in the synthesis of the evidence sources for this report. Appendix F in the Technical Annex presents the theoretical framework in detail.

The development of the initial framework was informed by workshops and consultations with key policy staff and stakeholders, as well as a review of key literature. This enabled the creation of a set of high- and mid-level outcome-focused theories focused on ‘what works’ within differing contextual configurations, both for the scheme as a whole and specifically for the key reforms.

The theoretical framework was continually tested and refined throughout the lifetime of the evaluation, reviewing the theory against emerging evidence, and building up evidence to help the evaluation team to understand ‘what works, for whom, in what circumstances, in what respects and why’. This happened both at a micro level – conducting detailed analysis of evidence to update reform-specific CMO sets – and at a macro level – organising evaluation evidence into tables to support systematic synthesis of evidence in relation to the higher-level theories and evaluation questions. This synthesis process is outlined further later in this chapter.

Note that use of theory-based and realist evaluation terms has been avoided in the findings sections of this report to make it more readable for a general audience.

Evidence Sources

This report synthesises findings from six evaluation workstreams, as set out in the table below.

Table 2: Summary of evidence sources used for the non-domestic synthesis

Workstream	Purpose	Method	Timing of work
Analysis of RHI administrative data	To provide evidence of scheme-wide application and outcomes data. This data was primarily used to test the layer 3 demand theory.	Desk-based analysis of lifetime non-domestic RHI administrative data (November 2011 – March 2021). Included analysis of lifetime application data over time, application data by technology, installed capacity data and other key variables to understand key scheme outcomes and outputs, insofar that these can be assessed within the timescale for this evaluation.	November 2021-February 2022

Workstream	Purpose	Method	Timing of work
Detailed applicant monitoring	To provide evidence on a range of areas including applicant demographics, reasons for installing a renewable heat technology, experiences of installation and using their technology, and fuels and feedstock details. This evidence was used to test all areas of theory (i.e. demand, supply, usage and fuel/feedstock theory).	Detailed applicant monitoring comprising collection and analysis of RHI application data from BEIS, supplemented by an online survey of applicants. The survey tracked a series of indicators including additionality, influence of RHI reforms, satisfaction with the technology, sources of information about renewable heat and technology-specific questions. Across all waves, the response rate was 13%. The total number of responses was 1,098 for the general non-domestic survey and 226 for the biogas/biomethane survey. The survey was originally intended to be a census of all accredited applications; it was sent to all applicants with at least one accredited application, provided that they had not been sent the survey in a previous wave. This is so that respondents were only able to complete this survey once. However, as c. 20% of applicants responded to the survey, it ended up being closer to an opportunity sample than a census.	A retrospective survey, covering applications that had gained accreditation status between 1st January 2015 and 31st August 2018, was completed in November 2018. It was followed by a survey round of new successful applicants every six months until the end of the scheme. Data from previous monitoring surveys, undertaken under the previous evaluation contract, which ran up to December 2014, were also used as evidence where appropriate.
Qualitative research	This workstream was designed to understand and identify the causal effects of the scheme reforms. This	This included concentrated qualitative fieldwork (i.e. interviews) on:	Fieldwork conducted between 2018 and 2021 (see previous column).

Workstream	Purpose	Method	Timing of work
	evidence was used to test all areas of theory (i.e. demand, supply, usage and fuel/feedstock theory).	• biomethane applications and installations (2018-19) • shared ground loop applications and installations (2019-20) • manufacturing process heat applications and installations (2019-20) • agriculture and forestry biomass applications and installations (2020-21) • large heat pump applications and installations supported by tariff guarantees (2021)	
Sustainable Markets Assessment (SMA)	To track progress towards a more sustainable market (defined as a market able to operate without – or with less – public subsidy, with the market growing to the size needed for deployment to meet Government decarbonisation targets for 2050). This evidence primarily tested supply theory but also drew on evidence about demand, usage and fuel/feedstocks.	This workstream tracked a set of indicators over time covering the key factors expected to indicate progress towards a more sustainable market. Many of these indicators measured interim outcomes, such as cost reductions, increased demand and increased supply for particular markets and technologies. Much of the data used by this workstream was collected in other workstreams (e.g. applicant surveys), however some additional data was collected from engagement with external stakeholders, reviews of industry data and wider sources such as Public Attitudes Tracker data.	Conducted every six months throughout the evaluation's lifetime, from winter 2017 through to summer 2021.
Subsidy Cost-Effectiveness	To provide insight into how the reforms have affected subsidy	This workstream used a mix of quantitative and qualitative evidence. The	Conducted in two waves, the first in

Workstream	Purpose	Method	Timing of work
Assessment (SCEA)	cost-effectiveness in key areas. This analysis examined the relationship between subsidy costs and outcomes in the overall policy map.	analysis presented an overall narrative on changes in relative cost-effectiveness of the scheme before and after the introduction of reforms, using the evidence that is available for each technology. A full cost-benefit analysis was not conducted for this evaluation, as full costs and benefits will not be known until programme financial closure.	2019, the second in 2021-22.
Competition & Trade Assessment (CTA)	To assess the extent to which the reformed RHI impacted competition in renewable heating related goods and services. This tested for potential 'perverse effects' in the overall policy map.	This workstream used a mix of quantitative and qualitative evidence to test the original assumptions around tariff setting and whether these held in practice, considering any implications of this for over or under compensation of applicants.	Conducted in two waves, the first in 2019, the second in 2021-22.

Sampling

For the qualitative research, the sampling approach was purposive, led by the specific research questions which framed each wave of fieldwork. Details of the approach applied for each wave of fieldwork are set out in the Technical Annex. Interviews were undertaken with applicants whose applications were either accredited, covered by tariff guarantees or (in a small number of cases) under review. With the exception of tariff guarantee applicants, whose projects might not yet be commissioned, these applicants had already commissioned their renewable heat technologies. At a high-level, the fieldwork waves involved interviews with the following:

- biomethane fieldwork: 18 biomethane applicants, with and without tariff guarantees (7 pre-reform, 11 post-reform), 9 biomethane stakeholders
- shared ground loop fieldwork: 11 shared ground loop applicants, 2 communal GSHP applicants,[21] 9 applicants who had installed multiple ASHPs in neighbouring properties rather than shared ground loops or communal GSHPs, and 6 shared ground loop installers

[21] See Appendix D for the difference between shared ground loop heat pumps and communal GSHPs.

- manufacturing process fieldwork: 11 applicants who installed biomass for process heating, 5 'non-applicants' (with manufacturing processes that had similar characteristics to those that had applied to the RHI for biomass boilers for process heating purposes)
- agriculture and forestry fieldwork: 10 biomass applicants from the agriculture sector, 8 biomass applicants from the forestry sector, 4 agriculture and forestry sector stakeholders
- tariff guarantee fieldwork: 17 tariff guarantee applicants for large heat pumps from either the housing or agriculture sectors, 5 non-tariff guarantee RHI applicants for large heat pumps from either the housing or agriculture sectors

The RHI detailed applicant monitoring survey aimed to cover all applications who had been accredited to the scheme. Given that each applicant could have more than one application to the scheme and so where applicants had more than one application, the application the survey relates to was chosen at random. Applicants who had already been sent the survey in previous waves for a different application were excluded from the sample to reduce the research burden on applicants. Aside from successful application status and an eligible date range, there were no other criteria for inclusion of the applicant / application in the monitoring survey.

Each survey wave covered applications from the previous six months and was conducted twice per year. The majority of the detailed applicant monitoring was conducted through an online survey, with a link to the survey being sent to all successful applicants whose application had gained accreditation status in the six-months period covered by each survey wave. In some waves, a telephone top-up survey was also conducted to boost representation of certain categories of applicants.

Further detail on the methods for each workstream is set out in Appendix B in the Technical Annex.

Synthesis Approach and Process

The synthesis process was led by CAG Consultants, with inputs from Winning Moves and Wavehill.

Key steps in the realist synthesis process were:

- step 1 - relevant data from across six workstreams (see Table 2: Summary of evidence sources used for the non-domestic synthesis

Workstream	Purpose	Method	Timing of work
Analysis of RHI administrative data	To provide evidence of scheme-wide application and outcomes data. This data was primarily	Desk-based analysis of lifetime non-domestic RHI administrative data (November 2011 – March 2021).	November 2021-February 2022

Workstream	Purpose	Method	Timing of work
	used to test the layer 3 demand theory.	Included analysis of lifetime application data over time, application data by technology, installed capacity data and other key variables to understand key scheme outcomes and outputs, insofar that these can be assessed within the timescale for this evaluation.	
Detailed applicant monitoring	To provide evidence on a range of areas including applicant demographics, reasons for installing a renewable heat technology, experiences of installation and using their technology, and fuels and feedstock details. This evidence was used to test all areas of theory (i.e. demand, supply, usage and fuel/feedstock theory).	Detailed applicant monitoring comprising collection and analysis of RHI application data from BEIS, supplemented by an online survey of applicants. The survey tracked a series of indicators including additionality, influence of RHI reforms, satisfaction with the technology, sources of information about renewable heat and technology-specific questions. Across all waves, the response rate was 13%. The total number of responses was 1,098 for the general non-domestic survey and 226 for the biogas/biomethane survey. The survey was originally intended to be a census of all accredited applications; it was sent to all applicants with at least one accredited application, provided that they had not been sent the survey in a previous wave. This is so that respondents were only able to complete this survey once. However,	A retrospective survey, covering applications that had gained accreditation status between 1st January 2015 and 31st August 2018, was completed in November 2018. It was followed by a survey round of new successful applicants every six months until the end of the scheme. Data from previous monitoring surveys, undertaken under the previous evaluation contract, which ran up to December 2014, were also used as evidence where appropriate.

Workstream	Purpose	Method	Timing of work
		as c. 20% of applicants responded to the survey, it ended up being closer to an opportunity sample than a census.	
Qualitative research	This workstream was designed to understand and identify the causal effects of the scheme reforms. This evidence was used to test all areas of theory (i.e. demand, supply, usage and fuel/feedstock theory).	This included concentrated qualitative fieldwork (i.e. interviews) on: • biomethane applications and installations (2018-19) • shared ground loop applications and installations (2019-20) • manufacturing process heat applications and installations (2019-20) • agriculture and forestry biomass applications and installations (2020-21) • large heat pump applications and installations supported by tariff guarantees (2021)	Fieldwork conducted between 2018 and 2021 (see previous column).
Sustainable Markets Assessment (SMA)	To track progress towards a more sustainable market (defined as a market able to operate without – or with less – public subsidy, with the market growing to the size needed for deployment to meet Government decarbonisation targets for 2050). This evidence primarily tested supply theory but also	This workstream tracked a set of indicators over time covering the key factors expected to indicate progress towards a more sustainable market. Many of these indicators measured interim outcomes, such as cost reductions, increased demand and increased supply for particular markets and technologies. Much of the data used by this workstream was collected in other workstreams (e.g. applicant surveys), however	Conducted every six months throughout the evaluation's lifetime, from winter 2017 through to summer 2021.

Workstream	Purpose	Method	Timing of work
	drew on evidence about demand, usage and fuel/feedstocks.	some additional data was collected from engagement with external stakeholders, reviews of industry data and wider sources such as Public Attitudes Tracker data.	
Subsidy Cost-Effectiveness Assessment (SCEA)	To provide insight into how the reforms have affected subsidy cost-effectiveness in key areas. This analysis examined the relationship between subsidy costs and outcomes in the overall policy map.	This workstream used a mix of quantitative and qualitative evidence. The analysis presented an overall narrative on changes in relative cost-effectiveness of the scheme before and after the introduction of reforms, using the evidence that is available for each technology. A full cost-benefit analysis was not conducted for this evaluation, as full costs and benefits will not be known until programme financial closure.	Conducted in two waves, the first in 2019, the second in 2021-22.
Competition & Trade Assessment (CTA)	To assess the extent to which the reformed RHI impacted competition in renewable heating related goods and services. This tested for potential 'perverse effects' in the overall policy map.	This workstream used a mix of quantitative and qualitative evidence to test the original assumptions around tariff setting and whether these held in practice, considering any implications of this for over or under compensation of applicants.	Conducted in two waves, the first in 2019, the second in 2021-22.

- step 2 - internal review - the consortium of CAG, Wavehill and Winning Moves conducted a workshop to review the matrix, identify evidence gaps and purposively explore additional analytical opportunities to be addressed through further analysis
- step 3 - following this review process, additional analysis was conducted of the applicant survey data by Winning Moves; data from the SMA, SCEA, CTA by Wavehill; and RHI application and administrative data by CAG Consultants
- step 4 - assessment of evidence - the evaluation evidence was assessed by the evaluation team to establish the extent to which it supported the existence of outcomes,

mechanisms and contexts in theory, with a particular focus on the scheme reforms. The assessment combined both the empirical evidence and emerging theoretical thinking to provide explanations of how the scheme worked, in what contexts and for whom

- step 5 - refinement of theory - the assessment was then used by CAG to confirm, refine or revise the CMO configurations in the theory and derive a synthesised assessment of evidence in relation to the key evaluation questions

Limitations

A more detailed consideration of the limitations for each individual workstream forms part of the detailed technical methodology appendix (Appendix B) in the Technical Annex. The limitations detailed in this section are the most important which pertain to the evaluation overall and should be noted when reading this report.

Lack of a control group

A key task in understanding causes is to compare the observed results to those you would expect if the intervention had not been implemented (the 'counterfactual'). This is often done through use of a control group. As the non-domestic RHI was open to all businesses, public sector bodies and non-profit organisations, however, an experimental design with a control group was not possible. In any case, the theory-based design of the evaluation meant that a control group was not necessary to assess the contribution of the reformed non-domestic RHI scheme to observed outcomes.

Analysis not based on whole-scheme data due to some applications still being processed

An analysis of whole-scheme data was not possible at the time of analysis (October 2021). While the scheme closed to new applications at the end of March 2021, the commissioning deadline for some full applications and for tariff guarantee applications was extended to the end of March 2023. Not all these applications (some of them for large installations) will become accredited, meaning final application figures will not be known until after March 2023. This means that certain figures included within the report (such as renewable heat generated and carbon abatement) are not final and should not be read as such.

Furthermore, payments for the non-domestic RHI will continue for up to 20 years after the scheme closure. A full value-for-money assessment was therefore not possible at the time of writing. Instead, the focus of cost-effectiveness analysis was limited to actual spend to date. Figures should therefore be interpreted by readers for comparative purposes, rather than taken as absolute.

Lack of data about non-applicants

Very limited direct evidence was gathered from potential applicants, i.e. those that considered installing, or could have installed, an RHI-supported heat technology but opted not to. It was therefore not possible to gather in-depth insights from consumers themselves about why they decided not to install an RHI-supported renewable heat technology (e.g. because they selected a non-renewable alternative).

Self-reported additionality statistics

The survey included questions that asked applicants what they would have done if the RHI scheme had not been in place. These questions were included to get an insight into the impact the scheme had on each applicant's decision to install a renewable heating system and the potential counterfactual actions. Self-reporting of additionality, however, is subject to biases resulting from respondent recall and distortions in perception. Consequently, the basic or 'core' additionality figures were more valuable in assessing the changes in motivations or counterfactual installations over time, or between groups, rather than providing an absolute assessment of the impact of the scheme on each applicant. Given the importance of additionality statistics within the SCEA, 'high' and 'low' estimates of additionality were constructed around the 'core' additionality assessment. This was done by cross-checking applicant responses to the survey question on additionality with their responses to other specific questions in the applicant survey. The final additionality statistics used were the average (mean) of the 'high' and 'low' additionality estimates. This process is explained further in the SCEA section of Appendix B.

Some analysis undertaken in nominal terms

The SCEA was undertaken in real terms, taking account of inflation, to provide an accurate comparison of cost-effectiveness pre- and post-reform. The CTA assessments were undertaken at 2016 prices. However, the CTA assessments of costs were based on nominal figures, meaning they were not adjusted for inflation. Although inflation was low during the non-domestic RHI period, this may in some cases lead to slight under-estimation of the risk of over-compensation from non-domestic RHI in the post-reform period.

What happened?

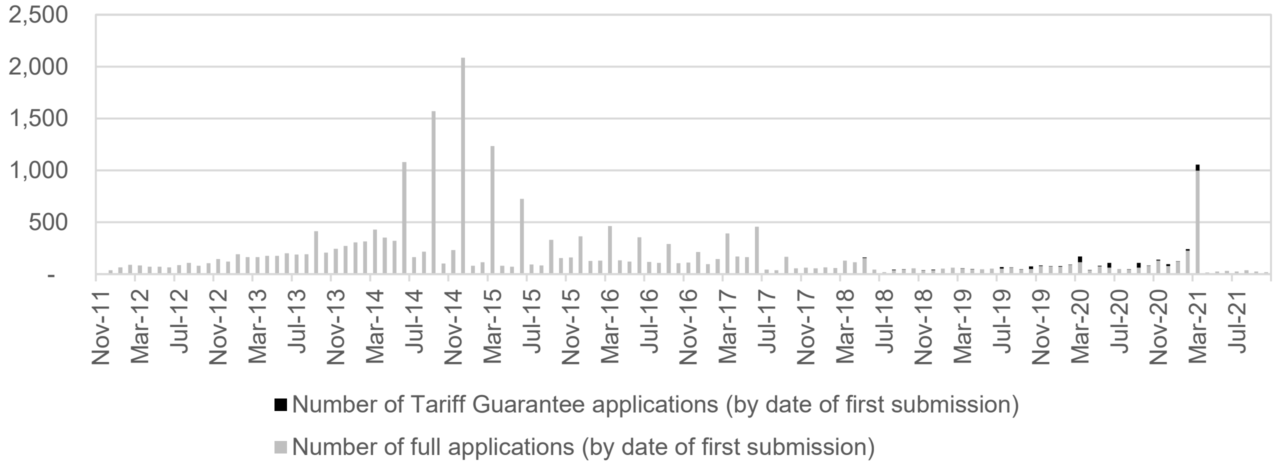
A summary of key scheme outcomes as they relate to the three scheme objectives: decarbonisation, better value for money, and supply chain development. More detail about how and why these outcomes happened, including the influence of the non-domestic RHI, is presented in the next chapter.

Overview

By the end of October 2021[22], 22,421 valid full applications[23] had been submitted to the non-domestic RHI[24]. There were an additional 350 applications for tariff guarantees and a further 609 non-tariff guarantee extension applications, which may convert to full applications before the commissioning deadline of 31 March 2023. Tariff guarantees became available following the introduction of the regulations for tariff guarantees on 22 May 2018. It should be noted that not all of these will go on to be accredited (120 of the 350 had been accredited by October 2021). As such, these data do not represent the number of completed projects.

The number of applications per month is shown in**Figure 1**. This illustrates the quarterly spike in applications, in response to potential quarterly tariff degressions, which characterised much of the scheme. Application numbers were highest between mid-2014 and early 2015. The number of applications remained relatively low from mid-2017 onwards, apart from a sharp spike in applications in the final month of the scheme (March 2021).

Figure 1: Number of non-domestic RHI applications per month



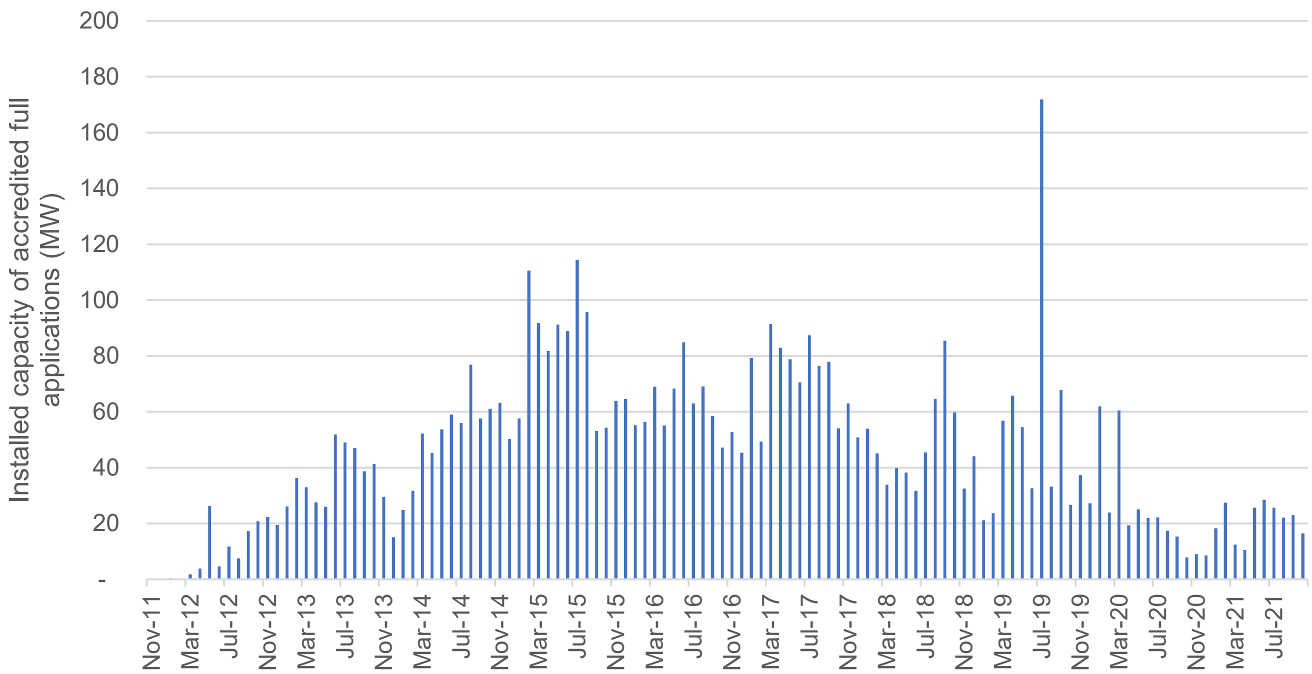
Source: RHI monthly deployment data: October 2021. https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2021

[22] The date on which analysis for this report commenced.
[23] Duplicate, rejected, withdrawn and cancelled applications are not included in this number.
[24] There continue to be 'full' applications beyond the closure of the scheme because relocated/replaced RHI plants get a new application and RHI number. In addition, non-tariff guarantee extension applications 'convert' to full applications when they are commissioned. The commissioning deadline is 31 March 2023.

At the end of October 2021, the total installed capacity of accredited full applications was 5,439 MW, excluding 143 biomethane applications[25] and 350 tariff guarantee applications. An additional 233 MW of capacity had been installed capacity from tariff guarantee applications that had been accredited by end October 2021. These capacity figures will increase when further tariff guarantee and non-tariff guarantee extension applications are included: additional tariff guarantees applications and a further 609 non-tariff guarantee extension applications may convert to full applications before the commissioning deadline of 31 March 2023. Capacity may also increase owing to expansions of ground source heat pump capacity linked to shared ground loop systems.[26]

The installed capacity per month is shown in Figure 2. When comparing this with Figure 1, it can be seen that the level of capacity represented by RHI applications remained more constant than the level of applications, illustrating the growth in the mean size of applications over the course of the scheme. This is discussed further in the section on Subsidy Cost-Effectiveness. The peak in capacity accredited in July 2019 is not mirrored in a peak in accredited applications at this time, so must relate to a few large applications being accredited in that month.

Figure 2: Total installed capacity of (MW) accredited full applications per month (by date of first approval)



Source: RHI monthly deployment data: October 2021. https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2021

Note: Excludes biomethane applications (they do not directly generate heat, therefore do not have an associated capacity which is recorded in the deployment data - an estimate is included below). This figure also excludes tariff

[25] This figure excludes biomethane applications because they do not directly generate heat and therefore do not have an associated capacity which is recorded in the deployment data - an estimate is included below. This figure also excludes tariff guarantee applications and non-tariff guarantee extension applications.

[26] Rules allowing Modified Capacity for shared ground loop systems were introduced on 1st April 2021. These rules are designed to support installations looking to connect heat pumps in phases, primarily for multiple domestic dwellings. https://www.ofgem.gov.uk/publications/plans-modify-capacity-shared-ground-loops

guarantee applications and non-tariff guarantee extension applications (because the capacity of these applications is not reported on a monthly basis).

Table 3 shows the breakdown of installed capacity by technology type, which highlights the noteworthy scale of biomass installed under the scheme. In addition to applications which have already been accredited, approximately 637 MW of further capacity may be installed under the scheme between the end of October 2021 and the end of March 2023, which was the commissioning deadline for full applications which were granted an extension and for tariff guarantee applications.

Table 3: Capacity of RHI applications, by technology type

Technology Type	Capacity of accredited full applications (MW)	Capacity of accredited Tariff Guarantee applications (MW)	Capacity of extension applications not yet accredited (MW)	Capacity of granted but not yet accredited Tariff Guarantee applications (MW)
Small Solid Biomass Boiler (< 200 kW)	1,533.2	-	3.4	-
Medium Solid Biomass Boiler (200-1000 kW)	2,181.2	-	70.5	-
Large Solid Biomass Boiler (> 1000 kW)	769.2	46	Not eligible	144
Solar Thermal (< 200 kW)	6.4	-	0.4	-
Small Water or Ground Source Heat Pumps (< 100 kW)	52.5	-	17.4	-
Large Water or Ground Source Heat Pumps (>100 kW)	218.7	187	Not eligible	225
Biomethane (estimated)*	990.9*	172.8*	Not eligible	135*
Biogas	328.2	-	4.0	-
Air Source Heat Pumps	33.4	-	4.8	-
CHP	316.6	-	Not eligible	34

Deep Geothermal	0.0	-	Not eligible	-
Total	6430	405.8	100.5	537

Source: RHI monthly deployment data: October 2021. https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2021 for all technologies except biomethane. Capacity of biomethane estimated, as described below, using data from the RHI application database, 31 October 2021.

* Biomethane plants do not directly generate heat and therefore do not have an associated capacity. Biomethane is injected into the gas grid. An estimate of the capacity equivalent of biomethane output can be derived from the flow rate of biomethane plants (in cubic metres). The expected annual gas generation of a biomethane plant in cubic metres is estimated at 90% of the flow rate (allowing for 10% maintenance time on the plant). kWh of gas generation is then calculated by multiplying the gas generation by 10, which is in turn converted to installed capacity on the assumption, taken from the 2014 RHI Impact Assessment, that 6MW plants will generate 40,000MWh of gas per year.

The geographic distribution of accredited full applications and the associated capacity is shown in Figures 3 and 4. The highest levels of accredited full applications were found in Scotland (4,102 applications) followed by the South West of England (2,031 applications) and West Midlands (2,347 applications). Similarly, the highest levels of capacity werefound in Scotland (1,093 MW) followed by the West Midlands (657 MW) and East Midlands (653 MW).

Figure 3: Number of accredited full applications by English region, or by country for Wales and Scotland

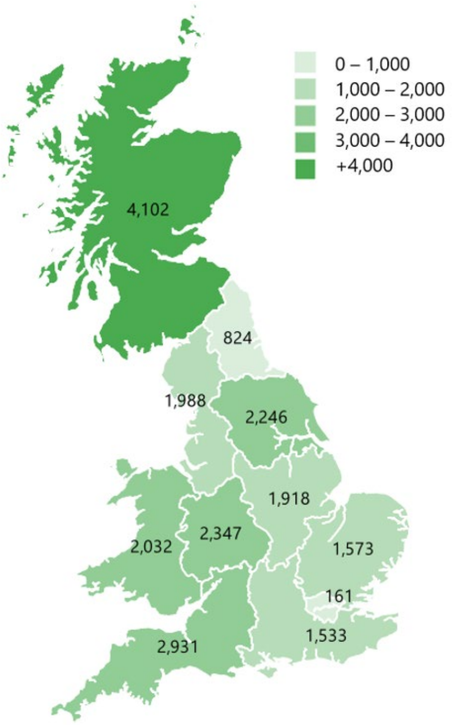
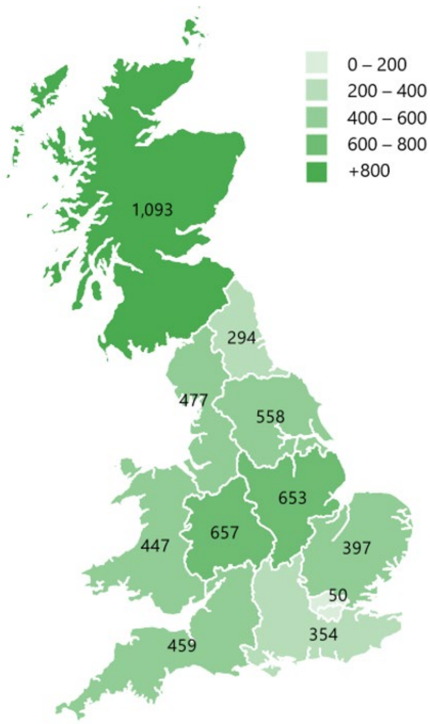


Figure 4: Capacity of accredited full applications (MW) by English region, or by country for Wales and Scotland



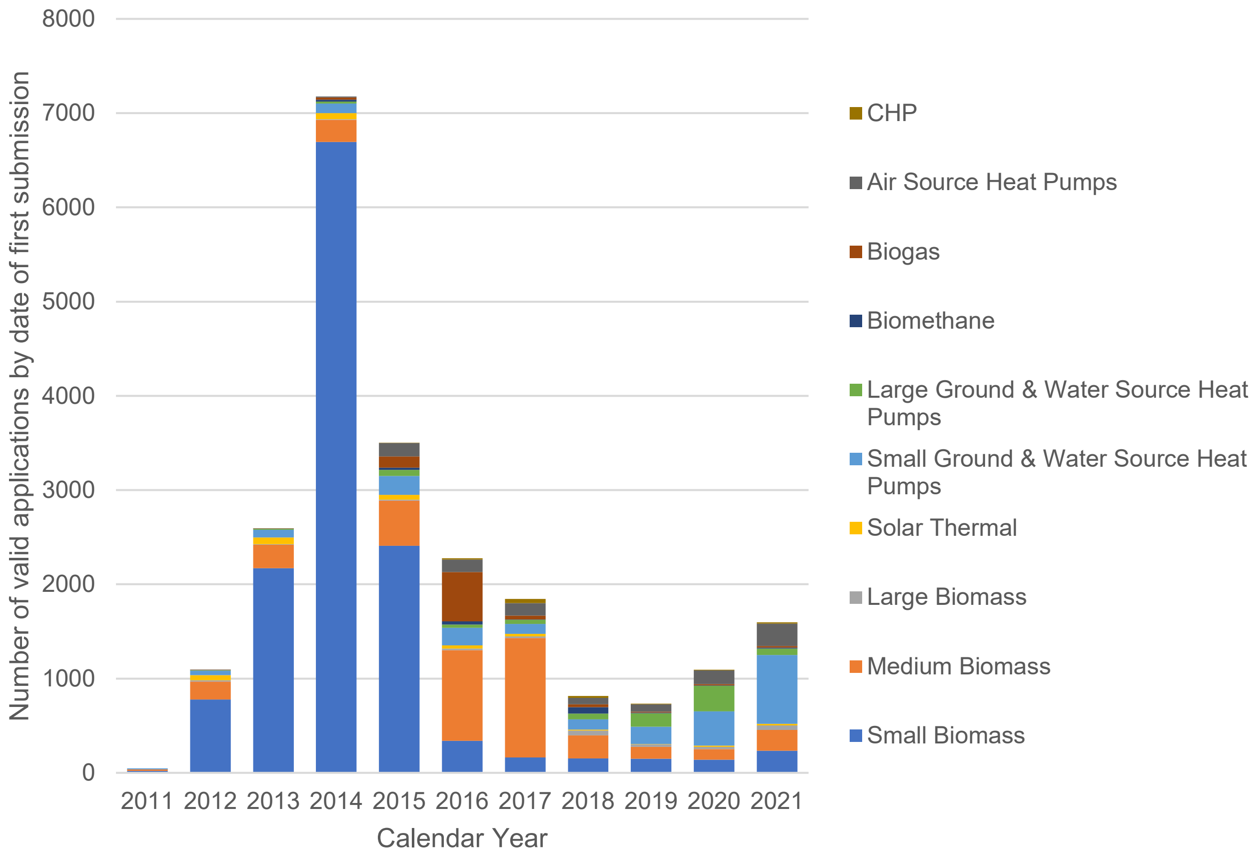
Source: RHI monthly deployment data: October 2021. https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2021

Excludes biomethane applications and all tariff guarantee applications

Analysis of the number of installations on a per capita basis shows the highest concentrations of installations are within Scottish Highlands and Borders, Wales and South West England. This correlates fairly closely with areas that have a high proportion of properties off the gas grid.

Figure 5 andTable 4 show the number of valid applications (full and tariff guarantee applications) over the course of the scheme, by technology. Applications for small biomass boilers were predominant until 2016 in terms of overall number of applications to the scheme. Medium biomass boilers were then the predominant technology during 2016 and 2017. In the latter years of the scheme, there was more diversity in the types of applications made. There were significant increases in the number of applications for ground and water source heat pumps, with small ground and water source heat pumps being the most common technology applied for from 2019 onwards. No valid applications were made for deep geothermal projects.

Figure 5: Total valid applications (full applications and tariff guarantee applications) (by date of first submission) per calendar year



Source: RHI monthly deployment data: October 2021. https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2021

Table 4: Total valid (full and tariff guarantee) applications (by date of first submission) per calendar year

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Small Biomass (less than 200kWth)	21	777	2171	6694	2408	341	162	153	148	140	235	13250
Medium Biomass (200-999kWth)	15	193	248	234	480	962	1268	245	127	111	221	4104
Large Biomass (more than 1MWth)	3	11	6	7	12	16	18	50	26	26	48	223
Solar Thermal	0	55	72	65	48	34	28	12	4	11	15	344
Small Ground & Water Source Heat Pumps (less than 100kWth)	7	49	83	102	203	186	104	106	183	363	731	2117
Large Ground & Water Source Heat Pumps (100kWth and above)	0	5	8	21	62	36	43	63	143	272	70	723
Biomethane	0	1	2	21	27	33	5	66	7	5	9	176
Biogas	0	2	1	21	117	523	42	33	12	15	18	784
Air Source Heat Pumps	0	0	0	11	142	132	131	68	77	143	238	942
CHP	0	0	0	0	1	15	45	18	7	9	13	108
Deep Geothermal	0	0	0	0	0	0	0	0	0	0	0	0

Source: RHI monthly deployment data: October 2021. https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2021

Decarbonisation

Outputs from the RHI

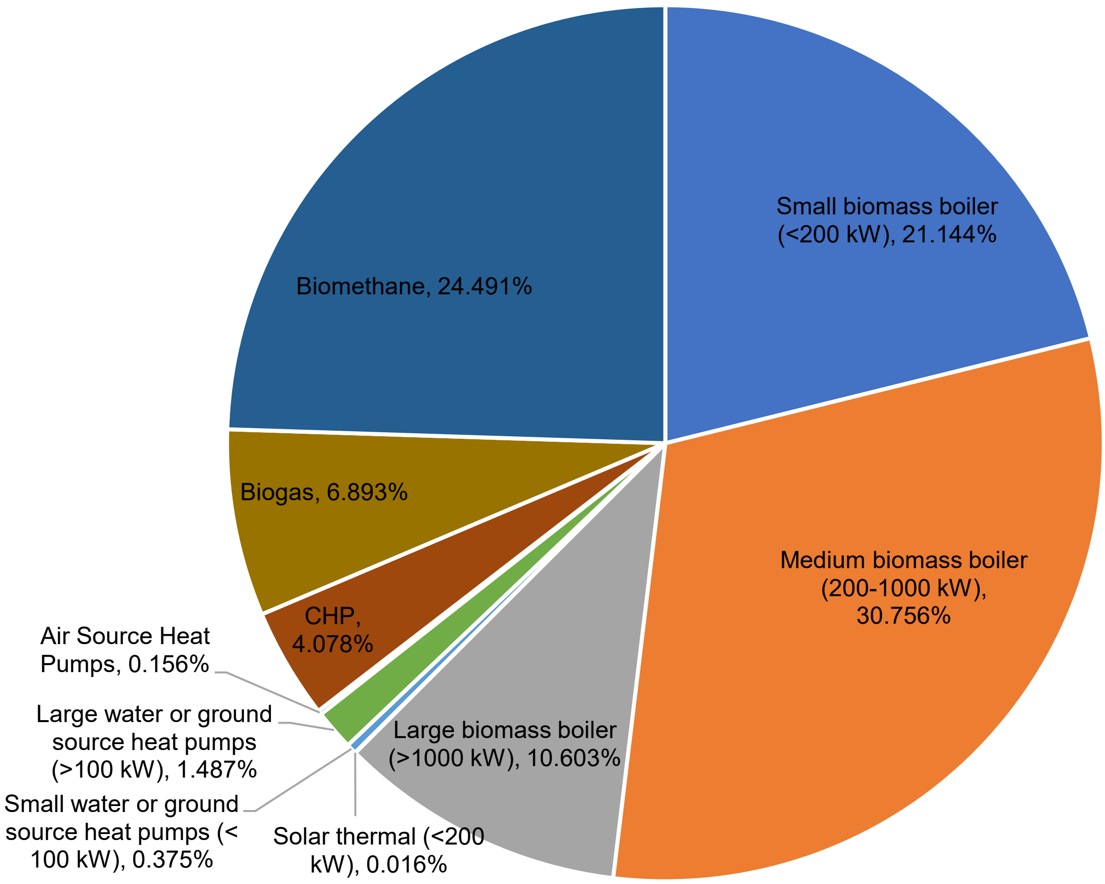
Heat generated

By the end of October 2021 [27], 68.6 TWh of heat had been paid for under the non-domestic RHI. As shown in Figure 6, biomass boilers were responsible for 63% of that heat.

Biomethane was responsible for almost 25% of the heat generated and paid for. Given that there were very few biomethane applications in the early years of the scheme and that biomethane projects tend to be very large, it is likely that the significance of the contribution from biomethane will increase over time.

Similarly, the significance of the contribution from heat pumps will also increase since these were the most common technologies in the latter years of the scheme and many of these projects have only recently started generating heat.

Figure 6: Heat generated and paid for to date, by technology



Source: RHI monthly deployment data: October 2021. https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2021

[27] This was the most recent data available at the time of the analysis on which this report is based. The analysis has not been updated with more recent data because full figures for accredited applications from the non-domestic RHI scheme will not be available until after the final commissioning deadline of March 2023. 'Heat paid for' will continue to increase during the 20-year period for which installations receive RHI payments.

Notes: Heat represented in this chart is based on meter readings received by Ofgem and does not record any activity for which there has been no reading. There can be a considerable time lapse between the generation of heat and the submission of meter readings to Ofgem. Biomethane plants do not directly generate heat, so an estimate of the heat generated from biomethane is calculated by multiplying a calorific value by the amount of subsiinto the gas grid.

The Impact Assessment for the reformed RHI[28] estimated that the non-domestic RHI would have supported 20.7 TWh of renewable heat during 2020/21, from both pre-reform and post-reform plants. During 2020/21, the total estimated heat produced by non-domestic technologies, including biomethane was actually 13.8 TWh.[29] However, it is not possible to compare these two figures directly as the Impact Assessment figure represents 'renewable heat' produced while the actual figures represent 'heat'.[30]

Carbon abatement

To end October 2021, evaluation evidence indicates that the non-domestic RHI had saved an estimated 16.1 million tonnes of CO2 equivalent. This estimate is based on carbon emissions associated with actual heat generated to date through renewable heat technologies compared to the assumed carbon emissions associated with the same energy being generated through the counterfactual technology,[31] assessed using applicant survey responses.[32] The scheme's contribution to carbon abatement will increase over time, as installations supported by the non-domestic RHI continue to generate heat that would otherwise have been generated from non-renewable sources.

Qualitative interview evidence and applicant survey evidence suggest that many non-domestic applicants retained their old heating systems as back-up and that non-renewable back-up heating systems were still used to a small extent to supplement or replace renewable heat technology use during periods where:

- the renewable heat technology was out of order or undergoing maintenance
- heating needs exceeded those that could be delivered by the renewable heat technology alone (e.g. in horticultural glasshouses during cold winter weather)
- RHI tariffs did not fully cover renewable heat technology running costs (e.g. for small and medium biomass systems, where biomass fuel costs were high and where applicants had used up their Tier 1 tariff allocation and were receiving lower Tier 2 tariffs)

[28] BEIS (2016) The Renewable Heat Incentive: A reformed and refocused scheme. Impact Assessment. IA No: BEIS032(F)-16-RH. 07/12/2016. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/577026/RHI_Reform_Govt_Response_Impact_Assessment_FINAL.pdf
[29] This figure was provided by the BEIS statistical team responsible for RHI Deployment Data publications.
[30] BEIS advise that, for the non-domestic RHI, overall renewable heat produced was greater than heat produced. Renewable heat is calculated by multiplying the heat produced by specific technologies by a certain factor, with the factor ranging from around 0.6 to 1.4 depending on the technology.
[31] Counterfactual technology means the heating system that the applicant would have installed or used in the absence of the non-domestic RHI scheme.
[32] Carbon abatement was calculated as part of the Subsidy Cost-Effectiveness Assessment. This was based on a sample of 83% of non-domestic RHI applications to October 2021, scaled up to represent the whole scheme. The sample on which the figures are based omitted installations/applications for which incomplete data was available on both costs and benefits.

The evaluation estimates of carbon abatement are based on the actual heat generated by RHI-supported installations, so they take account of these usage effects.

Impacts of the reforms

The SCEA estimates of pre-reform and post-reform outcomes are summarised in Table 5 below, based on 83% of applications.[33]

Table 5: Cumulative heat generation and carbon abatement to end October 2021

Units indicated below	Pre-reform installations	Post-reform installations	All installations	Proportion of applications accredited pre-reform
Number of accredited installations	18,864	3,318	22,182	85%
Number of installations included in SCEA analysis	16,643	1,809	18,452	90%
Capacity installed (MW)	3,667	485	4,152	88%
Renewable heat generation to end October 2021 (Twh)	59.1	3.6	62.7	94%
Carbon abatement (millions of tonnes CO2e)	15.6	0.5	16.1	97%

Source: Subsidy Cost-Effectiveness assessment, Wavehill. Heat generation and carbon abatement estimates were calculated based on a sample of 83% of RHI applications for which full cost and benefit data was available, and then scaled up to represent the whole scheme. The estimates of renewable heat generated are slightly lower than the BEIS statistics presented in Figure 6.

[33] Carbon abatement was calculated as part of the Subsidy Cost-Effectiveness Assessment and therefore omits installations/applications for which incomplete data was available on both costs and benefits, as explained in the previous footnote. Further details are given in Appendix B of the Technical Annex.

While these figures present total renewable heat generation from RHI-supported installations, there is a question about how far RHI installations were 'additional' (i.e. what proportion of these benefits would have happened anyway, without RHI support).

Additionality of non-domestic RHI

The Impact Assessment[34] for the reformed RHI assumed that 100% of renewable energy generation was additional and that the counterfactual technologies to be used in assessing additional carbon savings were based on non-renewable heat technology. For most non-domestic renewable heat technologies, the counterfactual technology was assumed to be 50% gas boilers and 50% oil boilers. In the case of biomethane, the assumed counterfactual was use of Qatari Liquified Natural Gas (LNG).

This evaluation has updated these assumptions using applicant survey data. A basic assessment of additionality was derived from applicants' statements about what heat technology they would have installed in the absence of RHI, with the options including both renewable heat technologies and non-renewable heat technologies. A number of internal sense-checks using other survey question responses were used to refine the assessment.[35]

As shown in Table 6 below, across all technology types, the percentage of non-domestic applicants suggesting that they would not have installed renewable heat technologies without the non-domestic RHI was 57% in the pre-reform period and 54% in the post-reform period. Additionality was highest for biomethane installations, which were largely driven by the RHI, and lowest for biogas and post-reform biomass. With hindsight, the Impact Assessment assumption of 100% additionality was possibly unrealistic. There is inevitably a trade-off between the level of subsidy offered and the extent to which it is sufficient to encourage people to invest in something that they would otherwise not have done. If subsidies had been larger, this might have encouraged more people to invest in renewable heat who would not otherwise have done so. But, because subsidy levels were carefully controlled, a significant proportion of those supported were people who would have installed these technologies anyway.

Table 6: Mean assessment of additionality (i.e. estimated proportion of applicants who would not have installed renewable heat technologies in the absence of the non-domestic RHI).

Additionality	Pre-reform	Post-reform
Non-domestic heat pump	52%	57%
Non-domestic biomass	58%	49%
Non-domestic solar thermal*	59%	59%
Non-domestic biogas*	52%	52%

[34] BEIS (2016) The Renewable Heat Incentive: A reformed and refocused scheme. Impact Assessment. IA No: BEIS032(F)-16-RH. 07/12/2016.
[35] Further detail is included in Appendix B of the Technical Annex on Subsidy Cost-Effectiveness Assessment method.

Non-domestic biomethane	62%	83%
All non-domestic	57%	54%

* Sample sizes were too small to allow separate analysis of pre and post-reform applications
Source: Applicant Survey data, n=893

These additionality factors are used in the value for money analysis presented below. Further analysis of the evidence on additionality is included in the next chapter of this report.

Value for Money

Outputs from the RHI

Subsidy cost-effectiveness for Government and taxpayers

The cumulative actual spend on the non-domestic RHI up to end October 2021 was £3.8 billion.[36] Participants who continue to meet scheme rules will keep receiving payments for a period of up to 20 years.

The subsidy cost-effectiveness analysis focused on the relative value for money of the different subsidies for each renewable heat technology under the non-domestic RHI. This is due to the lack of direct comparators to the non-domestic RHI scheme in terms of overall value for money. This analysis took into account the additionality factors outlined in the previous section to calculate the comparative benefits of the subsidies. The subsidy cost-effectiveness indicators for installations to date, by technology, are presented in Table 7. The non-domestic RHI scheme offered subsidies over a 20-year period: these figures are calculated on the basis of subsidy and estimated benefits to end October 2021. They do not include subsidies and benefits in future years.[37] It is important to note that this analysis focuses only on the direct value for money associated with factors such as renewable energy generated and carbon abatement, and does not capture more strategic benefits associated with factors such as developing supply chains and helping to reduce longer term costs of these technologies.

The four main indicators used, to analyse subsidy cost-effectiveness by technology, and comparing pre- and post-reform periods, are as follows:

1. Mean annual subsidy cost per kW of installed capacity
2. Subsidy cost per kWh of renewable heat generated to date
3. Subsidy cost per tonne of CO2 emissions abated to date
4. Value of Air Quality damage costs saved to date per £ subsidy invested

These indicators are not expected to change substantially over time, as the annual subsidy levels, associated heat generation and carbon abatement are expected to remain relatively

[36] BEIS payment data. Cumulative payments to end March 2021 were £3.31 billion, as presented in Ofgem (2021) Non-Domestic RHI Annual Report 2020-21.
[37] This method was chosen on the basis that a full cost-benefit analysis would be based on too many uncertain assumptions about the lifespan and future use of renewable heat technologies.

consistent over the lifespan of the technologies. As such, they are useful indicators of value for money, as they enable comparison between pre and post-reform periods.

The subsidy cost-effectiveness indicators for installations to date,[38] as presented in Table 7, show that:

- the mean annual subsidy cost for the non-domestic RHI (both pre and post-reform) was £232 per kW of installed capacity, but the cost ranged from £66 per kW for solar thermal to £599 per kW for biomethane[39]
- while solar thermal had the lowest subsidy cost per kW of installed capacity, it performed less well relative to other technologies in terms of subsidy cost per MWh of heat generated or per tonne of CO2e abated, because of lower load factors than other technologies
- the subsidy cost-effectiveness of large biomass plants was significantly better than that of small and medium biomass, owing to economies of scale
- similarly, biomass plants provided better subsidy cost-effectiveness than heat pumps, because they generally involved larger installations offering better economies of scale
- however, biomass plants incurred some air quality damage compared to air quality savings for other technologies
- the subsidy cost per tonne of carbon saved was lowest for large biomass and biomethane, because of economies of scale for both these technologies and because of upstream carbon savings for biomethane (e.g. diversion of food waste from landfill)

[38] As RHI payments continue, the subsidy cost for each technology will rise in proportion to the renewable heat generated from that technology. So, assuming that technology usage levels are broadly unchanged, the ratio of subsidy costs to benefits should not be affected by whether installations of specific technologies occurred earlier or later within the scheme.

[39] The methodology used to calculate these figures is set out in Appendix B of the Technical Annex.

Table 7: Non-domestic RHI subsidy cost per unit of benefit, by technology- whole scheme

Technology	Mean annual subsidy cost per kW of installed capacity (£)	Subsidy cost per MWh of renewable heat generated to end October 2021 (£)	Subsidy cost per tonne of CO2e abated to end October 2021 (£)	Value of Air Quality damage costs saved to date per £ of subsidy invested (£)
Heat pumps	200	134	774	0.02
Biomass (small and medium)	168	112	461	-0.47
Biomass (large)	120	40	167	-0.42
Solar thermal	66	192	593	0.09
Biogas*	460	127	282	0.26
Biomethane*	599	127	178	0.00
All technologies	232	113	280	-0.25

Source: Subsidy Cost-Effectiveness Assessment, Wavehill.
*For biogas and biomethane, these figures include both upstream and downstream emissions. Upstream emissions savings relate to diversion of food waste from landfill.

Effect of budget cap and degressions on Value for Money

Non-domestic tariffs were reviewed on a quarterly basis and were automatically degressed where specific technologies showed growth rates significantly higher than expected. The RHI reforms in May 2018 introduced new degression rules to take account of RHI subsidy potentially committed to projects in the tariff guarantee pipeline. The budget cap for the RHI scheme as a whole (domestic and non-domestic) was introduced on 1 April 2016, meaning that the RHI scheme would be closed to new applications if there was a risk that the RHI budget cap was going to be breached.

Degressions contributed to maintaining subsidy cost-effectiveness of the non-domestic RHI scheme, in terms of subsidy costs per unit of renewable heat generated and carbon abated. Key degressions included:

- significant degressions in the small and medium biomass tariff during the non-domestic RHI scheme, applied in a series of steps between July 2014 and September 2017
- one degression was applied to the tariff for large biomass, biomass CHP, solar thermal and air source heat pumps in April 2016

- two degressions were applied to small water/ground source heat pumps (in April 2016 and April 2020) and multiple degressions were applied to large water/ground source heat pumps (in April 2016 and multiple quarters during 2020/21)

The significant, multiple degressions for biomass, coupled with the impact of RHI reforms, contributed to the relatively good subsidy cost-effectiveness offered by biomass installations. However, the decline in biomass demand prompted by these degressions caused problems in the renewable heat technology supply chain, impacting on RHI's strategic objective of supply chain development, as discussed later in this chapter. Heat pump degressions did not appear to have an equivalent effect on supply chain development objectives, partly because these degressions were less significant than those for biomass and also because the main degressions occurred in the final stages of the non-domestic RHI scheme when any impact on demand was masked by heat pump investments being brought forward in anticipation of the end of the scheme. Appendix C of the Technical Annex presents tariff levels over time for each technology.

The budget cap for large water and ground source heat pumps was reached in December 2020, resulting in closure of the non-domestic RHI scheme to new applications for large water and ground source heat pumps. This is relevant to value for money because of the economies of scale provided by larger heat pump schemes. This was a temporary closure, resulting in delay for some applicants. The scheme was reopened to new applications for large water and ground source heat pumps, with an extended budget cap, from 1 February 2021. While the budget cap protected the non-domestic RHI scheme from overspending, qualitative research identified reports that the delay and uncertainty associated with application of the budget cap caused some large water and ground source heat pump schemes to be shelved, at least temporarily. There was no direct evidence of potential large-scale projects being permanently cancelled, given that the budget cap was subsequently extended.

Level of compensation to RHI applicants

The Competition and Trade Analysis (CTA) assessed the extent to which there was a risk of over or under compensation of applicants for their renewable heat technology investment. The CTA analysis provided a snapshot at the end of the scheme, based on the pre and post reform periods. As explained in Appendix B of the Technical Annex, this was based on comparing actual costs (including capital and fuel) and usage data to the assumptions made by BEIS when setting tariff levels. If actual costs to applicants were substantially less than those modelled by BEIS, for example, it would indicate greater risk that applicants may have been over-compensated through their RHI payments.

The factors assessed through this analysis included: the counterfactual technology (i.e. what heating technology would have been used by the applicant if they had not received funding through RHI), capital costs, design efficiency of technologies, fuel price, installed capacity, heat load factor and risk of gaming. These factors were all selected as they were used in the original modelling of tariff levels. The CTA then tested variance against the original assumptions, in order to draw inferences about the risk of over or under compensation.

The complexity of the original modelling meant that a more definitive assessment was not possible through the evaluation. Therefore, the purpose of this method was to provide an indication of where there was greater or lesser risk of over-compensation.

This analysis found that there was:

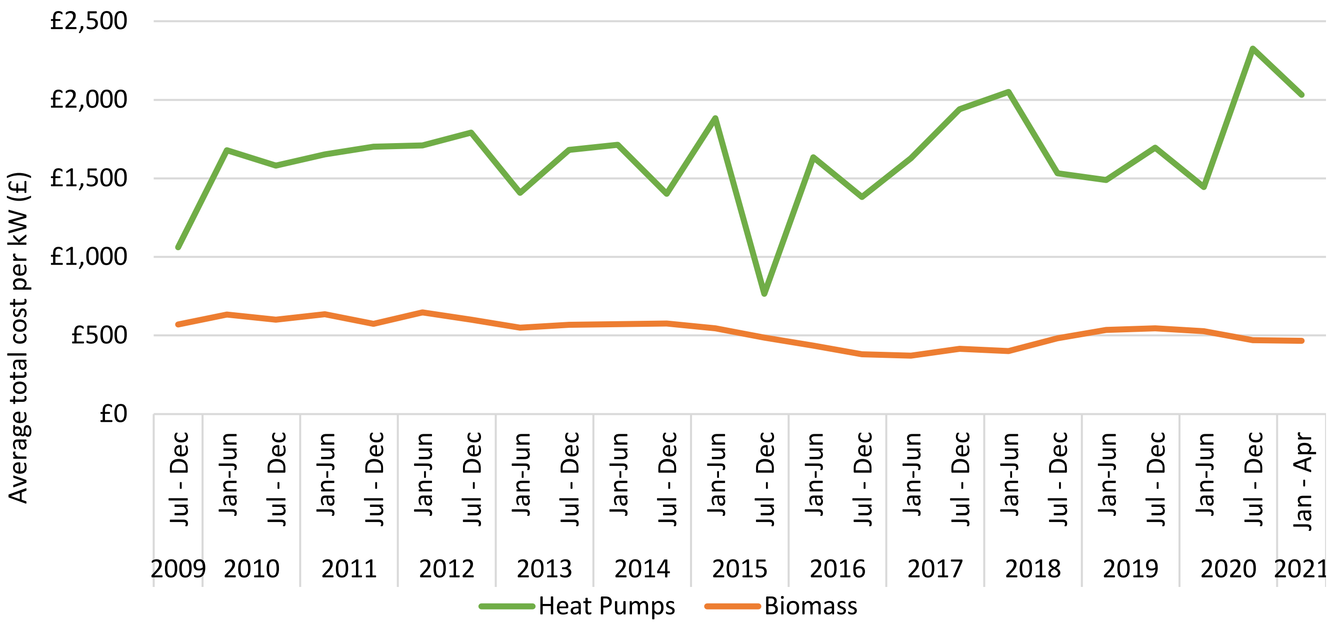
- a low risk of over-compensation for biomethane installations

- a medium risk of over-compensation for heat pump installations
- a low to medium risk of over-compensation for small-medium biomass installations
- a medium to high risk over over-compensation for large biomass plants

The capital costs of non-domestic biomass boilers were relatively stable over time, with a slight decline from the start of the scheme. Capital costs for small and medium biomass boilers were lowest in 2016-201, and biomass fuel costs were lower than the original assumed cost and efficiency levels higher than originally expected. As the fuel costs account for over three quarters of lifetime costs, the original tariff assumptions could have led to the over-compensation of non-domestic biomass applicants, particularly for larger installations where capital costs are also much lower.

The cost per unit of heat pump capacity was more volatile, with a spike in the final quarters of the scheme. This partly reflects the high proportion of small GSHPs in the final months of the scheme, as these have higher costs per unit of capacity than ASHP and large GSHP. It also reflects increasing unit costs for all types of heat pumps during the final months of the scheme, possibly owing to supply constraints which may have resulted in higher prices.

Figure 7: Median cost per unit of installed capacity (nominal prices)



Source: RHI application data by installation date (estimated as the earlier of the application submission date and commissioning date). (Note: the figure for non-domestic heat pumps in July-September 2020 was based on a small number of installations. Tariff guarantee applications are not included. Median figure used instead of the mean as the data provided on this varied in quality, so the median gave better assurance of more consistent data over time).

Value for money to applicants may have been influenced by supply chain issues. Some experienced non-domestic installers and applicants suggested during qualitative research that the RHI may have contributed to inflation in prices within heat pump and biomass supply chains (i.e. that the price of RHI-eligible equipment was higher than the price of equivalent non-eligible equipment). This would mean that some of the value generated by the RHI was retained by manufacturers and equipment suppliers, rather than installers and applicants. The evaluation was not able to find direct evidence to substantiate or refute these claims. Supply chain development is discussed in more detail in the next section.

Qualitative research with non-domestic RHI applicants in the manufacturing, agriculture and forestry sectors during 2020 found evidence of biomass fuels being subject to significant price increases. This was reported to be due, at least in part, to the RHI increasing demand for biomass fuel, although other factors such as COVID, EU exit and wider timber market factors may have played a part.

Similarly, qualitative research with biomethane applicants during 2019 found evidence of feedstocks for anaerobic digestion being more costly than predicted in the RHI Impact Assessment. While the IA predicted that applicants would receive 'gate fees' for using feedstock streams that would otherwise require disposal as waste, many applicants reported receiving low gate fees or having to pay for feedstock. This was linked to competition for certain waste streams: qualitative research with biomethane applicants found that, in areas with substantial anaerobic digestor capacity (e.g. London, North West, Midlands), competition for food waste streams was reported to be driving gate fees very low or close to zero.

Impacts of the reforms

The RHI reforms introduced in 2017/18 were intended to improve value for money from non-domestic installations. Subsidy cost-effectiveness indicators for pre-reform installations are shown below in Table 8 while post-reform cost/benefit ratios are shown in Table 9. Comparison of pre-reform and post-reform figures overall shows that the subsidy costs per unit of benefit were lower post-reform: mean annual subsidy cost per kW of installed capacity (when averaged across all renewable heat technologies) reduced from £244 per kW pre-reform to £134 per kW post-reform. This is likely to be due to a combination of reform effects (e.g. the removal of banding from biomass tariffs, which had the effect of reducing tariffs for small and medium biomass plants) plus automatic tariff degressions.

There were variations at technology level, with some technologies such as biogas and biomethane showing significantly improved subsidy cost-effectiveness post-reform. However, where the reforms introduced higher tariffs in order to stimulate demand (e.g. large biomass), the subsidy cost-effectiveness was obviously reduced post-reform. For heat pumps, additionality increased in the post-reform period (leading to an improvement in subsidy cost-effectiveness per kW from £214 pre-reform to £190 post-reform), but the reported mix of counterfactual technologies shifted post-reform so the subsidy cost per tonne of CO2e abated was slightly higher post-reform (£837 per tonne compared to £757 per tonne pre-reform).

Table 8: Non-domestic RHI subsidy cost per unit of benefit, by technology – pre-reform

Technology	Mean annual subsidy cost per kW of installed capacity (£)	Subsidy cost per MWh of renewable heat generated to end October 2021[40] (£)	Subsidy cost per tonne of CO2e abated to end October 2021 (£)	Value of Air Quality damage costs saved to date per £ of subsidy invested (£)
Heat pumps	214	136	757	0.02
Biomass (small and medium)	170	114	467	-0.47
Biomass (large)	93	35	145	-0.52
Solar thermal	63	192	588	0.09
Biogas	467	127	282	0.26
Biomethane	599	128	179	0.0
All technologies	244	115	281	-0.24

Source: Subsidy Cost-Effectiveness Assessment, Wavehill.

Table 9: Non-domestic RHI subsidy cost per unit of benefit, by technology – post-reform

Technology	Mean annual subsidy cost per kW of installed capacity (£)	Subsidy cost per MWh of renewable heat generated to end October 2021[41] (£)	Subsidy cost per tonne of CO2e abated to end October 2021 (£)	Value of Air Quality damage costs saved to date per £ of subsidy invested (£)
Heat pumps	190	129	837	0.02

[40] This table presents findings on installations that were accredited pre-reform, taking into account the subsidies and benefits generated by these installations up to end October 2021.
[41] This table presents findings on installations that were accredited post-reform, taking into account the subsidies and benefits generated by these installations up to end October 2021.

Biomass (small and medium)	133	63	267	-0.86
Biomass (large)	168	62	264	-0.19
Solar thermal	85	192	671	0.13
Biogas	202	77	172	0.45
Biomethane	N/A	56	105	0.00
All technologies	134	63	248	-0.38

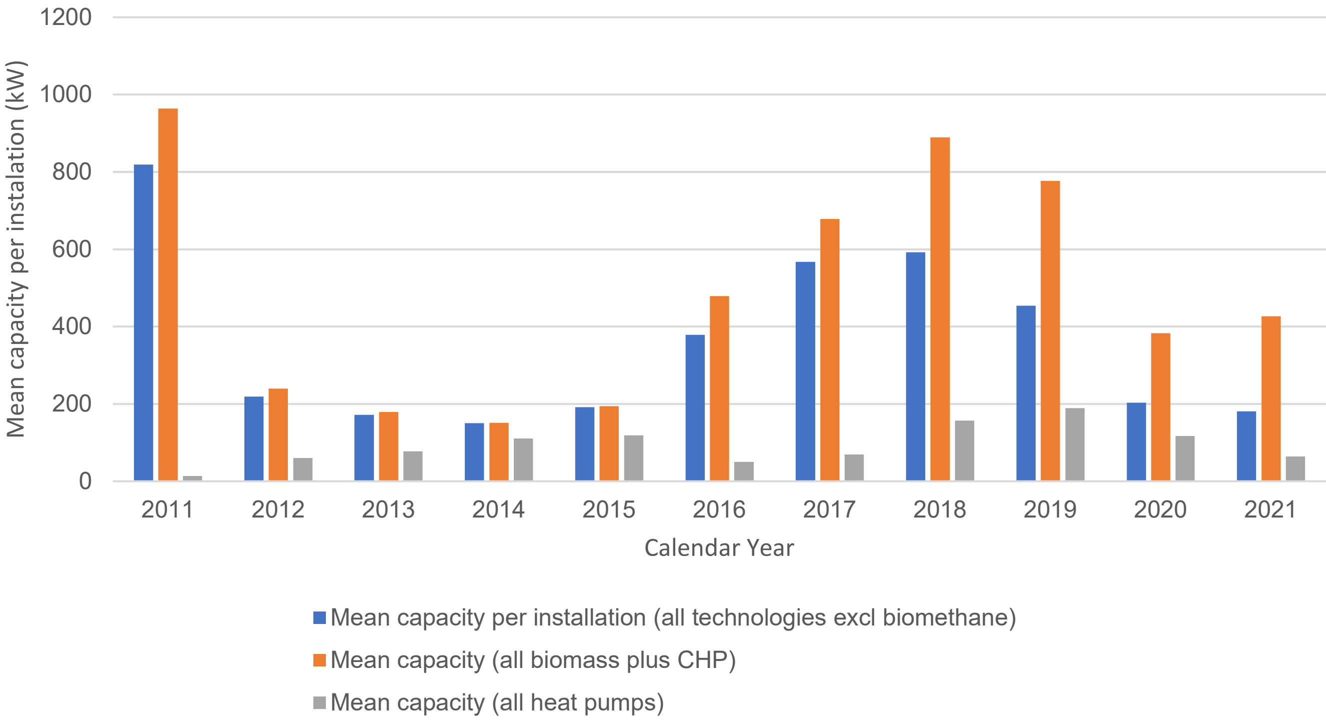
Source: Subsidy Cost-Effectiveness Assessment, Wavehill.

One of the ways in which the reforms were intended to improve value for money was by increasing the mean size of non-domestic RHI installations (e.g. through increasing tariff levels for large biomass compared to small and medium-scale biomass). Figure 4 shows that – as intended - there was an increasing trend in the mean size of non-domestic installations between 2014 (when small biomass applications were at their peak) and 2018 (post-reform). However, the mean size of applications was actually highest around the start of the scheme, in 2011, owing to a few large biomass applications being accredited in the first year of the scheme. The mean capacity per non-domestic RHI installation decreased again after 2018, at least in part because of a decline in accredited biomass applications, although this trend may be reversed when tariff guarantee and non-tariff guarantee extension applications are included.

The trends on mean heat pump sizes are less clear. While the mean size of heat pump applications was highest post-reform, in 2019, there has been some fluctuation in mean heat pump capacity from year to year. Again, tariff guarantee and non-tariff guarantee extension applications may increase capacity in the final year of the scheme as these include some large heat-pump projects that have not yet been commissioned.

Biomethane applications are excluded from Figure 8, because BEIS statistics do not assign a ‘capacity’ to biomethane plants. As noted above, tariff guarantee applications and non-tariff guarantee extension applications are also excluded from the chart. As all three categories include large applications, this may help to explain the apparent reduction in mean capacity beyond 2018, when tariff guarantees were introduced.

Figure 8: Mean capacity per non-domestic RHI installation (kW)



Source: RHI monthly deployment data: October 2021. This data excludes biomethane, tariff guarantee applications and non-tariff guarantee extension applications.

Supply Chain Development

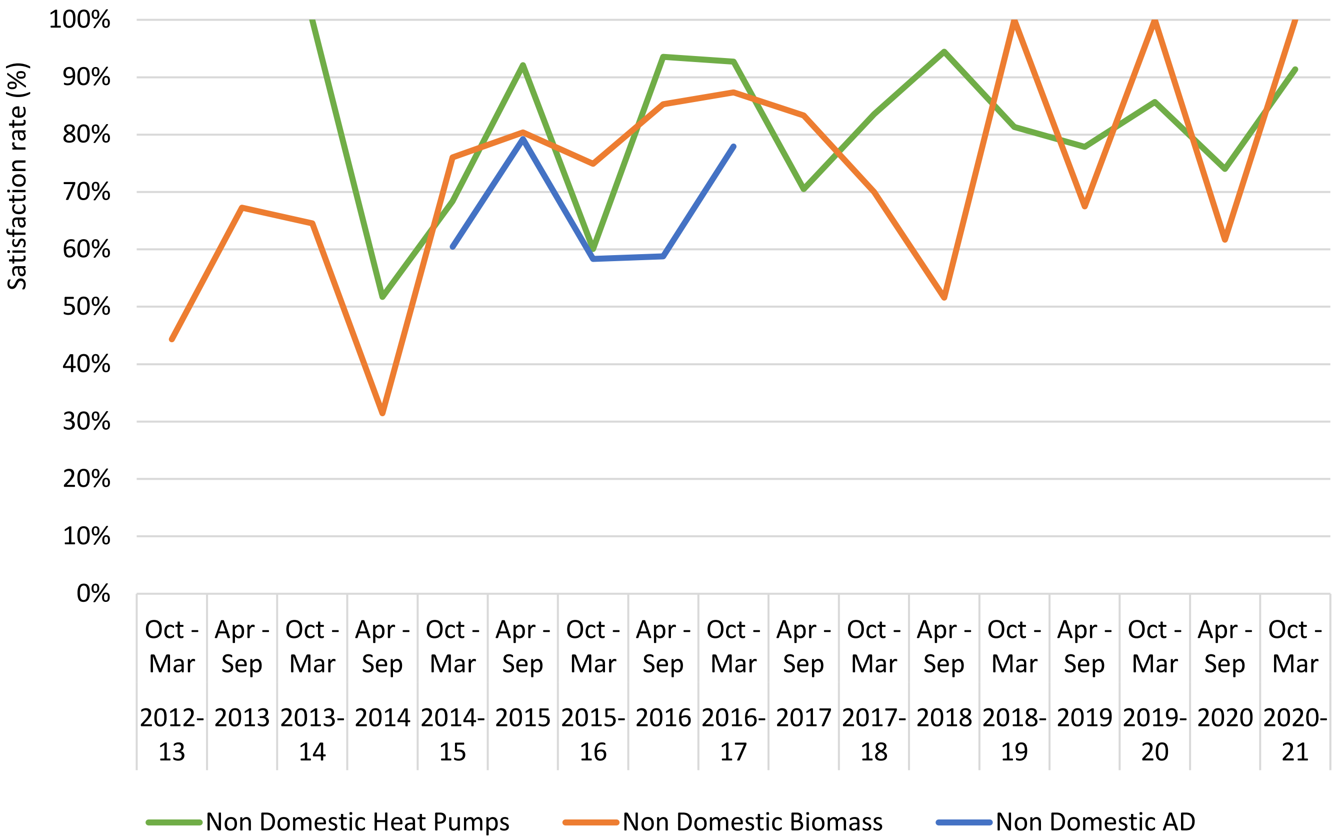
One objective of the RHI was to support the development of a sustainable market for renewable heat technologies, including development of the supply chain for renewable heat technologies. The first part of this section sets out the experiences of non-domestic RHI applicants in relation to the supply chain, while the second part presents evidence about supply chain development for different renewable heat technologies.

RHI applicant experiences of the renewable heat technology supply chain

User satisfaction with renewable heat technology, and the proportion of users experiencing faults with renewable heat technology, can be taken as indirect indicators of a sustainable market for renewable heat technology: a robust, good quality supply chain would be expected to generate high levels of satisfaction with the technology and low levels of faults. Most of the indicators of RHI experiences have been improving during the non-domestic RHI scheme, albeit with variation from year to year.

Looking first at user satisfaction levels, as shown in Figure 9, overall satisfaction levels amongst non-domestic biomass applicants responding to the applicant survey rose slightly during the scheme, albeit with variations from year to year. Overall satisfaction levels amongst heat pump users varied between 50% and 100%, with no obvious pattern. Small sample sizes for AD survey respondents mean that satisfaction data was only available for part of the pre-reform period, from October 2014 to March 2017, which showed slightly lower rates of satisfaction than for biomass and heat pumps during that period.

Figure 9: Proportion of applicants satisfied with their non-domestic renewable heat technology[42] (biomass, heat pumps, anaerobic digestion)

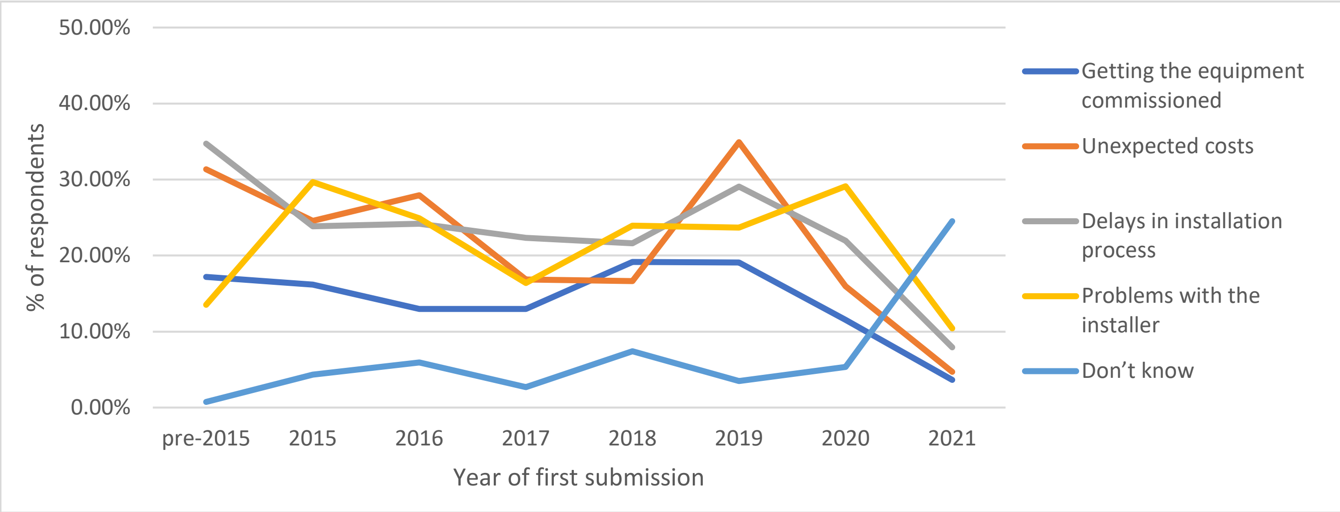


Source: Applicant survey data; n=899. Percentages refer to the proportion of respondents making installations in each 6-month period, by installation date (estimated as the earlier of the application submission date and commissioning date).

The applicant survey found that non-domestic applicants cited a range of installation problems. As shown in Figure 10, these included delays in the installation process, problems with the installer, problems getting the equipment commissioned and unexpected costs. There were slight downward trends in some indicators, but the reduction in the proportion reporting problems in 2021, and associated rise in 'don't knows', may reflect some final year applicants not having fully completed their installations at the time of the survey.

[42] How satisfied are you with the following: the Renewable Heat Technology overall?

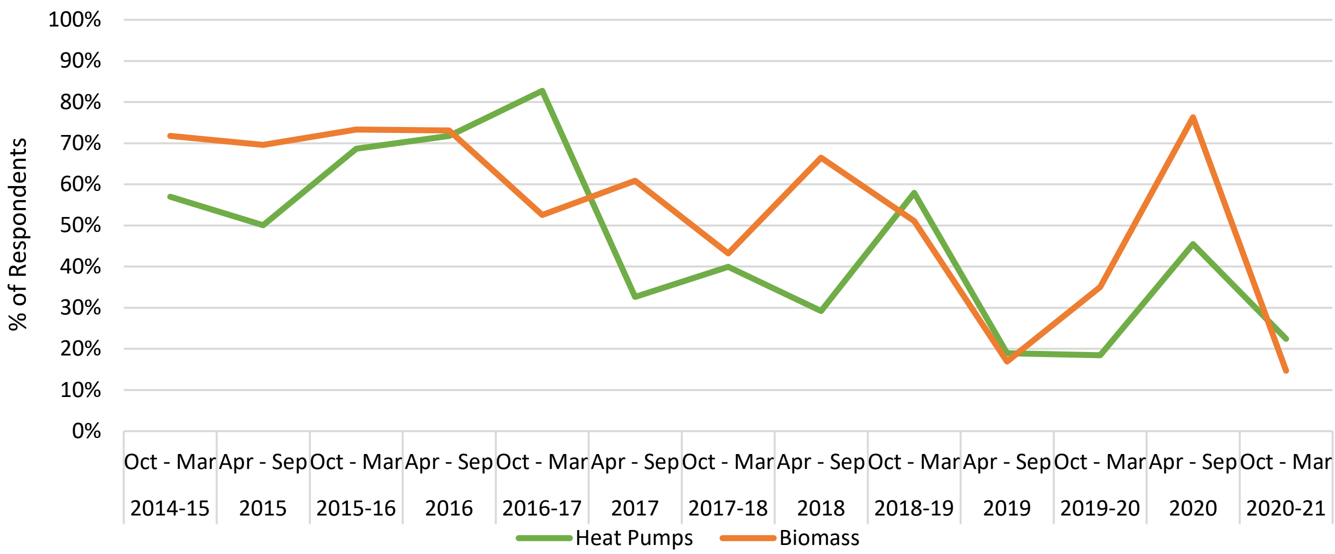
Figure 10: Proportion of applicants reporting problems with installation of their renewable heat technology (all technologies)



Source: Applicant survey data, n=1,966. Percentages refer to the proportion of applications first submitted within the relevant period.

As shown in **Figure 11**, the proportion of both biomass and heat pump applicants surveyed experiencing faults with their technology started at a relatively high level (57% for heat pumps and 72% for biomass). The proportion of applicants experiencing faults shows an overall decline during the scheme, albeit with variations from year to year. This is consistent with levels of satisfaction tending to increase over time, as shown in Figure 9. It is not clear why there was a spike in faults in April to September 2020 but this might be related to constraints imposed by the COVID pandemic.

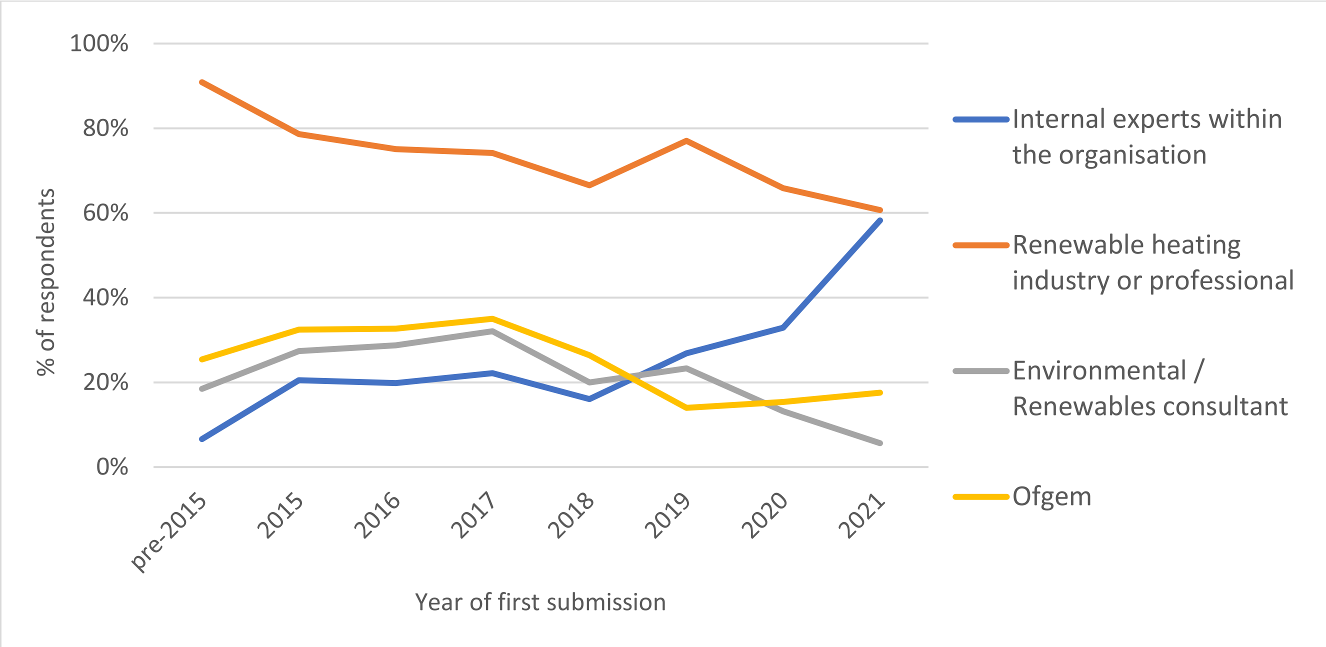
Figure 11: Proportion of applicants experiencing faults with their non-domestic renewable heat technology (heat pumps, biomass)



Source: Applicant survey data, n=562. Percentages refer to the proportion of respondents making installations in each 6-month period, by installation date (estimated as the earlier of the application submission date and commissioning date).

Applicant survey data also suggests that there was a growing understanding of renewable heat technologies within organisations making non-domestic RHI applications, over the course of the scheme. As shown in **Figure 12**, applicants increasingly accessed information via internal experts within their organisation rather than relying on renewable heating industry installers, professionals or consultants to advise on renewable heat technology installations, particularly towards the end of the scheme. This may reflect the increasing size of applications during the scheme, as a firm making a large tariff guarantee application in the later stages of the scheme may be more likely to have an internal expert than a firm making a small biomass application in the early stages of the scheme.

Figure 12: Proportion of applicants accessing different sources of information on installing renewable heat technologies (multiple responses allowed; all technologies)



Source: Applicant survey data, n=1,067. Percentages refer to the proportion of applications first submitted within the relevant period.

Supply chain development by technology

One of the objectives of the RHI scheme was to contribute to the development of a sustainable market for renewable heat technologies by stimulating demand. The expectation was that increased demand would stimulate greater supply, in turn driving down costs. While demand for installations under the scheme was stimulated overall, as shown in Figure 5 above, the level of stimulation varied over time for different technologies:

- the market for small and medium biomass boilers was strongly stimulated in the early years of the pre-reform RHI scheme (2012-2016) but declined strongly after small and medium biomass tariffs were degressed in 2014/15 and 2016/17 respectively
- demand for building biomethane and biogas plants was stimulated by the RHI but showed a stop-start pattern, reflecting the introduction of new feedstock rules with the reforms in 2018 (as discussed in the next chapter on 'How did the RHI contribute to observed outcomes?') and the details of evolving tariff guarantee rules

- the market for large biomass and for heat pumps (both large and small) showed steadier demand throughout the scheme, with some growth between the start and end of the scheme and some stimulation from the reforms
- demand for solar thermal remained low and slightly declined towards the end of the scheme, likely due to competition from solar PV installations[43]
- there was a final spike in demand for all technologies supported by the non-domestic RHI before closure of the scheme in March 2021

This complex and evolving situation impacted on supply chain development for different renewable heat technologies, as discussed below.

Biomass supply chain

Renewable heat technology installers and manufacturers reported in qualitative interviews that the early years of the pre-reform RHI had stimulated the supply chain for small and medium biomass installations. In this period, qualitative research with RHI applicants, installers and supply chain stakeholders suggest the RHI attracted good-quality installers into the renewable heat technology market, but also attracted some less competent or less scrupulous installers that were interested in generating a quick profit. Supply chain stakeholders reported that the small and medium biomass ‘boom’ in 2014/15, stimulated by the RHI, was followed by a decline between 2016 and 2018 when many installers and some manufacturers struggled to survive owing to significant reductions in RHI tariffs for biomass and consequent reductions in rates of biomass installations. The market for biomass boilers stabilised at a lower level after 2018, with a final spike in activity being observed before the end of the scheme in March 2021. Survival strategies during the decline, reported by supply chain stakeholders and identified in qualitative research with installers, included:

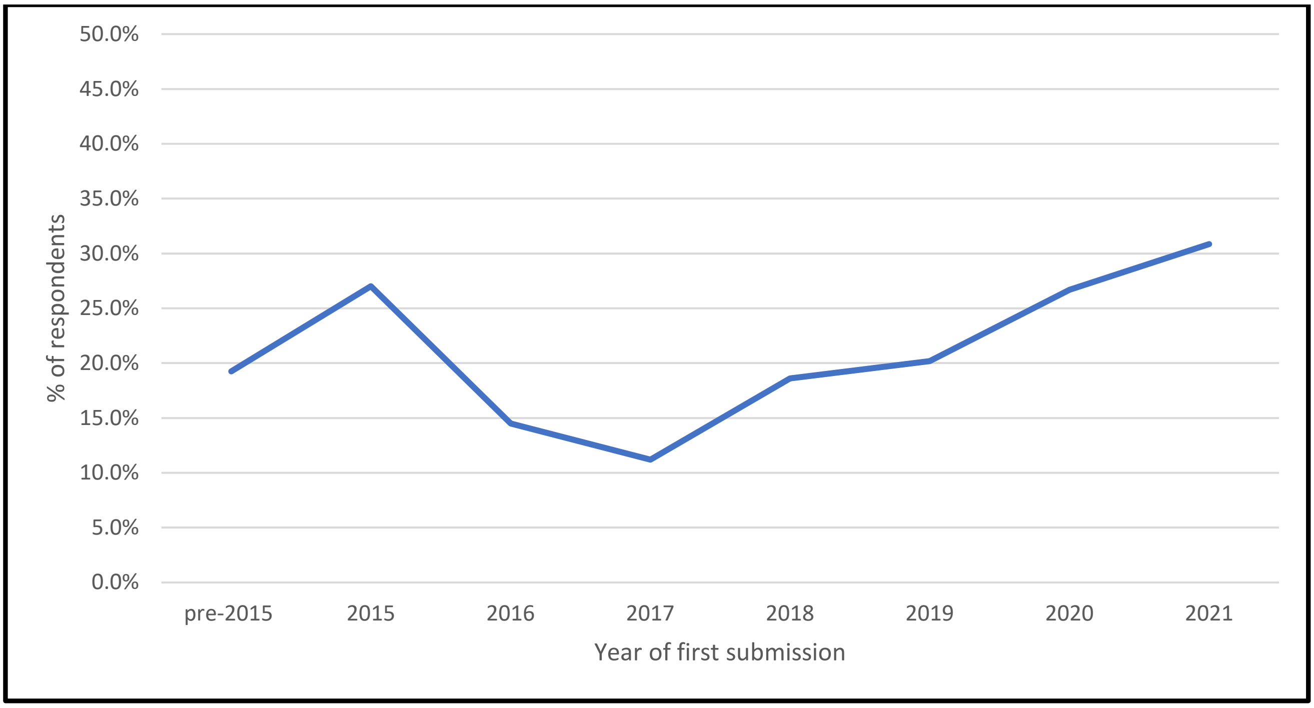
- focusing on larger commercial installations, involving a smaller number of ‘large’ biomass installations
- diversifying from installation into biomass fuel supply and equipment maintenance
- diversifying from biomass into other renewable heat technologies (e.g. heat pumps) and/or other renewables (e.g. solar PV, battery storage, electric vehicles)
- diversifying into wider building services or construction
- manufacturers focusing on non-UK markets for biomass installations

The evaluation examined evidence about difficulties that applicants experienced in finding suitable installers, as an indication of the state of the supply chain across all technologies, including biomass. Figure 13 shows the proportion of non-domestic applicants responding to the applicant survey who reported difficulty in finding a suitable installer, across all technologies. The proportion reporting difficulty was relatively high during the biomass ‘boom’ years (e.g. 26% from October 2014 to September 2015) but then declined during 2016-2017 when the biomass market began to decline in response to tariff degressions. The proportion of applicants having problems finding a suitable installer rose steadily from 2017 to 2021, primarily reflecting growth in the heat pump market during this period (see next sub-section).

[43] Although the solar PV was unsubsidised after the end of the Feed-In-Tariff in 2019, significant cost reductions in the supply cost for solar PV panels (arising from international market factors) have contributed to solar PV installations improving in cost-effectiveness in recent years.

Qualitative research with installers indicated that closure of the Renewables Obligation and Feed-in-Tariffs schemes contributed to supply chain shrinkage for biomass installations, in parallel with changes to the RHI scheme.[44]

Figure 13: Problems encountered before installing the renewable heat technology: Finding a suitable installer (% of respondents; all technologies)



Source: Applicant survey data, n=1,838. Percentages refer to the proportion of applications first submitted within the relevant period.

Supply chain stakeholders consulted for the SMA described biomass boilers as a mature technology with little or no scope for cost reductions, particularly given increased steel prices in recent years. They suggested that significant cost reductions would require economies of scale that were unachievable given the depressed state of the biomass boiler market in the UK in recent years, post-reform. Sector body and manufacturing consultees reported during 2021 that confidence in the UK market was low compared to other parts of Europe, such as Scandinavia and Switzerland, which had maintained more generous support for biomass.

Applicants sourced biomass boilers in a number of ways. Application data shows evidence of new biomass boilers being sourced from both UK and overseas manufacturers. However, qualitative research with agricultural and forestry applicants during 2020 also found evidence of a market in second-hand biomass boilers that were already accredited under the RHI. Qualitative research with agriculture and forestry sector stakeholders reported that boilers accredited under the pre-reform RHI had higher market values than those accredited in the post-reform period, because the owner would receive higher RHI tariff rates for heat

[44] The Feed-in-Tariff (FiT) scheme closed on 31 March 2019 and the Renewables Obligation (RO) scheme closed on 31st March 2017. These schemes had offered subsidies for renewable electricity generation. Some installers were active in both renewable heat and renewable electricity markets so were affected by changes to both heat and power subsidies. Closure of the FiTs and RO scheme also affected investment in biomass and biogas CHP plants as these could previously attract both FiTs/RO and RHI subsidies, for renewable electricity and renewable heat generation respectively.

generated. This was substantiated through observation of online adverts for second-hand RHI-accredited biomass boilers.

The evaluation also considered the impact of RHI on other elements of the supply chain (e.g. finance providers and fuel suppliers). Installers played a key role in marketing biomass boilers in the early stages of the RHI scheme, with finance sometimes being part of the package. Applicant survey data shows that the proportion of applicants using external finance varied from 64% in April to September 2016, down to 16% in the period October 2017 to March 2018, but recovered to 58% in the period October 2020 to March 2021. Qualitative evidence from applicants indicates that sources of external finance included banks and equipment-related finance[45]. Qualitative research with installers suggested that the non-domestic RHI also contributed to growth in the market for biomass fuels, as usage of existing systems continued despite the decline in the market for new biomass boilers in the post-reform period. However, the number of suppliers of woody biomass registered on the Biomass Suppliers List fell significantly from 2018 to 2022. There may be a number of reasons for the decline in the number of woody biomass suppliers, including the introduction of higher quality standards for wood fuels as well as RHI tariff degressions for biomass installations.[46]

Heat pump supply chain

The supply chain for heat pumps developed more steadily, stimulated by both the non-domestic and domestic RHI. The boundary between the non-domestic and domestic heat pump market was slightly blurred because some 'non-domestic' heat pump installations involved multiple properties owned by social landlords. For example, non-domestic heat pump installations included communal heat pumps serving blocks of residential flats and also 'shared ground loop' heat pumps where residential properties each had their own heat pump but were served by a common ground loop. Heat pump applications also included a number of post-reform tariff guarantee applications for large non-domestic heat pump systems (e.g. horticultural and/or urban heat networks).

The evaluation collected evidence about difficulties that applicants experienced in finding suitable installers, as an indication of the state of the heat pump supply chain. The proportion of non-domestic heat pump applicants responding to the applicant survey who reported difficulty in finding a suitable installer varied between 8% and 34%, with the highest rate being observed in the period April to September 2019. The rate was also high (32%) in the final six months of the scheme (October to March 2021). Application data suggests that stimulus to the heat pump market from the RHI reforms contributed to constraints in the supply chain during 2019, as heat pump installation rates were highest in that year. Consultations with supply chain stakeholders suggest that a final rush of demand for heat pumps prior to closure of the non-domestic RHI scheme appears to have contributed to constraints in the supply chain during the final months of the scheme. Supply chain stakeholders (as part of the SMA analysis) reported during 2020 that there was a shortage of skilled installers in the market and that EU exit and COVID had contributed to delays and additional costs in sourcing equipment.

Some ground source heat pump manufacturers and installers reported in qualitative research that the RHI did not stimulate as much growth as they had expected overall, largely because of the focus on biomass in the early stages of the scheme. However, the evaluation found evidence of the reformed RHI contributing to the roll-out of some technological innovations in

[45] Equipment-related finance involved finance companies providing asset-backed finance, sometimes provided via equipment suppliers.
[46] Data from the biomass suppliers list was accessed for the Market Definition research presented in Appendix C of the Technical Annex. https://biomass-suppliers-list.service.gov.uk/home

the ground source heat pump market (for example, the development of small heat pumps that could fit within small social housing properties, as discussed further in the next chapter on 'How did the RHI contribute to observed outcomes').

The evaluation also found that the proportion of applicants using external finance providers varied considerably. Applicant survey data shows that the proportion of applicants using external finance (e.g. bank loans) for heat pumps varied from 75% in the period October 2014 to March 2015, down to 18% in the period April to September 2018. The proportion using external finance then recovered to 62% in the period October 2019 to March 2020, with the reasons for these fluctuations being unclear. Qualitative evidence from applicants indicates that sources of external finance included banks and equipment-related finance.

Anaerobic digestion supply chain (biogas and biomethane)

Qualitative interviews with the anaerobic digestion (AD) stakeholders and manufacturers, together with SMA consultations with supply chain stakeholders during 2021, suggest that the biomethane and biogas supply chain was closely tied to RHI policy. Despite some growth in the UK market, supported by RHI, supply chain stakeholders reported that there was insufficient growth to encourage further AD supply chain companies to set up UK bases. Supply chain stakeholders reported that the AD market had been negatively impacted by COVID (e.g. because of temporary business closures leading to lower availability of food waste and lower operating yields at AD plants). They also reported that EU exit had contributed to delays and extra costs in sourcing equipment. The AD sample was too small for the applicant survey to generate meaningful evidence about trends in the availability of AD installers.

Qualitative research with biomethane applicants during 2018/19 found evidence that feedstock prices and availability were critical elements in the business case for AD investments. At that time, feedstock costs were higher than envisaged in the Impact Assessment for the reformed RHI. Across those biogas/biomethane applicants that provided specific feedstock tonnages in applicant survey responses, 31% suggested that they were using their own waste for at least one type of feedstock. Unless applicants were able to use their own waste streams as feedstock, many reported that they had to pay for waste feedstocks rather than receiving gate fees for processing them, as the Impact Assessment had envisaged. An annual survey of gate fees in 2020, undertaken by WRAP, found a wide range of gate fee levels across the country. According to the WRAP survey, gate fees were not consistently high but varied according to the regional supply and demand balance for different waste streams.[47]

Summary of impacts of the reforms on progress towards a sustainable market

The evaluation has assessed progress towards a 'sustainable market' for renewable heat technologies through the Sustainable Markets Assessment. The term 'sustainable market' is not straightforward to define. For the purposes of this evaluation, the stated aim with respect to a sustainable market was: 'for each renewable heat market to operate without (or with less) public subsidy, with the market growing to the size needed for deployment to meet Government decarbonisation targets for 2050'.

[47] Gate Fees report, 2020. (Published 27 January 2021). This report is prepared by WRAP, presenting findings from an annual survey of gate fees within the UK. Accessed at: https://wrap.org.uk/resources/report/gate-fees-report-2020.

As a starting point for monitoring progress towards a sustainable market, a logic model[48] was developed to describe how an increase in demand for renewable heat would help to stimulate supply, leading ultimately to cost reductions and further increases in demand. The sustainable markets analysis focused on assessing changes in the demand, supply and cost of renewable heat technologies, while also capturing change in a range of underlying drivers. The drivers monitored during the evaluation included:

- customer awareness of and perceptions about renewable heat technologies, product reliability and quality, and availability of finance, as drivers for increasing demand for renewable heat technologies
- investment appetite, skills development and fuel/feedstock availability as drivers for increasing supply of renewable heat technologies
- product innovation and economies of scale, as drivers for reducing renewable heat technology costs

While the impact of specific reforms is discussed in the next chapter, high-level findings on progress towards a sustainable market in the post-reform period, compared to the pre-reform period, were as follows:

- installation numbers were generally lower in the post-reform than pre-reform period, although there was a spike in applications during the final months of the scheme
- as outlined above, the size of the biomass market has declined since the reforms, but there has been slow but steady growth in the heat pump and AD markets since the reforms, while the non-domestic solar thermal market has remained very small
- other market indicators suggest overall progress towards a sustainable market, particularly for heat pump and AD technologies
- as shown above, the proportion of non-domestic applicants experiencing faults with their renewable heat technology installations varied from year to year but, overall, there was a lower level of post-reform applicants reporting faults, compared to pre-reform applicants
- similarly, the proportion of non-domestic RHI applicants reporting satisfaction with their non-domestic renewable heat technology was variable but, on average, was higher post-reform than pre-reform
- the level of understanding of renewable heat technology installations within applicant organisations has risen post-reform, as evidenced by the sources of advice used by renewable heat technology applicants

Detailed assessment of the impact of specific reforms is presented in the next chapter, while assessment of the future sustainability of the UK market for non-domestic renewable heat technology installations, and the market's resilience to the end of the non-domestic RHI scheme, is discussed in the final chapter of this report.

[48] The logic model is presented in the Sustainable Markets Assessment section of Appendix B in the Technical Annex.

How did the RHI Contribute to Observed Outcomes?

An exploration of the non-domestic RHI's role in supporting the installation of renewable heating technologies, focusing in particular on the impact of the scheme's reforms. This chapter explores how and why the RHI contributed to observed outcomes, and in what contexts, drawing on the evaluation's realist analysis for specific groups of applicants.

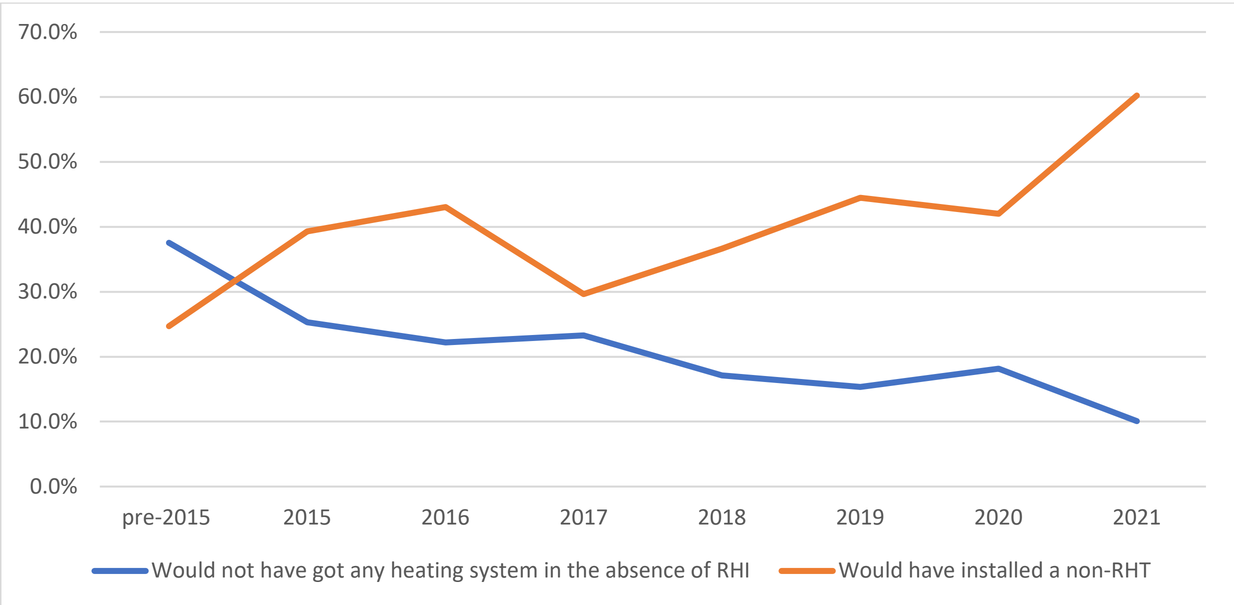
Introduction

This chapter summarises the evidence from the evaluation on the extent to which the reformed non-domestic RHI played a causal role in supporting the installation of renewable heating technologies. The first section provides an overview of the observed effects of the RHI on decisions to install renewable heat technologies. The subsequent sections synthesise the findings relating to each of the principal reforms to the scheme.

Overview

In recent years, and unlike the scheme's early years, applicants were more likely to suggest that they would have installed a non-renewable heating technology if RHI did not exist. A decreasing share of applicants said that they would not have installed any heating system at all.

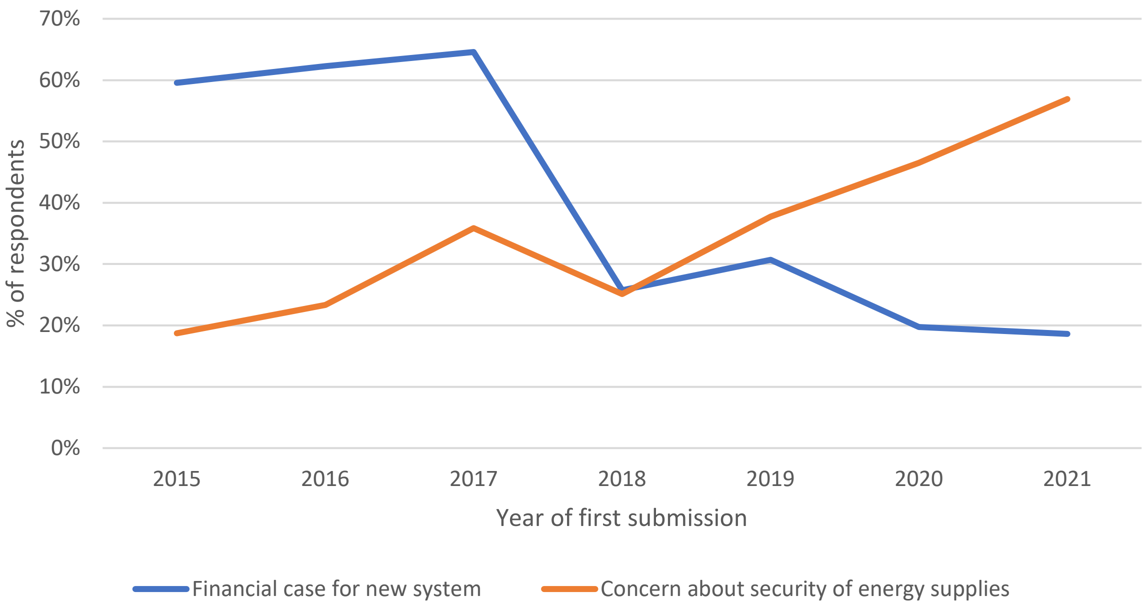
Figure 14: Effect of RHI on decision to install a renewable heating system by first submission year



Source: Applicant survey data, n=2,075. Percentages refer to the proportion of applications first submitted within the relevant period.

Among applications submitted after the reforms were enacted, concerns about the security of energy supplies replaced the financial case for the new system as the most common motivation for installing a new heating system.[49] This was mainly driven by the increase in heat pump installations in recent years and the shift away from biomass, as more than 40% of heat pump applicants expressed concerns about the security of energy supplies, compared to a little over 20% of biomass applicants. Qualitative research with social housing providers suggested that some non-domestic heat pump applicants may have had energy security concerns in relation to risks around the future cost and reliability of gas, oil or electric heating for their tenants.[50]

Figure 15: Motivations for installing a new heating system by first submission year (all technologies)



Source: Applicant survey data, n=1,092. Percentages refer to the proportion of applications first submitted within the relevant period.

The remaining sections in this chapter present evidence about the influence of specific elements of the RHI reforms. These reforms are considered in turn:

- restructuring of biomass tariffs
- changes to allowable heat uses
- the 50% waste requirement for biogas and biomethane
- introduction of tariff guarantees
- revised metering requirements for shared ground loop systems
- other reforms

[49] Multiple responses were allowed. Qualitative research with applicants suggested that concerns about security of energy supplies related to potential future increases in energy costs, as well as reliability of supply.
[50] The online applicant monitoring survey was delivered in six-monthly waves between October 2017 and June 2021.

There was evidence of a number of interactions between the reforms. For example, research with applicants and installers found that the restructuring of biomass tariffs, combined with changes to allowable heat uses and with degression of small and medium biomass tariffs, had a cumulative impact on small and medium biomass applications. These interactions are brought out within the sections below.

Review of Restructuring of Biomass Tariffs

The reforms

Revisions to the biomass tariff were announced in December 2016 and introduced on 20 December 2017. A single tariff for all new biomass boiler deployment replaced the previous banded tariffs for small, medium and large boilers. This represented a decrease in the small and medium biomass tier 1 tariffs, but an increase in the large biomass tier 1 tariff. This was intended to drive deployment of larger systems and of biomass-fired process-heating (as part of focusing support on those areas where the Government expected biomass technology to have a long-term role), such as in manufacturing processes, and to remove incentives for gaming (e.g. the practice of maximising tariff income by using multiple, smaller boilers rather than one large one).

Revised 'tiering' arrangements (based on heat load factor) were introduced for the new tariff – altering the tiering arrangements for the small and medium bands and introducing tiering for large biomass boilers for the first time. Under this approach each installation was eligible to receive an initial higher 'tier 1' tariff for a given amount of heat use each year. Once this amount of heat has been generated, further heat use would receive a lower 'tier 2' tariff[51].

The existing and revised arrangements are shown in Table 10 below. The revised tier 2 threshold was set at a level above that at which most plants operate, to ensure high heat load systems, including process-heating systems, were appropriately incentivised but not overcompensated. It was also designed to manage the risk of accredited applicants wastefully overproducing heat or oversizing plants to maximise their payments.

Table 10: Biomass tariffs, pre- and post-reform[52]

	Tier 1 tariff (p/kWh), pre-reform	Tier 2 tariff (p/kWh), pre-reform	Tier threshold, pre-reform	Tier 1 tariff (p/kWh), post-reform	Tier 2 tariff (p/kWh), post-reform	Tier threshold, post-reform
Small biomass	3.10	0.82	15%	2.91	2.05	35%

[51] The amount of heat eligible for tier 1 support is calculated in relation to the capacity of the plant, with plants eligible for tier 1 support for an amount of heat (measured in kWh) equal to 35% (the 'tier threshold') of the plant's capacity (in kW) multiplied by the number of hours in a 12-month period (8,760 hours).
[52] BEIS (2016) The Renewable Heat Incentive: A Reformed Scheme: Government response to consultation.

Medium biomass	5.24	2.27	15%	2.91	2.05	35%
Large biomass	2.05	2.05	N/A	2.91	2.05	35%

How did these reforms influence gaming behaviour?

While there is no single definition of gaming, gaming was defined for evaluation purposes as behaviour that was solely designed to maximise tariff income for financial gain, without generating other benefits. This does not break any rules and does not constitute fraud. However, the reformed non-domestic RHI attempted to discourage such behaviour.

Some evidence of potential gaming was reported in qualitative research conducted with applicants for the medium biomass tariff boilers in the interim period between December 2016 and September 2017 (between the reform announcements and the start of their implementation). The banding of the tariff was found to have enabled some applicants to access a higher tariff by installing a larger boiler than they needed at the time, for example installing a 200kW+ boiler to access the medium tariff when less than 200kW would have met their needs. However, this was sometimes a secondary driver: a further factor for some was allowing for future growth or expansion plans.

Mis-selling may have contributed to poorly informed customers being sold boilers that were inappropriate for their needs. Qualitative research with agriculture and forestry biomass applicants and supply chain stakeholders during 2020 found reports of possible mis-selling by less scrupulous or experienced installers during the pre-reform period, when high tariffs for small and medium biomass attracted new installers to the market. But the evaluation did not find direct evidence of mis-selling involving oversizing of boilers.

The tariff bands acted as a driver for the size of boilers, as shown by the prevalence of boilers at the lower and upper ends of the medium size tariff band. This was the case during the pre-reform period but continued even after the banding was removed (e.g. boiler sizes continued to cluster at former tariff boundaries such as 199 kW). Qualitative research with biomass applicants and supply chain stakeholders suggested this arose for two reasons: firstly, the influence of the secondary market with some ‘post-reform’ applications being for previously-accredited boilers and/or tariffs; and secondly a lag in the supply chain. The latter was described by stakeholders in qualitative research conducted in 2020 as a combination between boiler manufacturers needing time to adapt their boiler sizing to suit the new funding environment and installers preferring to install well-established and trusted products with which they had become familiar.

Tariff tiers further contributed to the risk of boilers being oversized in order to maximise RHI income. In announcing the reforms, BEIS recognised that “tiering will always yield some risk of oversizing systems to maximise tier 1 payments”, but went on to state “however, Government judges that this risk is lower under the newly proposed arrangements than under the current arrangements, given the smaller proportional difference between the tier 1 and tier 2 tariffs, and higher tiering threshold”.[53] Qualitative research with agricultural applicants, both in 2020

[53] BEIS (2016) The Renewable Heat Incentive: A Reformed Scheme: Government response to consultation.

and 2021, found evidence of applicants trying to maximise receipts from tier 1 payments and minimise use of the tier 2 tariff. Where viability was marginal, some applicants reported that it was not economic to run their biomass boilers or large heat pumps[54] at the tier 2 tariff level.

It was clear from qualitative research with applicants during the interim period that the pre-reform RHI was a factor in driving the installation of multiple boilers, although applicants also referred to other benefits such as greater resilience, flexibility and efficiency.[55] Later research with manufacturing sector applicants who had applied under the reformed tariffs encountered evidence of the ongoing practice of installing multiple smaller boilers rather than a single larger boiler. This confirmed the importance of the other, non-tariff related reasons for this practice.

How did these reforms influence investment in manufacturing process uses?

Analysis of the application database, along with qualitative research with manufacturing sector applicants and non-applicants, suggested that the reformed RHI had not led to an increase in projects involving heat use as part of manufacturing processes, as intended by these reforms. The findings indicated that biomass projects involved additional capital and operational costs[56] compared with non-renewable alternatives. These additional costs, coupled with the additional perceived risks associated with the technology and the fuel supply, were regarded by respondents as significant perceived barriers to investment.

There was no evidence that the variation in tariff and tiering arrangements (which led to higher tariffs for larger and higher heat demand installations) played a significant role in enabling or hindering investment in large biomass plants in the manufacturing sector. In the qualitative research all observed business cases would have been viable under both the pre- and post-reform tariffs, despite these being sampled across a range of manufacturing industries.

The types of businesses which had installed biomass-only or biomass CHP systems for manufacturing process uses under the reformed RHI, included:

- timber products businesses, mainly using heat for drying or heat treatment of construction timber or pallets
- paper/packaging manufacturers, utilising heat to dry raw materials
- food and drink manufacturers, principally utilising steam as part of their production processes

The qualitative research with manufacturing sector applicants identified a number of factors that had enabled RHI applicants to justify the additional costs and perceived risks associated with the use of biomass technologies relative to alternative fossil fuel technologies in manufacturing contexts. These were often present in combination, and included:

- an existing heat source being in need of replacement, meaning that the value of the existing heat source was not a factor in the investment decision

[54] Tiered tariffs applied to other large-scale technologies, including large heat pumps.
[55] Biomass boilers, in contrast to gas boilers, do not run efficiently at low load factors. So, where heat demand is highly seasonal or variable, it may make sense to install several smaller boilers rather than one larger boiler so that boiler usage can be modulated in response to heat demand.
[56] For example, the costs of regularly feeding the boilers, clearing ash from the boiler and performing other routine maintenance tasks.

- no, or limited, access to the gas grid, which made biomass more price-competitive (because fossil fuels other than mains gas are relatively expensive)[57]
- longer-term concerns about the costs of fossil fuels - whilst there were concerns about the costs of biomass fuel for some, concerns about the rising cost of fossil fuels was a motivator for others to pursue a biomass technology[58]
- a secure, low-cost fuel supply, e.g. on-site production waste from timber processing that was suitable as a fuel[59]
- financial motivations linked to environmental performance, i.e. there were business benefits to adopting a renewable heat technology - it was suggested by a number of research participants that there was growing supply-chain pressure on some manufacturers to improve their environmental performance
- applicants having previous experience of using biomass heating (in other locations or previous roles), which helped to mitigate the perceived risks associated with the technology
- access to internal or lower cost finance, which was particularly important in cases where the business case was more marginal or the perceived risks higher, e.g. where there was no on-site fuel supply
- perceived process benefits from using heat from biomass - an example encountered in the research was of a paint drying process which had previously relied on diesel fuel, and which benefited from the drier heat reportedly produced by a biomass boiler
- Even where such factors were present, qualitative research with applicants found that RHI was still critical to achieving a viable business case.

How did these reforms influence investment in larger biomass boilers?

Qualitative research with applicants and stakeholders in the agriculture and forestry sectors revealed some limited evidence of an increase in large biomass boilers in the agriculture sector but not in the forestry sector. It also found that the supply chain for large biomass boilers (above 1 MW) was limited at that time (late 2020). However, discussions with applicants and stakeholders during qualitative research provided some anecdotal evidence of large projects being in the pipeline.

In the qualitative research with agriculture and forestry sector applicants, one case was observed in the agriculture sector in which the higher tariff for large boilers was critical. This was a high heat load project (large greenhouse with year-round heat demands), in which the higher RHI tariff made biomass viable despite access to mains gas. Such cases may not be common however, as the business case in this observed example was still premised on a long-term payback (14 years).

[57] It was not simply a binary distinction between on or off-gas grid, however. The evaluation encountered manufacturers who had grid access but who had pursued or considered biomass because the supply from the grid in the area was constrained or inconsistent.
[58] Note that the qualitative research was conducted between 2018 and early 2021.
[59] It is important to note that none of the fuels being used in the observed cases were cost-neutral. Even where production wastes were being used, these wastes had a market value and income was therefore foregone in burning them on site. The security of supply offered by having an on-site source appears to have been as significant as the cost factor.

Qualitive research in the forestry sector did not identify any equivalent cases where the reforms to tariffs and tiering were critical to the business case for a large boiler. Analysis of the application database indicated that large boilers have been a rare occurrence in the forestry sector since at least 2016, wherein most applications would have been placed in the medium tariff band.

Other factors may have undermined the potential impact of the restructuring of the tariffs. In particular, reductions in the price of oil during the latter years of the RHI were reported to have made it more challenging to secure a viable business case for biomass in off-gas grid contexts.

How did these reforms influence boiler prices?

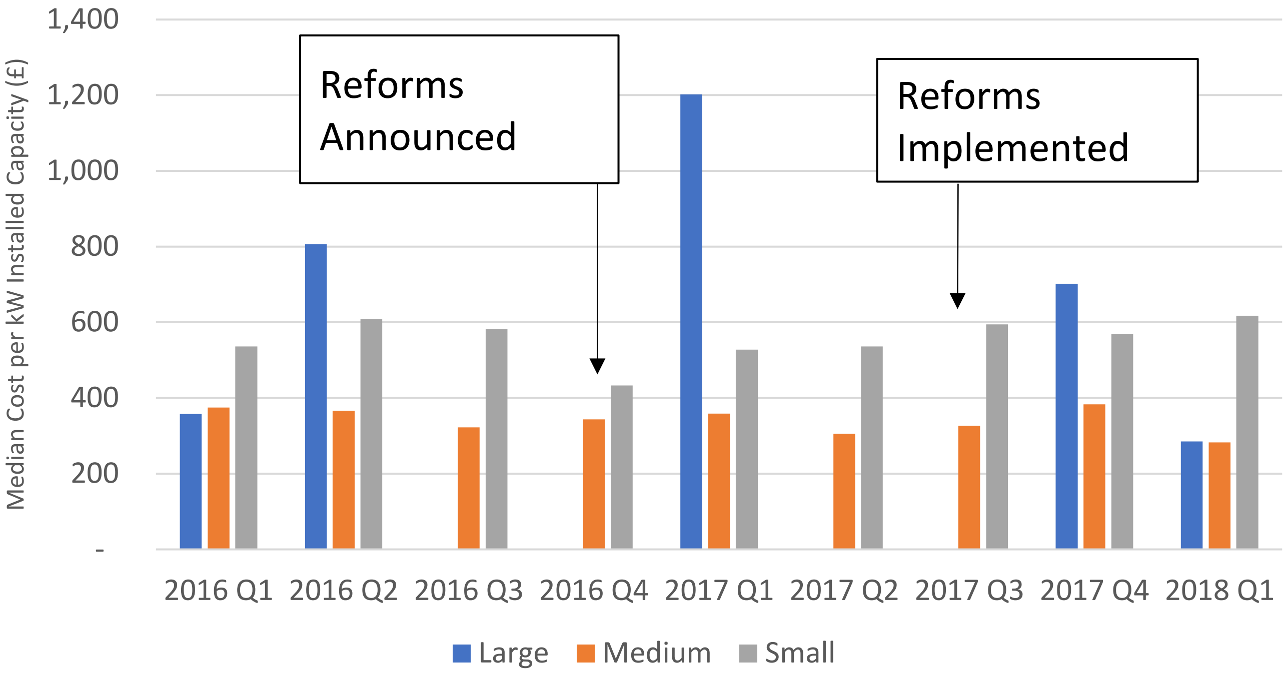
It was suggested by multiple interviewees (applicants and stakeholders) in multiple different phases of qualitative research that the impacts of changes to the RHI tariff were limited by the market responding to these changes by raising or lowering their prices for the boilers.

As part of the Competition and Trade Assessment, data was collected and analysed on median capital costs per kW of installed capacity for applicants, enabling an analysis of changing costs for each technology over time.

This data has been used to examine changes in cost per kW and review whether the data suggests any unexpected pricing changes around the time of the reforms, particularly by comparing cost data for medium sized biomass boilers, to those for other size categories.

Figure 16 shows quarterly data on cost per kW for each size of installation from Q3 2016 to Q1 2018, during which the tariffs for small and medium sized boilers declined substantially.

Figure 16: Median cost of biomass boiler per kW installed capacity, by quarter (£)



Source: RHI Application database, October 2021.
Note: overall analysis based on 456 small biomass (0-200kW), 2,273 medium biomass (201-1,000kW) and 97 large biomass installations (over 1,000kW). These figures are nominal and do not take account of inflation. In some quarters, there were no large biomass applications.

Based on this analysis, the differences quarter on quarter are small, but there is a notable difference between small and medium sized boilers in terms of the change in costs between the announcement and implementation of reforms. There is insufficient data for large biomass boilers over this period to detect a trend.

The reforms included reductions in the small and medium biomass tariffs, although when adjusted for inflation, the changes to the small tariff represented a slight increase, whereas for the medium biomass tariff this was a reduction.

For small boilers, from the point when the reforms were announced, the cost per kW rose quarter on quarter over the subsequent nine months, before levelling off somewhat after the reforms were implemented Q3 2017 and Q1 2018. Nevertheless, by Q1 2018, the cost per kW for small biomass was 42% higher than it was when reforms were announced in Q4 2016.

Over the same period for medium sized biomass boilers, from the point when the reforms were announced, the costs initially stay relatively stable in Q1 2017, before dropping over Q2 and Q3, rising in Q4 2017, but then falling again in early 2018. By Q1 2018, the cost per kW for medium biomass was 18% lower than it was when reforms were announced in Q4 2016.

Overall, the cost changes seen in this analysis show a price rise for smaller biomass following the reforms, which led to an increase in the small biomass tariff rate (when adjusted for inflation). Similarly, these cost changes show a price reduction for medium biomass following the reforms which led to a reduction in the tariff rate. This provides some evidence to support suggestions made in the qualitative research that the market may have responded in its pricing strategy to changes in the tariff rates.

The next section considers the impact of the reform of allowable heat uses, which also had significant implications for the biomass sector.

Review of Allowable Heat Uses

The reforms

From 22 May 2018 onwards, certain heat uses were no longer eligible for the RHI, including wood fuel drying, digestate drying and waste drying or processing. This reform was introduced due to concerns about the value for money of RHI support for these heat uses.[60] The changes applied to new accredited applicants (or existing accredited applicants who added capacity on or after 22 May 2018) or where a participant otherwise began to use heat generated by the installation for an ineligible heat use on or after 22 May 2018.

How did these reforms influence applicants and whom did they influence?

In 2018, around the time the reforms were enacted, this was the most influential reform. The applicant survey found that, within the biomass applicants submitting their applications in that year, approximately one in ten specifically highlighted the impact of this reform on their installation decisions. In particular, they suggested that the timing of their application, the

[60] The main reform announcements in December 2016 included the removal of digestate drying as an eligible heat use and reference to further detailed work which would be carried out with regard to the eligibility of wood fuel drying. This took place in 2017, with the further changes to eligible heat uses then confirmed in January 2018 – BEIS (2018) Non-Domestic Renewable Heat Incentive: Eligible Heat Uses. Changes to Eligible Heat Uses: Government Response to Chapter 2 of Consultation.

choice of technology, as well as the size of the installation had been influenced by the reforms. However, it became less influential as the reforms settled in. Among biomass applicants submitting their application after 2018, the change in eligible heat uses was not cited at all as a factor influencing their installation decision. It is possible that ongoing influence of this reform on installation decisions beyond 2018 may not have been picked up because the survey focused on applicants and did not include non-applicants.

For pre-2018 heat pump applicants, the 42% indicated that they had been influenced by the overall reforms (higher than for biomass), with 26% of those specifically highlighting the changes to eligible heat uses as having influenced their installation decision. The percentage of those influenced by the reforms overall dropped to only 6% in 2018/19 however. Of those, 29% indicated that they had been influenced by the change to eligible heat uses.

The qualitative research with agriculture and forestry sector biomass applicants provided further insights into the nature of reform impacts on biomass applicants and the contexts in which they occurred. For example, the reforms affected applicants who were involved in the biomass supply chain and sought to dry wood fuel for sale. Some applicants whose plans incorporated drying uses which would become ineligible (typically wood fuel drying), and who had the flexibility to bring forward the timing of their renewable heat projects, brought forward their projects or tried to do so.

Whilst the proportion of biomass and CHP applications in the agriculture and forestry sectors involving process heat uses (including drying uses) increased in the early part of 2018, it declined sharply after that point. This may indicate that changes in eligible heat uses were a significant factor in the rate of applications, i.e. the increase was driven by the forthcoming changes in eligible heat uses and the subsequent decrease was driven by the implementation of those changes (although there is no evidence about how many planned projects were made ineligible).

How did these reforms influence the supply chain?

The presence of a market for pre-accredited boilers is a further indication of the impact of this aspect of the reforms. The findings from the qualitative research with agriculture and forestry applicants and stakeholders indicated that securing access to pre-reform eligibility rules (and earlier, more lucrative tariffs) was a key driver of this market. Examples were encountered of used boilers with older RHI tariffs retailing at higher prices than an equivalent new boiler.

Based on the findings from the qualitative research with biomass applicants in the agriculture and forestry sectors, the circumstances in which applicants made use of these previously accredited boilers and/or tariffs can be broadly characterised as follows:

1. Cases in which the applicant moved a boiler from one site that they owned to another because of changing heat needs, such as business expansion leading to business relocation. Income from pre-reform RHI tariffs made it viable for these applicants to relocate their boiler.

2. Cases in which the boiler was owned by a third party who moved the boiler and/or the tariff as a result of changing heat demands on the part of their customers. Access to pre-reform RHI tariffs made the relocation viable.

3. Cases in the forestry sector in which there was an opportunity to introduce or expand biomass fuel drying operations using a pre-reform second-hand boiler. Access to pre-reform RHI tariffs enabled these applicants to invest in the business opportunity.

The emergence of a market for used boilers meant that a number of companies were operating in that market, either purchasing boilers to operate or acting as brokers for pre-accredited boilers. From interviews with applicants and wider stakeholders, it was found that the decline in demand for new installations in the run-up to the closure of the RHI had led these companies into the secondary market as a means of securing ongoing revenue streams.

Evidence from consultations undertaken as part of the Sustainable Markets Assessment suggested that there had also been impacts on the price of biomass fuel. Pre-reform, the permitting of feedstock drying was said to have disrupted the feedstock market, giving suppliers of dried feedstock a competitive advantage in terms of price.

There was also a sense from applicants and stakeholders during qualitative research and consultations that woodchip prices had been adversely affected by pre-reform drying plants, which had used tariffs to buy bulk quantities of wood and skew the market. Given their scale and buying power, this was reported to have given their operators strong influence over the price of woodchips.

The next section considers the impact of the reform introducing a 50% waste feedstock requirement for biogas and biomethane.

Review of the 50% Waste Requirement for Biogas and Biomethane

The reforms

The reform package announced in December 2016, and introduced in May 2018, aimed to support continued deployment of biogas and biomethane technologies while improving the carbon cost-effectiveness of these technologies. The reforms sought to improve the carbon abatement resulting from biomethane, and biogas, through the introduction of a minimum requirement that 50% of gas generated should come from waste feedstocks. The waste requirement was accompanied by a modest increase in biogas and biomethane tariffs, partially reversing earlier degressions.[61] Waste feedstocks such as food waste and wet manure were assumed to generate upstream carbon (or carbon equivalent) savings by diverting waste away from landfill and thereby reducing methane emissions.[62]

How did these reforms influence feedstock use?

According to qualitative research with pre- and post-reform biomethane applicants, the types of feedstocks used included:

- farm waste (e.g. slurry from dairy farms, belly grass from abattoirs, crop wastes and residues (e.g. straw, sugar beet pulp), straw/manure from poultry, pig and cattle)
- energy crops (e.g. maize, maize silage, rye silage, grass silage)
- sewage waste (sewage sludge, cesspit waste)

[61] Tariff levels for all technologies are presented in Appendix C of the Technical Annex.
[62] Assumptions for downstream and upstream carbon savings for different feedstocks were provided by BEIS and used in the Subsidy Cost-Effectiveness Assessment. These are explained further in Appendix B of the Technical Annex.

- manufacturing and industrial waste (e.g. whey and whey permeate from dairy processes; wastes and residues from distilleries and breweries; food waste from food processing;[63] effluent from paper manufacture)
- municipal and commercial waste (e.g. green waste from composting activities; household food waste – typically with no packaging; commercial food waste from restaurants, schools, shops, hospitals etc – which can involve packaging) [64]

Data on feedstock use by biomethane and biogas plants was collected from 159 pre- and post-reform applicants responding to the feedstock question in the biomethane and biogas applicant survey. No respondents using sewage waste responded to this question in the survey, and responses were dominated by biogas rather than biomethane respondents, so the results are not fully representative.

Data from this survey suggests that use of food waste was more than 50% of feedstocks used by both pre- and post-reform plants, compared to the 40% estimated in the BEIS Impact Assessment for the RHI reforms, as shown in Table 11 below. This suggests that upstream carbon savings from these plants, arising from diversion of food waste from landfill, are greater than estimated in the Impact Assessment.

Table 11: Mean feedstock mix for biomethane and biogas survey data

	Biomethane survey data (n=15)	Biogas survey data (n=144)	BEIS Impact Assessment assumptions
Food waste	55%	53%	40%
Maize	38%	28%	18%
Sewage sludge	0%	0%	25%
Wet manure	6%	19%	18%

Note: 218 pre- and post-reform biomethane and biogas applicants responded to the survey as a whole, of which 159 responded to the question about feedstocks.

The sample sizes in the biomethane and biogas survey were too small to allow detailed analysis of differences between feedstock in the pre- and post-reform periods. However, of 15 respondents who submitted applications since 2018, only one had a proportion of waste less than 50%. Conversely, among survey respondents who submitted applications prior to 2018, there were 97 plants (out of 199 from this period) where waste/residues accounted for less than 50% of total feedstock, of which 59 did not use any waste/residues at all. This suggests that the reforms were successful in increasing the proportion of waste within feedstocks.

[63] Permitting requirements vary according to whether the feedstock is classified as waste or a 'residue' or 'effluent'. Permits from the Environment Agency are required for handling waste streams but not residues/effluents. Food waste that requires pasteurisation (to meet the PAS110 standard for digestate) was reported to be more likely to command a gate fee.

[64] De-packaging and pasteurisation of food waste is required to ensure that the digestate produced as a by-product of biogas/biomethane production met the quality standards that would allow it to be used in agricultural applications.

How did these reforms influence carbon abatement and subsidy cost-effectiveness outcomes?

There was insufficient data to analyse the impact of the change in feedstocks between pre- and post-reform periods in the SCEA. However, the SCEA suggests that the cost-effectiveness of carbon abatement from biogas and biomethane improved post-reform, before taking account of any change in feedstocks. For biogas installations, the SCEA found that the subsidy cost per tonne of CO2 emissions abated to date declined from £282.40 per tonne pre-reform to £172.02 per tonne post-reform. For biomethane, the subsidy cost reduced from £179.23 per tonne pre-reform to £104.72 per tonne post-reform. These figures include both 'upstream' and 'downstream' carbon benefits associated with the observed mix of feedstocks across both the pre- and post-reform periods (see detailed SCEA figures biogas and biomethane presented in Annex 1 within Appendix B of the Technical Annex). However, the improvement in post-reform cost-effectiveness shown here was driven by other factors, including biomethane tariffs being lower post-reform than in the early years of the scheme.

There are two areas of uncertainty about these estimates. Firstly, the limited evidence available on feedstock changes suggest that the improvement in post-reform subsidy cost-effectiveness would be greater if there had been sufficient data to model the impact of the 50% waste feedstock rule.

Secondly, potential competition for feedstocks with renewable electricity generation might push in the other direction. The detailed SCEA figures presented in Annex 1 within Appendix B of the Technical Annex have been adjusted for the 'additionality' of biogas and biomethane investments, as set out in Table 6 above. While the additionality adjustment takes account of the RHI influencing the nature of investment in renewable heat, qualitative evidence suggested that, in some regions, biogas and biomethane plants may have been competing for feedstocks with other types of renewables – e.g. renewable electricity generation rather than renewable heat (supported by the Renewables Obligation and/or the Feed-in-Tariffs scheme rather than RHI).[65] If feedstocks have been diverted from renewable electricity generation, or if RHI-funded plants have contributed to higher prices for AD feedstocks, this would have the effect of reducing the cost-effectiveness estimates presented here.

How did these reforms affect viability and for whom?

Qualitative evidence from biomethane applicants and stakeholders, collected during 2018/19, indicated that feedstock restrictions may have enhanced sustainability but may have reduced the number of plants coming forward, despite the introduction of tariff guarantees (see below). This is supported by the much lower number of biomethane and biogas applications in the post-reform period (as shown in Table 4).

This qualitative research identified a number of key factors which affected the viability of biomethane investments post-reform. Viability was improved where applicants:

- had secure access to self-supplied waste feedstock which required use or disposal, reducing their feedstock costs and reducing uncertainty about feedstock supply
- were able to charge gate fees for receiving waste feedstocks, improving the business case

[65] The Feed-in-Tariff scheme closed on 31st March 2019 and the Renewable Obligation scheme closed on 31st March 2017. Both schemes provided subsidies for renewable electricity generation.

- had access to low cost finance (e.g. internal funding or asset-backed loans), improving the business case
- had wider business imperatives for biomethane production (e.g. pro-environmental stance) and could see wider benefits from the investment
- had access to tariff guarantees, reducing the uncertainty of their investment

The qualitative research with biomethane applicants and stakeholders found that:

- use of waste-based feedstocks increased following the reform announcements - this may, to some extent, have accelerated an ongoing trend, as reductions in tariff levels also led applicants away from more expensive crop-based feedstocks
- increases in demand for waste-based feedstocks may have contributed to a decline in gate fees for food waste during 2018/19 (resulting in reduced income for AD operators) - during this period, reductions in gate fees were reported by WRAP in areas with substantial AD capacity (London/SE in particular)[66]
- decreasing gate fee charges hindered the viability of plants - during qualitative research with biomethane applicants in 2018/19, some planned plants were reported to be unable to secure a cost-effective feedstock supply which met the feedstock restrictions

However, the downward pressure on gate fees observed in the 2018/19 research appears to have been temporary. As noted in the supply chain section above, higher levels of gate fees were reported in WRAP's 2020 gate fee report, despite reductions in the availability of food waste as a result of the early stages of the COVID pandemic.

Depending on future waste policies at local and national level, higher gate fees may arise from increasing collection of food waste. This should increase the viability and cost-effectiveness of future biomethane and biogas plants.

The next section considers another aspect of the reforms, involving changes to allowable heat users.

Review of Tariff Guarantees

The reforms

The introduction of tariff guarantees in the non-domestic RHI was announced in December 2016 as part of the wider package of reforms. Tariff guarantees became available on 22 May 2018.

The economies of scale from which larger projects can benefit were seen to offer the potential for better value for money to be achieved from Government spending on the RHI. However, tariff uncertainty was believed to act as a barrier to uptake for these larger projects. Therefore, tariff guarantees sought to facilitate larger scale projects, through reducing this uncertainty.

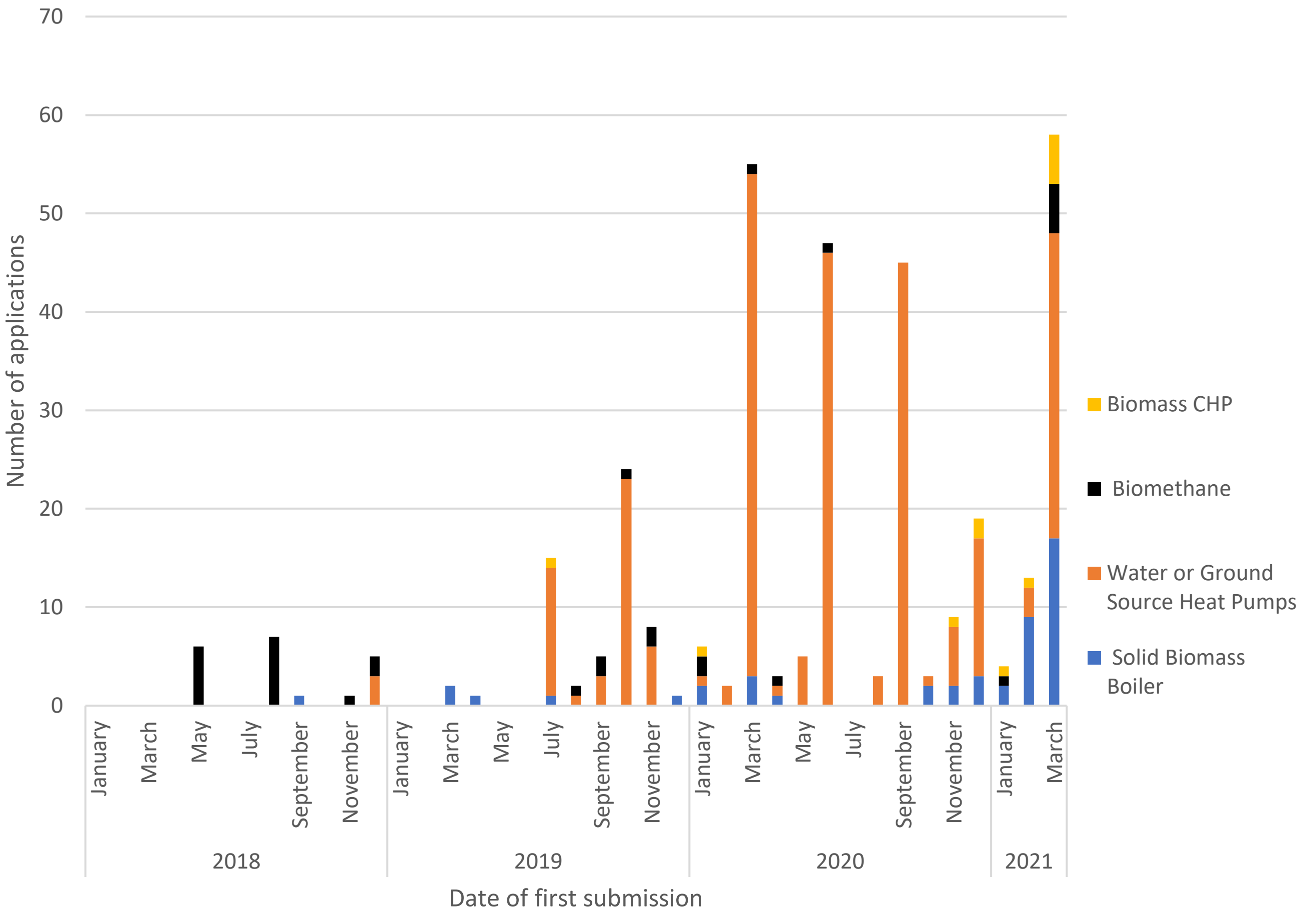
[66] Gate Fees report, 2020. (Published 27 January 2021). This report is prepared by WRAP, presenting findings from an annual survey of gate fees within the UK. Accessed at: https://wrap.org.uk/resources/report/gate-fees-report-2020.

Those seeking to install these technologies were able to apply to the scheme in advance of their commissioning date and to fix their tariff level, subject to demonstrating eligibility criteria. The intention was to protect applicants for large projects with long lead-times from potential tariff degressions that might occur between their decision to proceed and their commissioning date, thereby reducing their investment risk. Tariff guarantees were made available for a number of technologies, including deep geothermal, biomethane, biomass combined heat and power (CHP), large biogas (600kWth and above), large biomass (2MW and above) and ground- and water-source heat pumps (100kW and above).

How did the reforms influence applicants and whom did they influence?

Figure 17 provides a breakdown of tariff guarantee applications by technology, as of March 2021. Biomethane was the predominant technology in the early period of tariff guarantee availability but the number of biomethane applications has fallen since. Since then, applications for heat pumps (GSHP and WSHP) have been by far the most common, with noticeable spikes in applications in response to quarterly tariff degressions. Biomass has played a relatively minor role, although the numbers have increased in the most recent months. Biomethane and large heat pump projects were far less prevalent when looking at all RHI applications (Figure 5).

Figure 17: Tariff guarantee applications by month and technology



Source: RHI monthly deployment data: October 2021. https://www.gov.uk/government/statistics/rhi-monthly-deployment-data-october-2021
Where there are missing months, this is because there were no applications in those months.

The applicant survey found that 3% of those biomass applicants whose installation decision was influenced by the reforms had waited for the availability of tariff guarantees. Among heat pump applicants the figure was higher, at 20%. The factors which led to a reliance on tariff guarantees are outlined below and large heat pump projects were more likely than biomass projects to demonstrate these.

The survey also found that a high proportion (74%) of biogas and biomethane applicants whose installation decision was influenced by the reforms indicated that the reforms had influenced the timing of their application. Questions about which specific reforms influenced these applicants were not asked in the survey. However, many biomethane applications used a tariff guarantee (more than 70% of biomethane applications after tariff guarantees became available[67]) and the qualitative research found that some biomethane applicants had specifically waited for tariff guarantees.

Qualitative research found that some biomethane projects were able to proceed in advance of tariff guarantees becoming available by de-risking the project through a two-stage commissioning process. This enabled applicants to secure a tariff rate prior to completion of the biomethane installation by injecting some biomethane (potentially from another source, such as a tanker) to the grid at the planned entry point. This required a higher level of early investment than the tariff guarantee process but provided some similar benefits and did enable some biomethane projects to be pursued in advance of tariff guarantees becoming available, although some projects were able to proceed without either two-stage commissioning or a tariff guarantee.

Drawing on qualitative research with biomethane and large heat pump applicants, the following factors were identified as being particularly prevalent in determining the extent to which projects needed a tariff guarantee:

- commissioning timescales - projects with shorter commissioning timescales were less likely to need a tariff guarantee because they were less likely to be affected by tariff degressions, biomethane projects typically had long commissioning timescales so tended to require either a tariff guarantee or the two-stage commissioning route
- margins in the business case - those with tighter margins were less likely to be willing to risk a tariff degression putting further pressure on those margins, so were more likely to need a tariff guarantee
- political risk associated with the investment - public-sector led heat pump projects were more likely to rely on tariff guarantees because of the political risks attached to proceeding without such guarantees and potentially ending up with projects which represented poor value for money
- extent of wider business drivers - in some contexts, wider drivers for a project led to less reliance on tariff guarantees, e.g. some biomethane projects were driven by opportunities to improve waste management processes, while biomethane and heat pump projects often had significant drivers associated with carbon reduction, which also lessened reliance on tariff guarantees in some cases

[67] Based on the October 2021 application database. Excludes cancelled and rejected applications.

- project scale (relative to the wider business) - projects which were large, relative to the wider applicant business, were more risky for the applicant and therefore more likely to need the de-risking of investment offered by a tariff guarantee
- level of certainty required by funders - some of the reliance on tariff guarantees was driven by the requirements of funders (where debt-based, external finance was being utilised, tariff guarantees tended to be more important whereas internally financed projects were sometimes able to proceed without)
- awareness of tariff guarantees - there was some limited evidence of heat pump applicants not being aware of the tariff guarantee option

The next section considers the impact of the reform that restructured biomass tariffs.

Review of Revised Metering Requirements for Shared Ground Loops (Deeming)

The reforms

Shared ground loop heat pumps were encouraged under the reforms because they potentially offered a cheaper way of delivering ground source heat pumps. This technology involved a large underground or underwater loop serving multiple heat pumps in individual properties. Applications were made by the organisation providing the SGL, often a social landlord, rather than by the individual properties.

To incentivise the installation of SGLs, the reforms introduced ‘deeming’ of heat demand for domestic properties connected to SGLs. RHI payments were calculated using deemed heat demand, based on the Energy Performance Certificate for each property, rather than on metered heat use. For a more through definition of ‘deeming’, refer to the glossary.

The rationale for this reform was that metering had acted as a barrier to deployment of SGLs providing heat to domestic properties. Deeming avoided the need for meter reading and billing across multiple properties. Deeming also meant that future RHI payments were fixed in advance, rather than varying according to actual metered heat use. This reform was therefore intended to provide investors – particularly social landlords – with greater certainty over the RHI payments, aiding financial clarity and decision-making. The new regulations came into effect on 22 May 2018.

Definition of shared ground loop heat pump systems

For RHI purposes, SGLs were defined as systems where an underground or underwater loop provided low grade (i.e. low temperature) heat for multiple heat pumps in a range of properties. Some of these systems could be classed as heat networks. This reform did not apply to communal heat pumps where a single, large heat pump provided high grade (i.e. high temperature) heat for multiple properties. The distinction between these two types of systems is explained further in Appendix D. Both SGL and communal heat pump systems qualified for the non-domestic RHI because they were serving multiple properties, even if some or all of these properties were domestic.[68]

The reforms introduced deeming for domestic properties served by SGLs, where each property had its own heat pump. This made treatment of SGLs more similar to individual heat pump applications under the domestic RHI scheme, albeit with access to non-domestic rather than domestic RHI payments. Heat demand limits applied in respect of each domestic property, as they would under the domestic RHI. For non-domestic SGLs, and those serving a mixture of domestic and non-domestic properties, RHI payments for non-domestic properties continued to be on the basis of metered heat use.

How did these reforms influence the number of SGL applications?

By October 2021, a total of 702 SGL applications had been approved or were pending/subject to Tariff Guarantees[69]. Some of the SGLs served 100 or more properties, but the mean number of properties served was just under 5. The total number of properties served was 3,465, with a total capacity of 17,224 kWth.

The vast majority of these applications, 691, were for small GSHPs, while a small number of applications were for Large GSHP/WSHPs [70] or small WSHPs. Most of the SGL applications, at the time of the qualitative research, were in accommodation and housing settings.

Known SGL applications represented a relatively small proportion of all heat pump applications in the non-domestic RHI scheme, as shown in Table 12. This may understate the number of SGL applications because SGLs were only identified in RHI application statistics after the reforms. However, qualitative research suggests that the understatement is likely to be slight because most SGLs used small heat pump technology developed and marketed by installers around the time of the reforms.

While SGL applications represented nearly 29% of non-domestic applications for small GSHP (less than 100 kWth), they represented around 18% of small GSHP capacity. Out of all heat pump technologies, SGL applications represented just over 15% of non-domestic applications and 1.5% of capacity. The capacity statistics suggest that communal or commercial heat pumps that did not qualify as SGLs had higher mean capacity than SGL schemes.

[68] Under RHI rules, applications for installations serving multiple properties were defined as non-domestic RHI applications, irrespective of whether the properties were domestic or non-domestic.
[69] This estimate is based on applications being flagged as 'SGLs' in RHI application data and may underestimate the true number of post-reform SGLs. There is qualitative evidence that some SGLs were not flagged as such.
[70] Large GSHP and WSHP were defined as having a heat capacity exceeding 100 kWth.

Table 12. SGL applications compared to all non-domestic heat pump applications

Techno-logy Type	Total number of non-domestic RHI applications (pre- and post-reform)	SGLs (% of applications)	Total capacity of non-domestic RHI applications (pre- and post-reform, kW)	SGLs (% of capacity)	Mean capacity per application (kW)
Large GSHP	792	1.1%	756,503	0.4%	955
Large WSHP	142	0%	238,332	0%	1,678
Small GSHP	2400	28.8%	78,009	18.2%	33
Small WSHP	110	1.8	5,898	1.3%	54
ASHP	1065	0%	62,940	0%	59
Total	4509	15.6%	1,141,682	1.5%	253

Source: RHI application database October 2021 (approved, pending and TG applications, excluding cancelled and rejected applications)

How did these reforms influence SGL applicants and installers?

The introduction of deemed payments had small but positive effects on both the supply-side and demand-side of SGL delivery. This effect was particularly observed in the social landlord market.

Qualitative research with heat pumps applicants and installers found that increased up-take of SGLs was enabled by innovations in the heat pump supply chain, involving the development of small heat pumps that could fit within small social housing properties. The reforms, supported by manufacturers and installers of these smaller heat pumps, enabled these systems to be installed without requiring individual heat metering and billing.

Qualitative research with heat pump installers also found that the reforms stimulated installers to undertake widespread marketing of SGLs to social landlords, around the time of the reform announcements, to promote their benefits and increased viability under the reformed RHI.

The reforms also had an effect on demand for SGLs. Qualitative research with applicants found that the introduction of deemed payments encouraged investment by social landlords in

SGLs. This was particularly observed for clusters of off-gas housing or blocks of flats where the landlords needed to replace ageing or poorly performing heating systems (e.g. old electric storage heating) to reduce fuel poverty for their tenants. The subsidy offered by the reformed RHI helped to make SGL investments viable for these social landlords, compensating for the capital cost of SGLs being several thousand pounds higher per property than competing systems.

Deemed payments formed an important part of the business case for SGLs. Qualitative research found that this was primarily because social landlords wanted to avoid having to bill tenants for heat, although some had been involved in billing tenants for energy in previous systems. They were strongly motivated to avoid the administrative hassle of metering and billing, and the risks of non-payment in circumstances where it would be difficult or impossible to cut off the heating supply to vulnerable tenants.

Qualitative research also found that deeming contributed to investor certainty, and increased the attraction of offers from installers. This is because the business case was based on the EPC rating of properties (which was known in advance) rather than depending on eventual usage by tenants.

There was less evidence from qualitative research of deeming reforms influencing behaviour by other types of investors (e.g. developers, commercial organisations and private individuals). The application statistics in Table 12 support this because they show that the majority of heat pumps installed under the non-domestic RHI scheme did not meet SGL criteria.

The evaluation did not collect performance evidence that would have enabled an assessment of whether deemed heat use was higher or lower than actual heat use in SGL schemes. Interviews with social landlords suggested that deemed heat use tended to be lower than actual heat use in SGL schemes, so that SGL applicants would be under rather than over compensated, but it was not possible to corroborate this.

Other Reforms

In addition to the reforms above, various reforms were applied to the domestic RHI (e.g. increase in domestic heat pump tariffs, introduction of heat demand limits, introduction of Assignment of Rights). However, these other reforms applied to the domestic rather than non-domestic RHI. The research did not find any evidence that changes to the domestic scheme influenced outcomes in the non-domestic scheme. There is some evidence of the converse, as closure of the non-domestic scheme was reported as having implications for the supply chain for the domestic RHI scheme, because the latter extended for one year beyond the non-domestic scheme.

The detailed realist theory presented in Appendix F of the Technical Annex presents a summary of insights from synthesised evaluation evidence on how and why the reformed RHI scheme influenced the demand, supply and usage of renewable heat installations and supply of biomass fuel, in different contexts.

Future Lessons for Future Policies and Programmes on Renewable Heat

A summary of learning from the scheme for future policies and programmes on renewable heat.

Introduction

This chapter provides a summary of strategic learning from the scheme for future policies and programmes on renewable heat.

What did the non-domestic RHI scheme do well?

The non-domestic RHI was one of the first policies in the world to provide subsidies for generation of renewable heat. From the outset, it was designed as a 10-year policy that would make a significant contribution to the development of a sustainable market for renewable heat, providing subsidies over a 20-year period. The evidence presented in this report demonstrates that the policy was successful in stimulating take-up of renewable heat technologies. Qualitative research with applicants and supply chain stakeholders confirmed that long timeframes and policy certainty were important in supporting major investments in renewable heat.

As discussed in the previous two chapters, the various reforms introduced between September 2017 and May 20018 – together with degression and budget cap mechanisms - were effective in improving the subsidy cost-effectiveness of the scheme. BEIS monitored future spend commitments on the RHI scheme as a whole to ensure that the budget cap was not exceeded. Qualitative research with applicants and supply chain stakeholders found that the various reforms, together with the risk of quarterly tariff degressions, contributed to uncertainty about their investment decisions, despite the long timeframe of the scheme. But these changes were effective in reducing support for less carbon and cost-effective technologies and increasing support for larger scale and more carbon and cost-effective renewable heat technologies.

BEIS and Ofgem showed flexibility in managing the final stages of the scheme. Qualitative research with tariff guarantee applicants found that extensions to commissioning deadlines beyond the end of the scheme, and an additional round of tariff guarantees, helped to bring forward more capacity within the scheme. Evidence relating to this flexibility is presented in the next section.

Administration of the RHI

Nearly half of respondents to the applicant survey reported that they encountered no problems in completing their RHI application. Where problems were cited, these mainly related to technical problems with the application form, difficulty supplying the information requested by Ofgem or the application taking too long to complete. Over 70% of respondents to the applicant survey reported that they encountered no problems in providing regular meter readings to Ofgem.

In the qualitative research, applicants and stakeholders expressed mixed views on the effectiveness and efficiency of the administration of the non-domestic RHI by Ofgem. Changes took place within Ofgem which may not always have been reflected in the views expressed. For example, where respondents had made multiple applications, some comments may have related to experience on past applications. In short, some of the issues raised below may have been addressed during the lifetime of the scheme.

Some applicants interviewed in qualitative research expressed frustration because of delays experienced with the processing of applications and/or payments. Such delays were reported to have led to serious cash-flow problems for some businesses. In qualitative research, some applicants and supply chain stakeholders reported that awareness of the delays experienced in receiving RHI payments had held back investment in biomass installations in some sectors, but there was no direct evidence of this because research focused primarily on applicants.

During qualitative interviews in 2021, applicants for large schemes suggested four potential causes for the delays:

- insufficient capacity for application processing within Ofgem - there was a perception of there being a backlog of applications at times
- insufficient technical expertise within Ofgem in relation to some technologies, e.g. some applicants for large heat pump installations suggested that a shortage of expertise within Ofgem had delayed the processing of their applications
- unnecessarily complex and burdensome application procedures, such as the level of technical detail required about the installations and the documentation required to evidence different aspects of the application: whilst some perceived the level of rigour in the application process to be appropriate, others felt it was unduly onerous
- the application process being ill-suited to some types of installations, e.g. some applicants for heat network installations using renewable heat technologies reported that the scheme was ill-suited to applications involving multiple addresses and staged commissioning processes

Some applicants in the qualitative research did not report having experienced any undue delays and other aspects of the scheme administration (e.g. the processing of tariff guarantee applications) were viewed positively.

The flexibility which was applied by Ofgem towards the end of the scheme was welcomed. Several tariff guarantee applicants indicated that their projects would not have been able to proceed without the extensions to commissioning deadlines for tariff guarantee projects which was introduced. The third allocation of tariff guarantees, made available in July 2020 with a March 2022 deadline (later extended to March 2023) enabled some projects to accommodate delays associated not just with the direct impacts of COVID but also with wider supply chain issues, e.g. shortages of building materials.

However, in qualitative research with tariff guarantee applicants, some criticism was expressed about the approach to introducing this new commissioning deadline. The extension could only be accessed by submitting a new application, even where the applicant had already submitted an earlier tariff guarantee application. Some applicants who had submitted a previous tariff guarantee application reported that the work that they had done on their original application was not sufficiently recognised when their new application was processed. Some applicants also expressed frustration that the extension was not announced sooner.

Towards a Sustainable Market for Non-Domestic Renewable Heat

The evaluation has monitored progress towards a sustainable market for non-domestic renewable heat, examining impacts on demand, supply and costs. High-level findings on progress towards a sustainable market, across these three elements, can be summarised as follows.

Demand

Demand for small and medium biomass installations was high in the early years of the RHI but has declined significantly since the peak in 2014-15. For example, as shown in Table 4 above, small biomass applications rose from low numbers in 2011 to a peak of 6,694 in 2014 but then declined to 235 in 2021. There was fairly steady growth in demand for non-domestic heat pump installations from low numbers in the first year of the non-domestic RHI (pre-reform) to 1,039 in 2021. Demand for biomethane and biogas installations fluctuated but ultimately fell after the reforms, with the number of biogas installations peaking at 523 in 2016 and falling to 18 in 2021, while demand for solar thermal installations has remained low throughout. There was, however, an increase in demand for large biomass installations after Tariff Guarantees were introduced by the RHI reforms from 18 in 2017 to 48 in 2021. Tariff Guarantees also supported 66 applications for large biomethane plants in 2018, but applicants subsequently reduced to 9 in 2021, although the commissioning date extension meant that the final number of installations is not yet known. Analysis of additionality suggests that more than half of installations supported by the non-domestic RHI were subsidy dependent, with more subsidy dependency for certain technologies such as biomethane.

Supply

There is a degree of tension between high levels of additionality for the RHI (as presented in the chapter on ‘What happened’) and progress towards a sustainable market for renewable heat. Given that at least half of RHI-subsidised renewable heat demand appears to have been dependent on subsidy, supply chain activity and investment have been influenced by changes in RHI subsidies. Both the Sustainable Markets Assessment and qualitative research found evidence of a ‘boom’ in small and medium biomass supply chains during 2014/15, followed by a decline in the subsequent years. These found that many biomass companies diversified to survive, moving into; larger installations, biomass fuel supply and maintenance, construction services, supplying other renewable heat technologies (e.g. heat pumps) or non-UK markets. Qualitative research also found evidence of a market in second-hand biomass boilers, particularly those offering pre-reform RHI tariffs and conditions. In contrast, the heat pump supply chain was reported to have developed more steadily, stimulated by both the non-domestic and domestic RHI, except for disruptions during 2020 attributable to COVID, EU exit and closure of the non-domestic RHI scheme. Some innovations were observed in the heat pump supply chain, including the development of UK-manufactured small GSHPs suitable for installation in social housing properties and connection to shared ground loop (SGL) systems.

Cost reduction

Trends in technology costs during the scheme are shown in **Figure 7**. Supply chain stakeholders (e.g. sector bodies) consulted for the SMA described biomass boilers as a mature technology with little or no scope for cost reductions, although a slight reduction in cost per kW was observed from the beginning of the non-domestic RHI scheme (pre-reform) to the end of the scheme (post-reform). Costs for heat pumps varied through the scheme and then rose in the final months of the non-domestic scheme, possibly because of the supply-side challenges of meeting the final rush of demand for the non-domestic scheme. Cost reductions in renewable heat technologies are dependent on economies of scale and therefore closely linked to the volume of supply and demand.

Before reviewing needs for future support, the next section considers perceived market barriers and enabling factors for different elements of the renewable heat technology market. This sets the context for the final section on future support needs.

Perceived Market Barriers and Enabling Factors

In examining perceived barriers and enablers for the future market for renewable heat technologies, qualitative research suggested that the market comprises three main parts:

- renewable heat for space and water heating (usually associated with occupancy and use of a non-domestic building or multiple domestic buildings)
- renewable heat for process heating (usually associated with a commercial, agricultural or industrial process)
- biomethane for injection into the gas grid

There is some overlap between these categories since space heating can be required for a commercial process (as in the case of horticultural glasshouse heating) and biogas can be used to generate heat/power or can be converted into biomethane. However, this broad categorisation is useful because space and water heating usually require lower grade heat than process heat, and because the biomethane market is not exclusively heat-related, so the perceived market barriers and enabling factors differ.

Perceived market barriers and enabling factors for space and water heating

In the latter years of the non-domestic RHI, qualitative research and analysis of RHI applications suggest that there has been progress towards a sustainable market in certain parts of the non-domestic space and water heating market, supported by the non-domestic RHI. Areas where there has been most progress towards a sustainable market were:

- social housing schemes that are off gas or are unsuitable for gas heating, where heat pumps (ASHP or GSHP) have become the preferred solution for social landlords, although qualitative research found that many SGL heat pump systems were still dependent on the non-domestic RHI[71]

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[71] Findings from qualitative research with social landlords in relation to SGL reforms.

- large-scale commercial, horticultural and/or residential developments with low-cost access to renewable heat sources (e.g. water sources; sewage treatment works; deep boreholes etc) where large-scale heat pumps can be connected to a local heat network[72]
- agricultural and forestry businesses with low-cost access to biomass fuel, where biomass boilers can readily be integrated into the business system[73]
- new build commercial or residential premises, where heat pumps and high levels of insulation can be integrated into building design, driven largely by building regulations[74]

The synthesis of evaluation evidence indicates that other areas of the non-domestic space and heating market showed less progress towards a sustainable market. Qualitative research findings suggest that the main perceived barriers to further use of renewable heat in the non-domestic space and heating market include:

- a lack of user familiarity with, and investor confidence in, heat pumps - whilst familiarity is growing, this remains a barrier
- the high capital cost of heat pump systems compared to fossil fuel and/or biomass heating systems
- the cost and hassle of retrofitting buildings with high levels of insulation required for heat pumps to operate efficiently
- the complex arrangements and high up-front costs involved in installing renewable heat systems that serve multiple properties
- perceived and genuine risks to the cost, quality and sustainability of biomass fuel supplies and to the reliability of biomass boilers

However, perceived enabling factors that may support future development of the non-domestic space and water heating market, identified through qualitative research and the sustainable markets assessment, include:

- increases in the ratio of gas prices relative to electricity prices, which will tend to improve the viability of non-domestic heat pump investments
- increases in carbon prices which will also improve the viability of renewable heat investments for major industrial installations that are subject to the UK ETS scheme
- increases in the priority attached to Net Zero commitments by social landlords, commercial and industrial firms, including drivers in these organisations’ procurement processes
- scope for further technological improvements and cost reductions, particularly in heat pump technology

A summary of perceived needs for future support is given in the final section of this report.

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[72] Findings from qualitative research with tariff guarantee applicants.
[73] Findings from qualitative research with agriculture and forestry applicants.
[74] Findings from research with installers in relation to SGLs and other heat pump technologies.

Perceived market barriers and enabling factors for process heating

Qualitative research found that RHI support was critical to the business case for process heating. Fewer installations were viable post-reform because of the removal of drying uses from the list of processes eligible for RHI. Qualitative research identified the main perceived barriers to further use of renewable heat for process heating as being:

- dependency on biomass and biogas as sources of high-grade heat for process heating - heat pumps and solar thermal supply low-grade heat so there is currently less choice of renewable heat technologies for high-grade heat uses than for space and water heating[75]
- the high capital cost of renewable heating systems compared to conventional heating systems
- reports from users of higher operational risks for biomass boilers, compared to conventional boilers (e.g. more frequent breakdown; fuel quality issues; more extensive maintenance requirements)
- air quality concerns and regulations around use of biomass, and concerns about the sustainability of biomass fuel sources
- variability in the cost and quality of biomass fuels and waste feedstock, with biomass prices reported to be influenced by competition from major users such as biomass power stations
- waste regulations specifying quality requirements for digestate from biogas plants, which require pasteurisation of certain feedstocks to ensure that digestate can safely be spread on agricultural land (pasteurisation is a heat-intensive process that effectively increases the production cost of biogas)
- challenging business cases for investment in renewable heat and/or renewable electricity for process heating, without Government support

Many of the perceived enabling factors for the process heating market, identified in qualitative research with applicants, are similar to those for the space and water heating market, namely:

- expectations of rising fossil fuel and carbon prices, including gas prices
- increased commitment to Net Zero by many companies and organisations

Consultation with supply chain stakeholders suggested that cost reductions through innovation were less likely for a well-established technology such as biomass. Supply chain stakeholders reported some innovations in Austrian and German markets relating to new systems with very low emissions coming to market, although the evaluation does not have further evidence about these.

A summary of perceived needs for future support is given in the final section of this report.

[75] In future, hydrogen may provide a low carbon source of high-grade heat for process heating.

Perceived market barriers and enabling factors for biomethane

Qualitative research identified a number of perceived market barriers to wider investment in biomethane including:

- the high capital cost and scale of biomethane investments, together with the complexity and risk involved in these investments
- locational issues, given the need for biomethane plants to be close to the gas grid and/or a gas injection point where planning permission can be obtained, and to have ready access to agricultural land for spreading of digestate
- difficulties in establishing long-term contracts for feedstocks that would support the long-term investment required in biomethane plants
- variability in the cost and quality of waste feedstocks, and variability of gate fees for waste in different locations
- waste regulations specifying quality requirements for digestate from biogas/biomethane plants, which require pasteurisation of certain feedstocks to ensure that digestate can safely be spread on agricultural land - as for biogas, pasteurisation is a heat-intensive process that effectively increases the production cost of biomethane

On the other hand, a number of perceived enabling factors were identified through qualitative research with biomethane stakeholders and applicants, in addition to the perceived enabling factors flagged for other renewable heat technologies:

- during the post-reform period of the non-domestic RHI, the closure of the ROCs and FiTs subsidy schemes reduced the attraction of using biogas to generate renewable electricity - this meant that more biogas producers considered biomethane production as a market for biogas
- wider collection of food waste (possibly driven by regulatory requirements) could lead to increases in gate fees, enhancing the viability of biogas and biomethane investments
- increases in the monetary value of Renewable Transport Fuel Certificates and Green Gas Certificates, arising from increasing demand for certificates from major gas users with commitments to net zero carbon - increased revenues from sale of these certificates by biomethane producers would increase the viability of biomethane investments
- biomethane processes involve relatively new technology so there is scope for innovation to improve efficiency or reduce costs

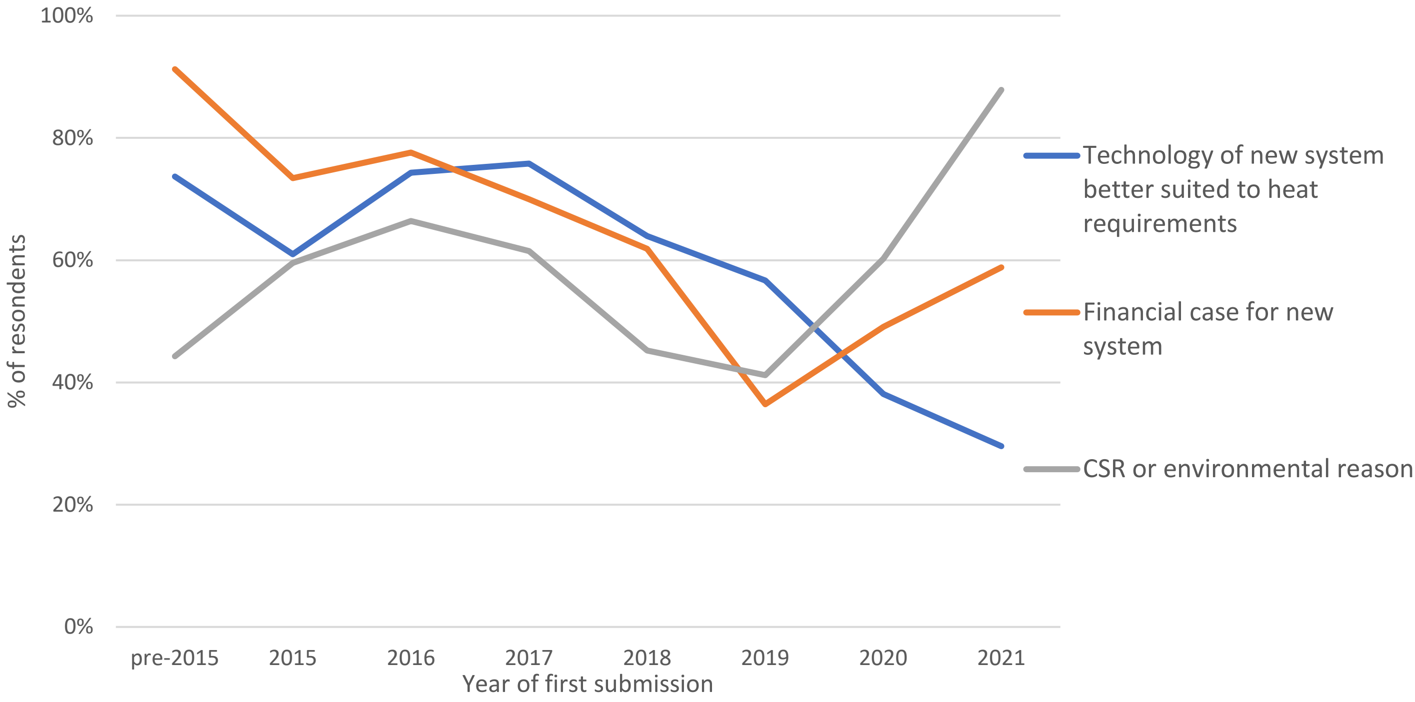
A summary of perceived needs for future support is given in the final section of this report.

Consumer motivations for installing renewable heating systems

Across all technologies, environmental and corporate sustainability motivations have risen in importance during the non-domestic RHI scheme as shown by Figure 18 below. By the end of the scheme, they were the most commonly-cited motivating factors reported by surveyed non-domestic applicants, followed by the financial case for the new system (including the RHI subsidy). Conversely, by the end of the non-domestic scheme, fewer applicants reported that they had chosen a renewable heating technology because it better suited their heating needs.

There was further evidence of strong environmental and corporate sustainability motivations from qualitative research with tariff guarantee applicants in 2021.

Figure 18: Factors in decisions to install a renewable heating system



Source: Applicant monitoring survey (n = 1,509), multiple responses allowed. Percentages refer to the proportion of applications first submitted within the relevant period.
Note: CSR means 'Corporate Social Responsibility' or Environmental, Social and Governance.

This chart illustrates the growth in corporate commitments to Net Zero during 2020-2021 which, if maintained, would support the future market for non-domestic renewable heat to some degree. The next final section below considers perceived needs for future support in different parts of the renewable heat market.

Perceived Needs for Future Support

Just over half of the non-domestic applicants reported that they would not have installed renewable heat technologies without the non-domestic RHI. This provides an indication of the scale of the likely impact on demand from the loss of the RHI, in the absence of other forms of support.

The perceived level of need for future support varies between technologies, depending on the level of additionality. Relative to the other eligible technologies, the additionality of the RHI was highest for biomethane installations, which were largely driven by RHI. Additionality was lowest for biogas (where most respondents reported that they would still have installed biogas or another renewable heat technology in the absence of RHI). The technologies perceived as being most in need of support, and the contexts affecting this need for support, are summarised below.

Biomethane

Previous synthesis of the evaluation findings relating to biomethane[76] concluded that the removal of the biomethane tariff would dramatically reduce investment in biomethane in the UK if all other factors remained the same. It found that reducing subsidy reliance would require wider market transformation, including enhancing the opportunities for, and the reducing the costs of, grid injection and increased gate fees for feedstocks. The level of incentives for biogas-produced renewable electricity were also found to be critical to the prospects for biomethane since many applicants had a choice between using biogas for CHP and biomethane. However, the Green Gas Support Scheme, which provides financial incentives for new biomethane plants, has been introduced since the research with biomethane applicants was conducted.

Evidence from qualitative research with biomethane applicants and stakeholders indicated that subsidy dependence would be lower for potential biomethane investors who:

- had secure access to self-supplied waste feedstock which required use or disposal, reducing their feedstock costs and reducing uncertainty about feedstock supply
- were able to charge gate fees for receiving waste feedstocks, improving the business case
- had access to low cost finance (e.g. internal funding or asset-backed loans), improving the business case
- had wider business imperatives for biomethane production (e.g. pro-environmental stance) and could see wider benefits from the investment

Large-scale biomass including process heat

Findings from the qualitative research suggested that non-domestic biomass installations were also largely dependent on the RHI. Ongoing support was found to be important not just in terms of maintaining investment in biomass, but also in continuing to develop and improve the technologies and associated supply chains.

Reforms to the RHI sought to incentivise large-scale biomass, as well as systems with high heat load factors, such as systems in use for process heating; and use in energy intensive industries. It was evident from the qualitative research that to achieve this, further targeting of future Government support on such uses for biomass would be needed. Evidence from the qualitative research suggested that the factors affecting the level of need for support included:

- whether there was an existing heat source was in need of replacement
- the level of access to the gas grid
- longer-term concerns about the costs of fossil fuels[77]
- the availability of secure, low-cost fuel supplies (e.g. from self-supply)

[76] CAG Consultants, Winning Moves & Hatch (2020) Evaluation of the reformed RHI: Biomethane Synthesis Report.
[77] Note that the qualitative research was conducted between 2018 and early 2021.

- perceived business benefits to adopting a renewable heat technology
- the potential investor's previous experience of using biomass heating
- whether internal or lower cost finance was available
- perceived process benefits from using heat from biomass

Large-scale heat pumps

There was limited evidence in relation to small-scale heat pumps, but the qualitative research found that the perceived barriers to large heat pump projects were sufficiently large that market prospects were limited in the absence of ongoing financial support. Some heat pump investments linked to heat networks may be able to obtain funding from the Green Heat Network Fund or other decarbonisation funds. Evidence from the qualitative research suggested that the opportunities for future projects without Government support would be limited to cases where:

- the environmental drivers were particularly strong
- where very low returns on investment could be accepted (e.g. in public sector contexts)
- where alternatives were limited
- where there were optimum combinations of large-scale heating and cooling demands

As noted in the previous section however, the need for future support in all these technology areas will be dependent on wider factors, particularly the relative costs of fossil fuel alternatives and the level of demand in supply chains for reductions in carbon emissions.

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