Department for Energy Security & Net Zero

Evaluation of the reformed Renewable Heat Incentive

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

Technical annex

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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. See Appendix D for more detail.
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 which involves exploring 'what works, for whom and in what circumstances' (or 'contexts').
Renewable heat (RH)	Heat energy that comes from a renewable source, such as biomass, the sun or the earth.
Renewable heat technology (RHT)	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.
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

Appendix A: Evaluation Questions

An initial set of EQs were originally set out in the invitation to tender (ITT) for the evaluation of the reformed Renewable Heat Incentive (RHI)[1]. These were then revised following the scoping phase of the evaluation, in consultation 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?
    a. How far have the scheme's carbon abatement and renewable heat generation aims been achieved, for whom and in what contexts, and is this additional to what would otherwise have happened?
    b. For whom and in what contexts has the reformed RHI influenced target beneficiaries to come forward for prioritised technologies, and was this at an expected scale?
2. How has design and implementation of the reformed RHI influenced these outcomes, in what respects and for whom?
    a. Has the reformed RHI more effectively removed barriers or enabled uptake for beneficiaries in some contexts and for some groups rather than others, and if so, how?
    b. Which aspects of the reformed RHI have been most effective in triggering desired changes, and how has this worked for different contexts/groups?
    c. Have there been unintended consequences and outcomes of the reformed RHI and, if so, how has the reformed RHI influenced how these operate and for whom?
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?
    a. What is the subsidy cost (per KW of installed capacity, per kWh of renewable heat generated to date and per tonne of CO2 abated to date) for installations completed pre- and post-reform, and how does this differ across technologies and between domestic/non-domestic beneficiaries?
    b. What is the value of Air Quality damage costs saved per £ of subsidy cost, for installations completed pre- and post-reform, and how does this differ across technologies?
    c. Drawing on analysis from the Competition and Trade Assessment (CTA) evaluation workstream, have there been any areas of

[1] These questions applied to both the non-domestic and domestic RHI schemes.

overcompensation, and if so, how and for which types of beneficiaries and contexts?

d. Drawing on analysis from the Sustainable Markets Assessment (SMA) evaluation workstream, how far has the reformed RHI stimulated market development, and if so how and for which types of beneficiaries and contexts?

e. What do the subsidy costs and delivery of the scheme tell us about the overall cost-effectiveness of the reformed RHI scheme in comparison to the pre-reform scheme, from the taxpayer's perspective?

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?

    a. In what ways has the reformed RHI contributed to improved marketing, financing and installation of renewable heat in different contexts?

    b. What have been the effects of the reformed RHI, across different market segments and technologies, to building up skills and capacities needed if renewable heat is to scale-up?

    c. Has the reformed RHI supported, sped up or created barriers to technological innovation in renewable heat, across different market segments and technologies?

    d. Has the reformed RHI contributed to the development of more favourable contexts within which the case for consumer adoption of renewable heat is stronger. If so, for whom, for which technologies and in which contexts?

5. What lessons can be drawn for the Department for Business, Energy and Industrial Strategy (BEIS) from the evaluation of the RHI regarding future renewable heat policy?

    a. Which renewable heat markets and supply chain models have promise for the future without RHI support, and how?

    b. Without RHI support, would there be any priority groups of suppliers or potential customers of renewable heat that would be left behind and for whom new policy instruments are needed, and how can take-up of renewable heat best be encouraged for these groups?

    c. To what extent, and in what contexts, have RHI priority heat technologies made progress towards becoming sustainable in the marketplace, with less need for further subsidies?

    d. What forms of public policy action (e.g. regulation, support for research and development (R&D), etc.) are needed to encourage take-up of renewable heat by different priority groups, sustain positive outcomes from RHI in different contexts and remedy unintended consequences?

Appendix B. Technical Methodology

This appendix sets out the methodology. It details the technical method employed for each piece of research conducted as part of the evaluation, from which evidence has been drawn in the production of this non-domestic RHI synthesis report.

Qualitative research

Introduction

About qualitative research

Although the analysis of each wave of qualitative fieldwork was informed by some quantitative analysis of the application database, it was primarily based on qualitative interviews and was therefore a presentation of the different views and experiences of those interviewed. It did not aim to quantify the number of research participants who held particular views or had particular experiences. This is because “the purpose of qualitative research is not to measure prevalence, but to map range and diversity, and to explore and explain the links between different phenomena.”[2]

The evaluation plan sets out key policy questions relating to the expected reforms and how they were intended and expected to work. These were defined in conjunction with BEIS. For each policy question, we identified ‘clusters’ of contexts that would enable testing of that policy question. Defining these clusters formed part of the initial scoping work, taking account of the findings of previous RHI evaluations, the objectives of the reformed scheme and current policy issues.

Realist glossary

Each wave of qualitative fieldwork was underpinned by a ‘realist’ approach, involving the development of theories (sets of CMOs) ahead of each wave of fieldwork, which were then tested during the fieldwork and refined post-fieldwork.

The table below sets out key ‘realist’ terms referred to in the methodology sections for each wave of qualitative fieldwork below.

[2] Ritchie, J., Lewis, J., McNaughton Nicholls, C. and Ormstom, R., (2014), Qualitative Research Practice (2nd edition.). London: SAGE.

Table 1: CMO glossary

Realist evaluation	A realist approach[3] to evaluation emphasises the importance of understanding not only whether a policy contributes to outcomes and impacts (which may be intended or unintended) but how, for whom and in what circumstances it contributes to these outcomes. It does this through exploring the factors that influence the generative 'mechanisms' (see definition below) that lead to outcomes of interest.
CMOs	Context-Mechanism-Outcome configurations. These are realist hypotheses about how the policy is expected to work, which are tested during the evaluation. See 'realist evaluation'.
Context	The circumstances which affect whether a policy 'works' and for whom. Consideration of 'context' forms an important part of realist approaches to evaluation.
Mechanism	A change in people's reasoning, brought about through the resources provided or actions taken by a policy, which leads to a policy outcome. Identification of causal 'mechanisms', which operate in particular 'contexts', forms an important part of realist approaches to evaluation.
Outcome	A change in the state of the world, brought about as a result of a policy or other influences. Realist approaches to evaluation attempt to identify the 'contexts' and 'mechanisms' that lead to a particular 'outcome'.

Biomethane fieldwork

This research was conducted during 2018-19.

Research questions

The following primary research questions were agreed:

- what role did the RHI play in the business case for biomethane installations which were the subject of RHI applications, and how did this interact with the other factors in the marketplace?
- what role did the different elements of the RHI and scheme reforms (in particular the feedstock rule, tariff uplift, tariff guarantees and removal of two-stage commissioning) play in the business case for biomethane plants?

[3] Pawson and Tilley (1997), Pawson (2006)

- what would have happened without the RHI and without the reforms to the RHI? How would this have altered the business case for biomethane plants?

Scope

A workshop was held with BEIS staff in September 2018 to further clarify the rationale and research questions for the biomethane cluster of research. Further to the above research questions, this identified additional interest in future policy development. Although it was recognised that the evaluation may not be able to address them directly, it was hoped that it may generate some useful insights. These questions included:

- Was the RHI the most appropriate way to support the industry? What were the alternatives?
- What is the right size of plant? Smaller numbers of large plants or larger numbers of small plants?
- How would the market respond to other potential policy changes, e.g. could operators react to tightening Greenhouse Gas (GHG) emissions limits?

To further enhance our understanding of the dynamics of the biomethane market, which could then inform our approach to research design, it was agreed at that workshop that a small number of scoping interviews (sampled purposively) would be conducted with key stakeholders. Interviews were subsequently conducted with technical experts/consultants/advisers, a technology manufacturer, a financier and a sector representative.

The scoping interviews explored:

- the types of biomethane applicants to the RHI, and how they are best categorised
- the extent of two-stage commissioning by RHI applicants
- the key factors determining applicants' progress with construction and commissioning
- the key factors determining the timing of applications vis-à-vis the RHI reforms
- how to identify the principal decision-maker within applicant organisations
- other key stakeholders in biomethane installations, to inform the selection of case study interviewees

The findings from the scoping interviews informed the approach to sampling and the design of the research instruments, described below. They also generated some useful data relating to the research questions, so the findings have been included in our analysis and incorporated in this report.

Sampling

The findings from the scoping calls, discussions with BEIS policy staff and an initial review of the applicant database suggested that the factors shown the table below would be important considerations for sampling.

Table 2: Sampling considerations for research with biomethane applicants

Factor	Reason	Data source
Date of application	Analysis of the application database and the scoping calls confirmed that the reforms were significant in the decision-making regarding the decision to proceed with a biomethane application. It was suggested in the scoping calls that some applicants were keen to apply prior to the reforms being implemented, for example to avoid feedstock restrictions, or due to a lack of certainty over tariff guarantees. It was also suggested that other applicants waited until the reforms became effective because of the higher tariffs available and/or the availability of tariff guarantees.	Applicant database.
Feedstock type	The scoping calls indicated that the following categories of feedstock were utilised: Farm waste; Energy crops; Sewage waste; Manufacturing/industrial waste; and Municipal food waste. Those who planned to utilise more than 50% energy crops in their plant would have been directly influenced by the reforms.	There was no readily accessible source of data on this prior to the applicant interviews. It was considered that the applicant type is a more significant determinant in the decision-making process and that including a range of applicant types would automatically capture a range of feedstock types.
Applicant type	The scoping calls indicated that there were some distinct types of applicants and that the decision-making and business cases will be	The applicant database included the applicant name and

Factor	Reason	Data source
	significantly different in each. The following typology was therefore developed: Farm-based. The applicant was a farmer or a developer on a farm site, and the feedstock was agricultural (typically farm waste or energy crops). Utility Company. The applicant was a utility company with their own feedstock (sewage waste). Manufacturer or linked to a manufacturer. The applicant was a manufacturer, or subsidiary company, with their own feedstock (waste from the manufacturing process). Developer. The applicant is a developer who may be developing multiple plants and may share equity in the schemes with a third party.	application company address. Research into the details of these enabled basic categorisation by applicant type for the purposes of sampling. Through the applicant interviews it became apparent that the categories were rather more complex than this, e.g. farm-based plants utilising more than just agricultural feedstock, or developers working closely with manufacturers on a manufacturing site.
Plant size	There was significant variation in the size of plant, which was likely to impact on the levels of investment risk and the nature and complexity of decision-making.	Applicant database.
Type of grid connection	The scoping calls indicated that some schemes had been able to lower development costs by adopting different types of grid connection. Two types were mentioned: Multiple plant with a single injection point; and Plants with lower pressure injection point (a National Grid scheme was mentioned). The type of grid connection may have had a bearing on the business case.	There was no readily accessible source of data on this prior to the applicant interviews so it was not possible to include it as a sampling criteria. Grid connection type was explored in the interviews.

Factor	Reason	Data source
Development stage	The scoping calls confirmed the use of 'two-stage commissioning' in the pre-reform RHI and that some plants did not go beyond the first stage. Some of these plants may have reached the first stage of commissioning without having secured finance or feedstock for the scheme or addressed all of the necessary planning/permitting issues, and these may have prevented the plant proceeding to completion. They highlighted that two-stage commissioning might also be evidenced in meter-readings for other cases (e.g. if early injection was required to test equipment, or if the initial installation was faulty and had to be stopped). With post-reform applications, two issues were identified: Achieving a tariff guarantee is challenging. Whilst this may serve to eliminate some of the more speculative schemes, it means that some will fail to secure the guarantee and be withdrawn or rejected; and The timescales for commissioning plant are challenging, which presents risks for applicants and may deter them from taking some plants through to completion.	Applicant database and admin database (for payments data).

A purposive sampling approach was taken for the main research. Table 3 provides details a breakdown of the sample for the subsequent applicant interviews.

Table 3: Sample details – applicant interviews

Sampling criteria	Number/description of interviewees[4]	Number/description of interviewees[5]
Application date	7 applications from the period 15 December 2016 – 21 May 2018 (pre-reform), of which:	11 applications from the period after 21 May 2018 (post-reform), of which:
Applicant type	1 was farm-based 2 were utility companies 1 was a manufacturer, or linked to one 3 were developers	4 were farm-based 1 was a utility company 2 were manufacturers, or linked to one 4 were developers
Development stage (at time of research)	2 had used 2-stage commissioning, under construction 2 had used 2-stage commissioning and were now fully commissioned 1 had not used 2-stage commissioning and was fully constructed but awaiting final commissioning 1 had not used 2-stage commissioning and was fully commissioned	7 had received tariff guarantee approval but were not yet commissioned 3 were awaiting stage 2 tariff guarantee approval 1 had received a tariff guarantee and was fully commissioned 1 was fully commissioned but the RHI application related to a change of ownership

Source: Non-Domestic RHI Application Database, November 2019 (excludes cancelled and rejected applications)

As can be seen in the table above, one of the post-reform cases sampled turned out to be an early 2016 application which was being re-registered with the RHI in May 2018 as a result of a change in ownership. The data from this case therefore had more limited relevance to our analysis. It did not readily relate to our theory as this was focused on the reforms. However, the data from the applicant interview was useful context and was used as far as possible.

[4] Details refer the type of biomethane plant the interviewee had installed.
[5] As above.

In addition to the applicant interviews, interviews were sought with other stakeholders involved in each of applications subject to interview above. The concept was to carry out a 'case study' approach, conducting interviews with multiple stakeholders involved in each of the applications/installations in question. The selection of these stakeholders was informed by discussion with the applicants – the applicant interviews included a question about the other most significant stakeholders in, or influencers of, the decision-making process for the plant in question.

From this sample, interviews were sought with a range of stakeholders including investors/financiers, feedstock providers, landlords, gas shippers, an AD plant owner, gas network operator, digestate user, consultant advisers and technology providers.

Despite extensive recruitment efforts (as outlined below) we were only able to secure three interviews with other stakeholders involved in our sample of schemes:

- a gas shipper
- a gas network operator
- a financier

Following discussion with BEIS, we used the remaining interview time to:

- carry out a stakeholder mapping exercise, to better understand the range of stakeholders involved in the biomethane supply chain, and to create a sample for wider stakeholder interviews
- conduct non case-specific stakeholder interviews with stakeholder types who it was felt could add to our understanding of the biomethane market and the role of the RHI in it (using the sample generated from the stakeholder mapping exercise)

This led to us conducting six further interviews with the following types of biomethane stakeholders:

- the operator of an AD plant, supplying biogas to a separately owned biomethane plant
- a digestate user
- a digestate distributor
- a food waste feedstock supplier
- a biomethane technology supplier
- a biomethane injection plant owner

Recruitment

CAG Consultants developed a recruitment process, agreed with BEIS. Recruitment involved the following stages:

- selection of sample to be contacted, and adaptation of the sample as recruitment progressed (as per the process described above)
- recruitment log developed to track communications to and responses from selected research participants
- invitation email sent to applicants and stakeholders in the sample. The email outlined details about the study and what their involvement in it would entail. It is also included a briefing note which provided information about consent terms, topics to be covered and interview practicalities

Data collection

The research involved undertaking semi-structured in-depth telephone interviews with applicants in January and February 2019, with interviews with stakeholders taking place in March and April 2019. Interview length was approximately 45-60 minutes per interview for applicant interviews and 30-45 minutes for other stakeholder interviews.

Topic guides were developed for applicants and each of the other stakeholders. The topic guides were focused primarily on the demand theory being tested.

The main topics covered in the applicant interviews were:

- introductions and consents
- application background, including feedstock, grid connection and stage of development
- organisations and decision-makers involved
- principal benefits of the business model
- the most significant elements of the business case for the installation
- the significance of the RHI in the business case
- the role of the RHI reforms in the timing of the application and the business case for the installation
- final reflections
- thank you and close
- the main topics covered in the stakeholder interviews were:
- introductions and consents

- their role in the supply chain and the nature of their relationships with other organisations
- principal benefits of their involvement in biomethane schemes
- the most significant elements of the business case for their involvement in biomethane schemes (if applicable)
- the impact of the RHI, and the reforms to the RHI, on their role
- their views on the future of the market for biomethane
- final reflections
- thank you and close

Interviews were recorded for research and quality assurance purposes, and then transcribed.

The interviews were conducted in confidence. No organisations or individuals were named in the report and some detail, including numbering of cases, was left out in order to avoid the risk of indirect identification of respondents.

Analysis

The analysis employed both Computer Assisted Qualitative Data Software Analysis (CAQDAS) and Excel spreadsheets. CAQDAS was used to code interview transcripts[6] and other data sources, including application data and survey evidence. The coded material relating to the theory was then exported to Excel.

An analysis framework was created within Excel to further code and analyse the evidence against contexts, mechanisms and outcomes (CMOs), enabling the theory to be tested and refined.

We analysed the extent of support for different CMOs in the framework and the potential for refining existing, or developing new, CMOs (see Table 1 for an explanation of CMOs). The coding and analysis was undertaken by two researchers and was quality checked for consistency by another research team member not directly involved in the coding and analysis process.

Limitations

Some limitations of the research are worth noting.

- our ability to conduct a ‘case study’ approach was constrained by difficulties in recruiting stakeholders specifically connected to the installations that the applicants interviewed had installed (i.e. stakeholders involved in specific cases), as well as challenges in accessing documentation about schemes, due to applicants’ concerns about commercial confidentiality - this limited the depth to which we were able to explore individual cases. However, all of the

[6] Coding involved a process of indexing, sorting and categorising interview transcript data, by case and by theme, so that it could then be analysed.

applicants/interviewees were the principal decision-makers for their applications, and so were able to talk about all aspects of their schemes in depth. This implied that the limited number of case-based ‘wider stakeholder’ interviews did not greatly affect the depth achieved for each case (i.e. each application/installation studied). Furthermore, a benefit in conducting more generalised wider stakeholder interviews instead was that we were able to gain a wider understanding of the market

- our research was exclusively focused on the reformed RHI, i.e. the RHI which was available to biomethane applicants from 15 December 2016 onwards -he significance of these reforms mean that the findings will be of limited benefit in understanding the role of the pre-reform RHI
- a relatively large sample was incorporated in the research (approximately 36% of all applications submitted after 15 December 2016 were included in our sample), which gives us confidence in the robustness of the conclusions drawn - however, given the heterogeneity of the market, understanding the variety of contexts for biomethane investment was challenging and it is likely that some contexts were missed or not fully explored and, inevitably, the findings represented generalisations to one degree or another

Shared ground loops fieldwork

This research was conducted 2019-20.

Research questions

The research focused on one key question and four sub-questions:

- how did the introduction of deemed payments for shared ground loops (SGLs) influence investment decisions by different types of stakeholders, for example social landlords?
- what role did the reformed RHI play in social landlord decision-making about the procurement and installation of SGLs?
- what influence did the reformed RHI have on wider consideration of heating systems and asset management (including investment in housing fabric) for social landlords?
- to what extent did the RHI reforms enable SGL installations: for whom, why and in what circumstances?
- what barriers prevent more SGL installations in the social housing sector: for whom, why and in what circumstances?

Scope

At the outset of the fieldwork, a workshop was held with BEIS policy staff to discuss and agree the scope of the research. Following the workshop, a final set of research questions was agreed (above), and the sampling strategy and other research instruments were developed.

Definitions

The following definitions were agreed with BEIS and used for the purposes of classifying the different types of heating systems studied in this research.

Table 4: Heat pump technologies covered in the research

Heat pump technology	RHI treatment pre-reform	RHI treatment post-reform
Shared ground loops systems – these comprise a shared loop in the ground[7] that serves as the heat source for multiple heat pumps in different properties (or different parts of the	Eligible for non-domestic RHI (twenty-year subsidy), even if buildings served are domestic	Eligible for non-domestic RHI (twenty-year subsidy), even if buildings served are domestic Payment for domestic properties made on the basis

[7] A ground loop can be laid out horizontally (in a long, shallow trench) or vertically (in a deep borehole). Shared loops for water source heat pumps can be located within a river, lake or other water source.

property). In these systems, the pipes running between properties carry water at fairly low temperatures. See also Figure 2 (Appendix D).	Received variable payments based on metered heat use	of the deemed heat demand of the property Heat demand limits for payments in respect of each domestic property For mixed use projects and non-domestic projects, payments in relation to the non-domestic properties continued to be on the basis of metered heat use
Communal ground source heat pumps – these comprise a large, central heat pump (normally GSHP rather than ASHP) that generates hot water and circulates it to a number of different properties. In these systems, the pipes running between properties carry hot water. See also (Appendix D).	Eligible for non-domestic RHI (twenty-year subsidy), even if buildings served are domestic Received variable payments based on metered heat use	Eligible for non-domestic RHI (twenty-year subsidy), even if buildings served are domestic All payments continued to be on the basis of metered heat use Heat metering and billing may also be required for individual properties under Heat Network Regulations (2014), where this is cost-effective[8]
Individual air source heat pumps – an individual domestic heat pump serving one property.	Eligible for domestic RHI (seven-year subsidy)	Eligible for domestic RHI (seven-year subsidy) Heat demand limits for payments

Sampling

The initial sampling framework was focused on achieving a spread of interviews across five main types of respondents:

- SGL applicants – social landlords
- SGL applicants – other applicant types

[8] The rules relating to metering of individual properties within new-build developments that use a communal heating system within a single building were subject to consultation in December 2019 and were under review by BEIS at the time of this research.

- multiple heat pump applicants – social landlords
- social landlords known to be active in relation to renewable energy and energy efficiency that had not installed renewable heating technologies under the RHI
- SGL installers

Table 5 provides more detail on the initial sampling framework.

Table 5: Initial sampling framework

Respondent type	Criteria	Population size	Sample source	Target no. of interviews
SGL applicants – social landlords	RHI applicants SGL installations serving domestic properties Social landlords Mixture of applicants: - post-reform (from 22 May 18) - 'interim' (14 Dec 16 – 21 May 18) - pre-reform (before 14 Dec 16)	14 total: 11 post-reform 2 interim 1 pre-reform	RHI application database	11 total: 9-11 post-reform 1-2 interim 1 pre-reform
SGL applicants -other applicant types	RHI applicants SGL installations serving domestic properties Individuals/organisations other than social landlords	Up to 52 total*: 3 post-reform Up to 16 interim* Up to 33 pre-reform*	RHI application database	6 total: 2 post-reform 2 interim 2 pre-reform

Respondent type	Criteria	Population size	Sample source	Target no. of interviews
	Mixture of applicants: - post-reform (from 22 May 18) - 'interim' (14 Dec 16 – 21 May 18) - pre-reform (before 14 Dec 16)			
Multiple heat pump applicants – social landlords	RHI applicants ASHP applications made for multiple neighbouring properties Applications made post-reform (22 May 18)	56	RHI application database	5
Non-RHI applicants – social landlords	Social landlords Active on energy efficiency Not applied to RHI scheme	Unknown	Purposively selected through BEIS/CAG contacts	5
SGL installers	Installers of SGL systems	Unknown	Identified through SGL applicant interviews	5

Source: Non-Domestic RHI Application Database, December 2019 (excludes cancelled and rejected applications)

*Only post-reform applications include a 'shared ground loop' column in the RHI database. This meant it was not possible to definitively identify SGL applications made prior to the reforms. Potential 'interim' and 'pre-reform' SGL applications were identified by searching for clusters of GSHP applications in neighbouring properties. Screening questions were therefore set up to help identify actual SGL installations.

Recruitment results

Recruitment was challenging.

With limited sample for post-reform applicants, reaching the stretching interview targets was always going to be ambitious. We therefore took a pragmatic approach to recruitment. We interviewed as many post-reform applicants as possible (11 in total) and supplemented these with two communal GSHPs (on the assumption they would provide useful comparative cases), using a sample provided by Ofgem.

Recruiting interim and pre-reform SGL applicants was also challenging as our screening of those who did respond revealed that most of the initial sample population were not SGL applicants. In total, just two interim period applicants were recruited, one SGL applicant and one communal GSHP applicant.

Multiple ASHP applicants were more straightforward to recruit. Early on in the fieldwork we took the decision to recruit more multiple ASHP applicants in lieu of non-applicant social landlords. This was because (a) we found that initial multiple ASHP applicant interviews were rich in data and provided valuable comparisons with SGL applicants, and (b) non-applicant sample were likely to be more challenging to recruit and provide less value as it would be difficult or time-consuming to identify non-applicants that had recently upgraded heating systems in properties suitable for SGLs.

SGL applicant interviews were not successful in generating sample for the installer interviews. In total, only three existing installers were identified. We therefore approached the Ground Source Heat Pump Association to ask for their assistance in recruiting installers. They asked their members for volunteers to take part in the research, which result in a sample population of ten (including the three installers identified through applicant interviews). The sample included other supply chain stakeholders (including consultants and manufacturers, for example) so our interviewees ended up being a mixture of relevant supply chain respondents with knowledge of supporting SGL system installations.

We agreed with BEIS not to go ahead with any interviews with non-applicant social landlords as BEIS and CAG could not identify sufficient numbers of social landlords in this category (many of the active social landlords were RHI applicants, for example).

The final composition is summarised in Table 6.

Table 6: Final sample composition

Type of interviewee	Pre-reform	Interim	Post-reform	Total
SGL applicants (social landlords)	0	0	9	9
SGL applicants (other)	0	1	1	2
Communal GSHP applicants (other)	0	1	1	2
Multiple ASHP applicants (social landlords)	0	0	9	9
Total applicants	0	2	20	22
Installers	N/A	N/A	N/A	6

The 'other' SGL applicants were a small business (with the installation serving a small mixed-use development) and a small private developer. The communal GSHP applicants were an installer serving retirement home developments and a private homeowner with multiple properties on their land.

Data collection

The research involved undertaking semi-structured in-depth telephone interviews, conducted between November 2019 and March 2020. Note that fieldwork was interrupted as a result of the 2019 General Election announcement and the subsequent purdah period.

Topic guides were developed based around the candidate theory and the research questions. Interviewers attended briefing sessions on the policy and technical background to the research, as well as the use of the topic guides. Interview length was typically 30-60 minutes per interview, depending on the respondent type.

The main topics covered in the applicant interviews were:

- introductions and consents
- organisation background
- the reasoning and contexts behind participant decisions to consider installing a new heating system
- factors influencing the respondent's decision on their choice of renewable heating technology (SGLs, individual ASHPs or communal GSHPs)
- the role of the RHI in the decision-making process about installing a new heating system

- installation and usage issues
- final reflections
- thank you and close

The main topics covered in the installer interviews were:

- introductions and consents
- organisation background
- installer insights into how their SGL clients make choices about new heating systems, including SGLs
- installer insights into the role of RHI and recent reforms on client decisions to install SGLs
- installer perspectives on the impact of shared round loop reforms on the wider market
- views on the future of the SGL market
- final reflections
- thank you and close

Interviews were recorded for research and quality assurance purposes and transcribed.

Analysis

The analysis employed both Dedoose (a type of Computer Assisted Qualitative Data Analysis Software (CAQDAS)), and Excel. Dedoose was used to code interview transcripts.[9] Each interview transcript was coded, with the coded material organised by topic and by participant. An additional framework was then created within Excel to further code, organise and analyse the evidence against contexts, mechanisms and outcomes (CMOs).

We analysed the extent of support for different CMOs in the candidate theory and the potential for refining existing, or developing new, CMOs. The coding and analysis were quality checked for consistency by another research team member.

Limitations

Key limitations of the research were:

- SGL applications eligible for deemed payments were only identifiable in the database from May 2018 - all other SGL applications prior to this date did not

[9] Coding involved a process of indexing, sorting and categorising interview transcript data, by case and by theme, so that it could then be analysed.

carry identifiers, which meant it was not possible to ascertain a quantitative view of the numbers of SGL applications over time

- the challenges in identifying domestic SGL applications prior to May 2018, noted above, meant we could not successfully identify and interview any applicants that may have installed SGLs prior to the RHI reforms
- a limited sample of new build SGLs. Installer interviews suggested a number of new build projects were in progress or had been completed but these projects did not appear in the RHI database - the implication here is that an important part of the SGL market, new build developers, was not engaged with for this research
- the researched focused mainly on the experiences of social landlords - while the sample included a few other types of applicants for SGLs or communal GSHPs, the non-social landlord sample was too small to provide conclusive evidence for these other types of applicants
- the recruitment method for supply chain respondents meant that the sample population was self-selecting, which may have introduced an element of self-selection bias amongst respondents - however, it is worth noting that the supply chain for SGLs is likely to be small because it is a niche technology and those interviewed for the research suggested there were only a very small number of SGLs in the market at the time, meaning the sample population would have been limited in any case

Manufacturing process fieldwork

This research was conducted 2019-20.

Research questions

The following primary research questions were agreed:

- have projects involving manufacturing process heat use been incentivised by the reformed RHI?
- what types of applicants are bringing schemes forward?
- what are the key factors which lead to schemes coming forward?
- what has been the role of the RHI and the scheme reforms (tariffs, tiering and tariff guarantees) and how have they interacted with other factors in the marketplace?

Scope

It was also agreed that a number of secondary research questions would be explored in the qualitative research and through the other workstreams, to the extent that this was possible within the constraints of the research, including:

- have the reforms delivered other value-for-money objectives of the reforms?
- have larger biomass schemes been incentivised?
- is there any evidence of overcompensation?
- is there any evidence of over-sizing?
- what have been the wider market impacts of RHI support, e.g. on the prices of biomass fuels and other raw materials such as paper pulp?
- what alternative policy approaches are there and how might they address barriers to the use of renewable heat in industrial processes, e.g. what difference would grant funding make?

The scope of the research and the approach to sampling was informed by detailed analysis of the data in the applicant database. The purpose of this analysis was primarily to understand the number and nature of applications which had been made for manufacturing process uses. The findings are summarised below.

Heat use and tariff band

The reforms had a wider focus on promoting larger biomass, not just manufacturing process use. The extent to which this had been achieved was of interest to BEIS (as outlined above), so the application database was analysed to assess the extent to which a larger pool of biomass applications would be missed by focusing just on applications for process heat use. See Table 7 below. The used date for the implementation of the reforms was 20 September 2017. This was the date when the single biomass tariff was introduced. However, the changes to eligible heat uses were introduced at a later date.

Table 7: Pre- and post-reform biomass applications by size band and heating type

Technology type	No process heating	Includes process heating	No process heating	Includes process heating
Large Biomass	26	49	41	58
Medium Biomass	2140	1421	172	192
Small Biomass	11549	1376	256	44
Total	13715	2846	469	294

Source: Non-Domestic RHI Application Database, August 2019 (excludes cancelled and rejected applications). Pre-reform period: 28 Nov 2011 - 19 Sep 2017; post-reform period: 20 Sep 2017 – Aug 19

The data indicated that an increasing proportion of applications involved process heating post-reform.

The proportion of all biomass applications which were in the large category increased following the reforms. However, the data also indicated that most biomass applications involving process heating were medium-sized, both pre- and post-reform. To better explore the research questions, the sample was extended to include medium-sized biomass applications with process heating.

Summary

Analysis of Standard Industrial Classification (SIC) code data highlighted that applications for manufacturing process uses (SIC codes 10-33) appeared to be a small but distinct cluster which were primarily reliant on biomass heat, plus a smaller amount of CHP, and with a wider range of usage types than the drying uses which are typical in the other primary SIC codes.

Sampling

Applicants

Based on the above analysis, we developed an applicant sample frame using the following criteria:

- manufacturing sector, i.e. SIC code = 10-33
- process use only (to avoid cases in which the application has been mistakenly classified as including process use or in which the process use is only a small proportion of the overall heat use)
- includes medium biomass, large biomass and CHP technology types

- includes post-reform announcement (16 Dec 2016) but pre-tariff guarantee (22 May 2018) applications and post-tariff guarantee applications
- excludes cancelled and rejected applications but includes pending applications

The proposed composition of the applicant sample is outlined in Table 8.

Table 8: Proposed sampling approach

Criteria	Pre-reform sample	Post-reform sample
Application date	16 Dec 2016 - 21 May 2018	Post—22 May 2018
Target sample size	8 applicants	4 applicants
Type of heat use	Process use only Including both drying and higher heat demand uses if possible	Process use only Including both drying and higher heat demand uses if possible
Technology type	2 CHP, 3 large biomass, 3 medium biomass	1 CHP, 1 large biomass, 2 medium biomass
SIC sector	From across as many of the SIC sectors 10-33 as possible	From across as many of the SIC sectors 10-33 as possible

Initial analysis of the applicant database indicated that the sample population comprised 153 applications from 74 applicants.

However, to ensure that we were able to include higher heat demand uses in the sample (as opposed to just drying uses), we:

- obtained further free text data with installation details on the relevant applications from Ofgem
- reviewed responses from the detailed applicant monitoring work from applications in the sample frame

- carried out further web-based research into the applicants in the sample frame in order to include both in the sample

This revealed that the majority of the 153 applications exclusively involved drying uses which would become ineligible post-reform, typically woodfuel, crop or waste drying. BEIS regarded the potential learning from these applications as limited because they were not part of the strategic direction of government policy. We therefore sought to exclude them from the sample frame using the information available to us. This resulted in a sample frame of 20 applications as of January 2020, with a further 5 applications identified as suitable in newer data supplied in March 2020.

Non-applicants

BEIS policy staff wanted to include a non-applicant sample in the research so that the barriers to the use of renewable heat in manufacturing processes could be better understood. These would be operators with similar characteristics and within the same SIC categories as the applicant sample so as to enable greater clarity to be gained about the distinctive contexts and mechanisms which lead to some pursuing renewable heat applications and others not.

A sample frame for non-applicants was generated from respondents to a survey carried out as part of the evaluation of the Energy Saving Opportunities Scheme (ESOS).[10] It was possible from the survey data to identify those which:

- were coded as manufacturing sector
- said they had implemented or planned measures in all three of the 'heating', 'hot water' or 'process' categories
- consented to be recontacted

Further web-based analysis of the nature of the non-applicants enabled us to refine the sample frame so that the types of manufacturing undertaken were similar to those within the applicant sample frame. This resulted in a non-applicant sample frame of 15 manufacturers, from which six interviews were sought.

Recruitment

CAG Consultants developed a recruitment process, agreed with BEIS. Recruitment involved the following stages:

- Selection of sample to be contacted, and adaptation of the sample as recruitment progressed (as per the process described above)
- recruitment log developed to track communications to and responses from selected research participants
- invitation email sent to applicants and stakeholders in the sample. The email outlined details about the study and what their involvement in it would entail. It

[10] ESOS is a mandatory energy assessment scheme for large organisations in the UK.

also included a briefing note which provided information about consent terms, topics to be covered and interview practicalities

Recruitment of applicants and non-applicants[11] proved to be challenging and given the limited sample frames, it was not possible to fully meet the intended sampling criteria. 11 applicants and 5 non-applicants were recruited and interviewed. The distinctions between the intended applicant sample and the achieved applicant sample are summarised below.

Table 9: Sample composition – variation from sampling criteria

Sampling criteria	Number in sample frame	Intended number in sample	Achieved number in sample
Application timing			
16 Dec 2016 – 21 May 2018	15	8	6
Post 22 May 2018	10	4	5
Technology/tariff band			
Biomass CHP	6	3	5
Large biomass heat-only	5	4	2
Medium biomass heat-only	10	5	4
Non-applicants	15	6	5

Data collection

The research involved undertaking semi-structured in-depth telephone interviews with applicants and non-applicants in January to March 2020. Interview length was approximately 60-75 minutes per interview for applicant interviews and 30-45 minutes for non-applicant interviews.

Topic guides were developed for applicants and non-applicants. The topic guides were focused primarily on the demand theory being tested.

Interviewers attended briefing sessions on the policy and technical background to the research, as well as the use of the topic guides. Interviewers were encouraged to use the guides to explicitly test different propositions within the theory to test whether they applied, using the topic guide flexibly to achieve this outcome.

[11] Note that, in some cases, interviews were conducted with a third-party representative of the applicant or non-applicant organisation, i.e. a consultant acting on their behalf.

In advance of the interview, interviewers were provided with information about the applicant and application from the administrative data. This enabled the interviewer to have an informed conversation with the applicant and reduce time collecting information the applicant had already provided elsewhere.

The main topics covered in the applicant interviews were:

- introductions and consents
- application background – nature and history of the site and planned installation
- fundamentals of the business case for the installation
- role of the reformed RHI in making the installation viable
- final reflections
- thank you and close
- the main topics covered in the non-applicant interviews were:
- introductions and consents
- background to the business/site
- extent to which new heating systems have been considered
- extent to which renewable heat installations have been considered
- if relevant, reasons why a renewable heat installation was considered but rejected
- if relevant, reasons why a renewable heat installation was not considered
- future potential for renewable heat
- final reflections
- thank you and close

Interviews were recorded for analysis and quality assurance purposes, and then transcribed.

The interviews were conducted in confidence. No organisations or individuals are named in this report and some detail, including numbering of cases, has been left out in order to avoid the risk of indirect identification of respondents. Quotes and other references to specific sources are identified using general labels, e.g. ‘large biomass applicant’, ‘CHP applicant’, ‘non-applicant’ etc.

Analysis

The analysis employed both Dedoose, a Computer Assisted Qualitative Data Software Analysis (CAQDAS), and Excel spreadsheets. Dedoose was used to code interview transcripts[12] and other data sources, including application data and survey evidence. The coded material relating to the theory was then exported to Excel. A framework was created within Excel to further code and analyse the evidence against contexts, mechanisms and outcomes and the theory being tested.

We analysed the extent of support for different CMOs in the candidate theory and the potential for refining existing, or developing new, CMOs. The coding and analysis were quality checked for consistency by another research team member.

Limitations

Some limitations of the research are worth noting:

- our research was exclusively focused on the reformed RHI, i.e. the RHI which was available to biomass applicants from 15 December 2016 onwards - most of the reforms were only fully implemented in September 2017 and May 2018 so the findings will provide some insight into the role of the RHI in the pre-reform period but the focus of the findings is on the impact of the reforms

- our samples were relatively limited and our use of the data was even more constrained by two factors:

    - one of the interviewees in the applicant sample was with a consultant who needed sign-off of the interview transcript from the applicant organisation - the applicant organisation was unable to respond to this request so that interview transcript has not been fully analysed and is not quoted in this working paper (we have, however, checked to see that the case fits with one of the CMOs in our revised theory)

    - in another of the applicant cases, the reforms, and therefore our theory, were not relevant as the installation was being re-accredited following the relocation of the boiler so was eligible for the original tariff (from 2014 in the case) - the findings from the interview were still useful, however, in informing the wider findings

[12] Coding involved a process of indexing, sorting and categorising interview transcript data, by case and by theme, so that it could then be analysed.

Agriculture and forestry biomass fieldwork

This research was conducted 2020-21.

Research questions

The following primary research question was set:

- to what extent have biomass projects in agriculture and forestry sectors been incentivised by the RHI?

Scope

A number of sub-questions followed from this and, linked to these sub-questions, some of the specific issues arising from the applications database were also incorporated. These sub-questions are informed by the realist approach to the RHI evaluation which seeks to explore not just what outcomes were achieved by the reformed RHI and why but also for whom they occurred, in what circumstances and how.

- for whom, i.e. what types of applicants are bringing biomass projects forward? What is the heat being used for?
- is biomass essential to these projects or are applicants choosing between biomass and other technologies such as CHP, biogas and heat pumps? Are applicants choosing between pre-accredited and new boilers? How does this differ between the two sectors and why?
- why has process heat use declined in the post-reform period? What types of process heat use have continued?
- in what circumstances, i.e. what are the key factors which lead to schemes coming forward? Conversely, what are the key factors which prevent schemes coming forward and how might they be overcome?
- what factors have been critical in the post-reform period, when the overall number of applications have been far lower than pre-reform?
- do the key factors differ between different sizes of projects?
- do the key factors differ between pre-accredited and new boilers?
- what has been the role of the RHI and the scheme reforms (tariffs, tiering and tariff guarantees) and how have they interacted with other factors in the marketplace?
- was the spike in applications in the first two quarters of 2017 and in the second quarter of 2018 a result of the anticipation of the reforms being implemented? If so, which aspects of the reforms in particular drove these spikes?
- to what extent have larger projects been incentivised by the tariff changes?

- have gaming incentives been reduced? If so, why is there still clustering around the old tariff boundaries?
- why have tariff guarantees been utilised so sparsely in the agriculture sector and not at all in the forestry sector?[13]
- have the reforms incentivised the use of pre-accredited boilers?

A further secondary question was explored, to the extent that it was possible within the constraints of the research:

- what have been the wider impacts of the RHI and the reforms on the rural economy?

Sample frame

Based on the analysis of the application database and the focus of the research questions, an applicant sample frame was developed which met the following criteria:

- agriculture or forestry sector, i.e. SIC code of the heat generator was ‘01’ or ‘02’
- technology type was ‘solid biomass boiler’
- post-reform applications (i.e. first submission date after 22 May 2018, when the eligible heat use changes were introduced and tariff guarantees were available, although the tariff changes were introduced earlier on 20 September 2017)
- applications that had not been cancelled, withdrawn or rejected

The above sample frame constituted 207 applications (based on the August 2020 non-domestic applications database).

Sample composition

The intended and achieved composition of the sample is outlined in Tables 10 and 11 below, with the number of applications in the sample frame meeting each criteria shown in brackets. Applicants were selected purposively to meet the sampling criteria set out below.

[13] Our analysis of the August 2022 RHI application data found that there were had been no tariff guarantee applications in the forestry sector (based on Generator SIC) and only 11 in the agriculture sector. This represented only 7% of the 160 applications in the agriculture sector since the third quarter of 2018 (after tariff guarantees became available) and less than 6% of all of the 195 tariff guarantee applications made (excluding cancelled and rejected).

Table 10: Sample composition for the agriculture sector (generator SIC = 01) (169) (number of applications in the sample frame which meet each criteria is shown in brackets)

Proposed no. of interviews	Achieved no. of interviews
10 applicants	10, although one was a poor fit with this sector (although some agricultural uses were present on the site, the site was primarily a visitor attraction)
As even a mix as possible of: small (58), medium (87) and large (25) installations	4 small, 3 medium, 3 large
Including 2 pre-accredited boilers/tariffs	3
As far as possible (given sample size constraints) seeking to prioritise projects which include process use (rather than space heating)	2 applications involved grain drying. All of the others were for space heating, but as part of a process, e.g. rearing poultry or growing crops
Include 1 or 2 tariff guarantee applications	0 (there was only 1 tariff guarantee application in the sample frame and they declined to participate)
Including a mix of new build and replacement heating systems	5 new build, 5 retrofit
Including a mix of and off-gas grid projects	6 off-gas grid, 4 on-gas grid

Source: Non-Domestic RHI Application Database, August 2020 (excludes cancelled and rejected applications)

Table 11: Sample composition for the forestry sector (generator SIC=02) (38) (number of applications in the sample frame which meet each criteria is shown in brackets)

Proposed no. of interviews	Achieved no. of interviews
8 applicants	8
As even a mix as possible of: small (16), medium (21), large (1)	4 small, 3 medium, 1 large
Including 2 pre-accredited boilers/tariffs	4, plus 2 that were effectively pre-reform application (one had been originally rejected but was then appealed. Another was an application for biomass heat-only, which had been approved pre-reform for use in a CHP system)
As far as possible (given sample size constraints) seeking to prioritise projects which include process use (rather than space heating)	7 of the 8 projects involved process uses, principally fuel or timber drying
Including a mix of new build and replacement heating systems	4 new build, 4 retrofit
Including a mix of and off-gas grid projects	All off-grid

Source: Non-Domestic RHI Application Database, August 2020 (excludes cancelled and rejected applications)

We also included four interviews with stakeholders with knowledge or experience of the supply chain to gain wider insights on the impact of the reforms on the use of biomass in the agriculture and forestry sectors. These included representatives from:

- The Wood Heat Association – the UK trade association for the biomass heating industry, bringing together wood fuel suppliers, biomass boiler and stove installers and distributors, energy companies and developers
- Re-heat – a large and long-standing biomass consultancy and installer, working nationally
- NFU Energy – a large energy consultancy working extensively in the agriculture sector
- National Farmers Union (NFU) – a member organisation/industry association for farmers in England and Wales

Recruitment

CAG Consultants developed a recruitment process which was agreed with BEIS. Recruitment involved the following stages:

- selection of sample to be contacted, and adaptation of the sample as recruitment progressed
- recruitment log developed to track communications to and responses from selected research participants
- invitation email sent to applicants and stakeholders in the sample – the email outlined details about the study and what their involvement in it would entail. It also included a briefing note which provided information about consent terms, topics to be covered and interview practicalities

As shown in Tables 10 and 11, it proved to be challenging to meet all of the sampling criteria so some modification of the intended sample composition had to be accommodated. In particular, we were unable to include any tariff guarantee applications – there was only one in the sample frame and that applicant declined to participate – and we were unable to recruit any of the limited number (7 of 38) forestry applications that were labelled as being on the gas grid. The distinctions between the intended applicant sample and the achieved applicant sample are summarised above in Tables 10 and 11.

Data collection

The research involved undertaking semi-structured in-depth telephone interviews with applicants and stakeholders in October and November 2020. The typical interview length was approximately 60-75 minutes.

Topic guides were developed for applicants and stakeholders. The topic guide for applicants was focused primarily on the demand theory being tested. Variants were developed for those making a new application and those applying to relocate a boiler and/or tariff. The topic guide for stakeholders included fuller exploration of the pre- and post-reform impacts of the RHI on demand for biomass and the supply chain.

Interviews were recorded for analysis and quality assurance purposes, and then transcribed.

The interviews were conducted in confidence. With the exception of the sector stakeholder organisations, who gave consent to be named, no organisations or individuals are named in this report. Some detail, including numbering of cases, has been left out of the detailed analysis sections in order to avoid the risk of indirect identification of respondents.

Analysis

The analysis employed both Dedoose, a Computer Assisted Qualitative Data Software Analysis (CAQDAS) package, and Excel. Dedoose was used to code interview transcripts[14] and other data sources, including application data and survey evidence. The coded material relating to the theory was then exported to Excel. A framework was created within Excel to further code and analyse the evidence against contexts, mechanisms and outcomes and the theory being tested.

We analysed the extent of support for different CMOs in the candidate theory and the potential for refining existing, or developing new, CMOs. The coding and analysis were quality checked for consistency by another research team member.

Limitations

Key limitations of the research were:

- as highlighted in the sampling section above, it was not possible to fully achieve our intended sample composition as only one tariff guarantee application was in the sample frame and this applicant declined to participate. – whilst one or two of the non-tariff guarantee applicants had considered the tariff guarantee route and commented briefly on their reasons for rejecting it, we do not have data on the contexts in which this reform could have played a role in enabling projects to proceed
- not all the applicant interviews turned out to be directly relevant to the research – one in the agriculture sample turned out to be largely non-agricultural in nature (it was a visitor attraction with some agricultural uses on site which were unrelated to the heat usage), while two of the applications in the forestry sector turned out to be pre-reform applications
- the three applications described above, although not directly relevant to the research questions, were used to provide more general insights into the demand for biomass and allowed some hypothetical exploration of how the reforms might have impacted their business cases
- although the resulting sample was more limited than anticipated, we do not feel that this significantly impaired our ability to fully test the theory – some of the individual reform-specific variants in the theory were not tested but each of the categories of CMOs was explored, where it was possible for us to test with applicants
- with regard to the wider insights and the market prospects for biomass findings in this fieldwork, we were largely reliant on a limited number of stakeholders – each of these was very knowledgeable about the use of biomass heat in the agriculture and forestry sectors and were able to share valuable insights and views but some caution needs to be attached to the findings in these sections, since each of them to some extent had vested interests in the deployment of biomass in the two sectors

[14] Coding involved a process of indexing, sorting and categorising interview transcript data, by case and by theme, so that it could then be analysed.

Tariff guarantees fieldwork

This research was conducted in 2021.

Research questions

The following primary research question was set:

- to what extent have large heat pump projects been incentivised by the reformed RHI?

Several sub-questions followed from this, some of them linked to the specific issues arising from the analysis of the applications database. These sub-questions were informed by the realist approach to the RHI evaluation which seeks to explore not just what outcomes were achieved by the reformed RHI and why, but also for whom they occurred, in what circumstances and how.

- for whom, i.e. what types of applicants brought forward large heat pump projects under the reformed RHI? What is the heat being used for?
- were heat pumps essential or were applicants choosing between different renewable technologies?
- in what circumstances, i.e. what were the key factors which lead to projects coming forward? Conversely, what are the key factors which prevented projects coming forward?
- how did the key factors differ between agricultural and housing contexts?
- what were the key factors which lead to heat network applications coming forward?
- how? i.e., what has been the role of the RHI and the scheme reforms (particularly tariff guarantees) and how have they interacted with other factors in the marketplace?
- could the projects have proceeded without tariff guarantees? How would the projects have differed in the absence of these guarantees?
- what was the impact of the changes to the tariff guarantees in July 2019 (extension of commissioning deadline to Jan 21) and July 2020 (flexible allocation and further commissioning deadline extension) on current (i.e. those which were already registered) and prospective applications?
- what was the impact of the budget cap on current and prospective applicants?
- how did the prospect of the closure of the RHI affect applicant behaviour?
- how will the closure of the RHI affect the prospects for large heat pumps? What role has the additional allocation of tariff guarantees on the transition?
- what has been the role of other funding sources?

Sample composition

A purposive approach to sampling was adopted.

Based on the application database analysis, the sample populations available (discussed below in Section 2.23), and given the focus of the research questions, we developed a tariff guarantee application sample frame which met the following criteria:

- agriculture or housing sector (i.e. Generator SIC code = 01 for agriculture or SIC code = 55 as a proxy for the housing sector, and/or application was for a heat network)[15]
- the technology type was ground source heat pump or water source heat pump
- cancelled and rejected applications were excluded

The above sample frame constituted 229 applications (based on the March 2021 non-domestic applications database).

From that sample frame, we sought to sample an even split of agriculture and housing sector applications. We also tried to ensure diversity in the sample through seeking a mix of ground- and water-source heat pumps in both sectors and a mix of sizes in both sectors. The sample frame was divided into three size categories (as shown in Table 12 below) to facilitate this.

We also sought to include diversity in the timing of the applications in the sample. This was partly to ensure that we included some of those applications which benefited from the additional allocation of tariff guarantees in July 2020 but also to ensure that we included some later applications, when application numbers had declined. It was felt that this may be useful in generating insights on the impacts of the budget cap, the end of the scheme and any other factors which may have contributed to this decline.

Since the promotion of heat networks was a specific objective of the reforms, we also sought to ensure the inclusion of some such applications in the sample through using the limited data on this in the application database.

We also developed a sample frame for non-tariff guarantee applications from the same two sectors (agriculture and housing), excluding cancelled and rejected applications. We focused this sample frame on very large (1MW+) heat pump applications. These were seen to have been ideal candidates for utilising a tariff guarantee so it was hoped that they would provide useful primary evidence on the decision-making around tariff guarantees and the additionality they delivered. This sample frame constituted 40 applications (based on the March 2021 non-domestic applications database), representing approximately 25 separate applicants. Other than sampling applications from both sectors, no further sampling criteria were applied to this sample frame.

[15] These sectors were selected as most of the applications for large heat pumps were from these two sectors.

The composition of the resulting sample is shown in the table below.

Table 12: Sample composition

	Housing Sector (generator SIC = 55)	Agriculture Sector (generator SIC = 01)	Total
Non-tariff guarantee application	2	3	5
Tariff guarantee application	8	9	17
Housing sector	10	0	10
Agriculture sector	0	12	12
Installation size 100-999kW	7	4	11
Installation size 1-1.99MW	1	1	2
Installation size 2MW+	2	7	9
GSHP – borehole	4	1	5
GSHP – ground loops	1	8	9
WSHP – borehole	3	1	4
WSHP – water body	2	1	3
Other/uncertain[16]	0	1	1
Standalone	0	10	10
Communal heat network[17]	1	0	1
District heating[18]	3	0	3
Other heat network[19]	3	2	5
SGL	3	0	3
Applied pre-20 July 2020	3	8	11

[16] One of the applications involved using heat from refrigeration plant.
[17] Networks supplying heat to multiple units within the same building.
[18] Networks supplying heat to multiple separate buildings under different ownership.
[19] This category was included to capture cases which were identified in which networks were supplying heat to multiple separate buildings under the same ownership.

Applied post-20 July 2020 (flexible allocation of tariff guarantees introduced)	7	4	11
New heating system	4	8	12
Replacement heating system	6	4	10

Source: Non-Domestic RHI Application Database, March 2021 (excludes cancelled and rejected applications)

We also conducted three stakeholder interviews to obtain a broader view of the market before and after the introduction of tariff guarantees. Interviews were conducted with representatives from the Heat Pump Association, the Ground Source Heat Pump Association and NFU Energy.

Recruitment

CAG Consultants developed a recruitment process which was agreed with BEIS. Recruitment involved the following stages:

- selection of the sample to be contacted, and adaptation of the sample as recruitment progressed
- a recruitment log was developed to track communications to and responses from selected research participants
- an invitation email was sent to applicants and stakeholders in the sample - the email outlined details about the study and what their involvement in it would entail, and also included a briefing note which provided information about consent terms, topics to be covered and interview practicalities

Data collection

The research involved undertaking semi-structured in-depth telephone interviews with applicants and stakeholders during June and July 2021. The typical interview length was approximately 60-75 minutes.

Topic guides were developed for applicants and stakeholders. The topic guide for applicants was focused primarily on testing 'demand theory' for the reformed RHI.[20]

Interviews were recorded for analysis and quality assurance purposes, and then transcribed.

Analysis

The analysis employed both Dedoose, a Computer Assisted Qualitative Data Software Analysis (CAQDAS) package, and Excel. Dedoose was used to code

[20] This evaluation uses a theory-based approach. A high-level theory of change for the reformed RHI is underpinned by detailed theory on demand, supply, usage and (where relevant) fuel/feedstock supply for renewable heat in the domestic and non-domestic RHI scheme. The focus of this research was demand theory.

interview transcripts[21] and other data sources, including application data and survey evidence. The coded material relating to the theory was then exported to Excel. A framework was created within Excel to further code and analyse the evidence against contexts, mechanisms and outcomes and against the theory being tested.

We analysed the extent of support for different CMOs in the candidate theory and the potential for refining existing, or developing new, CMOs. The coding and analysis were quality checked for consistency by another research team member.

Limitations

- the principal limitation of the research stemmed from the exclusion of non-applicants to the RHI (i.e. either projects that proceeded in the absence of the RHI or potential projects which did not proceed) who were excluded because there was no means of identifying such non-applicants with the resources available for this research - this meant that our ability to fully test the theory relating to projects which did not proceed was limited (i.e. whether applicants who had received RHI would have readily acknowledged it if there project could have proceeded without the RHI?)
- evidence gathered from stakeholders helped to fill this gap and test the findings from applicants to some extent, although it should also be noted that whilst the stakeholders who were interviewed had a good overview of the non-domestic heat pump market, only three stakeholder interviews were conducted - the stakeholder sample should not be seen as representative of the population of stakeholders in the market for non-domestic heat pumps
- the decision was taken to focus this research on two sectors, agriculture and housing - whilst some of the findings will have relevance across other sectors, caution needs to be taken in applying the conclusions from this research more widely

[21] Coding involved a process of indexing, sorting and categorising interview transcript data, by case and by theme, so that it could then be analysed.

Detailed applicant monitoring

This appendix sets out the methodology used to conduct surveys with applicants[22] to the RHI scheme.

The overall evaluation aimed to both assess the impact of the scheme and provide strategic learning to support heat policy development. To help achieve these aims, surveys of non-domestic applicants took place from 2014 (i.e. starting in the pre-reform period as part of the original RHI evaluation), up until scheme closure as part of the evaluation of the reformed RHI.

The applicant surveys described in this appendix were necessary because the application process, and further administration of the scheme, did not collect sufficient evidence to address the evaluation questions. This application and administrative data were however used in combination with the survey data to provide a full picture of scheme applicants (for example the application includes details of the technology installed, but the survey was required to provide applicant demographics or motivations for applying).

The applicant surveys were originally intended to be a census of all accredited applications. For that reason, they were sent to every single non-domestic applicant. However, due to practical limitations, the obtained responses were closer to an opportunity sample than a census. These limitations were:

- despite the invitation being sent to all applicants, only a fraction of those (c. 20%) responded to the survey
- applicants could only be sent the survey once, regardless of how many applications they had submitted

The sample was not randomly selected, and therefore it was not appropriate to undertake statistical significance testing. This meant that differences in results between survey waves could only be descriptively reported. Overall, it was still deemed appropriate to maintain this opportunity sampling approach, to maximise responses and ensure continuity with earlier waves.

Applicant surveys completed

Nine accredited non-domestic applicant survey waves have been completed. These include two accredited non-domestic applicant waves pre-dating the current evaluation project, as well as seven waves of monitoring surveys of reformed non-domestic RHI applicants for this evaluation (including two retrospective surveys and five waves of an ongoing bi-annual monitoring). These are outlined in the table below.

[22] Specifically, 'recipient' as the survey has focused upon successful applicants only.

Table 13: Table outlining application dates eligible and the dates over which the survey was active for each survey wave by applicant group.

Survey wave	Applicant type (online survey unless stated)	Eligible dates	Dates the survey was active
Non-Domestic waves 1-2. These waves pre-date this evaluation project and are not discussed in detail in this document[23].		Applicants who applied between November 2011 – 4th January 2014 and 5th January 2014 – 31st December 2014	3rd March 2014 to 31st March 2014 and 23rd February 2015 and 6th March 2015
25[24]	Non-domestic	1st January 2015 – 20th September 2017	November 2017 – January 2018
25	Biogas/biomethane (telephone)	1st January 2015 – 20th September 2017	December 2017 – January 2018
25	Specific non-domestic sub-samples (telephone)	1st January 2015 – 20th September 2017	January – February 2018
26	Non-domestic	21st September 2017 – 31st August 2018	October - November 2018
26	Biogas/biomethane	21st September 2017 – 31st August 2018	October - November 2018
27	Non-domestic	1st September 2018 – 28th February 2019	April - May 2019
27	Biogas / biomethane	1st September 2018 – 28th February 2019	April - May 2019

[23] Full details and methodology https://www.gov.uk/government/publications/non-domestic-survey

[24] For consistency within the survey fieldwork discussed in this appendix, the non-domestic surveys conducted from 2017 onwards are numbered in line with the domestic survey waves, which for the post-reform period, begin from wave 25.

Survey wave	Applicant type (online survey unless stated)	Eligible dates	Dates the survey was active
28	Non-domestic	1st March 2019 – 31st August 2019	October 2019 - January[25] 2020
28	Biogas / biomethane	1st March 2019 – 31st August 2019	October 2019 - January[26] 2020
29	Non-domestic	1st September 2019 – 29th February 2020	April 2020 – June 2020
29	Biogas / biomethane	1st September 2019 – 29th February 2020	April 2020 – June 2020
30	Non-domestic	1st March 2020 – 31st August 2020	October – November 2020
30	Biogas / biomethane	1st March 2020 – 31st August 2020	October – November 2020
31	Non-domestic	1st September 2020 – 30th March 2021	May-June 2021
31	Biogas / biomethane	1st September 2020 – 30th March 2021	May-June 2021

Sample selection

The RHI accredited applicant survey covered all applications that had been accredited to the scheme. 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.[27] Applicants who had already been sent the survey in previous waves for a different application are excluded from the sample. 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. There were a number of fields used to weight the data, as described in the section on ‘data preparation’, but these do not form part of the selection criteria. Every unique applicant was invited to participate, and the application date range was used to select those that should be approached within each wave of monitoring.

[25] Fieldwork period was extended to accommodate purdah.
[26] Fieldwork period was extended to accommodate purdah.
[27] The survey asks questions which are specific to the installation, so it is necessary to ask applicants for multiple installations to think about one in particular when responding to the survey.

The RHI accredited applicant survey covered two main groups: non-domestic RHI applicants (for all technologies except biogas/biomethane) and non-domestic RHI applicants for biogas/biomethane plants. Biogas / biomethane were different from other technologies covered as they were not generating heat but a fuel which is then used elsewhere. This could be pumped into the gas grid or used for on-site heat/transport. Some plants were set up as a completely independent business. The question areas of interest to BEIS were therefore different to non-domestic applicants generally, therefore two separate surveys were created.

For consistency with previous monitoring work, Winning Moves approached only successful applications with an accreditation date in the period under examination. This reduced the risk of approaching cases where an application had been made but the Renewable Heating Technology was yet to be installed, as well as the risk of approaching applicants that had already been approached in a previous wave[28].

Survey mode

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 in the period of interest, as documented above.

Advantages of conducting the survey online were that:

- it was consistent with the approach used in historic monitoring
- the questionnaire contained several lengthy questions and questions featuring a large list of options - a telephone interviewer reading these out would be inefficient at scale and likely lead to lower quality answers or respondent drop-out due to length and perceived complexity
- it enabled the inclusion of applicant information that customised the survey for each applicant
- it enabled respondents to complete the survey in multiple stages at their leisure (as their progress was saved) and so potentially reduced drop-out

Potential drawbacks and issues when conducting online surveys include:

- low response rates. This is less of an issue in contexts such as this, however, where only successful RHI applicants were approached - successful applicants are more engaged in the process and therefore more likely to complete the survey compared to asking those that were unsuccessful.
- as the sample was self-selecting, there can be limited control over which applicants choose to respond, e.g., where a sub-sample of a particular characteristic is small to begin with, representation of a particular group of interest could be too small to allow for meaningful analysis - for this reason,

[28] Unsuccessful applicants were the focus of qualitative workstreams within the wider evaluation project.

follow-up telephone interviews were conducted to improve response rates in the online sample

- ‘bounce-back’ of emails to invalid email accounts, and non-response suspected to be due to the survey going into ‘junk’ folders (whereby potential respondents may be unaware of the survey) - whilst there is no obvious bias introduced through this issue, it can reduce the overall response rate. It was partly for this reason that Winning Moves switched software platforms shortly prior to Wave 25 being launched, due to the rate of emails going to junk folders had been increasing using the previous platform, as well as a greater number of respondents encountering accessibility issues due to an ever-increasing range of devices and browsers being used to access surveys. Invalid email addresses were minimal (approximately 1%) within the applicant database as they were entered as part of the scheme administration, where the contact details were used to contact the applicant about payments

Resource was set aside in each wave for telephone interviewing to boost the number of responses achieved with particular subgroups. To determine how this resource was used, following the close of the online survey, Winning Moves:

- analysed the sample of online responses and compare it to the overall population for that wave
- produced a short note for discussion with BEIS on:
    - data tables for the sample compared to the population by key database fields (e.g. type of housing, size of installation)
    - a proposal for use of the telephone resource, focused on coverage of groups of applicants that map to scheme reforms, coverage of groups of interest identified in the wider evaluation, and areas of under-representation compared to the population

The table below summarises the survey modes used in each wave.

Table 14: Survey mode for each wave of the RHI accredited applicant survey by wave

Survey	Applicant group	Main survey mode	Telephone boost?
25	Non-domestic	Online	Yes
25	Biogas/biomethane	Telephone*	No
26	Non-domestic	Online	No
26	Biogas/biomethane	Online	No
27	Non-domestic	Online	No
27	Biogas/biomethane	Online	Yes
28	Non-domestic	Online	Yes
28	Biogas/biomethane	Online	Yes
29	Non-domestic	Online	Yes
29	Biogas/biomethane	Online	No
30	Non-domestic	Online	Yes
30	Biogas/biomethane	Online	Yes
31	Non-domestic	Online	Yes
31	Biogas/biomethane	Online	Yes

* due to complexity and multiple applications

Survey design

Separate survey scripts were produced for non-domestic and biogas / biomethane RHI accredited applicants.

The surveys for Wave 25 onwards were adapted from the scripts used during the previous evaluation of the RHI. Between Waves 1 and 2, new questions were added and code frames had been amended. These changes were retained in the Wave 25 survey, but otherwise survey questions were kept as comparable as possible in terms of focus, wording and options to enable the amalgamation of all survey data into a combined dataset. This was achieved through a comprehensive question review with BEIS to understand fit with post-reform evaluation needs.

Each survey script was then reviewed and adjusted prior to launching each subsequent wave.

Pilot

Due to the changes made and the time elapsed since the previous evaluation, a full pilot of Wave 25 was conducted to inform considerations of question comprehensibility, survey length, whether questions were eliciting a sufficient quality of response, etc. This is summarised in the following section. The table below provides the key numbers on the pilots for each of the respondent groups:

Table 15: Summary of the Wave 25 pilot by applicant group.

Metric	Non-domestic	Biogas / biomethane
Sample invited to participate in the pilot	200 applicants, randomly selected across dates of application and technology.	The survey was reviewed by several stakeholders and telephone interviews were conducted with two volunteer applicant organisations. The piloted sample was not therefore a fully representative sample, but testing was deemed adequate to progress with the survey.
Number (and proportion) clicking on the link to access the survey	61 (53% of those that opened the email and 31% of the whole pilot sample) clicked the link to start the survey.	N/A
Number (and proportion) completing the survey	37 (18.5% of the whole pilot sample) completed the survey.	N/A
Representativeness	The % splits of respondent profiles (in terms of technology and year of application) for those that completed the survey, very closely matched the % of the applicant population i.e. we could be confident that the pilot responses were representative of the wider population.	N/A

The key changes arising from the pilot were as follows:

- the pilot found that only around half of those opening the email advertising the survey were then clicking on the link to the survey itself - in response the introduction to the survey, in both the email containing the link and within the survey itself, was made more concise
- the pilot found a substantial number of ‘partial completes’ i.e. respondents starting but not completing the survey - to minimise drop out, overall survey length was reduced (through removing certain questions and reducing options list size)

Summary of key survey changes

The survey was reviewed and amended after each wave to take account of emerging evaluation and policy needs. Survey 25, for example, included a question about the survey respondents; awareness of the announced reforms, while survey 26 included additional questions about Tariff Guarantees after they were introduced in May 2018.

Maximising response rates

Several measures were taken to try to maximize response rates for the applicant monitoring surveys:

- a compelling introduction to the survey, clearly stating the purpose of the survey and the value of participating and reassuring on data protection- the introduction also signposts a contact within BEIS to reassure respondents of the survey’s validity
- applicants are also invited to contact a named survey manager at Winning Moves should they have any queries on the survey / encounter technical issues
- managing the length of the survey, though due to the range of stakeholders involved in survey design - and commensurate areas of interest – this was challenging. Respondents partially completing surveys and then dropping out was significant (39% in the most recent wave – Wave 28[29]) but would likely have been more so without the efforts to limit survey length. It should be noted, Winning Moves also uses telephone resource to re-contact partial responses and complete the survey and so this percentage is reduced in final numbers
- formatting survey questions to be ‘non-mandatory’ i.e. respondents could skip questions. Whilst this can affect quality (e.g. missing data) it in theory reduces the likelihood of respondents dropping out as they could if needed move on from a question

[29] Based on the percentage of all responses that are partial i.e. start to complete the survey but do not continue to the final question.

- following the survey launch weekly reminder emails were sent to those yet to respond. Winning Moves found that the most effective time to send reminders was on a Monday morning. Reminders also note the survey closing date to further motivate timely responses

- telephone follow ups have included quotas focusing on specific groups of interest to boost samples for under-represented groups

Response rates have been good throughout the evaluation, comparing favourably with response rates in Waves 1-2. This is especially when considering that bounced and auto-junking of emails likely reduced the population of potential respondents. Response rates achieved for each online survey are as follows, within Waves 25, 27 and 28 response rates were further improved with telephone boost.

Table 16: Table summarising the population and online response rate achieved in each wave.

Survey	Applicant group	Population[30]	Sample	Online survey response rate[31]
25[32]	Non-domestic	7,208	483	7%
25	Biogas/biomethane	816	189	N/A: fixed telephone interview quota
26	Non-domestic	305	53	17%
26	Biogas/biomethane	20	6	30%
27	Non-domestic	50	9	18%
27	Biogas/biomethane	19	2	11%
28	Non-domestic	249	26	10%
28	Biogas/biomethane	54	3	6%
29	Non-domestic	243	47	19%

[30] All accredited applications with an email in the database supplied by BEIS.
[31] Invalid emails and bounce-backs, accounting for no more than 1% of total population, are still included in the population count and therefore treated as non-response. The response rate would therefore be marginally higher if only those known to receive the survey without a bounce back were included in the population.
[32] It was anticipated that response rate would be lower for the first retrospective survey due to the large time elapsed for some sample between application and survey (e.g. early 2015 for some non-domestic sample). However, analysis of response rates by application and accreditation date did not seem to bear out this hypothesis.

29	Biogas/biomethane	16	0	0%
30	Non-domestic	236	36	15%
30	Biogas/biomethane	11	0	0%
31	Non-domestic	417	44	11%
31	Biogas/biomethane	14	2	14%

Dataset preparation

Following survey completion and obtaining of the response datasets, a number of steps were taken to creating files ready for analysis; all steps – and subsequent analysis - were undertaken in SPSS:

- removal of partial responses: there were a number of dataset records which were partially complete as the respondent had stopped completing the survey but the responses to that point were recorded. There was a discussion as to whether to include these – especially where the respondent had responded to key questions e.g. around attribution. It was ultimately agreed to remove these records (and so their responses) from the dataset as there are quality considerations on partially completed responses (e.g. at what point was the respondent rushing / not concentrating) and completed survey sample sizes were large enough to mean the addition of these relatively small number of partial completes was not critical for boosting sample size or reducing confidence intervals. Responses from those completing the survey, but not responding to all questions, are retained, as we could be more confident they had given a considered response to the questions to which they had responded
- dataset merging and adding records: for Wave 25, it was necessary to merge the online and telephone survey datasets for the non-domestic groups. For all both groups (non-domestic and biogas), an application dataset was created to split responses from multiple applicants into responses per application. This step was not required in subsequent waves as cases of multiple applications from the same source within the shorter time period were much less common and where applicants did have multiple applications one was chosen at random for the purposes of the survey. For selected key variables, it was necessary to merge the relevant variables from the latest wave into a dataset of all historic monitoring survey responses. This required some re-coding to ensure as far as possible that the codes / options for the questions being analysed were comparable e.g. the options for ‘motivations to install an RHT’ have altered since Wave 1 and therefore headline analysis of all historic survey data for that question required consistent codes to be established.

Work was undertaken to create a single dataset of all monitoring responses received from successful non-domestic applicants since monitoring began

- data cleaning: this was especially important for the online survey as there was no interviewer to pick up on inconsistencies etc. The cleaning includes the following:
    - where questions ask for an open-end response and then for the respondent to also choose a coded/categorical response, checking these to ensure consistency, potentially recoding based on the open-end response if obviously contradictory
    - where respondents selected ‘other’ on questions featuring options lists, checking the attached open-end response to see whether the closed question response could be re-coded in the existing code frame or whether – if there were sufficient ‘other’ of a particular type – a new code/option should be created
    - sense checking any numeric responses and creating a variable to ensure these are in a uniform unit and suitable for analysis e.g. any wording removed

Weighting

Weighting is used to correct potential discrepancies between a sample obtained through a survey and the underlying population with respect to key variables.

Weights were calculated through a process called calibrated weighting. The primary aim of this process was to create weighting factors by considering several variables at the same time.

For the non-domestic survey, the weighting variables were:

- technology type
- sector
- Government Office Region
- whether the business is on or off the gas grid

In Waves 25-31, weights were calculated at the application level only.

However, historically, weights had been calculated at both the application and the applicant level. However, calculation of applicant weights was discontinued and there were no such weights for Waves 25-31.

The calibrated weighting method worked as follows:

- a set of inflationary weights with respect to the first weighting variable was created:

$$weight_1 = \frac{application\ population\ frequency}{survey\ sample\ frequency}$$

Thus, for example, if there were 15 ground source heat pumps in the application population and 5 in the sample, the weighting factor for applications for ground source heat pumps was 15/5=3.

- the dataset was then weighted using this set of weights.
- a weighted frequency of the next weighting variable was calculated.
- using the weighted frequency from Step 3, a set of inflationary weights with respect to the next weighting variable was created. These new weights were calculated as follows:

$$weight_2 = weight_1 * \frac{application\ population\ proportion}{weighted\ survey\ sample\ proportion}$$

Thus, for example, if the agriculture sector accounted for 50% of all applications and, after weighting the sample with the set of weights from Step 1, the sector accounted for 80% of all applications in the survey sample, then the weighting factor for applications from the agricultural sector for a ground source heat pump was 3*(50/80)=1.875.

These steps were then followed for all weighting variables in turn.

Finally, using the same formula, the weights are again calibrated with respect to technology type, as this variable was considered to be the most important weighting variable. The weights obtained from this final step are the final weights, and the ones that are reflected in the weighted data in the main report.

For combining weights from all datasets into one single weighting variable, historical weights were converted into inflationary weights. Thus, the combined weighting variable contained inflationary weights only.

The initial wave of the biogas/biomethane survey (Wave 25) was weighted in the same way as the non-domestic survey. However, subsequent waves had very small sample sizes and decisions on weighting were made on an ad-hoc basis, always in agreement with BEIS:

- Waves 26-27 (n=11): Joint weights were calculated, i.e. populations and samples from the two waves were pooled. The weights equated to the population/sample ratio. There was no weighting with respect to other variables
- Wave 28 (n=14): The weights equated to the population/sample ratio. There was no weighting with respect to other variables. Sample size was a bit higher in this wave because we did a telephone boost for biogas/biomethane applications
- Waves 29-31 (n=8): Due to the sample size being very small in these waves, the weighting factor equates to 1

Analysis

Data tables provided tabular outputs for the questions. These used weighted frequencies, and were analysed by key profile variables e.g. technology. Where the question was multiple-response (more than option was allowed to be picked by respondents), responses without any option picked were excluded from the analysis.

The charts and graphs in the main report are based on these data tables, and these are set out in Appendix E.

Accreditation date

The table below outlines the database field used in defining accreditation date for each wave. For Waves 25-27, BEIS agreed that accreditation date should be used for the non-domestic survey. Accreditation date was used rather than tariff rate date because for non-domestic the long accreditation process means that tariff rate date could often be quite different from final accreditation date, hence accreditation date was used instead.

In Wave 28 the review of non-domestic applications showed that there were many applications whereby a long period of time elapsed between their accreditation date and ultimate approval. Our review also showed that the original application was often subject to such substantive amendments that Ofgem considers them to constitute a new submission, thereby updating the application submission date. BEIS and Winning Moves therefore agreed to send the survey to all approved applications with an application submission date within the last six months (1st March 2019 – 31st August 2019) regardless of when their accreditation date was.[33]

In subsequent waves of the non-domestic survey (29-31), the survey was sent to all approved and accredited applications that did not have that status in the previous wave. The only exception was those with an accreditation date prior to 2015 and applicants who had been previously sent the survey.

[33] An exception was made for applications whose accreditation date was prior to 2015 as there was a high risk that they had already been sent the survey historically and because these applicants were deemed unlikely to have a satisfactory recall of the application process.

Table 17: Data field used to select sample for each wave of the RHI accredited applicant survey.

Survey wave	Applicant group	Date field used
25	Non-domestic	Accreditation date
25	Biogas/biomethane	Accreditation date
26	Non-domestic	Accreditation date
26	Biogas/biomethane	Accreditation date
27	Non-domestic	Accreditation date
27	Biogas/biomethane	Accreditation date
28	Non-domestic	Application submission date
28	Biogas/biomethane	Application submission date
29-32	Non-domestic	All approved and accredited applications that did not have that status in the previous wave. Exception: applications with accreditation date prior to 2015 and applicants who have previously been invited to complete the survey.
29-32	Biogas/biomethane	All approved and accredited applications that did not have that status in the previous wave. Exception: applications with accreditation date prior to 2015 and applicants who have previously been invited to complete the survey.

Summary of work undertaken and number of responses

Table 18: Summary of work undertaken in each wave of the RHI accredited applicant survey.

Survey Wave	Applicant group	Population *	Number of responses	Response rate (primary data collection mode)**	Telephone boost	Number of interviews conducted (telephone boost)	Total number of responses for analysis	Overall response rate**
25	Non-domestic	7,208	483	7%	Yes	275 (100 distinct respondents responsible for multiple applications)	758	11%
25	Biogas / biomethane	816	189	N/A fixed telephone quota	No	n/a	189	N/A fixed telephone quota
26	Non-domestic	305	53	17%	No	n/a	53	17%
26	Biogas / biomethane	20	6	30%	No	n/a	6	30%
27	Non-domestic	50	9	18%	No	n/a	9 (due to small sample size no analysis	18%

Survey Wave	Applicant group	Population *	Number of responses	Response rate (primary data collection mode)**	Telephone boost	Number of interviews conducted (telephone boost)	Total number of responses for analysis	Overall response rate**
							was conducted)	
27	Biogas / biomethane	19	2	11%	Yes	3	5	26%
28	Non-domestic	249	26	10%	Yes	25	51	20%
28	Biogas / biomethane	54	3	6%	Yes	11	14	26%
29	Non-domestic	243	47	19%	Yes	5	52	21%
29	Non-domestic (tariff guarantee applicants)	12	-	-	Yes	3	3	25%
29	Biogas / biomethane	16	2	13%	No	-	-	13%
29	Biomethane (tariff	17	-	-	Yes	3	3	18%

Survey Wave	Applicant group	Population *	Number of responses	Response rate (primary data collection mode)**	Telephone boost	Number of interviews conducted (telephone boost)	Total number of responses for analysis	Overall response rate**
	guarantee applicants)							
30	Non-domestic	236	36	15%	Yes	29	65	28%
30	Biogas / biomethane	11	0	0%	Yes	1	1	9%
31	Non-domestic	417	44	11%	Yes	63	107	26%
31	Biogas / biomethane	14	2	14%	Yes	-	2	14%

* All accredited applications with an email in the database supplied by BEIS.
**Invalid emails and bounce-backs, accounting for no more than 1% of total population, are still included in the population count and therefore treated as non-response. The response rate would therefore be marginally higher if only those known to receive the survey without a bounce back were included in the population.

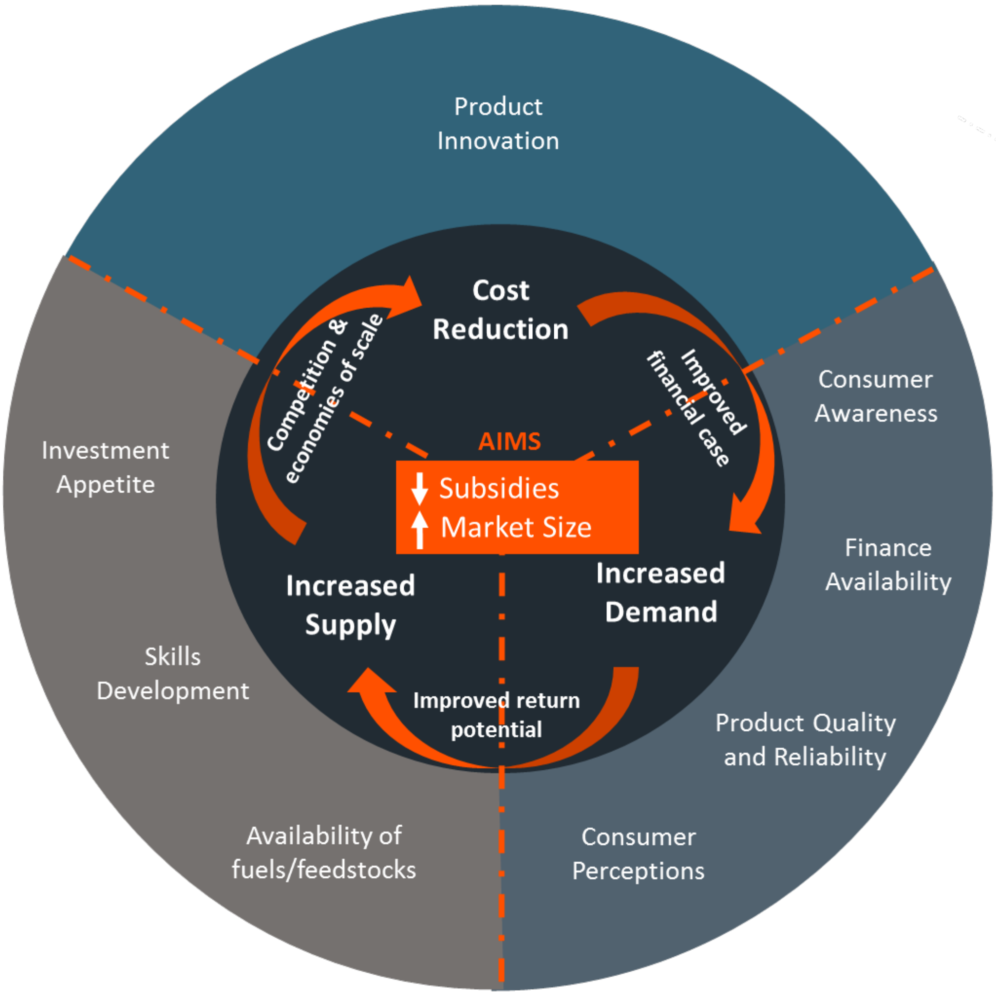
Sustainable markets assessment

Introduction

The Sustainable Markets Assessment (SMA) analysed the extent to which the markets for supported renewable heat technologies moved towards 'market sustainability' for the longer term, in the sense of not being dependent on subsidies. The workstream was led by Hatch Regeneris and Wavehill.

As a starting point for monitoring progress towards a sustainable market, a logic model 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. As shown in Figure 1, the sustainable markets analysis focused on assessing changes in the demand, supply and cost of RHTs. This included capturing change in a range of drivers for increasing demand, increasing supply and reducing costs, as shown in the outer ring of the diagram.

Figure 1: Sustainable markets - logic model



The key outputs from the SMA were a series of dashboards of indicators, informed by the logic model. The dashboard was produced on a 6-monthly basis, drawing on indicators of demand, supply and cost for each renewable heat technology. The dashboard drew from a range of evidence sources, with varying levels of robustness, including government data, RHI applicant survey data, and data provided by other third parties.

The technologies were grouped into four categories for the SMA analysis, with the breakdown of technologies summarised in the table below.

Table 19: Summary of Technology Categories

Technology Category	Specific technologies included
Heat Pumps (split by domestic and non-domestic)	Air Source Heat Pumps Ground Source Heat Pumps Water Source Heat Pumps
Biomass (split by domestic and non-domestic)	Solid Biomass Boiler Solid Biomass CHP
Anaerobic Digestion (non-domestic only)	Biogas Biomethane
Other (combined for domestic and non-domestic)	Solar Thermal Waste Geothermal

This section provides a summary of the SMA indicators, their sources, the level of robustness and limitations of each data source, and our approach to quality assuring the analysis undertaken on each.

Limitations of the Sustainable Markets Assessment

The Sustainable Markets Assessment was constrained by the availability and quality of data on different aspects of demand, supply and costs for non-domestic renewable heat technologies. The main sources of evidence for non-domestic SMA indicators were BEIS application data, the BEIS Public Attitudes Tracker, applicant survey data collected by Winning Moves and data gathered directly from finance and supply chain stakeholders by the Hatch Regeneris/Wavehill team. This was cross-checked against qualitative insights gathered by both CAG Consultants and the Hatch Regeneris/Wavehill team.

The robustness of data for the SMA indicators varied widely depending on the data source and the sample size on which they were based. The level of robustness is clearly flagged in the indicator tables above.

The SMA analysis was updated every six months but there was not always new data for all indicators and for all technologies for each update. Similarly, there were not always sufficient numbers of responses in survey data for each technology in each reporting period to capture sufficiently robust data for that RHT.

While some of the indicators were available for the whole period of the non-domestic RHI scheme, a number of indicators were based on questions that were only included in the applicant survey from wave 25 onwards. This limited the extent to which comparisons could be made to the end of the scheme.

The cost data used in the SMA was presented in nominal terms, as inflation was low during the research period.[34]

Attachment 1 presents an example of the SMA Consultation Aide Memoire that was used for consultation with supply chain stakeholders and industry representatives. While most of the questions remained consistent throughout the successive rounds of consultation, to inform the SMA analysis, additional questions were added when necessary to explore issues identified via the qualitative research workstream.

The following sections set out this overview for each indicator, split by indicators of demand, supply and cost.

Demand Indicators

Table 20: Indicator A1

Indicator	Number of RHI-backed products installed with RHI subsidy
Data Source	RHI Application Data
Description of Indicator Analysis	This data was taken from the raw data gathered by Ofgem and reported to BEIS. The data was cleansed by BEIS analysts using a consistent data cleansing approach. The first year benchmark was based on the installation date rather than the accreditation date of products (which overcame the challenge that many installations from preceding years were accredited in the first full year of the policy thus distorting the first year accreditation figures). For non-domestic installations, the installation date was determined based on the earlier of two reported dates (the

[34] The final sustainable markets assessment was completed in September 2021.

	reported accreditation date and the reported commissioning date). Installation numbers were difficult to interpret over time, as BEIS publish figures for accredited installations. There was typically a significant time gap between installation and accreditation (c.34 weeks). This meant that there was a time lag between installations being undertaken and these installations showing in BEIS published figures. To address this, the indicator made an assumption about how many of the installed but not yet accredited installations would go on to be accredited, on the basis of historic levels of conversion for each technology. Those which had been installed but had been refused accreditation or that had withdrawn were not included in this calculation. Geographic mapping of all installations to date was undertaken using the local authority location for each installation.
Robustness of Data	High
Description of Robustness	Data came directly from Ofgem/BEIS Application Data Analysis and cleansing of data was undertaken by BEIS.
Approach to Quality Assurance of Data	Review of overall approach with BEIS data analysts during the SMA scoping stage. Spot checks undertaken for a random sample of data to test that numbers correspond with raw data. If any errors were found, modelling formulae were checked for errors. When the issue was resolved, the analysis was re-run and the QA process was repeated. Figures were compared to official published statistics to ensure alignment.

Table 21: Indicator B1

Indicator	Changes in the proportion of users experiencing technology faults or issues
Data Source	RHI Applicant Survey
Description of Indicator Analysis	This data was taken from the raw applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation (see previous methodology section). The data was cleansed by Winning Moves analysts using a consistent data cleansing approach and weighted according to the overall survey sample. As the SMA presented data for six monthly periods or greater, the evaluation team was confident that the overall survey weighting would deliver sufficiently robust findings. The indicator was based on the proportion of respondents who responded 'yes' to the question 'Since installation of the technology, have you experienced any faults with the technology?', recorded by technology and by installation date. The indicator was based on responses over the previous 12-month period, compared with the preceding 12-month period. The question was asked for non-domestic scheme applicants, but was not included in the separate survey for anaerobic digestion applicants. This data was only collected from wave 25 of the applicant survey onwards, so comparison to the beginning of the policy period is not possible.
Robustness of Data	Medium-High
Description of Robustness	The applicant survey was carried out as part of the evaluation work with a representative sample of applicants for each technology type, and weighted.
Approach to Quality Assurance of Data	Review of overall approach with BEIS data analysts during the SMA scoping stage. Spot checks undertaken for a random sample of data to test that numbers correspond with raw data. If any errors were found, modelling formulae were checked for errors. When the issue was resolved, the analysis was re-run and the QA process was repeated. Findings were sense checked against findings from sector body / manufacturer consultation feedback.

Table 22: Indicator C3

Indicator	Overall consumer satisfaction with their renewable heat technology
Data Source	RHI Applicant Survey
Description of Indicator Analysis	This data was taken from the raw applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation (see previous methodology section). The data was cleansed by Winning Moves analysts using a consistent data cleansing approach and weighted according to the overall survey sample. As the SMA presented data for six monthly periods or greater, the evaluation team was confident that the overall survey weighting would deliver sufficiently robust findings. The indicator was based on the proportion of that answered very satisfied and fairly satisfied to the question 'How satisfied overall are you with your [technology type]. For the Anaerobic Digestion applicant survey the question was marginally different: 'With regard to THE WAY THE TECHNOLOGY WORKS. On a scale of 1 to 5, where 1 is very dissatisfied and 5 is very satisfied, how satisfied were you?' The indicator was based on responses over the previous 12-month period, compared with the preceding 12-month period. This data has only been collected since wave 25 of the non-domestic applicant survey so no comparison to the beginning of the policy period was possible.
Robustness of Data	Medium-High
Description of Robustness	The applicant survey was carried out as part of the evaluation work with a representative sample of applicants for each technology type, and weighted
Approach to Quality Assurance of Data	Review of overall approach with BEIS data analysts during the SMA scoping stage. Spot checks undertaken for a random sample of data to test that numbers correspond with raw data. If any errors were found, modelling formulae were checked for errors. When the issue was resolved, the analysis was re-run and the QA process was repeated. Indicator findings sense-checked by CAG Consultants before being submitted to BEIS.

Table 23: Indicator D1

Indicator	Proportion using external finance to support deployment
Data Source	RHI Applicant Survey
Description of Indicator Analysis	This data was taken from the raw applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation (see previous methodology section). The data was cleansed by Winning Moves analysts using a consistent data cleansing approach and weighted according to the overall survey sample. As the SMA presented data for six monthly periods or greater, the evaluation team was confident that the overall survey weighting would deliver sufficiently robust findings. The indicator was based on the proportion of applicants using external finance to deliver their installation. This related to the proportion of respondents that reported using any type of external finance (the question covered a range of options, of which all were included in this indicator other than 'own finance' and 'other'). The indicator was based on responses over the previous 12-month period, compared with the preceding 12-month period. This data has only been collected since wave 25 of the non-domestic applicant survey so no comparison to the beginning of the policy period was possible.
Robustness of Data	Medium-High
Description of Robustness	The applicant survey was carried out as part of the evaluation work with a representative sample of applicants for each technology type, and weighted.
Approach to Quality Assurance of Data	Review of overall approach with BEIS data analysts during the SMA scoping stage. Spot checks undertaken for a random sample of data to test that numbers correspond with raw data. If any errors were found, modelling formulae were checked for errors. When the issue was resolved, the analysis was re-run and the QA process was repeated. Indicator findings sense-checked by CAG Consultants before being submitted to BEIS.

Table 24: Indicator D2

Indicator	Appetite to lend for renewable heat equipment purchase and installation
Data Source	Consultations with finance institutions
Description of Indicator Analysis	This indicator was limited to the non-domestic component of RHI only, due to external finance being sought for larger-sale commercial renewable heat installations The indicator assessed the level of confidence that Renewable Energy Association Finance Forum members had in increasing levels of investment in the next year, compared with the previous 12 months. Data was generated via regular questionnaire circulation to Finance Forum members. Forum members were chosen via a purposive sampling approach, recognising this group as a consistent group, willing and able to provide insights on a regular basis, allowing for comparable findings over the evaluation period. There were typically 5-10 members of the Forum. Data drew on a sample of responses to a questionnaire issued to members asking which statement best reflected their investment confidence level for the upcoming 12 months: Expect investment in this area to expand significantly Expect investment in this area to expand slightly Expect investment to stay about the same Expect investment in this area to reduce slightly Expect investment in this area to reduce significantly. No data was available from the pre-reform period, therefore no comparison to the beginning of the pre-reform period could be made for this indicator.
Robustness of Data	Low
Description of Robustness	This indicator was based on consultation with a very small sample of financiers, with potential for bias in the findings as it only incorporated financiers engaged with the REA Finance Forum. The findings could therefore only be considered as indicative. It

	was important to interpret this data alongside more qualitative insights.
Approach to Quality Assurance of Data	Review of overall approach with BEIS data analysts during SMA scoping stage. Review of data to check for any anomalies. Any identified anomalies were verified with internal analysts before data was incorporated. Findings were sense checked against qualitative consultation feedback gathered by CAG Consultants.

Supply indicators

Table 25: Indicator F1

Indicator	Consumers with fuel/feedstock supply contracts in place
Data Source	RHI Applicant Survey
Description of Indicator Analysis	This data was taken from the raw applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation (see previous methodology section). The data was cleansed by Winning Moves analysts using a consistent data cleansing approach and weighted according to the overall survey sample. As the SMA presented data for six monthly periods or greater, the evaluation was confident that the overall survey weighting would deliver sufficiently robust findings. The indicator was based on the proportion of non-domestic biomass and AD applicants who reported having a supply contract in place for supply of biomass / biofuel fuels/feedstocks. The indicator was based on responses over the previous 12-month period, compared with the preceding 12-month period. This data was not collected in previous surveys, meaning comparison to the beginning of the policy period was not possible.
Robustness of Data	Medium-High
Description of Robustness	The applicant survey was carried out as part of the evaluation work with a representative sample of applicants for each technology type, and weighted.
Approach to Quality	Review of overall approach with BEIS data analysts during the SMA scoping stage.

Assurance of Data	Spot checks undertaken for a random sample of data to test that numbers correspond with raw data. If any errors were found, modelling formulae were checked for errors. When the issue was resolved, the analysis was re-run and the QA process was repeated. Indicator findings were sense-checked by CAG Consultants before being submitted to BEIS.

Table 26: Indicator G2

Indicator	Difficulty in finding a suitable installer
Data Source	RHI Applicant Survey
Description of Indicator Analysis	This data was taken from the raw applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation (see previous methodology section). The data was cleansed by Winning Moves analysts using a consistent data cleansing approach and weighted according to the overall survey sample. As the SMA presented data for six monthly periods or greater, the evaluation team was confident that the overall survey weighting would deliver sufficiently robust findings. The indicator was based on the proportion of applicant survey respondents who reported having had difficulties in finding an installer for their renewable heat technology. The question asked about a range of problems that might have been encountered before installing the technology, with ‘finding a suitable installer’ being one option, alongside other possible problems. The indicator was based on responses over the previous 12-month period, compared with the preceding 12-month period. This data was not collected prior to wave 25 of the applicant survey so no comparable data is available for the non-domestic scheme back to the beginning of the project period.
Robustness of Data	Medium-High
Description of Robustness	The applicant survey was carried out as part of the evaluation work with a representative sample of applicants for each technology type, and weighted.
Approach to Quality	Review of overall approach with BEIS data analysts during the SMA scoping stage.

Assurance of Data	Spot checks undertaken for a random sample of data to test that numbers correspond with raw data. If any errors were found, modelling formulae were checked for errors. When the issue was resolved, the analysis was re-run and the QA process was repeated. Indicator findings were sense-checked by CAG Consultants before being submitted to BEIS.

Cost Indicators

Table 27: Indicator H1

Indicator	Median capital costs both for technology purchase and installation (based on cost per unit of installed capacity)
Data Source	RHI Application Data
Description of Indicator Analysis	This data was taken from the raw data gathered by Ofgem at the application stage and reported to BEIS. The data was cleansed by Hatch Regeneris/Wavehill using the same approach as taken by BEIS analysts (i.e. removing all zero costs from non-domestic application data). The indicator produces a median cost per kW of installed capacity for each technology, for non-domestic applicants.
Robustness of Data	Medium
Description of Robustness	Data came directly from Ofgem/BEIS Application Data, with analysis and cleansing of data undertaken by BEIS. Previous analysis of this data however has shown varying quality in reported evidence. This may reflect applicants being unclear on what they should include in the figures they provide (for example this could be product itself and installation, but could also include wider preparation costs or additional installation costs such as new radiators being installed). Although cleansing partially addressed this challenge, the resulting data did not provide fully robust cost information.
Approach to Quality Assurance of Data	Review of overall approach with BEIS data analysts during the SMA scoping stage. Spot checking random sample of data. Comparison with industry commentary on this to sense check findings.

Table 28: Indicator I1

Indicator	Progress in improving cost efficiency in the supply chain (e.g. as a result of product or process innovation, increased economies of scale, reduced costs of inputs)
Data Source	Consultation with manufacturers / sector bodies
Description of Indicator Analysis	The indicator assessed the level of confidence that manufacturers / sector bodies have in delivering cost efficiencies for their respective renewable heat technologies. Data drew on a sample of responses to the following question: ‘What prospects do you see for reduced costs due to economies of scale or new technology innovation over the next year?’ Expect costs to increase a lot Expect costs to increase a little Expect no significant change in costs Expect costs to decrease a little Expect costs to decrease a lot’ Data was generated via regular consultation with sector bodies. Sector body / manufacturer consultees were chosen via a purposive sampling approach, recognising this group as a consistent group, willing and able to provide insights on a regular basis, allowing for comparable findings over the evaluation period. Consultees were identified based on making contact and seeking the regular input of leading sector bodies and technology manufacturers for the key technologies supported by RHI. The consultation aide memoire, provided in advance of stakeholder consultations to guide telephone / video conference discussions, is presented in Attachment 1. Qualitative discussion with consultees was used to explore factors affecting changes in cost efficiency and responses were then classified in quantitative terms using the categories above.
Robustness of Data	Low
Description of Robustness	This indicator was based on consultation with a very small sample of sector bodies and manufacturers with potential for bias in the findings as it only incorporated a specific set of sector bodies and manufacturers. The findings could therefore only be considered as

	indicative. It was important to understand this data alongside more qualitative insights.
Approach to Quality Assurance of Data	Review of overall approach with BEIS data analysts during the SMA scoping stage. Review of data to check for any anomalies. Any identified would be verified with analyst before incorporating. Findings were sense-checked against qualitative consultation feedback gathered by CAG Consultants.

Attachment 1: SMA Consultation Aide Memoire (Sector Stakeholder)

Hatch has been appointed by the Department for Business, Energy and Industrial Strategy (BEIS), as part of a consortium to deliver an evaluation of the reformed Renewable Heating Incentive (RHI) scheme, over the period 2017-21. One of the key aims of the RHI scheme is to contribute to the development of a sustainable market for renewable heat. Hatch is leading on an assessment of impacts against this aim.

Following on from the third phase of research completed in early 2020, we have further developed a view of renewable heat technology (RHT) markets and have a stable monitoring dashboard in place. To inform the next phase of research, we will be updating this dashboard to observe changes and the extent to which the RHT market is moving towards a position of sustainability. This will include looking at a number of indicators focused on costs, supply and demand for RHTs, and assessing the drivers behind these any changes.

To ensure we capture insights from those operating in the market and with a strong oversight of RHT performance in the UK, we are once again seeking inputs from a range of organisations and sector stakeholders. Specifically, we are keen to:

- build on our existing data baseline and feed into our ongoing monitoring dashboard
- update our understanding of the operation of the sector and performance of RHT technologies at present, particularly in the context of macroeconomic change and wider environmental policy reform
- re-affirm your support to assist with the feeding in of inputs on a six-monthly basis
- identify relevant supplementary sources of information and data that will add value to our sustainable market analysis

We would greatly appreciate if you would be free for a short discussion by telephone, to talk through the questions below. This should take no more than 30-45 minutes, dependent on your ability to provide responses to the questions. This can be conducted on MS Teams or alike.

Following these initial discussions, we will be sharing findings with both BEIS and market stakeholders. We will be repeating this process on a systematic basis moving forward and would very much value your/your organisation’s input to help inform findings and ultimately shape BEIS renewable energy policy in perpetuity.

Questions

Introduction

If we haven't engaged previously, could you begin by giving a brief overview of your role and how the RHI supports/affects you/your organisation's work?

Sector Overview

Can you give an overview of the renewable heat market from your perspective, relevant to your role/organisation and RHTs you focus on?

- what are the main products serving this market?
- to what extent has the UK market grown over the last 6-12 months?
- what is the structure of the supply chain and the extent to which this is UK based?
- has there been any change in the scope for significant cost reductions?
- what is the current role of research and innovation activity in this sector and what has been the focus for this over the last 6-12 months?

  (NOTE: relevant only to anaerobic digestion/biogas/biomethane/biomass) What are the main sources for fuels / feedstocks serving the current market? Has this changed in the past year and is domestic supply increasing?

With respect to the main manufacturers and equipment providers operating in the RHT market(s) most relevant to your organisation:

- can you comment on who the main market players are?
- has anything changed in the last 6-12 months in relation to market structure? Have there been any significant new market entrants?

In terms of the manufacturing base (new or expanded facilities) for this type of RHT:

- have there been any significant developments by manufacturers, such as those on-shoring production or supply chain activities?
- have manufacturers made any other investments in the UK, including those which are R&D or innovation related?
- do you have any views on supply side barriers to growth, such as the availability of skilled installers? Have you observed any changes in the past 6-12 months?
- is a lack of installers holding back the growth of the market?
- are there any key disincentives which may be stifling the supply of skilled and accredited RHT installers? - this could include MCS accreditation requirements for instance

- are you observing any improvements in cost efficiency within the supply chain (e.g. as a result of product/process innovation, increased economies of scale, reduced costs of inputs etc)?
- are you aware of RHT installations being accelerated or aided by new financial instruments, such as the introduction of new Assignment of Rights products?
- have you noted any fluctuations in customer experiences and satisfaction with RHT products in the last 6-12 months?

Supporting Information and Supplementary Data

- are you aware of any data sources that may have recently become available that could inform our research, particularly that relevant to the questions cited above?
- do you know of any relevant reports or publicly available research that you feel would add value our sustainable market analysis?

RHI Scheme Reflections

Finally, do you have any observations regarding the RHI scheme and the impact of recent policy changes in terms of:

- the expansion or retraction of RHT markets, including those relevant to your products and renewable heat technologies
- the extent to which RHT markets are dependent on RHI subsidies
- the broader market reaction to RHI policy and government sustainable energy strategy

Subsidy Cost-Effectiveness Assessment

Introduction

The Subsidy Cost-Effectiveness Assessment analysed the overall cost-effectiveness of the reformed RHI subsidies, with particular focus on how the reforms have helped to improve the cost-effectiveness of scheme delivery. This workstream was led by Hatch Regeneris and Wavehill.

The analysis assessed progress against a range of factors that affected overall cost-effectiveness and compared this between pre- and post-reform applications. This enabled the cost-effectiveness of the reformed RHI policy to be benchmarked against the pre-reform RHI policy – enabling a like-for-like comparison.

The key factors the Subsidy Cost-Effectiveness Assessment (SCEA) focused on included the following:

- average annual subsidy cost per kW of installed capacity (based on installations completed pre- and post-reform) - this was based on an analysis of total subsidy paid towards each installation divided by the respective number of years it has been receiving subsidy
- subsidy cost per kWh of renewable heat generated to date (for installations completed pre- and post-reform)
- subsidy cost per tonne of CO2 emissions abated to date (for installations completed pre- and post-reform) - this calculation included direct and upstream savings for biogas/biomethane
- value of Air Quality damage costs saved to date per £ subsidy invested (for installations completed pre- and post-reform) - This figure could be positive or negative given high biomass damage costs
- Value for Money (VfM) from Applicant Returns on Investment – drawing on analysis from the CTA evaluation workstream to assess areas of over-compensation (i.e. where the same outcomes could have been achieved with lower inputs)
- contribution to Market Development – drawing on analysis from the SMA evaluation workstream to assess evidence of market development (assumed to be primarily stimulated by the RHI)

For the first four indicators, the SCEA analysis included adjustments for additionality (i.e. whether changes were attributable to the RHI or not) and for ramp-up profiles (i.e. for the time taken for biomethane plants to reach full production after initial commissioning).The analysis would have taken account of non-compliance (e.g. whether post-reform biomethane/biogas plants were actually complying with the rule that 50% of feedstocks should be from waste) but no data was available from Ofgem to support this analysis.

Underlying these measures, key indicator data gathered at technology level to inform these has included:

- total subsidy cost to date
- average annual subsidy cost
- renewable heat capacity installed
- total renewable heat generation
- carbon abatement
- air quality damage cost savings
- additionality (pre- and post-reform)
- % Spend on non-compliant activity (pre- and post-reform), where not clawed back

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.[35]

As the introduction of reforms has been staggered, in each case an assumption has been made on the timing of the introduction of the most significant reforms for each technology, to enable a before-after analysis of cost-effectiveness. The assumed timing of the reforms for each technology is summarised in the table below.

Table 29: Technology Types and Assumed Timing of Reforms

Technology	Assumed Timing of Introduction of Reforms
All non-domestic RHI	Mixed
Non-domestic Heat Pumps	22nd May 2018
Non-domestic Small and Medium Biomass Boilers	22nd Sept 2017
Non-domestic Large Biomass Boilers	22nd Sept 2017
Non-domestic Solar Thermal	22nd May 2017
Non-domestic Biogas	22nd May 2018
Non-domestic Biomethane	22nd May 2018
Non-domestic Geothermal	22nd May 2018

[35]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1087229/GDP_Deflators_Qtrly_National_Accounts_June_2022_update.xlsx

For each technology, the analysis also seeks to answer specific questions about the extent to which the evidence suggests key reforms introduced have helped to improve cost-effectiveness compared to the pre-reform RHI. The limitations of this analysis are set out below.

Limitations of the Subsidy Cost-Effectiveness Assessment

The Subsidy Cost-Effectiveness Assessment was not able to analyse whole life costs and benefits of the RHI scheme because the timing of evaluation meant that much of the total costs and benefits would not be realised until many years after the completion of the evaluation.

Standard approaches to cost-effectiveness or cost benefit analysis were deemed inappropriate for the nature of this policy. This is because there were effectively two levels of impact that the policy was expected to deliver:

- direct impact – whereby carbon reductions arise from installed renewable heat technologies subsidised by the RHI policy
- long term impact - whereby carbon reductions will arise from installed renewable heat technologies delivered at a stage when these technologies have become cost competitive with non-renewable heating technologies without subsidy (within the prevailing policy context of that period). Moving the renewable heat markets towards this position is a key policy objective of the RHI

The direct impact costs and benefits to date could be assessed through the evaluation, although findings would be skewed to a degree as costs were incurred proportionally earlier than benefits were realised. There was no robust way to assess the long-term impacts at this stage however, and these impacts would be expected to be significantly greater.

The alternative approach used was therefore to compare subsidy cost-effectiveness analysis for the pre- and post-reform policy periods, and across technology types within the RHI scheme.

A further limitation was the absence of comparators for similar renewable heat policies, nationally or internationally, because of the pioneering nature of the RHI scheme. There were also no straightforward comparators in terms of the impacts that the scheme was expected to generate, because there were multiple BEIS Impact Assessments across the original RHI and reformed scheme. The Impact Assessment for the RHI reforms provided estimates of future outcomes but not the pre-reform RHI.[36] This meant that the Subsidy Cost-Effectiveness Assessment, and other assessments of outcomes, focused primarily on comparing outcomes between the pre- and post-reform periods rather than comparing them to other schemes or to the intended outcomes from the RHI policy as a whole.

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[36] 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

Subsidy cost-effectiveness analysis could only be undertaken for installations where full data relating to quantifiable costs and benefits was available, meaning that the analysis undertaken was based on a sample of installations for each technology.

The analysis did not include applications which were not yet accredited.

Preparation of indicator data

Several of the SCEA indicators used raw data gathered by Ofgem and reported to BEIS. Minor cleansing was done by BEIS on sending the data (primarily removing any duplicates).

The SCEA analysis only included non-domestic RHI applications with data for three key variables (total subsidy to date, capacity installed, and heat generated) to ensure that the overall findings compared the same sample.

This data was further cleansed by Hatch Regeneris/Wavehill to remove:

- negative entries
- those equal to 0 across all three indicators
- non-live installations (even where some payments had been made)
- installations without an accreditation date
- the top and bottom 5% of installed capacity figures for each technology to remove anomalous data

Analysis of the cost-effectiveness of biomethane subsidies was complicated by the fact that biomethane plants can take up to a year to reach full production after initial commissioning. To enable fair comparison of the cost-effectiveness of biomethane pre- and post-reform, indicators for subsidy costs, capacity installed and gas generated were only included in the analysis after the initial ramp-up period.

The indicators used in the SCEA analysis are detailed in the tables below.

Table 30: Total Subsidy Cost to Date and Average Annual Subsidy

Indicator	Total Subsidy Cost to Date Average Annual Subsidy Cost to Date
Source	RHI Payments Data
Description of Evidence Analysis	Raw RHI payments data was cleansed as outlined above. An average annual subsidy cost for each RHT was assessed on the basis of the total subsidy paid to date for each RHT installation and the number of years over which payments had been made (modelled based on number of quarterly payments divided by 4). The average for each RHT was based on a mean value of the annual subsidy for each of the projects of that technology type. Data on the total subsidy cost to date was split into pre- and post-reform data in accordance with Table 29, dependent on the technology and accreditation date.
Robustness of Data	High
Description of Robustness	This data came directly from Ofgem/BEIS RHI payment data. Analysis and cleansing of data was undertaken by Hatch Regeneris, following data cleansing guidance from BEIS. The internal analysis approach was discussed and agreed with BEIS.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the SCEA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

Table 31: Capacity Installed

Indicator	Capacity installed
Source	RHI Application data
Description of Evidence Analysis	Raw application data on capacity installed was cleansed as outlined above. In the case of biomethane, installed capacity is not listed directly, however flow rate is provided. Based on advice from BEIS, an installed capacity figure can be derived from the flow rate figure, based on the following assumptions: • Expected annual gas generation in m3 = FLOW RATE * 0.9 (allowing 10% maintenance time). • kWh of gas generation = m3 * 10 • 6MW plants will generate 40,000kWh of gas per year Drawing these assumptions together means that flow rate can be translated to installed capacity using a multiplier of 0.00135. Data on the total capacity installed to date was split into the pre- and post-reform data in accordance with Table 29, dependent on the technology and accreditation date.
Treatment of Deadweight	The initial analysis did not account for additionality and 'deadweight' effects. (Deadweight is the change that would have happened anyway, irrespective of the RHI policy intervention). This was applied at the stage of calculating the relevant cost-effectiveness indicator (see section below on 'Calculating Counterfactual Technology and Deadweight').
Robustness of Data	High
Description of Robustness	Data came directly from Ofgem/BEIS Application Data. Analysis and cleansing of data was undertaken by Hatch Regeneris, following data cleansing guidance from BEIS. The internal analysis approach was discussed and agreed with BEIS.
Approach to Quality	The overall approach was reviewed with BEIS data analysts during the SCEA scoping stage.

Assurance of Data	Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

Table 32: Heat Generated

Indicator	Heat generated
Source	RHI Payments Data (based on actual metered data for non-domestic installations)
Description of Evidence Analysis	Raw data on heat generated was cleansed as outlined above. For biomethane, RHI Payments data provided figures for the energy content (kWh) of eligible gas injected into the gas grid. Data on the total heat generated to date splits the pre- and post-reform data in accordance with Table 29, dependent on the technology and accreditation date.
Treatment of Deadweight	The initial analysis did not account for additionality and ‘deadweight’ effects. (Deadweight is the change that would have happened anyway, irrespective of the RHI policy intervention). This was applied at the stage of calculating the relevant cost-effectiveness indicator (see section below on ‘Calculating Counterfactual Technology and Deadweight’).
Robustness of Data	High
Description of Robustness	Data came directly from Ofgem/BEIS RHI Payments Data Metered data reported was audited by BEIS contractors, to check accuracy. Analysis and cleansing of data was undertaken by Hatch Regeneris, following data cleansing guidance from BEIS. The internal analysis approach was discussed and agreed with BEIS.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the SCEA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were

	resolved, the analysis was re-run and the QA process was repeated.

Table 33: Calculation of Counterfactual Technology and Deadweight

Indicator	Calculation of counterfactual technology and deadweight
Source	Applicant Survey
Description of Evidence Analysis	Identifying the Counterfactual Applicant survey responses were used to estimate the mix of counterfactual technologies applicable to each RHT both pre- and post- reforms. This data was taken from the raw applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation. The data was cleansed by Winning Moves analysts using a consistent data cleansing approach and weighted according to the overall survey sample. To determine the counterfactual technology, the analysis drew on a number of key survey questions. Any respondents who failed to reply to all questions were removed from the analysis. For the non-domestic applicant survey, these were: 1. Without the RHI, what heat technology would have been installed? (please select one) 2. You mentioned that you may not have picked the same technology type without the RHI. What technology type would have been chosen instead? (please select any that apply) If answer to (1) was ‘the same technology’, the counterfactual was the same as their installed RHT If answer to (1) was ‘no new heating system’, the counterfactual was their previous technology. If answer to (1) was ‘a different technology’, the counterfactual was the technology stated at (2) Responses were excluded if the answer to (1) was ‘a different technology’ and (2) was missing. For the AD applicant survey, the questions were: 1. Without the RHI, would you have proceeded with the same installation?

	2. What technology would have been installed instead? For biogas, the response levels on previous heating technology were too low to be able to undertake this analysis. It was therefore not possible to undertake an analysis of counterfactuals or deadweight for biogas. Biomethane plants produced gas that is injected into the gas grid, so the counterfactual at the point of the end user was always natural gas. As such: If answer to (1) was yes (or 'yes for all installations'), the counterfactual was the same as their installed RHT If answer to (1) was no (or 'no for all installations'), the counterfactual is natural gas If answer to (1) was 'no for some installations', responses were excluded from analysis. The Core Counterfactual Assumption was based on the analysis above. This was used in two ways: Firstly the stated counterfactuals provided an overall mix of counterfactual technologies for each RHT, which was used in the calculations of net carbon abated and air quality damage savings Secondly, by drawing out an overall percentage (%) additionality based on the proportion of installations for which a non-RHT was the counterfactual technology. This was applied to the other cost-effectiveness metrics to remove the benefits that would have been achieved in the counterfactual case without any RHI subsidy. Sensitivity Analysis of Counterfactual / Deadweight The self-reported counterfactual position was subject to bias due to it being applicant reported. These questions were not included in the survey to provide an objective measure of counterfactual behaviours or technology, instead they were to allow for comparison between technologies. To improve their robustness for use as an objective counterfactual measure in cost-effectiveness analysis, these responses were cross checked against other survey responses. The rationale for this was that, if the other responses provided evidence that conflicted with self-reports, then that applicant's reported counterfactual should be amended.

	The sensitivity analysis was only undertaken on the overall deadweight figure, as insufficient information is available from this analysis to be able to adjust the counterfactual mix in alternative scenarios. The selection of which other responses to use as evidence was drawn from the wider evaluation findings. For example, there was evidence that heating professionals were driving installations by informing consumers of RHTs and the RHI. Consumers might not be aware of the influence of the RHI in this indirect influence scenario, so their self-reports would be unreliable. Given the uncertainty that remain in these deadweight estimates, the SCEA used sensitivity testing to produce high and low deadweight scenarios, based on alternative sets of identified counterfactuals. A central deadweight was then derived as the mid-point between high and low scenarios. The maximum and minimum deadweight scenarios were derived based on responses to the applicant survey as described below. **Non-domestic applicant survey – Maximum Deadweight Scenario:** Q - Which of the following were triggers for you in considering installing a new heating technology at all? If this question was answered and core analysis showed this applicant as 'non-deadweight', the assessment was changed to 'deadweight' if they replied that one of the triggers was: • Technology of the new system was better suited to heating requirements Q - Which of the following were factors in your decision to install a renewable heating technology in particular? If this question was answered and core analysis showed this applicant as 'non-deadweight', the assessment was changed to 'deadweight' if they replied that one of the triggers was: • Technology of the new system was better suited to heating requirements

	Q – What type of system was the old system / What heating system was installed previously? If this question was answered and core analysis shows applicant this as 'non-deadweight', the assessment was changed to 'deadweight' if they replied that the previous technology was an RHT. **Non-Domestic Survey – Minimum Deadweight Scenario:** Q - Which of the following were triggers for you in considering installing a new heating technology at all? If this question was answered and core analysis showed this applicant as 'deadweight', the assessment was changed to 'non-deadweight' if their response included any of the following: • Financial case for new system • Investment or revenue opportunity Q - Which of the following were factors in your decision to install a renewable heating technology in particular? If this question was answered and core analysis showed this applicant as 'deadweight', the assessment was changed to 'non-deadweight' if their response included any of the following: • Financial case for new system • Investment or revenue opportunity Q - Where did you find your installer? (historic survey); or How did you find an installer for the RHT? If this question was answered and core analysis showed this applicant as 'deadweight', the assessment was changed to 'non-deadweight' if their response included: • Installer approached you directly. **AD Survey – Maximum Deadweight Scenario:** No adjustments – same as core analysis

	AD Survey – Minimum Deadweight Scenario: Q - Which of the following were factors in your decision to install the RHT? If this question was answered and core analysis showed this applicant as 'deadweight', the assessment was changed to 'non-deadweight' if their response included any of the following: • To claim the RHI • More profitable use of land/biomass/waste compared to other opportunities Using these scenarios, a high deadweight and low deadweight % was produced for each RHT. For cost-effectiveness indicators where a flat deadweight figure was applied to the gross indicator findings, the core analysis was based on the mean of the high and low deadweight scenario figures.
Robustness of Data	Medium
Description of Robustness	Survey carried out as part of the evaluation work with a representative sample of applicants for each technology type, and weighted.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the SCEA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

Table 34: Carbon Abatement

Indicator	Carbon Abatement
Source	Heat generated and Renewable heat technology type - from Application Data (see Heat Generation indicator above) Applicant Survey – Identifying counterfactual technology Average ‘in situ efficiency’ assumptions from BEIS, by technology kgCO_2e per kWh by technology from HMT Green Book / BEIS (note: these are fixed assumptions for most energy sources, but vary by year for electricity). These assumptions include: • Biomass Boiler: 0.037 kgCO_2e per kWh • Combined Heat and Power: 0.183 kgCO_2e per kWh • Coal Boiler: 0.324 kgCO_2e per kWh • Gas Boiler: 0.183 kgCO_2e per kWh • LPG Boiler: 0.214 kgCO_2e per kWh • Oil Boiler: 0.247 kgCO_2e per kWh • Qatari LNG: 0.183 kgCO_2e per kWh Assumptions on savings from Biogas / Biomethane were provided by BEIS. These assumptions were: • Downstream emission savings being calculated relative to the counterfactual technology (see emissions factor above) • Biogeneration emissions being netted off these downstream emissions savings (with emissions ranging from 78g CO_2/kWh for sewage waste to 130g CO_2/kWh for maize, generated by the process of converting feedstocks to biomethane or biogas) • Upstream emissions savings for food waste and wet manure, arising from the diversion of these wastes from landfill being • 561gCO_2/kWh and -366 gCO_2/kWh respectively

Description of Evidence Analysis	The calculation of carbon abatement was based on subtracting the CO2e emissions associated with heat generated using the RHT technology, from the CO2e emissions associated with heat generated using the counterfactual technology. The calculation for CO2e emissions for each side of the equation used the same formula: CO2e emissions = (net heat usage (kWh)/in situ efficiency) x CO2e emissions per kWh for that technology. Net heat usage was drawn from the RHI data as outlined above. In situ efficiency data for each RHT and non-RHT were provided by BEIS (note: non-domestic technology efficiencies have drawn on the same efficiency levels as domestic technology efficiencies, on BEIS' instruction) CO2e emissions per kWh for each technology drew on HMT guidance. For biogas and biomethane, extra allowance needed to be made for the additional carbon abatement associated with upstream carbon savings (e.g. the savings associated with redirecting food waste from going to landfill) which would otherwise generate additional methane. This was addressed using estimates from BEIS on upstream kgCO2e emissions savings per kWh for biogas and biomethane. These upstream savings were included within the assessment of CO2e emissions per kWh for biomethane, within the formula above. As shown in the detailed cost-effectiveness findings for biomethane presented in Attachment 1, upstream savings were presented separately. Estimates of carbon abatement to date were split into pre- and post-reform data (relating to heat generated, split of counterfactual technologies and electricity carbon abatement per kWh assumptions) in accordance with Table 29, depending on the technology and accreditation date. Additional analysis was undertaken on BEIS' request to analyse the carbon abatement that would have been achieved on the basis of the counterfactual mix originally expected by BEIS in the impact assessment. This was undertaken as a cross-check in case the survey evidence on which the counterfactual mix was based was not representative of the wider population of RHT installations. This additional analysis used the same approach as above, except with the counterfactual mix from the BEIS Impact Assessment assumptions being used instead of those sourced from survey analysis.

	For some technologies a counterfactual mix was not stated. For non-domestic solar thermal and biogas, the same assumed mix was used as for both non-domestic heat pumps and biomass (i.e. 50% oil boilers and 50% gas boilers) because these were assumed to be substituting for broadly similar heat uses in similar contexts.
Treatment of Deadweight	By using the counterfactual technology in the core calculation, the carbon abatement figure for each RHT had already taken account of deadweight and so this did not need to be applied again in calculating the relevant cost-effectiveness indicator.
Robustness of Data	Medium
Description of Robustness	Survey carried out as part of the evaluation work with a representative sample of applicants for each technology type, and weighted. Calculations involved numerous assumptions, with a degree of uncertainty around each which reduced overall levels of data robustness. For biogas / biomethane there was greater uncertainty around the upstream savings, suggesting lower levels of data robustness for these figures.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the SCEA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

Table 35: Air Quality Savings

Indicator	Air Quality Savings
Source	Heat generated and Renewable heat technology type - from Application Data (see Heat Generation indicator above). Air Quality Damage Cost per kWh from HMT Green Book (note: these vary by energy source and by year).
Description of Evidence Analysis	The calculation of air quality savings was based on subtracting the air quality damage costs associated with heat generated

	using the RHT, from the air quality damage costs associated with heat generated using the counterfactual technology. The calculation for air quality damage costs for each side of the equation used the same formula: Air quality damage costs = (net heat usage (kWh) / in situ efficiency) x air quality damage costs per kWh for that technology. Net heat usage was drawn from the RHI data as outlined above. In situ efficiency data for each RHT and non-RHT were provided by BEIS (note: non-domestic technology efficiencies have drawn on the same efficiency levels as domestic technology efficiencies, on BEIS' instruction) Air quality damage costs per kWh for each technology draw on HMT guidance. Estimates of air quality savings to date were split into pre- and post-reform data (relating to heat generated, split of counterfactual technologies and air quality damage per kWh assumptions) in accordance with Table 29, depending on the technology and accreditation date. Additional analysis was undertaken on BEIS' request to analyse the carbon abatement that would have been achieved on the basis of the counterfactual mix originally expected by BEIS in the impact assessment. This was undertaken as a cross-check in case the survey evidence on which the counterfactual mix was based was not representative of the wider population of RHT installations. This additional analysis used the same approach as above, except with the counterfactual mix from the BEIS Impact Assessment assumptions being used instead of those sourced from survey analysis. For some technologies a counterfactual mix was not stated. For non-domestic solar thermal and biogas, the same assumed mix was used as for both non-domestic heat pumps and biomass (i.e. 50% oil boilers and 50% gas boilers) because these were assumed to be substituting for broadly similar heat uses in similar contexts.
Treatment of Deadweight	By using the counterfactual technology in the core calculation, the air quality savings figure for each RHT had already taken

	account of deadweight and so this did not need to be applied again in calculating the relevant cost-effectiveness indicator.
Robustness of Data	Medium-High
Description of Robustness	Survey carried out as part of the evaluation work with a representative sample of applicants for each technology type, and weighted.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the SCEA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

Table 37: Calculating Cost-Effectiveness Indicators

SCEA Indicator	Average annual subsidy cost per kW of installed capacity
Calculation	For each RHT: Average annual subsidy cost / total installed capacity (kW) For each RHT this was broken down for pre- and post-reform periods.
Treatment of Deadweight	Deadweight was applied to the annual subsidy cost based on a flat proportion, as described in the Indicator on Counterfactual Technology and Deadweight. Core deadweight figures were applied in the analysis, with upper and lower boundaries set out in the accompanying comments.

SCEA Indicator	Subsidy cost per kWh of renewable heat generated to date
Calculation	For each RHT: Total subsidy cost / total renewable heat generated (kWh) For each RHT this was broken down for pre- and post-reform periods.
Treatment of Deadweight	Deadweight was applied to the annual subsidy cost in the normal way. Core deadweight figures were applied in the analysis, with upper and lower boundaries set out in the accompanying comments.

SCEA Indicator	Subsidy cost per tonne of CO2e emissions abated to date
Calculation	For each RHT: Total subsidy cost / total CO2e emissions abated to date (kgCO2e) For each RHT this was broken down for the pre- and post-reform periods.
Treatment of Deadweight	This indicator required testing CO2e emissions under RHT and comparing with CO2 emissions in the counterfactual case, so deadweight was already incorporated in the calculation Core deadweight figures were applied in the analysis, with upper and lower boundaries set out in the accompanying comments.

SCEA Indicator	Value of Air Quality damage costs saved to date per £subsidy invested
Calculation	For each RHT: Total subsidy cost / total value of air quality damage savings to date For each RHT this was broken down for the pre- and post-reform periods.
Treatment of Deadweight	This indicator required testing air quality damage costs under RHT and comparing with air quality damage costs in the counterfactual case, so deadweight was already incorporated in the calculation Core deadweight figures were applied in the analysis, with upper and lower boundaries set out in the accompanying comments.

SCEA Indicator	Value for Money (VfM) based on Applicant Returns on Investment
Approach	Summary of findings from tariff setting analysis undertaken as part of Competition and Trade Assessment Workstream This provided an overview for the post-reform period. However, it cannot provide a comparison of findings to the pre-reform period.
Treatment of Deadweight	N/A

SCEA Indicator	Contribution to Market Development
Approach	Summary of findings on market development undertaken as part of

	Sustainable Markets Assessment Workstream This provided an overview for the post-reform period. However, it cannot provide a comparison of findings to the pre-reform period.
Treatment of Deadweight	N/A

Attachment 1: Detailed Subsidy Cost-Effectiveness Assessment for Biogas and Biomethane

Subsidy Cost-Effectiveness Assessment findings for all technologies are presented in the main report. Detail of Subsidy Cost-Effectiveness Assessment is presented here for biogas and biomethane to illustrate the role of upstream and downstream carbon savings for these technologies.

Table 38: Comparison in cost-effectiveness of carbon abatement for AD, based on those commissioned pre- and post-reform and included in the Subsidy Cost-Effectiveness Assessment

	Biogas pre-reform	Biogas post-reform	Bio-methane pre-reform	Bio-methane post-reform
Number of accredited installations in total	741	44	131	11
Number of accredited installations included in SCEA analysis[37]	618	15	73	5
Total subsidy cost to date to October 2021	£232m	£1.0m	£1,009m	£7.7m
Renewable heat capacity installed (MW)[38]	199MW	5.2MW	560MW	39MW
Renewable heat generation to end October 2021 (GWh)	3,532 GWh	24 GWh	12,663 GWh	166 GWh
Carbon abatement (downstream only – based on evaluation evidence), TCO2e	18,881	128	920,355	12,061
Carbon abatement (upstream – based on IA assumptions), TCO2e	802,194	5,458	4,709,685	61,721
Carbon abatement (tonnes of CO2) (downstream and upstream – based on evaluation evidence)	821,075	5,586	5,630,040	73,782

[37] Accredited installations were excluded from the analysis if data was incomplete. The first 12 months of operation of biomethane plants were also excluded as it was assumed that there is a 12 month ramp-up period before the technology is operating at full capacity, which would skew cost-effectiveness estimates.
[38] The capacity of biomethane installations was based on the annual biomethane injection rate, using a conversion factor of 0.00135 to convert flow rate to installed capacity.

	Biogas pre-reform	Biogas post-reform	Bio-methane pre-reform	Bio-methane post-reform
Subsidy cost per tonne of CO2 emissions abated to date (downstream)	-£12,280[39]	-£7,481	£1,096	£641
Subsidy cost per tonne of CO2 emissions abated to date (downstream plus upstream)	£282	£172	£179	£105

Source: Subsidy Cost-Effectiveness Assessment

[39] Negative figures in both periods for this indicator for biogas reflect findings that without the RHI most applicants would have opted for installing biomass or going ahead with a biogas installation anyway as the counterfactual position.

Competition and Trade Assessment

This workstream which analysed the extent to which the assumptions used in developing tariff levels for the RHI, may have led to over or under compensation of applicants. The workstream was led by Hatch Regeneris and Wavehill.

One of the key outputs from the Competition and Trade Assessment (CTA) workstream was a dashboard showing latest evidence on the extent to which assumption values used in modelling tariff levels were realised in practice. Any variance from these original assumptions indicated instances where there may have been over or under compensation of applicants through the tariff levels applied.

The CTA drew on a range of evidence sources, with varying levels of robustness, including scheme data, RHI applicant survey data, and wider government data sources.

Where RHI applicant survey data was used, this was weighted data unless otherwise specified in the assumptions below.

Limitations

The Competition and Trade Assessment analysis included a number of important limitations. A critical limitation was that the full methodology for setting tariff levels was not in the public domain, and so the methodology for tariff setting needed to be drawn together by collating the range of assumptions that went into this and understanding how those assumptions were used together to set tariff levels. This allowed for those original assumptions to be tested, and for the effects of any variance in those assumptions to be assessed.

The original assumptions used by BEIS in developing tariff levels were drawn from the series of published impact assessments undertaken for both the domestic and non-domestic scheme. A full set of tariff setting assumptions was not available for all technology types, so the CTA analysis was only undertaken for the following technology groups:

- non-domestic Biomass (ND Biomass)
- non-domestic Air Source Heat Pumps (ND ASHP)
- non-domestic Ground Source Heat Pumps (ND GSHP)
- biomethane

Data was not available to enable all assumptions to be tested through the evaluation, so only those where this was possible were incorporated into the methodology.

Also, not all of the assumptions used in modelling tariff levels could be tested through the analysis during the evaluation. Those which could not be fully tested at this stage included:

- average lifetime of installed Renewable heat technologies – unlikely to be known for another 10-20 years

- rate of return of installed renewable heat technologies – not possible to test full participant rate of return in the timeframe for this evaluation
- average Annual Operational Costs – annual operational (maintenance) costs were expected to be greater towards the latter period of a technology's lifespan so could not be reliably captured during the timeframe of this evaluation

The analysis only assessed potential risk of over or under compensation, as it was not possible to analyse the fully modelled costs and tariffs received for each project. Nor was it possible to fully account for the impact of degressions in this analysis: instead, the overall effect of degressions was assessed in the final stage, with adjustments made to conclusions on the basis of the impact of degressions.

There were weaknesses in some of the data available for testing assumptions, including cost data weaknesses relating to 'average capital cost of technology and installation', as detailed for the cost indicator below, as well as limitations associated with available survey data for assessing the counterfactual technology (as outlined in the relevant indicator section below).

Details of analysis

The indicators that this analysis could and did test are shown in Table 39.

Table 39: Tariff-setting assumptions tested in CTA analysis

Assumption	Assumption Origin	Description
Assumed Counterfactual Technology	BEIS, Reformed RHI Impact Assessment, 2016	Assumption about the mix of heating technologies replaced by the new Renewable heat technology.
Average Capital Cost (£ per kW) of Technology and Installation	BEIS, Reformed RHI Impact Assessment, 2016; BEIS, RHI Biomethane Tariff Review Impact Assessment, 2014	Assumption about the average costs of purchase and installation of the new Renewable heat technology.
Average Technology Design Efficiency	BEIS, Reformed RHI Impact Assessment, 2016; BEIS, RHI Tariff Review Impact Assessment, 2013	Assumption about the average design efficiency of technologies installed.
Fuel Price (pence per kWh)	BEIS, Reformed RHI Impact Assessment, 2016	Assumption about average fuel price of inputs to the new Renewable heat technology.
Gate Fees Income (% from each	BEIS, Policy Assumption	Assumption about average value generated from gate fees for receiving waste fuel for biomethane technology.

source and £/tonne)		
Average Installed Capacity (kW)	BEIS, Reformed RHI Impact Assessment, 2016; BEIS; RHI – Biomethane Tariff Review Impact Assessment, 2014; BEIS, RHI Tariff Review Impact Assessment, 2013	Assumption about the average size (installed capacity) of the new renewable heat technology.
Average Heat Load Factor (%)	BEIS, Reformed RHI Impact Assessment, 2016; BEIS	Assumption about the average heat load factor applied to newly installed renewable heat technologies.
Risk of Gaming (Qualitative Assessment)	BEIS, Policy Assumption	Assumption about the extent to which applicants might 'game' the scheme in order to derive greater compensation, in a way that is not in keeping with the aims of the policy.

This section provides a summary of the eight indicators above, how the original assumptions have been tested using evidence from actual data and our approach to quality assuring the analysis undertaken on each.

Where appropriate, additional analysis for each of the eight indicators by installation capacity size was conducted and presented in the dashboard. Typologies of size were defined for each of the RHTs by:

- ND ASHP: where an individual RHT with an installation capacity less than the population's median was defined as 'Small' and where it was greater than 'Large' to ensure an even number of installations across both categories
- ND GSHP: in alignment with policy tariff rate bandings:
    - Small = where RHT has an installed capacity of less than 100kWth
    - Large = where RHT has an installed capacity of 100kWth or more
- Biomass Boilers: as agreed with BEIS' boilers sizes have been categorised as:
    - Small = where RHT has an installation capacity less than or equal to 200kWth
    - Medium = installation capacity greater than 200kWth but less than or equal to 1,000kWth
    - Large = installation capacity greater than 1,000kWth

Table 40: Assumed Counterfactual

Indicator	Assumed Counterfactual Technology
Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016 BEIS, Domestic RHI Impact Assessment, 2013
Basis of original assumptions	Policy Assumption by BEIS team
Source for testing assumptions	RHI Applicant Monitoring Survey for Non-domestic and Biomethane
Description of Evidence Analysis	Applicant survey data analysis This data was taken from the applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation. The data was cleansed by Winning Moves analysts using a consistent data cleansing approach. Note the data used was unweighted, as only a subset of data was used, corresponding to specific accreditation dates. This cut across several waves of survey analysis, but did not fully align with them, meaning that weightings relating to waves of the survey could not be used. For the non-domestic scheme (excluding biomethane), the data covered respondents from Wave 25 of the applicant survey (from October 2015 onwards). The indicator was based on the information provided by respondents to the following non-domestic RHI survey questions: ‘Without the RHI, what heat technology would have been installed?’ ‘What technology type would have been chosen instead?’ In each case, responses were based on the alternative technology that would have been used without RHI, or the previous technology, where respondents said they would not have installed a new heating system. For non-domestic biomethane installations, the biomethane was being fed into the gas grid as an alternative to natural gas and as such the latter was assumed to be the counterfactual.

Robustness of Data	Medium
Description of Robustness	The applicant survey was carried out as part of the evaluation work which is sent to all RHI applicants (response rate 12.6%). The data was unweighted, in order to capture data only covering the post-reform period where possible and to allow data to be combined across several waves of the survey, where more data was needed to improve sample size and robustness.[40] As the sample was self-selecting, there was limited control over which applicants chose to respond. This meant that there was potential for self-selection bias if respondents were not fully representative of the applicant population. As described under the applicant survey method section above, telephone follow-up calls were used to improve response rates from groups that were of interest to the analysis but were under-represented in online responses to the applicant survey. The self-reported nature of the survey may have introduced an additional layer of bias in that answering hypothetical deadweight questions may not accurately reflect the true counterfactual.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the CTA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

[40] Please see the methodology for detailed applicant monitoring above.

Table 41: Average Capital Cost of Technology and Installation

Indicator	Average Capital Cost (£ per kW) of Technology and Installation
Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016 BEIS, RHI Tariff Review Impact Assessment, 2013 BEIS, RHI Biomethane Tariff Review Impact Assessment, 2014 (Note: Estimate based on evidence from chart)
Basis of original assumptions	Sweett, Cost and Performance Report (2013), Scheme data and AEA data
Source for testing assumptions	RHI Application Data on costs for Renewable heat technologies
Description of Evidence Analysis	Application data cleansing and analysis This data was taken from the raw application data gathered by Ofgem and reported to BEIS. Minor cleansing was done by BEIS on sending the data (primarily removing any duplicates). The application data was cleansed by Hatch Regeneris: removing all negative entries and those equal to 0, and removing all non-live installations for non-domestic applications. Data on the average costs drew only on installations which were accredited from October 2017 onwards, in order to capture only those applications made under the reformed scheme. Consistent with BEIS recommendations and internal approach, for the analysis of cost per kW data, Hatch Regeneris then removed the 5% highest and 5% lowest cost per kW figures for each technology reported, to remove anomalous entries. The average capital cost per kW data for each installation was a function of total capital cost of technology and installation (reported jointly), and installed capacity of the Renewable heat technology. For each technology, the average figure reported was based on the median figure. Median figures for the smaller and larger half of all installations by kW capacity were also assessed for each technology.

Robustness of Data	Medium-High
Description of Robustness	Data came directly from Ofgem/BEIS Application Data. Analysis and cleansing of data was undertaken by Hatch Regeneris, following data cleansing guidance from BEIS. BEIS highlighted that there were weaknesses in the costs data collection, with a significant number of unrealistic estimates in the data, and potential for inconsistency in how the question was interpreted by applicants (e.g. some may only have included costs for the technology but not installation; some may have included technology, installation and ancillary activities e.g. new radiator installation). The risks posed by these weaknesses were reduced through data cleansing and use of the median rather than mean were implemented to improve data robustness. The internal analysis approach was discussed and agreed with BEIS.
Approach to Quality Assurance of Data	The overall approach was reviewed with Winning Moves and BEIS data analysts during the CTA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated. Cost per kW data was sense-checked against cost per kW findings from survey data (where survey questions also captured some insights).

Table 42: Average Technology Design Efficiency

Indicator	Average Technology Design Efficiency
Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016 BEIS, RHI Tariff Review Impact Assessment, 2013
Basis of original assumptions	Design Performance (Product Characteristics Database), Heat Emitter Guide and policy judgement
Source for testing assumptions	RHI Application Data
Description of Evidence Analysis	Application Data Analysis The application data was cleansed as described for the Capital Cost indicator above. Data on the average design efficiency drew only on installations which were accredited from October 2017 onwards, in order to only capture those under the reformed scheme. Consistent with BEIS recommendations and internal approach, the design efficiency data was further cleansed by Hatch Regeneris, by removing the 5% highest and 5% lowest design efficiency figures for each technology reported, to remove anomalous entries. For each technology the average design efficiency figure reported was based on the mean figure. The average mean was chosen as it was considered better suited once the 5% highest and lowest design efficiency figures, where outliers were considered to lie, were removed. Mean figures for the smaller and larger half of all installations by kW capacity were also assessed for each technology. In-Situ Efficiency Evidence Where available, recent secondary evidence from trials commissioned by BEIS[41] around in-situ efficiency for renewable heat technologies was incorporated.

[41] BEIS (Feb 2018) Monitoring of Non-Domestic Renewable Heat Incentive Ground-Source & Water-Source Heat Pumps; BEIS (Dec 2018) Measurement of the in-situ performance of solid biomass boilers.

Robustness of Data	High
Description of Robustness	Data came directly from Ofgem/BEIS Application Data. Analysis and cleansing of data was undertaken by Hatch Regeneris, following data cleansing guidance from BEIS. The internal analysis approach was discussed and agreed with BEIS. The assessment was primarily based on design efficiency rather than in-situ efficiency because of the lack of data on in situ efficiency. Wider evidence on in situ efficiency from recent secondary sources was included where possible.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the CTA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated. Where possible, Hatch Regeneris sense checked findings against the median design efficiency of the top five products supported by each technology group through desk-based research.

Table 43: Fuel Price

Indicator	Fuel Price per kWh (For Biomethane, feedstock cost per tonne)
Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016
Basis of original assumptions	Non-domestic Heat Pumps – DECC Fuel Price Series Non-domestic Biomass – market intelligence (set out by BEIS in relevant Impact Assessment papers referenced above)
Source for testing assumptions	BEIS data on cost per kWh for each fuel type (Energy and Emissions Projections Dataset) RHI Application Data Applicant Survey / desk research – price of biomass / biomethane fuels
Description of Evidence Analysis	Electricity Input Costs Data on energy costs from the BEIS Energy and Emissions Projections Dataset took the average overall fuel cost figures between October 2017 and the date of the analysis. In particular this drew on data from Annex M of the 2017 data.[42] Non-Domestic Biomass Fuel Price This data was taken from the applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation. The data was cleansed by Winning Moves and prepared as described for the Counterfactual Technology indicator above. The indicator was based on the information provided by respondents in response to the following question: 'If any biomass fuel is purchased. How much is paid for the biomass fuel per tonne, including transport?' The number of kWh generated per tonne of different biomass fuels was based on data from Horticultural sector body

[42] BEIS (2017), Energy and Emissions Projections Data. Annex M. Reference Scenario. Prices: Retail Prices. https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017

	GrowSave.[43] For a small number of fuel types, data was not available and therefore an average (mean) from other fuels was used. The fuel price per kWh by biomass fuel was then calculated by using the formula: Fuel price per kWh = Price per tonne / kWh per tonne The reported figure was based on an average (mean) of the price per kWh per biomass fuel associated with survey respondents across all sizes of boilers. Non-Domestic Biomethane Fuel Price This data was taken from the applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation. The data was cleansed by Winning Moves analysts using a consistent data cleansing approach, as outlined above. The indicator was based on the information provided by respondents in response to the following questions: 'Please indicate the tonnage (tonnes per year) of each of the following feedstocks that are used in your plant' 'How much is paid for the feedstock you purchase (per tonne, including transport)?' The reported figure was then based on an average (mean) of the survey responses.
Robustness of Data	Electricity Input Costs – High Biomass and Biomethane Fuel Costs – Medium-Low
Description of Robustness	Survey carried out as part of the evaluation work which was sent to all RHI applicants (response rate 12.6%). It was unweighted, in order to capture data only covering the post-reform period where possible and to allow data to be combined across several waves of the survey, where more data was needed to improve sample size and robustness.[44]

[43] https://www.growsave.co.uk/userFiles/biomass_heating__july_2013.pdf

[44] For further information please refer to survey method sub-section of this annex.

	Data from Waves 26-31 of the applicant survey (post-October 2017 i.e. post-reform) was limited for non-domestic applicants and very limited for biomethane. As such, the non-domestic analysis drew on data from the earlier Wave 25 survey (covering October 2015 – September 2017) which provided a significantly larger sample. Biomethane survey data was used across surveys from Wave 25 onwards (i.e. October 2015 onwards), but was unweighted, reflecting the low sample and population size for this technology type. These approaches have aimed to increase robustness of the analysis. As the sample was self-selecting, there was limited control over which applicants chose to respond. This meant that there was potential for self-selection bias if respondents were not fully representative of the applicant population. As described under the applicant survey method section above, telephone follow-up calls were used to improve response rates from groups that were of interest to the analysis but were under-represented in online responses to the applicant survey. Overall, the additional assumptions involved in calculating biomass and biomethane fuel costs are likely to impact on the robustness of the evidence provided.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the CTA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated. Biomass fuel costs were sense checked using BEIS research on wood pellet market from 2017.[45] That analysis covered approximately 60% of the ~500,000 tonnes/year UK domestic and commercial heating market.

Table 44: Gate Fees Income

Indicator	Gate Fees Income (Biomethane only)

[45] BEIS (May 2017) - BEIS UK wood pellet market study

Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016
Basis of original assumptions	Policy Assumption by BEIS team
Source for testing assumptions	Applicant survey – testing types of feedstock used, prices paid for feedstocks and whether gate fees paid to receive waste
Description of Evidence Analysis	The indicator was based on the information provided by respondents to the following question: 'Please indicate the tonnage (tonnes per year) of each of the following feedstocks that are used in your plant' 'How is this sourced?' 'How much is paid for the feedstock you purchase (per tonne, including transport)?' In response to the final question, respondents could indicate that they were paid for receipt of feedstocks (i.e. that they received gate fees payments for receipt of waste) rather than having to purchase their feedstock. In the CTA analysis, this assumption was combined with the feedstock costs assumption, as the two were closely related for biomethane feedstocks. The biomethane applicant survey explored whether respondents received gate fees for some or all of their feedstocks but response levels on feedstock prices were extremely low and so have not been included.
Robustness of Data	Low
Description of Robustness	No firm data was available to test levels of gate fees income. However survey evidence provided a useful indication of extent to which original tariff setting assumptions still held. Where analysis was based on limited data, this was highlighted in the presentation of CTA findings and results were used carefully.

Approach to Quality Assurance of Data	The overall approach was reviewed with Winning Moves and with BEIS data analysts during the CTA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated. Additional secondary evidence drawn on gate fees nationally from the WRAP Gate Fees 2017/18 Final Report.[46]

Table 45: Average Installed Capacity

Indicator	Average Installed Capacity (kW)
Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016 BEIS, RHI – Biomethane Tariff Review Impact Assessment, 2014 BEIS, RHI Tariff Review Impact Assessment, 2013
Basis of original assumptions	Policy Assumption by BEIS team
Source for testing assumptions	RHI Application Data – installation capacity
Description of Evidence Analysis	This data was taken from the raw data gathered by Ofgem and reported to BEIS. The application data was cleansed as described for the Capital Cost indicator above. Data on the average installed capacity drew only on installations which were accredited from October 2017 onwards, in order to only capture those under the reformed scheme. Consistent with BEIS recommendations and internal approach, the installed capacity data was further cleansed by Hatch Regeneris, by removing the 5% highest and 5% lowest installed

46 https://wrap.org.uk/resources/report/gate-fees-reports

	capacity figures for each technology reported, to remove anomalous entries. For each technology the average installed capacity figure reported was based on the mean figure.
Robustness of Data	High
Description of Robustness	Data came directly from Ofgem/BEIS Application Data. Analysis and cleansing of data was undertaken by Hatch Regeneris, following data cleansing guidance from BEIS. The internal analysis approach was discussed and agreed with BEIS.
Approach to Quality Assurance of Data	The overall approach was reviewed with BEIS data analysts during the CTA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

Table 46: Average Heat Load Factor

Indicator	Average Heat Load Factor
Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016 BEIS, RHI Tariff Review Impact Assessment, 2013
Basis of original assumptions	RHI Scheme Data; Sweett, Cost and Performance Report (2013)
Source for testing assumptions	RHI Application and Payments Data - tested using heat demand data and installed capacity
Description of Evidence Analysis	This data was taken from the raw data gathered by Ofgem and reported to BEIS. The application data was cleansed as described for the Capital Cost indicator above. Data on the average heat load factor drew only on installations which were accredited from October 2017 onwards, in order to only capture those under the reformed scheme. The average heat load factor figure is calculated using the following formula: Average heat load factor = Annual heat load for the installation / (installed capacity x number of hours in a year) Annual heat demand data was gathered through Payments Data for all non-domestic installations. Consistent with BEIS recommendations and the internal approach, calculated heat load factor data was further cleansed by Hatch Regeneris, by removing the 5% highest and 5% lowest HLF figures for each technology reported, to remove anomalous entries. For each technology the average heat load factor figure reported was based on the mean figure. Mean figures for the smaller and larger half of all installations by kW capacity were also assessed for each technology.

Robustness of Data	High
Description of Robustness	Data came directly from Ofgem/BEIS Application Data. Analysis and cleansing of data was undertaken by Hatch Regeneris, following data cleansing guidance from BEIS. The internal analysis approach was discussed and agreed with BEIS.
Approach to Quality Assurance of Data	The overall approach was reviewed with the BEIS data analysts during the CTA scoping stage. Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

Table 47: Risk of Gaming

Indicator	Risk of Gaming Assumption
Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016
Basis of original assumptions	Policy assumption of no gaming
Source for testing assumptions	The CTA analysis tested potential sources of gaming for any evidence that this was taking place. Key potential sources of gaming included the following: Biomass – self supply of fuel introduced risk of gaming as it increased risk of fuel costs being significantly below market rate, which could lead to heat generation to generate profits. Similarly, there was a risk of poor quality biomass being used, which was not in line with sustainability rules which could also indicate over-compensation through gaming. Both of these gaming risks were covered in the CTA analysis. Non-Domestic biomass - installing multiple smaller boilers instead of one large boiler to access the higher tariffs for smaller

	boilers. This was not covered in the CTA analysis as this type of gaming was not possible post September 2017 due to shift to a single biomass tariff. Multiple biogas plants on the same site – similar to biomass gaming of the different tariff bands. This was not covered in this analysis as biogas was not one of the technologies tested in the CTA analysis, for reasons explained at the start of this method section. Creating new heat uses where this would not have been desirable without RHI: limited data was available to evidence this, but some analysis undertaken around non-domestic RHI survey data on capacity compared to previous technology.
Description of Evidence Analysis	This data was taken from the applicant survey data produced by Winning Moves, as part of the reformed RHI evaluation. The data is cleansed by Winning Moves analysts using a consistent data cleansing approach, as described above. Note the data used was unweighted, as only a subset of data is used, corresponding to specific accreditation dates. Non-domestic biomass - survey data (Wave 25 - October 2015 onwards) on the proportion of respondents which self-supply their own biomass fuel, based on the following question: ‘How is the fuel sourced?’ Non-domestic technologies – survey data on proportion of respondents which installed larger capacity technologies than their previous technology, based on the following question: ‘How does the capacity of the renewable heat technology compare to the capacity of the old system?’
Robustness of Data	Low
Description of Robustness	Survey data was relatively robust (as outlined in other sections above). However, the method for analysing the potential for gaming activity provided limited insight as a proxy, only presenting evidence which could suggest or indicate the potential for gaming.
Approach to Quality Assurance of Data	The overall approach was reviewed with Winning Moves and the BEIS data analysts during the CTA scoping stage.

	Spot checking of random sample of data was undertaken to test whether numbers corresponded with raw data. If any errors were found, modelling formulae were checked for errors, issues were resolved, the analysis was re-run and the QA process was repeated.

Appendix C: Tariff Levels

Table 48: Tariff levels

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Small Biomass (Less than 200 kWth)	before 1 July 2014	10.26	Tier 1
Small Biomass (Less than 200 kWth)	before 1 July 2014	2.69	Tier 2
Small Biomass (Less than 200 kWth)	between 1 July and 30 September 2014	9.79	Tier 1
Small Biomass (Less than 200 kWth)	between 1 July and 30 September 2014	2.59	Tier 2
Small Biomass (Less than 200 kWth)	between 1 October and 31 December 2014	8.87	Tier 1
Small Biomass (Less than 200 kWth)	between 1 October and 31 December 2014	2.33	Tier 2
Small Biomass (Less than 200 kWth)	between 1 Jan and 31 March 2015	7.91	Tier 1
Small Biomass (Less than 200 kWth)	between 1 Jan and 31 March 2015	2.09	Tier 2
Small Biomass (Less than 200 kWth)	between 1 April and 30 June 2015	6.73	Tier 1
Small Biomass (Less than 200 kWth)	between 1 April and 30 June 2015	1.80	Tier 2
Small Biomass (Less than 200 kWth)	between 1 July and 30 September 2015	5.05	Tier 1
Small Biomass (Less than 200 kWth)	between 1 July and 30 September 2015	1.34	Tier 2
Small Biomass (Less than 200 kWth)	between 1 October and 31 December 2015	4.80	Tier 1
Small Biomass (Less than 200 kWth)	between 1 October and 31 December 2015	1.28	Tier 2

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Small Biomass (Less than 200 kWth)	between 1 January and 31 March 2016	4.32	Tier 1
Small Biomass (Less than 200 kWth)	between 1 January and 31 March 2016	1.14	Tier 2
Small Biomass (Less than 200 kWth)	between 1 April and 30 June 2016	3.94	Tier 1
Small Biomass (Less than 200 kWth)	between 1 April and 30 June 2016	1.05	Tier 2
Small Biomass (Less than 200 kWth)	between 1 July and 30 September 2016	3.55	Tier 1
Small Biomass (Less than 200 kWth)	between 1 July and 30 September 2016	0.94	Tier 2
Small Biomass (Less than 200 kWth)	between 1 October and 31 December 2016	3.37	Tier 1
Small Biomass (Less than 200 kWth)	between 1 October and 31 December 2016	0.89	Tier 2
Small Biomass (Less than 200 kWth)	between 1 January and 31 March 2017	3.21	Tier 1
Small Biomass (Less than 200 kWth)	between 1 January and 31 March 2017	0.85	Tier 2
Small Biomass (Less than 200 kWth)	between 1 April and 30 July 2017	3.06	Tier 1
Small Biomass (Less than 200 kWth)	between 1 April and 30 July 2017	0.80	Tier 2
Small Biomass (Less than 200 kWth)	between 1 July and 19 September 2017	2.91	Tier 1
Small Biomass (Less than 200 kWth)	between 1 July and 19 September 2017	0.76	Tier 2
Small Biomass (Less than 200 kWth)	on or after 20 September 2017	3.17	Tier 1

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Small Biomass (Less than 200 kWth)	on or after 20 September 2017	2.22	Tier 2
Medium Biomass (above 200 kWth and & less than 1MWth)	before 1 July 2013	6.29	Tier 1
Medium Biomass (above 200 kWth and & less than 1MWth)	before 1 July 2013	2.69	Tier 2
Medium Biomass (above 200 kWth and & less than 1MWth)	between 1 July 2013 and 31 March 2016	5.94	Tier 1
Medium Biomass (above 200 kWth and & less than 1MWth)	between 1 July 2013 and 31 March 2016	2.59	Tier 2
Medium Biomass (above 200 kWth and & less than 1MWth)	between 1 April 2016 and 31 June 2017	5.70	Tier 1
Medium Biomass (above 200 kWth and & less than 1MWth)	between 1 April 2016 and 31 June 2017	2.47	Tier 2
Medium Biomass (above 200 kWth and & less than 1MWth)	between 1 July and 19 September 2017	5.13	Tier 1
Medium Biomass (above 200 kWth and & less than 1MWth)	between 1 July and 19 September 2017	2.22	Tier 2
Medium Biomass (above 200 kWth and & less than 1MWth)	on or after 20 September 2017	3.17	Tier 1
Medium Biomass (above 200 kWth and & less than 1MWth)	on or after 20 September 2017	2.22	Tier 2
Large Biomass (1MWth and above)	before 21 January 2013	1.16	N/A
Large Biomass (1MWth and above)	between 21 January 2013 and 31 March 2016	2.33	N/A
Large Biomass (1MWth and above)	between 1 April 2016 and 19 September 2017	2.22	N/A
Large Biomass (1MWth and above)	after 20 September 2017	3.17	Tier 1
Large Biomass (1MWth and above)	after 20 September 2017	2.22	Tier 2

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Solid Biomass CHP Systems (All capacities)	before 1 April 2016	4.79	N/A
Solid Biomass CHP Systems (All capacities)	on or after 1 April 2016	4.60	N/A
Small water/ground-source heat pumps (Less than 100Kwth)	before 21 January 2013	5.72	N/A
Small water/ground-source heat pumps (Less than 100Kwth)	between 21 January 2013 and 31 March 2016	10.15	Tier 1
Small water/ground-source heat pumps (Less than 100Kwth)	between 21 January 2013 and 31 March 2016	3.03	Tier 2
Small water/ground-source heat pumps (Less than 100Kwth)	between 1 April 2016 and 1 April 2020	9.74	Tier 1
Small water/ground-source heat pumps (Less than 100Kwth)	between 1 April 2016 and 1 April 2020	2.91	Tier 2
Small water/ground-source heat pumps (Less than 100Kwth)	on or after 1 April 2020	9.74	Tier 1
Small water/ground-source heat pumps (Less than 100Kwth)	on or after 1 April 2020	2.91	Tier 2
Large water/ground-source heat pumps (100kWth and above)	before 21 January 2013	4.20	N/A
Large water/ground-source heat pumps (100kWth and above)	between 21 January 2013 and 31 March 2016	10.15	Tier 1
Large water/ground-source heat pumps (100kWth and above)	between 21 January 2013 and 31 March 2016	3.03	Tier 2
Large water/ground-source heat pumps (100kWth and above)	between 1 April 2016 and 1 April 2020	9.74	Tier 1
Large water/ground-source heat pumps (100kWth and above)	between 1 April 2016 and 1 April 2020	2.91	Tier 2
Large water/ground-source heat pumps (100kWth and above)	between 1 April 2020 and 30 June 2020	8.77	Tier 1

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Large water/ground-source heat pumps (100kWth and above)	between 1 April 2020 and 30 June 2020	2.62	Tier 2
Large water/ground-source heat pumps (100kWth and above)	between 1 July and 30 September 2020	7.02	Tier 1
Large water/ground-source heat pumps (100kWth and above)	between 1 July and 30 September 2020	2.09	Tier 2
Large water/ground-source heat pumps (100kWth and above)	between 1 October 2020 and 31 December 2020	5.61	Tier 1
Large water/ground-source heat pumps (100kWth and above)	between 1 October 2020 and 31 December 2020	1.67	Tier 2
Large water/ground-source heat pumps (100kWth and above)	on or after 1 January 2021	4.49	Tier 1
Large water/ground-source heat pumps (100kWth and above)	on or after 1 January 2021	1.34	Tier 2
Air source heat pumps (All capacities)	before 1 April 2016	2.90	N/A
Air source heat pumps (All capacities)	on or after 1 April 2016	2.81	N/A
Deep geothermal (All capacities)	before 1 April 2016	5.83	N/A
Deep geothermal (All capacities)	between 1 April 2016 and 31 December 2021	5.59	N/A
Deep geothermal (All capacities)	on or after 1 January 2021	5.03	N/A
Solar collectors (Less than 200 kWth)	before 21 January 2013	10.95	N/A
Solar collectors (Less than 200 kWth)	between 21 January 2013 and 31 March 2016	11.66	N/A
Solar collectors (Less than 200 kWth)	on or after 1 April 2016	11.19	N/A
Biomethane injection (All capacities)	before 1 January 2015	8.73	N/A
Biomethane injection (First 40,000 MWh)	before 1 July 2015	8.73	Tier 1

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Biomethane injection (Next 40,000 MWh)	before 1 July 2015	5.12	Tier 2
Biomethane injection (Remaining MWh)	before 1 July 2015	3.96	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 July and 30 September 2015	8.31	Tier 1
Biomethane injection (Next 40,000 MWh)	between 1 July and 30 September 2015	4.87	Tier 2
Biomethane injection (Remaining MWh)	between 1 July and 30 September 2015	3.76	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 October and 31 December 2015	7.49	Tier 1
Biomethane injection (Next 40,000 MWh)	between 1 October and 31 December 2015	4.39	Tier 2
Biomethane injection (Remaining MWh)	between 1 October and 31 December 2015	3.39	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 January 31 March 2016	6.73	Tier 1
Biomethane injection (Next 40,000 MWh)	between 1 January 31 March 2016	3.96	Tier 2
Biomethane injection (Remaining MWh)	between 1 January 31 March 2016	3.05	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 April 2016 and 30 June 2016	5.82	Tier 1
Biomethane injection (Next 40,000 MWh)	between 1 April 2016 and 30 June 2016	3.42	Tier 2
Biomethane injection (Remaining MWh)	between 1 April 2016 and 30 June 2016	2.63	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 July and 30 September 2016	4.95	Tier 1

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Biomethane injection (Next 40,000 MWh)	between 1 July and 30 September 2016	2.91	Tier 2
Biomethane injection (Remaining MWh)	between 1 July and 30 September 2016	2.24	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 October and 31 December 2016	4.70	Tier 1
Biomethane injection (Next 40,000 MWh)	between 1 October and 31 December 2016	2.78	Tier 2
Biomethane injection (Remaining MWh)	between 1 October and 31 December 2016	2.13	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 January and 31 March 2017	4.24	Tier 1
Biomethane injection (Next 40,000 MWh)	between 1 January and 31 March 2017	2.49	Tier 2
Biomethane injection (Remaining MWh)	between 1 January and 31 March 2017	1.91	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 April and 31 June 2017	3.82	Tier 1
Biomethane injection (Next 40,000 MWh)	between 1 April and 31 June 2017	2.25	Tier 2
Biomethane injection (Remaining MWh)	between 1 April and 31 June 2017	1.72	Tier 3
Biomethane injection (First 40,000 MWh)	between 1 July 2017 and 21 May 2018	3.43	Tier 1
Biomethane injection (Next 40,000 MWh)	between 1 July 2017 and 21 May 2018	2.03	Tier 2
Biomethane injection (Remaining MWh)	between 1 July 2017 and 21 May 2018	1.55	Tier 3
Biomethane injection (First 40,000 MWh)	between 22 May and 31 December 2018	5.82	Tier 1

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Biomethane injection (Next 40,000 MWh)	between 22 May and 31 December 2018	3.42	Tier 2
Biomethane injection (Remaining MWh)	between 22 May and 31 December 2018	2.63	Tier 3
Biomethane injection (First 40,000 MWh)	on or after 1 January 2019	4.95	Tier 1
Biomethane injection (Next 40,000 MWh)	on or after 1 January 2019	2.92	Tier 2
Biomethane injection (Remaining MWh)	on or after 1 January 2019	2.25	Tier 3
Small Biogas combustion (Less than 200KWth)	before 1 April 2016	8.73	N/A
Small Biogas combustion (Less than 200KWth)	between 1 April and 30 June 2016	7.56	N/A
Small Biogas combustion (Less than 200KWth)	between 1 July and 30 September 2016	6.42	N/A
Small Biogas combustion (Less than 200KWth)	between 1 October and 31 December 2016	4.83	N/A
Small Biogas combustion (Less than 200KWth)	between 1 January and 31 March 2017	3.61	N/A
Small Biogas combustion (Less than 200KWth)	between 1 April and 30 June 2017	3.43	N/A
Small Biogas combustion (Less than 200KWth)	between 1 July 2017 and 21 May 2018	3.09	N/A
Small Biogas combustion (Less than 200KWth)	on or after 22 May 2018	4.83	N/A
Medium biogas combustion (above 200 kWth and & less than 600 kWth)	before 1 April 2016	6.86	N/A
Medium biogas combustion (above 200 kWth and & less than 600 kWth)	between 1 April and 30 June 2016	5.95	N/A

Eligible Technology	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Tier
Medium biogas combustion (above 200 kWth and & less than 600 kWth)	between 1 July and 30 September 2016	5.03	N/A
Medium biogas combustion (above 200 kWth and & less than 600 kWth)	between 1 October and 31 December 2016	3.79	N/A
Medium biogas combustion (above 200 kWth and & less than 600 kWth)	between 1 January and 31 March 2017	2.84	N/A
Medium biogas combustion (above 200 kWth and & less than 600 kWth)	between 1 April and 30 June 2017	2.69	N/A
Medium biogas combustion (above 200 kWth and & less than 600 kWth)	between 1 July 2017 and 21 May 2018	2.42	N/A
Medium biogas combustion (above 200 kWth and & less than 600 kWth)	on or after 22 May 2018	3.79	N/A
Large biogas combustion (600 kWth and above)	before 1 April 2016	2.59	N/A
Large biogas combustion (600 kWth and above)	between 1 April and 30 June 2016	2.21	N/A
Large biogas combustion (600 kWth and above)	between 1 July and 30 September 2016	1.88	N/A
Large biogas combustion (600 kWth and above)	between 1 October and 31 December 2016	1.42	N/A
Large biogas combustion (600 kWth and above)	between 1 January and 31 March 2017	1.07	N/A
Large biogas combustion (600 kWth and above)	between 1 April and 30 June 2017	1.02	N/A
Large biogas combustion (600 kWth and above)	between 1 July 2017 and 21 May 2018	0.93	N/A
Large biogas combustion (600 kWth and above)	between 22 May and 31 December 2018	1.42	N/A
Large biogas combustion (600 kWth and above)	on or after 1 January 2019	1.21	N/A

Source: Ofgem

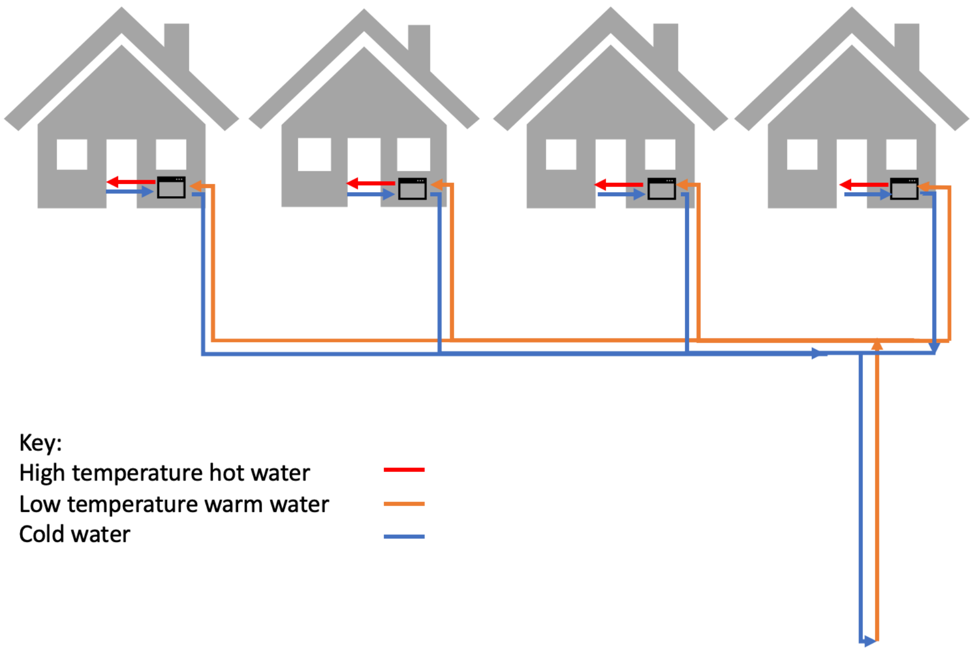
Appendix D: Shared Ground Loop Systems

Shared ground loop systems involve a shared ground loop[47] serving multiple heat pumps in different properties, as shown in Figure 2. The system delivers low-grade (i.e. low temperature) warm water to each property via a network of pipes, returning cooled water to the heat source. An individual heat pump in each property upgrades this heat to high temperature water that can be used to meet each property's heat needs.

In contrast, communal heat pumps use a single, large heat pump to deliver high-grade heat to multiple dwellings or properties, as shown in Figure 3. In these systems, a single, large heat pump generates high-temperature water and a network of pipes delivers this directly to each property. Again, cooled water is returned to the heat source. In communal systems, individual properties do not have their own heat pump. These systems were not classed as shared ground loops for RHI purposes and were referred to as 'communal heat pumps' for the purposes of the evaluation research.

Some SGL and communal heat pump systems might be classed as heat networks.

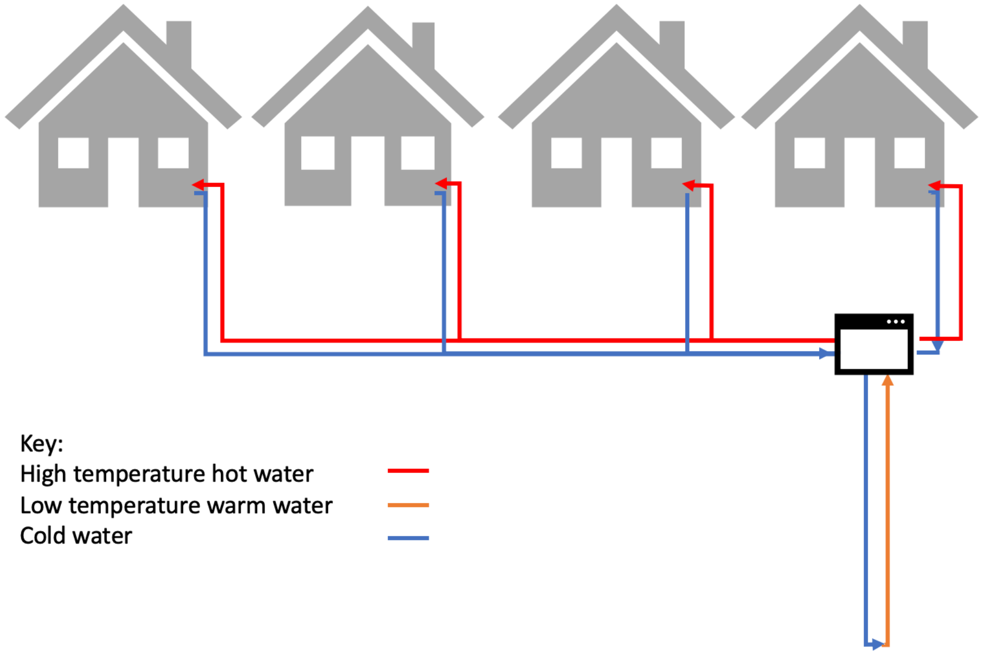
Figure 2: Shared ground loop illustration



Source: CAG Consultants

[47] A series of pipes buried underground allowing a heat pump to use the earth as a heat source. Shared loop systems could also involve underwater pipes, using a water source as a heat source.

Figure 3: Communal GSHP illustration



Source: CAG Consultants

Appendix E: Data Tables

Where figures are provided in the main report but the table from which they originated does not feature, the corresponding table can be found below.

Data Tables from Non-domestic Applicant Survey

Table 49: [SINCE 2017] Did you access information on installing renewable heat systems from any of the following sources? (Please select any that apply)

	First submission date (calendar year)								
	pre-2015 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	Total (%)
Internal experts within the organisation	6.6	20.5	19.8	22.1	16.1	26.9	32.9	58.2	21.8
National government including BEIS (e.g. guidance published on a government website)	-	14.9	20.1	17.9	8.4	13.9	14.6	6.7	16.1
Ofgem	25.4	32.5	32.7	35.0	26.4	14.0	15.4	17.6	31.4
Energy Saving Trust	10.7	23.2	19.2	22.4	24.7	11.7	14.0	10.1	21.2
Renewable heating industry or professional	90.9	78.6	75.1	74.2	66.5	77.0	65.8	60.7	75.6
General heating industry or professional	22.6	17.4	23.1	24.1	16.8	9.5	14.4	1.2	19.5
Industry partners or competitors	28.0	23.2	25.2	23.2	15.6	19.8	8.4	7.5	22.5
Environmental / Renewables consultant	18.4	27.4	28.8	32.1	20.0	23.3	13.2	5.6	27.3
Energy consultant	29.2	21.1	24.7	22.3	8.6	10.0	13.6	16.7	21.1

None of the above	9.1	0.8	4.0	0.5	4.7	2.4	-	1.1	1.7
Don't know	-	2.4	5.3	6.6	1.3	2.4	5.4	1.2	4.0
Other	-	6.4	9.1	14.5	4.7	12.3	13.3	16.1	9.2
Unweighted bases	n = 10	n = 418	n = 202	n = 191	n = 68	n = 62	n = 62	n = 54	n = 1,067

*Base: All respondents excluding refusals / not answered

Table 50: [SINCE 2011] Were any of the following problems encountered before installing the RHT? (Please select any that apply)

	First submission date (calendar year)								
	pre-2015 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	Total (%)
Getting suitable advice	17.8	21.2	18.0	10.0	13.9	20.2	14.6	[12.7]	17.6
Finding a suitable installer	19.2	27.0	14.5	11.2	18.6	20.2	26.7	[30.9]	19.8
Finding a building designer	7.3	1.8	3.3	3.3	1.6	4.2	3.7	[1.2]	5.1
None	72.2	61.2	71.1	79.9	64.3	64.4	53.7	[67.9]	70.0
Don't know	0.6	4.1	4.4	4.5	7.5	3.9	12.0	[1.2]	2.4
Unweighted bases	n = 873	n = 396	n = 181	n = 167	n = 64	n = 56	n = 53	n = 48	n = 1,838

* Base: All respondents excluding refusals / not answered

Table 51: [SINCE 2011] Were any of the following problems encountered with the installation of the RHT? (Please select any that apply), cross tabulated by application submission date

	pre-2015 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	Total (%)
Getting the equipment commissioned	17.2	16.2	13.0	13.0	19.2	19.1	11.5	[3.6]	16.1
Unexpected costs	31.3	24.6	27.9	16.8	16.6	34.9	16.0	[4.7]	27.3
Delays in installation process	34.7	23.9	24.2	22.3	21.6	29.1	22.0	[7.9]	29.4
Specific problems with the installer (this might include mistakes made by the installer)	13.5	29.7	24.9	16.4	24.0	23.7	29.1	[10.4]	19.0
Had no problems with the	45.7	45.7	49.6	57.8	59.0	47.6	46.8	[58.4]	47.7

installation process									
Don’t know	0.7	4.3	5.9	2.7	7.4	3.5	5.4	[24.5]	2.7
Unweighted bases	n = 995	n = 376	n = 184	n = 177	n = 64	n = 61	n = 60	n = 49	n = 1,966

* Base: All respondents excluding refusals / not answered

Table 52: [SINCE 2011] Attribution categories

	First submission date (calendar year)								
	pre-2015 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	Total (%)
Would not have got any heating system in the absence of RHI	37.5	25.3	22.2	23.3	17.1	15.4	18.2	10.1	30.6
Would have got an RHT but different	9.4	12.4	10.4	22.9	14.1	6.2	14.0	7.1	11.6
Would have installed a non-RHT	24.7	39.3	43.1	29.7	36.6	44.5	42.0	60.2	31.3
Would have chosen the same installation in the absence of RHI	22.1	15.4	16.7	12.7	15.7	17.3	14.3	15.9	18.8
Don't know	6.2	7.6	7.6	11.5	16.5	16.7	11.5	6.6	7.6
Unweighted bases	n = 991	n = 426	n = 204	n = 193	n = 73	n = 66	n = 67	n = 55	n = 2,075

* Base: All respondents excluding refusals / not answered

Table 53: [SINCE 2011] Which of the following were factors in your decision to install a renewable heating technology in particular? (Please select any that apply)

	First submission date (calendar year)								
	pre-2015 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	Total (%)
Technology of new system was better suited to heat requirements	73.7	61.0	74.3	75.8	64.0	56.7	38.1	29.6	69.3
Financial case for new system	91.2	73.4	77.6	70.0	61.9	36.4	49.1	58.8	79.9
CSR or environmental reason	44.3	59.6	66.4	61.5	45.2	41.2	60.2	87.9	53.7
Regulatory requirements	8.7	2.8	5.5	10.8	-	4.9	-	1.1	6.6
Don't know	0.3	-	0.4	-	3.1	-	-	-	0.2
Other (please specify)	4.0	3.6	2.0	1.9	4.9	6.7	5.6	2.3	3.5
Unweighted bases	n = 503	n = 396	n = 187	n = 185	n = 65	n = 59	n = 62	n = 52	n = 1,509

* Base: All respondents excluding refusals / not answered

Table 54: [SINCE 2017] Which of the following were triggers for you in considering installing a new heating technology at all? (Please select any that apply)

	First submission date (calendar year)								
	pre-2015 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	Total (%)
The building is new and heating was needed	***	25.0	34.9	45.5	27.6	21.8	22.3	31.8	31.7
Concerns about performance of previous system	***	35.4	26.1	23.8	13.2	10.0	15.9	26.0	28.4
Existing system nearing end of life	***	39.4	39.3	26.4	24.1	38.1	11.3	18.0	34.5
Technology of the new system was better suited to heating requirements	***	47.9	56.7	59.1	20.6	28.9	29.1	26.8	49.2
Financial case for new system	***	59.6	62.3	64.6	25.8	30.7	19.8	18.6	56.6
Investment or revenue opportunity	***	36.0	43.4	37.8	36.3	33.8	33.5	29.8	37.8
Corporate Social Responsibility or environmental reason	***	48.1	55.0	50.9	21.3	6.7	9.2	2.7	45.6

Concern about security of energy supplies	***	18.7	23.4	35.9	25.1	37.7	46.5	56.9	26.0
Regulatory requirements	***	3.8	10.6	7.6	2.1	13.7	6.1	8.9	6.6
It was not my / our decision	***	0.6	1.4	1.5	3.0	3.4	1.7	-	1.2
Other reasons (please specify)	***	6.2	7.6	4.5	6.9	6.1	0.8	-	6.0
An approach / offer from a renewable heating salesperson or installer	***	0.1	-	-	5.6	-	-	-	0.3
There was an existing building where there was no previous heat technology in which heating was now needed	***	0.2	0.2	1.7	11.0	16.6	6.4	3.9	1.8
Unweighted bases	n = 11	n = 425	n = 203	n = 193	n = 73	n = 66	n = 66	n = 55	n = 1,092

*Base: All respondents excluding refusals / not answered

*** responses redacted owing to small sample size

Table 55: [SINCE 2011] What problems - if any - did you encounter when completing the RHI application for the Renewable Heat Technology? (please select any that apply)

	First submission date (calendar year)								
	pre-2015 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	Total (%)
I have not encountered any problems	56.4	38.2	38.5	33.9	7.9	17.4	22.4	44.0	46.2
Technical problems with the application form	22.8	24.2	21.6	17.8	34.1	28.5	29.9	19.7	22.8
Difficulty supplying or identifying the requested information	30.2	32.3	31.7	31.7	63.7	66.3	50.8	27.1	32.5
The application took too long to complete	29.1	25.6	37.5	50.8	50.2	45.2	37.6	12.7	32.1
Don’t know	0.8	12.2	9.1	4.5	7.7	5.6	7.5	14.4	4.9
Other (please specify)	4.0	5.7	5.0	7.1	10.9	16.8	23.1	22.9	5.6
Unweighted bases	n = 905	n = 398	n = 193	n = 178	n = 68	n = 66	n = 65	n = 54	n = 1,927

*Base: All respondents excluding refusals / not answered

Table 56: [SINCE 2011] Have you encountered any of the following problems with providing regular meter readings to Ofgem? (Please select any that apply)

	First submission date (calendar year)								
	pre-2015 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	Total (%)
I have not encountered any problems	87.2	62.3	62.1	66.9	48.6	50.8	42.0	24.0	72.6
A small window available for taking readings	4.4	17.2	17.0	4.9	22.3	10.4	12.3	-	9.6
A small window available for submitting readings	4.5	13.1	16.3	4.2	14.1	11.4	7.4	-	8.3
The resource required to read the meter on time	2.3	6.6	7.3	3.7	5.2	6.5	5.0	-	4.3
The capability required to read the meter on time	2.8	3.7	4.3	5.4	8.2	3.6	1.8	-	3.6
A fault with the meter	2.9	7.9	12.5	3.5	3.3	-	3.9	-	5.3
Don’t know / too early to tell	2.3	2.0	4.7	18.6	16.5	18.3	25.5	73.1	6.5

Other (please specify)	0.8	14.8	11.6	5.6	11.0	15.7	31.2	2.9	7.0
Unweighted bases	n = 714	n = 402	n = 199	n = 184	n = 67	n = 63	n = 66	n = 55	n = 1,750

*Base: All respondents excluding refusals / not answered

Data tables from Subsidy Cost-Effectiveness Assessment

Table 57: Cumulative heat generation and carbon abatement to end October 2021

	Pre-reform installations	Post-reform installations	All installations	Proportion 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 of the main report.

Table 58: Mean additionality (i.e. estimated proportion of applicants who would not have installed renewable heat technologies in the absence of non-domestic RHI).

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

Table 59: 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.

Table 60: 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 (£)	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 61: 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 (£)	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
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.

Appendix F: Theoretical Framework

Overview of the theoretical framework

This evaluation was theory led, involving the development and refinement of theory at four different layers of detail.

Note that whilst this evaluation was informed by realist evaluation approaches, layers one and two were not realist because they presented an overview or 'average' of the overall impact of the scheme and were used to guide other evaluation workstreams which took a more traditional, non-realist, approach, to assessing impact, as well as the overall synthesis process. Layers three and four, on the other hand, took a directly realist approach and considered in more detail 'what works for whom, in what circumstances and why'. These were used to frame the qualitative strands of research in particular, and also formed a key element of the synthesis process.

Layer 1

The top layer of theory – set out in Table 63 – is a high-level 'if, then, because' statement summarising the aims of the RHI reforms, to inform the evaluation as a whole.

Table 62: Layer one of the theoretical framework for the evaluation of the reformed RHI

If … the Government subsidises renewable heat generation through to 2041, via applications to the non-domestic RHI scheme up to 2021, and introduces demand-side reforms (e.g. tariff guarantees, changes to biomass support) … **then** … this will encourage people and organisations to invest in renewable heating systems… **because** … people and organisations will be motivated by the financial incentives and reduced investment risk.

Layer 2

At the start of this evaluation, a high-level 'policy map' was developed, setting out how the reformed RHI was intended to influence demand and supply of renewable heat technologies, as well as their usage and the supply of feedstocks and fuels.

Layer 3

This high-level policy map was underpinned by a level of 'generic theories' for the non-domestic RHI's four main areas of influence. These theories, set out in realist terms as 'Context-Mechanism-Outcome' (CMO) hypotheses, provided granularity on the links between the different elements of the overall policy map, explaining the nature of influence expected from the reformed RHI in different contexts. The initial and final versions of the 'layer 3' theory are set out later in this appendix.

This involved realist theory,[48] set out as 'context-mechanism-outcome' configurations, covering the four areas of influence:

- demand theory – who and what aspects of RHT demand were influenced by the non-domestic RHI, in what contexts and why?
- supply theory – who and what aspects of RHT supply were influenced by the non-domestic RHI, in what contexts and why?
- usage theory – who and what aspects of RHT usage were influenced by the non-domestic RHI, in what contexts and why?
- fuel/feedstock theory – for RHTs that use fuel or feedstocks, who and what aspects of fuel and feedstock supply were influenced by the non-domestic RHI, in what contexts and why?

A definition of what is meant by Contexts, Mechanisms and Outcomes is given in Table 1 of Appendix A.

Layer 4

In addition, the evaluation developed reform-specific CMOs for each wave of qualitative fieldwork conducted during the evaluation. These described the contexts in which particular actors were expected to change their reasoning as a result of particular reforms, resulting in particular outcomes (e.g. investment decisions in renewable heating technologies). In addition to providing evidence to understand the impact of the reformed RHI scheme, this approach also provided a granular level of detail to support assessment of key reforms. These detailed levels of theory were used to refine the 'layer 3' theory and inform assessment of 'layer 2' theory, as presented further below.

Theory testing and synthesis process

Findings from qualitative research were used to test and refine the detailed theory for specific clusters, as part of the research process for each cluster.

Findings from all workstreams, including the detailed cluster theory and qualitative research findings, together with application data analysis, applicant survey findings, SMA, SCEA and CTA findings, were systematically mapped against key elements of the evaluation framework on a periodic basis. This 'wider mapping' process was undertaken roughly once per year, involving structured mapping of evidence in spreadsheet form against the following:

- the overall evaluation questions
- key policy questions of interest to BEIS (closely linked to the 'clusters' for qualitative research)

[48] Pawson and Tilley (1997), Pawson (2006)

- the ‘layer 3’ CMOs in the ‘generic’ demand, supply, usage and fuel/feedstock theory

The wider mapping was used to inform periodic reviews and refinement of the generic mid-level theory and assessments of the high-level theory. The final assessment of these two levels of theory for the non-domestic RHI are presented in the diagrams and tables that follow this section.

In addition to the wider mapping process, a fuller synthesis process, involving workshops with workstream leads and BEIS evaluation officers, was undertaken at key points in the evaluation. These synthesis processes focused primarily on responding to the evaluation questions and key policy questions:

- an early synthesis of evidence on the effects of reform announcements, and delays to reforms, on interim applicants in both the domestic and non-domestic RHI schemes (2018)
- a synthesis of findings on the influence of reforms to the non-domestic RHI affecting biomethane investments, drawing on evidence from multiple workstreams (2019)
- this synthesis of findings on the non-domestic RHI as a whole, focusing specifically on the impact of reforms (2022)

The overall findings from this synthesis process is presented in this final synthesis report on the non-domestic RHI scheme.

The attachments below present:

- an overall assessment of the non-domestic RHI’s contribution to the high-level theory
- initial and final versions of the generic mid-level theory, describing the contexts and mechanisms by which the non-domestic RHI has contributed to different outcomes in relation to the demand, supply and usage of RHTs, and the supply of fuel and feedstocks for these RHTs

Attachment 1: Overall assessment of the ND RHI's contribution to high-level theory

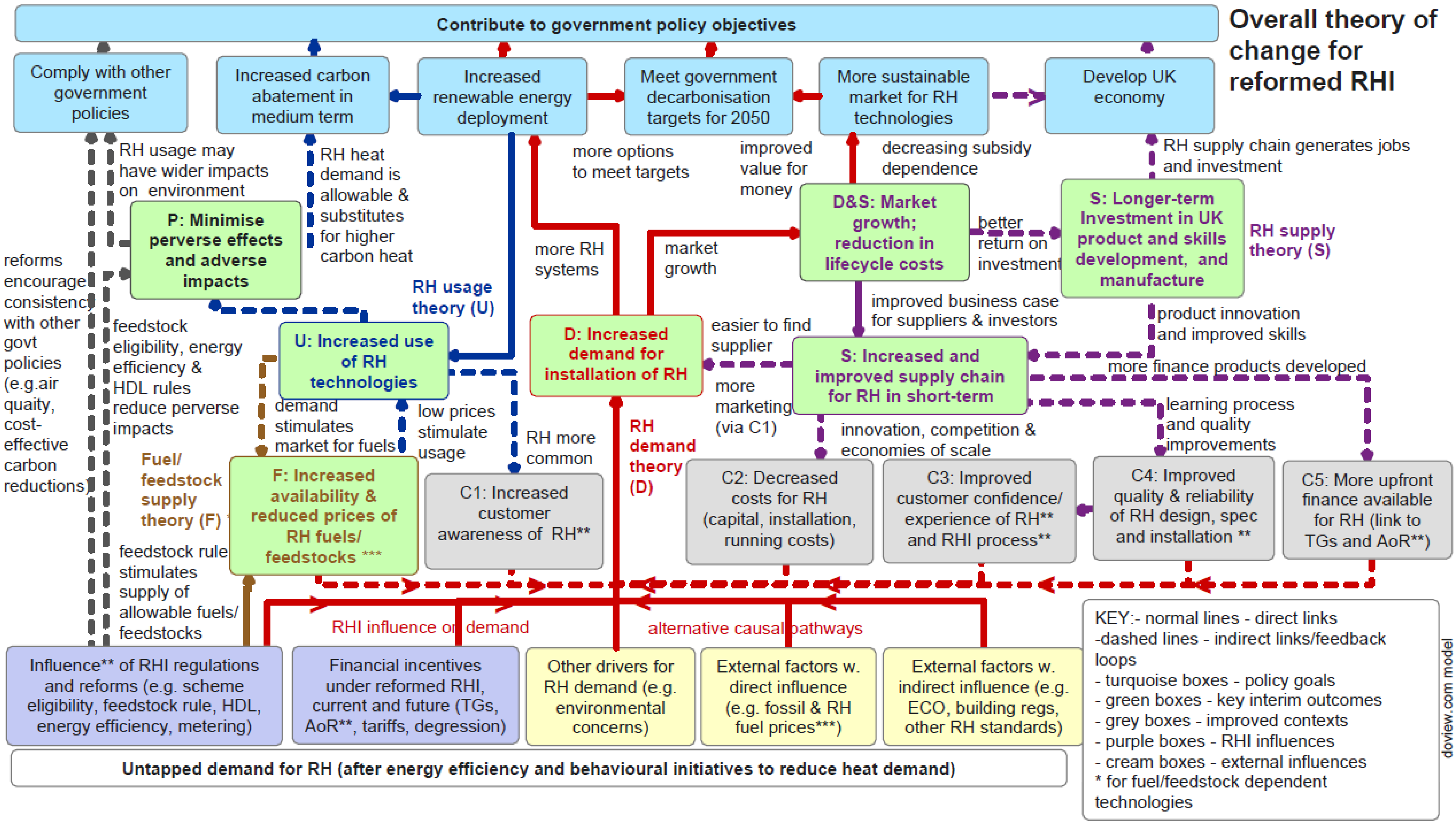
This attachment presents the overall 'policy map' (or high-level theory of change) for the non-domestic reformed RHI, which was developed in the early stages of the evaluation.

It then presents an overall assessment of the main elements of this theory, at high-level, based on evidence collected by the evaluation up to the end of 2021.

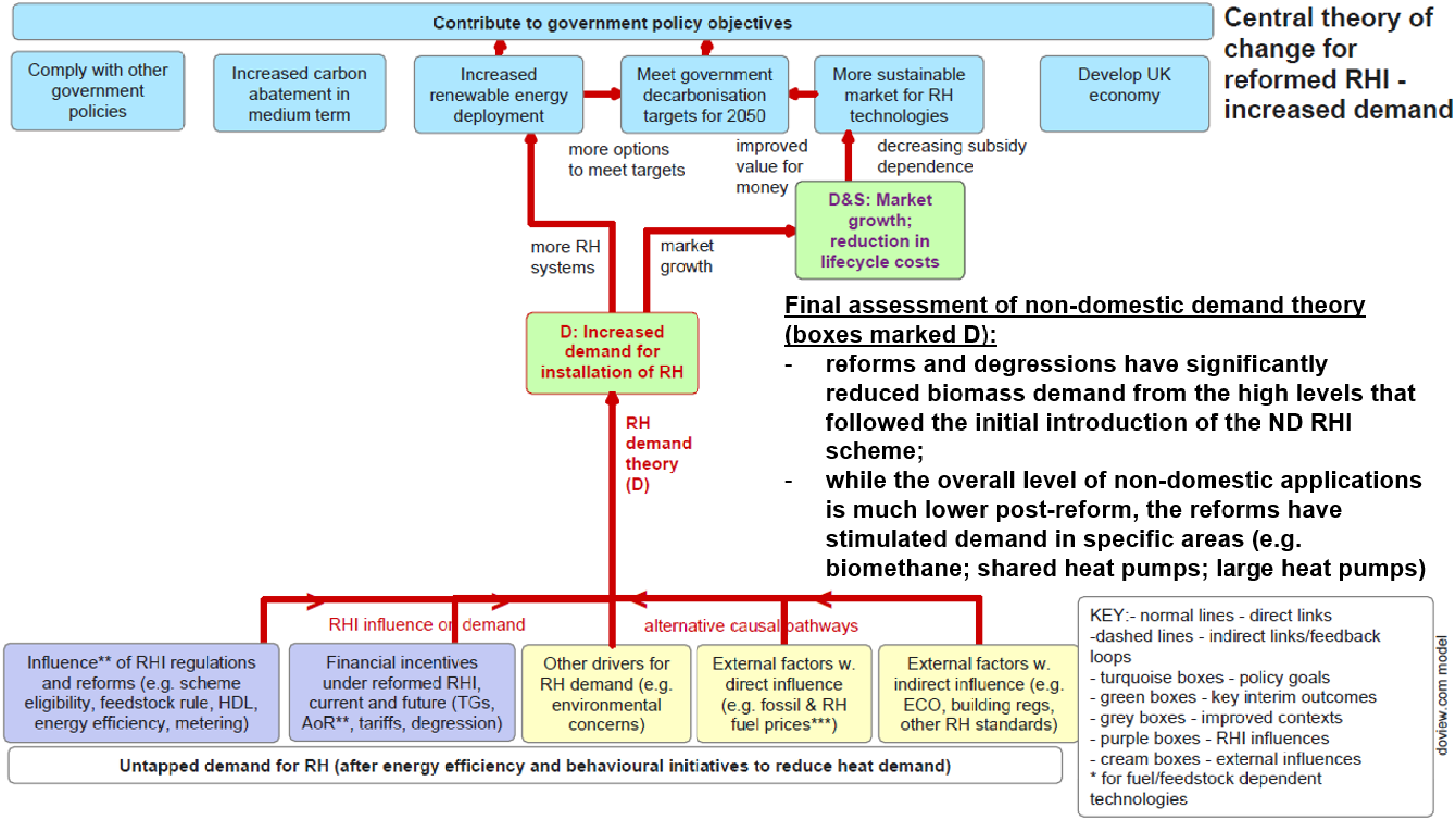
Notes on interpretation of the high-level theory diagram:

- the diagram is inevitably simplified and generalised, since it attempts to encompass all RHI technologies and all scales. It originally covered both the domestic and non-domestic RHI. The diagram aims to achieve a balance between being comprehensive and being comprehensible
- the logic starts at the bottom of the diagram and works upwards to the top, with various feedback loops en route
- RHI and other inputs are shown at the bottom of the diagram while policy goals and desired outcomes are shown at the top
- key interim outcomes are shown in green boxes, while grey boxes show ways in which the context for renewable heat (RH) demand is improved
- more detailed theory has been developed for four sub-systems, as presented in Attachment 2. These sub-systems are highlighted using coloured arrows/text:
    - RH demand theory (D) - central theory - highlighted in red
    - RH usage (U) - highlighted in blue
    - RH supply (S) - highlighted in purple
    - RH fuel/feedstock supply (F) - highlighted in brown
- some influences of the reforms are shown by asterisks (**) rather than arrows, to avoid further complicating the diagram. Further linkages are highlighted in the detailed CMOs
- potential perverse effects and wider impacts (P) are indicated by grey arrows

A brief 'walk through' of the Theory of Change is presented after the diagrams.



Central theory of change for reformed RHI - increased demand

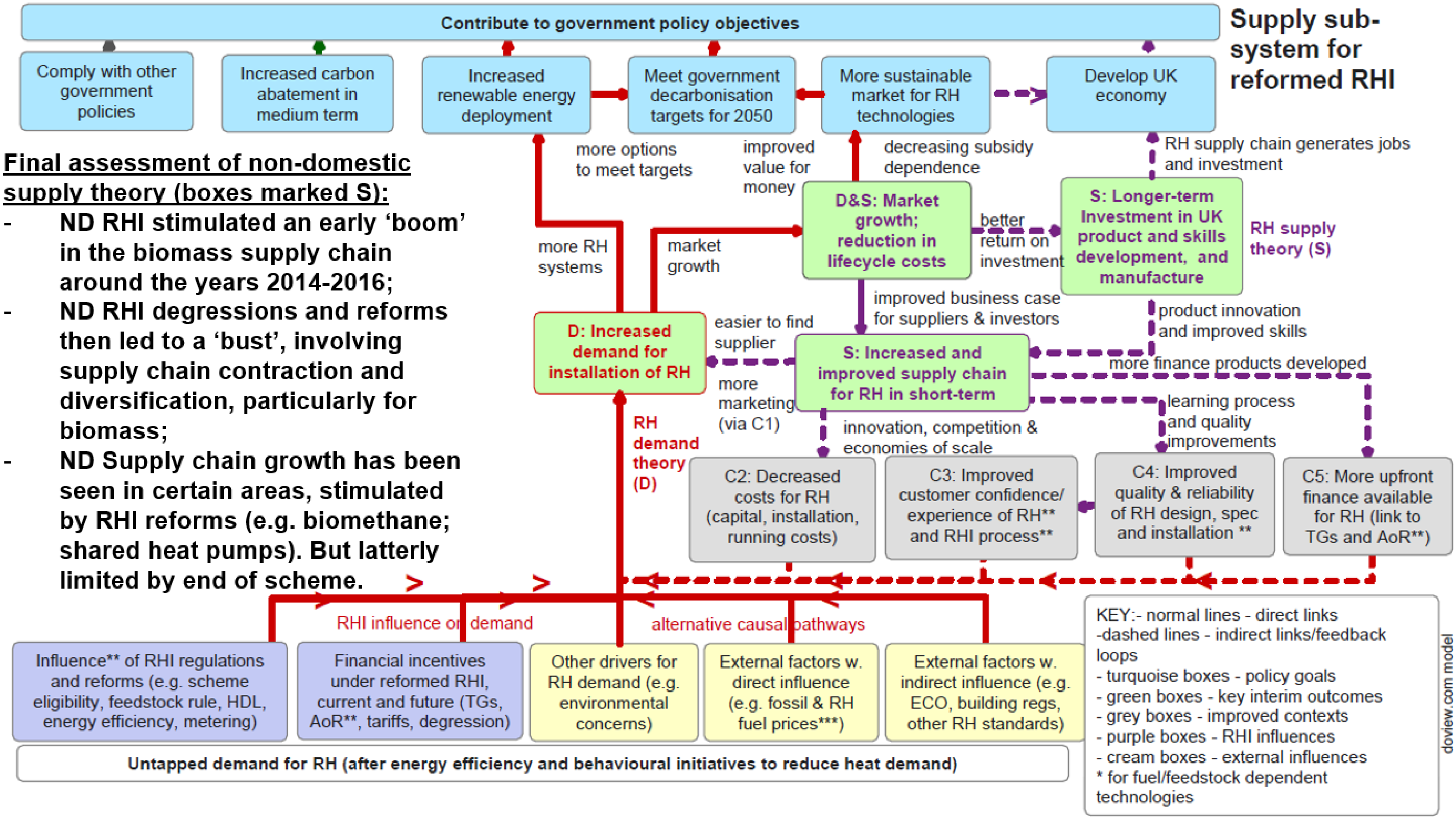


<u>Final assessment of non-domestic demand theory (boxes marked D):</u>

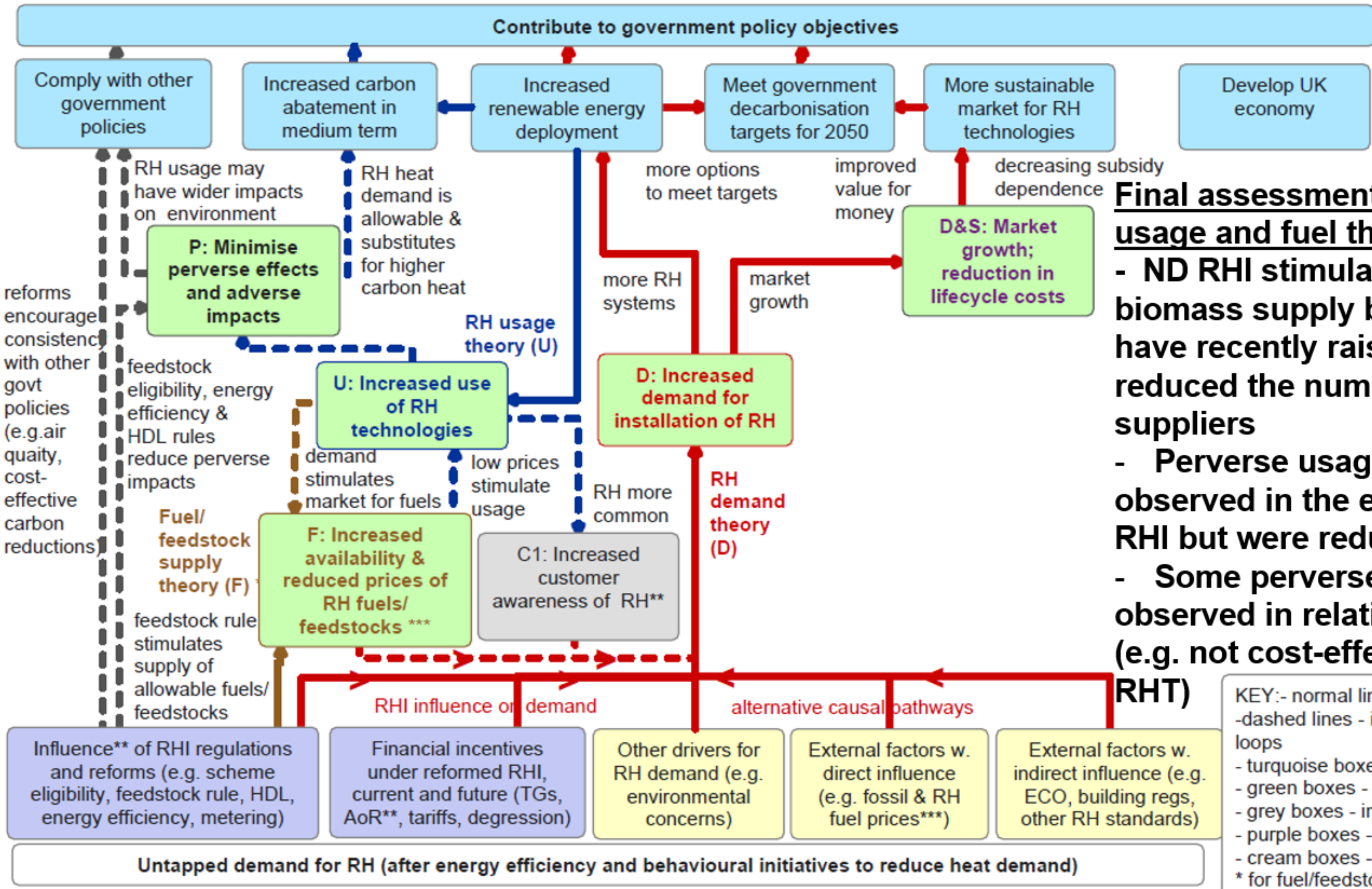
- **reforms and degressions have significantly reduced biomass demand from the high levels that followed the initial introduction of the ND RHI scheme;**
- **while the overall level of non-domestic applications is much lower post-reform, the reforms have stimulated demand in specific areas (e.g. biomethane; shared heat pumps; large heat pumps)**

Final assessment of non-domestic supply theory (boxes marked S):

- ND RHI stimulated an early 'boom' in the biomass supply chain around the years 2014-2016;
- ND RHI degressions and reforms then led to a 'bust', involving supply chain contraction and diversification, particularly for biomass;
- ND Supply chain growth has been seen in certain areas, stimulated by RHI reforms (e.g. biomethane; shared heat pumps). But latterly limited by end of scheme.



Fuel supply and wider impacts theory for reformed RHI



Final assessment of non-domestic usage and fuel theory:

- ND RHI stimulated early growth in biomass supply but external factors have recently raised prices and reduced the number of wood fuel suppliers
- Perverse usage effects were observed in the early non-domestic RHI but were reduced by the reforms
- Some perverse usage effects observed in relation to tier 2 tariffs (e.g. not cost-effective to operate RHT)

KEY:- normal lines - direct links
-dashed lines - indirect links/feedback loops
- turquoise boxes - policy goals
- green boxes - key interim outcomes
- grey boxes - improved contexts
- purple boxes - RHI influences
- cream boxes - external influences
* for fuel/feedstock dependent technologies

doview.com model

Brief description of Theory of Change, to accompany the diagrams

The rationale for the reformed RHI was that there was untapped demand for RH, after energy efficiency and behavioural initiatives to reduce heat demand.

The Theory of Change identified a range of central government policy goals for the reformed RHI:

- compliance with other government policies
- increase renewable energy deployment
- meet government decarbonisation targets for 2050
- more sustainable market for renewable heat (RH) technologies
- increase carbon abatement in the medium term
- comply with other government policies
- develop the UK economy

The ways in which the reformed RHI sought to influence demand for RH were:

- financial incentives under the reformed RHI (reformed to include tariff guarantees, Assignment of Rights, tariffs as well as degression mechanisms)
- the influence of other aspects of RHI regulations and reforms (e.g. adjustments to scheme eligibility, 50% waste feedstock rules, Heat Demand Limits, energy efficiency and metering)

Non-RHI influences that might explain observed changes in RH demand were identified in the Theory of Change as being:

- other drivers for RH demand (e.g. environmental concerns)
- external factors with direct influence on RH demand (e.g. fossil and RH fuel prices)
- external factors with indirect influence on RH demand (e.g. the Energy Company Obligation, building regulations, other RH standards outside the RHI)

The overall Theory of Change is described below in three parts: ‘Demand theory’ relating to installation of RH systems, which is central to the Theory of Change; ‘Supply theory’, which relates to the RH supply chain and how supply chain changes feedback to influence demand for RH; and ‘RH usage/fuel theory’ which relates to usage of RH systems. These three inter-linked parts of the Theory of Change are all influenced by the reformed RHI and all contribute to the overall policy objectives, as described below.

Central 'Demand theory' for the reformed non-domestic RHI

Both RHI and non-RHI causal factors were expected to lead to increased demand for installation of RH equipment, leading to more RH systems being installed. This was expected to contribute to the policy objectives of increasing renewable energy deployment, and give the government more options to meet decarbonisation targets for 2050.

Increased demand for installation of RH equipment was also expected to lead to growth in the RH market, contributing to a reduction in lifecycle costs. This was expected to decrease subsidy dependence, leading to a more sustainable market for Renewable heat technologies and improved value for money, also contributing to meeting government decarbonisation targets for 2050.

The evaluation team's final high-level assessment of this overall demand theory for the reformed non-domestic RHI was that:

- reforms and degressions significantly reduced biomass demand from the high levels that followed the initial introduction of the non-domestic RHI scheme
- while the overall level of non-domestic applications was much lower post-reform, the reforms stimulated demand in specific areas (e.g. biomethane; shared heat pumps; large heat pumps)

Theory for the 'supply sub-system' of the reformed non-domestic RHI

The Theory of Change hypothesised that stimulus to RH demand would also stimulate the supply chain for RH, contributing to wider UK economic objectives. Specifically, growth in the RH market was expected to lead to a reduction in lifecycle costs for RH. This was expected to provide a better return on investment for RH, leading to longer term investment in product development, skill development and manufacture within the UK. Through this, the RH supply chain was expected to generate more jobs and investment, contributing to development of the UK economy.

The stimulus to the RH supply chain was also expected to increase and improve the supply chain for RH in the short-term, both by improving the business case for suppliers and investors, and (in the longer term) by encouraging product innovation and improved skills. The increased and improved RH supply chain was then expected to feedback into contexts for RH demand in a number of positive ways, including:

- making it easier for RH customers to find a supplier for RH systems
- decreasing costs for RH (including capital, installation and running costs)
- improving customer confidence in and experience of RH and RHI processes
- improving the quality and reliability of RH equipment design, specification and installation
- making upfront finance for RH more widely available (linked to Tariff Guarantees)

The evaluation team's final high-level assessment of non-domestic supply theory was that:

- the non-domestic RHI stimulated an early 'boom' in the biomass supply chain around the years 2014-2016
- non-domestic RHI degressions and reforms then led to a 'bust', involving supply chain contraction and diversification, particularly for biomass
- the non-domestic supply chain growth has been seen in certain areas, stimulated by RHI reforms (e.g. biomethane and shared heat pumps). But this has been limited latterly by the upcoming end of the non-domestic scheme

Theory for 'RH usage and fuel supply' for the reformed non-domestic RHI

RH usage: Increased usage of Renewable heat technologies was expected to result from increased deployment of renewable heat installations, stimulated by the reformed non-domestic RHI and other factors. This was itself expected to influence other parts of the RH system in a number of ways through:

- RH installations becoming more common feeding back to demand by contributing to increased customer awareness of RH
- increased usage of Renewable heat technologies was expected to stimulate the supply chain for RH fuels (as described in the 'fuel supply' theory below)
- the influence of RHI reforms (e.g. the 50% waste rule for feedstock, the removal of drying uses from eligible heat uses; the removal of banding from biomass tariffs and changes to tiering for biomass tariffs) were expected to reduce perverse effects and adverse impacts from the RHI

RH Fuel supply: This theory focused on the use of biomass fuels rather than the supply of electricity for heat pumps because the latter was not expected to be influenced by the RHI reforms. Fuel supply for biomass and biogas/biomethane installations was expected to be affected by the reformed non-domestic RHI due to:

- increased use of RH was expected to stimulate the market for fuels, leading to increased availability and reduced prices of RH fuels and feedstocks
- the introduction of the 50% waste rule for feedstocks for new biogas and biomethane plants was expected to stimulate the supply of allowable fuels and feedstocks

As outlined above, cheaper and more readily available biomass fuels and waste feedstocks were expected to stimulate and support usage of already-installed renewable heat technologies as well as contributing positively to demand for new RH installations.

Minimisation of perverse effects and adverse impacts of the non-domestic RHI: several RHI reforms aimed to reduce perverse effects and adverse impacts of the non-domestic RHI, ensuring compliance with other government policies or increasing carbon abatement from RH generation. Specifically, the reforms encouraged consistency with other government policies in terms of air quality and cost-effective carbon reductions. Similarly, the 50% waste feedstock rule and energy efficiency provisions were expected to reduce perverse impacts and improve the cost-effectiveness of RH generation. Together, the reforms were expected to contribute to RH heat demand substituting for higher carbon heat, rather than representing an increase in heat usage. However, there was recognition in the theory that increased RH usage may have wider impacts on the environment and that impacts need to be consistent with other government policies.

The evaluation team's overall high-level final assessment of non-domestic RH usage and fuel theory were that:

- the non-domestic RHI stimulated early growth in biomass fuel supply but external factors then raised prices and reduced the number of wood fuel suppliers in the latter years of the scheme
- perverse usage effects were observed in the early non-domestic RHI but have been reduced by the reforms
- some perverse usage effects were observed in relation to post-reform Tier 2 tariffs (e.g. it was not cost-effective to operate some RHTs at Tier 2 tariff levels)

Detailed theory for demand, supply, fuel and usage are set out in the sections below.

Initial and revised generic CMOs for reformed Non-Domestic RHI

This attachment presents realist ‘Context-Mechanism-Outcome’ (CMOs) configurations for the four broad areas considered in the high-level theory: demand for and supply of Renewable Heat Technologies (RHTs), usage of these technologies and supply of fuel/feedstock (where relevant to RHTs).

For each area of theory, the initial CMOs are presented first, followed by the revised set of CMOs. These CMOs have been revised in the light of the mapping and synthesis of evidence across all the evaluation workstreams, as summarised in the main report.

The CMOs are colour coded in terms of whether the outcomes are desirable, neutral or undesirable in terms of supporting the Government’s overall policy goals (as set out in the pale blue boxes at the top of the overall policy map above).

Desirable	Neutral	Undesirable

The CMOs have also been annotated to reflect the extent to which each CMO has been observed for the reformed non-domestic RHI:

- limited evidence for a few technologies
- considerable evidence for a few technologies
- widespread evidence across multiple technologies

Those CMOs in the initial theory for which there was no evaluation evidence have been omitted from the revised theory. The CMOs have not been renumbered so, where a CMO has been omitted from the revised theory, the numbering is not sequential.

Table 63. Initial demand theory

Name	Desirability	Contexts	Mechanism	Outcome
D1 - 'Increase in genuine demand for RH which is additional (i.e. largely attributable to reformed RHI) '	Desirable	Some or all of: • Rural and off-gas grid location • Trigger point for RH system (e.g. expanding, refurbishing, new build) • Access to trusted, informed RH adviser and installer • RH marketing by potential installers • Recommendations from other users • RH technology sounds usable for this/these buildings (e.g. for heat pumps - well insulated property and/or underfloor heating; for biomass – availability of storage space and access to biomass; for biogas/biomethane - access to waste feedstock)	RHI subsidy makes it worthwhile for me/us to invest in this RH system now, which is well-specified for my/our heating needs	Decide to proceed with a well-specified RH system that would not otherwise have gone ahead (or not to this timescale) (positive feedback to supply system contexts via market growth – D&S on overall policy map)

Name	Desirability	Contexts	Mechanism	Outcome
		• RH impacts acceptable to neighbours • Attractive balance between costs/ benefits/risks/hassle, given relative capital costs of RH and other heating options, predicted tariffs and (where relevant) RH & fossil fuel prices • Access to own capital (or finance) • Willingness to invest		
D2 - 'Increased genuine demand for RH which is non-additional (i.e. would probably have gone ahead without reformed RHI)'	Neutral	As above, plus a strong commitment to some or all of: • Environmental concerns • Energy security concerns • Suitability of building for a particular RH technology • Meeting planning requirements	I/we invested in a well-specified RH system primarily for one or more of these other reasons, and RHI subsidy is a bonus	Decide to proceed with a well-specified RH system that would probably have gone ahead now anyway, without RHI (feedback to supply system contexts, but not attributable to reformed RHI)

Name	Desirability	Contexts	Mechanism	Outcome
		• Desire to make use of readily available biomass or waste feedstock		
D3 - 'Increased genuine demand for RH which is partly additional (i.e. some RHI influence on decision to proceed)'	Desirable	• Mix of the contexts above (e.g. fairly strong commitment to environment) • Clear preference for one RH system	I/we invested in a well-specified RH system or a mixture of reasons, but the subsidy helped me/us to go ahead	Decide to proceed with a well-specified RH system now that is partly attributable to RHI scheme (positive feedback to supply system contexts via market growth – D&S on overall policy map)
D4 - 'Increased genuine demand for RH which is non-additional, but RHI influence technology choice, scale or investment timing'	Desirable	As above, plus one or more of: • More than one RH technology looks feasible • Flexibility in terms of scale/timing • Upcoming change in RH rules	I/we would have invested in RH anyway but the details of RHI subsidy and rules influenced our choice of technology, scale or timing	Decide to proceed with a particular technology, at a particular scale or at a particular time because of RHI incentives and/or change in rules (possibly feedback to supply system contexts (S);

Name	Desirability	Contexts	Mechanism	Outcome
				possible link to gaming or mis-selling mechanisms below)
D5 - 'No increase in genuine demand for RH - don't proceed with renewable heating system at this time'	Undesirable	AT LEAST ONE of the contexts fails: • On gas grid and/or urban location OR • Adviser or installer not trusted, not well-informed about RH or not readily available OR • RHI scheme/Government not trusted OR • Reservations about RH technology OR • Unattractive balance between costs, benefits, risks, hassle, given RH capital costs and predicted future RH/fossil fuel prices OR	Despite potential RHI subsidy, I'm not willing to invest in RH system now	Proceed with a non RH system or no new heating system at this time (no feedback to supply system contexts)

Name	Desirability	Contexts	Mechanism	Outcome
		• Problems accessing capital/finance OR • Unwilling to invest OR • Not enough time for RH choice (e.g. emergency boiler replacement) OR • Biomass/feedstocks not readily available OR • Property not well insulated OR • No space for biomass storage OR • Concerns about impact on neighbours		
D6 - 'Invent/overstate heat demand to get RHI'	Undesirable	Well-informed customer or adviser, with ill intent	Invest in RH primarily to obtain RHI, using inflated heat demand	Proceed with RH but carbon savings reduced or nil (negative feedback to RH usage (U) and perverse effects (P) on carbon abatement

Name	Desirability	Contexts	Mechanism	Outcome
				and cost effectiveness
D7 - ‘Mis-sold RHI’	Undesirable	Poorly informed customer, with contexts that are not particularly favourable for RH, receives active marketing of RH finance deals from finance or RH providers	I am going ahead with RH because my adviser says that I should but I don’t fully understand it myself	Proceed with an RH system that is inappropriate for their property (negative feedback to contexts in usage theory (U))

Table 64. Revised demand theory (with feedbacks to supply sub-system (S), demand sub-system (D) and usage theory (U))

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
D1.'Increase in genuine demand[49] for RH which is additional (i.e. largely attributable to reformed RHI)'	Desirable	Widespread evidence across multiple technologies and multiple evidence sources (observed for Air Source Heat pumps (ASHP), Ground Source Heat Pumps (GSHP), Water Source Heat Pumps (WSHP), biomass and biomass Combined Heat and Power (CHP), biogas and biomethane technologies)	• Rural and off-gas grid location OR on-gas grid locations (where associated with strong environmental concerns OR high heat loads) • Trigger point for RH system (e.g. expanding, refurbishing, new build, need to replace heating system) • Access to trusted, informed RH adviser and installer • RH marketing by potential installers OR recommendations from other users	RHI subsidy makes it worthwhile for me/us to invest in this RH system now, which is well-specified for my/our heating needs	Potential applicant decides to proceed with a well-specified RH system that would not otherwise have gone ahead (or not to this timescale) (positive feedback to supply system contexts via market growth – D&S on overall policy map)[50]

[49] Genuine demand means demand that does not involve perverse effects (e.g. creating unnecessary heat demand in order to claim RHI).
[50] The feedback comment highlights linkages between demand outcomes and improved contexts for other parts of the renewable heat system (e.g. supply, fuel, usage and so on). These linkages are shown as feedback arrows within the overall policy map above.

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Other contexts favourable for at least one RHT (e.g. for heat pumps - well insulated property(ies) and/or underfloor heating; for biomass – availability of storage space, self-supply or confidence in fuel supply; heat use suitable for dry heat; for biogas/biomethane – high electricity/heat demand onsite and/or access to electricity or gas grid connection to export electricity/heat) • RH impacts acceptable to neighbours/planning authority • Attractive balance between costs/benefits/risks/		

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			hassle, given relative capital costs of RH and other heating options, predicted tariffs and (where relevant) RH & fossil fuel prices - perceived benefits include greater self-sufficiency, environmental/carbon considerations • RHI subsidy forms a key part of an applicant's financial considerations as to whether to install RHT AND/OR RHI triggered consideration of RHT • Access to internal capital (or external finance) • Willingness to invest		

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
D2a. 'Rebound effect: increased demand for RH enabled by RHI-subsidised heat'	Neutral	Limited evidence for a few technologies (observed in qualitative research, for some biomass, ASHP, GSHP cases)	As in D1, plus: • Low-cost heat generated by RHT enables investment in a new business plant or opportunity This CMO primarily covers investments enabled by non-domestic RHI. (Any domestic rebound effect is covered under usage of RH systems rather than under demand for RH systems.)	RHI subsidy makes it worthwhile for me/us to invest in this new business opportunity, premised on low-cost heat from this RH system	Potential applicant decides to proceed with a well-specified RH system that involves additional heat demand, where RHT is not substituting for fossil fuel use (positive feedback to supply system contexts via market growth – D&S on overall policy map)
D2b.'Increased genuine demand for RH which is eligible for RHI but non-additional (i.e. would probably have gone ahead	Neutral	Considerable evidence for a few technologies, across multiple evidence sources (primarily biomass, ASHP, GSHP, WSHP, biogas technologies)	As in D1, plus at least one of: • Strong commitment to environmental concerns (e.g. via supply chain drivers; public sector investor	I/we invested in a well-specified RH system primarily for one or more of these other reasons, and RHI subsidy is a bonus	Potential applicant decides to proceed with a well-specified RH system that would probably have gone ahead now

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
without reformed RHI)'			with strong local policy drivers) • Energy security concerns • Suitability of building for a particular RHT • Installation required to meeting planning requirements • Desire to make use of readily available biomass OR access to large water source suitable for WSHP • High onsite heat load • Potential to benefit from electricity as well as heat generation (e.g. onsite electrical loads and/or access to export connection to electrical grid)		anyway, without RHI (feedback to supply system contexts, but not attributable to reformed RHI – D&S on overall policy map)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Rising gas prices (for on-gas applicants) OR no access to mains gas • Low finance costs (e.g. agricultural applicants able to offer land as security for loans; public sector investor with access to low-cost finance and low requirements for internal rate of return) • Process advantages from use of biomass heat (e.g. dry heat suitable for poultry-rearing)		
D3.'Increased genuine demand for RH which is partly additional (i.e. some RHI influence on	Desirable	Limited evidence for a few technologies (observed in qualitative research, for some ASHP,	Mix of the contexts above (e.g. fairly strong commitment to environment) • Clear preference for one RH system	I/we invested in a well-specified RH system or a mixture of reasons, but the subsidy helped me/us to go ahead but it's difficult to say what would	Potential applicant decides to proceed with a well-specified RH system now that is partly attributable to

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
decision to proceed)'		GSHP and WSHP cases)	• Other external drivers for RH investment (e.g. building regulations, standards for rented properties, safety concerns about use of gas) • Off-grid social housing with ageing electric storage heating, where heat pumps offer greater efficiency and economy for tenants (extensive evidence) • Social housing flatted properties with electric storage heating, unsuitable for gas heating, where shared ground loops offer greater efficiency and economy for tenants (emerging evidence)	have happened in the absence of RHI	RHI scheme (positive feedback to supply system contexts via market growth – D&S on overall policy map)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
D4. 'Increased genuine demand for RH which may or may not be additional, but RHI influences technology choice, scale or investment timing' (not mutually exclusive from other CMOs)	Desirable	Widespread evidence across multiple technologies (multiple examples from qualitative research on biomass, CHP, biomethane, ASHP, GSHP and WSHP)	As above, plus one or more of: • More than one RHT looks feasible • Flexibility in terms of scale/timing • Upcoming change in RH rules, upcoming tariff guarantee requirements, or upcoming end of non-domestic RHI • Experience of changes to previous renewables schemes (such as tariff reductions in the Feed-in-Tariff scheme)[51]	I/we would have invested in RH anyway but the details of RHI subsidy and rules influenced our choice of technology, scale or timing (for example: TIMING: applicant brought forward investment to access more favourable pre-reform rules, to meet tariff guarantee or end of scheme deadlines or to reduce the risk of being affected by tariff degression; SCALE: projected RHI improved the rate of return for investors and hence enabled a larger project;	Potential applicant decides to proceed with a particular technology, at a particular scale or at a particular time because of RHI incentives and/or change in rules (possibly feedback to supply system contexts; possible link to gaming or mis-selling mechanisms below- see overall policy map)

[51] Hence a sense of urgency to lock in RHI benefits while available

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
				TECHNOLOGY: applicants chose between RH technology options and chose the one that offered the best business case for them, given respective levels of RHI support at the time.)	
D5 - 'No increase in genuine demand for RH - don't proceed with renewable heating system at this time'	Undesirable	Widespread evidence across multiple technologies and multiple evidence sources (observed for Air Source Heat pumps (ASHP), Ground Source Heat Pumps (GSHP), Water Source Heat Pumps (WSHP), biomass and biomass (CHP), biogas and biomethane technologies)	AT LEAST ONE of the contexts is present: • On-gas grid OR • Adviser or installer not trusted, not well-informed about RH or not readily available OR • RHI scheme/Government not trusted OR • Planning barriers to RHT installation OR	Despite potential RHI subsidy, I'm not willing to invest in RH system now because I perceive this RH project to be (depending on which context applies) insufficiently reliable, OR not feasible, OR too risky, OR to have too low a rate of return OR to involve too much upfront spending (OR to	Potential applicant proceeds with a non-RH system or no new heating system at this time (no feedback to supply system contexts in overall policy map)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Expensive upgrades required to electricity supply infrastructure to support RHT • Reservations about performance of RHT OR • Concerns about running costs of RHT OR • Unattractive balance between costs, benefits, risks, hassle, given RH capital costs and predicted future RH/fossil fuel prices OR • Unwillingness or inability to access capital/finance (or high cost of finance) OR • Unwilling to invest OR	require costly external finance) relative to my other options	

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Biomass/feedstocks not readily available or highly priced OR • No space for biomass storage OR • Competing opportunities offering more profitable business investments OR • Supply chain constraints for RHT or supporting works		
D6 - 'Invent/overstate heat demand to get RHI'	Undesirable	Limited evidence for a few technologies – but reduced by reforms (primarily reported for biomass)	Well-informed customer or adviser, with ill intent	I am investing in RH primarily to obtain RHI, using inflated heat demand (e.g. installing an oversized boiler to maximise tier 1 payments)	Potential applicant proceeds with RH but carbon savings reduced (negative feedback to RH usage and perverse effects on carbon abatement and cost effectiveness in

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
					overall policy map)
D7 - 'Mis-sold RHI'	Undesirable	Limited evidence for a few technologies (primarily reported for biomass)	Poorly informed customer, with contexts that are not particularly favourable for RH, receives active marketing of RH finance deals from finance or RH providers and/or advice from third party RH adviser.	I am going ahead with RH because my adviser says that I should but I don't fully understand it myself	Potential applicant proceeds with an RH system that is inappropriate for their property (negative feedback to contexts in usage theory in overall policy map)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
D10.[52] 'Aware but did not actively consider RHT investigate'	Undesirable	Limited evidence for a few technologies (primarily observed for non-applicants in manufacturing sector who might have considered biomass)	Positive contexts that would suggest RHT might be suitable: • Off gas-grid • Access to capital/finance • Aware of RHT • Possibly – considering investment in new, refurbished or expanded facilities Key negative contexts leading them not to actively consider an RHT: • They did not see RHT options as relevant to their heating decision	We did not actively consider an RHT when deciding to go ahead with our heating system, despite being aware of RHTs, because we thought they were not suitable for us.	Potential applicant proceeds with a non-RHT without actively considering an RHT (no feedback to RHT supply theory in overall policy map)

[52] The numbering of CMOs is not sequential because there was no evidence for some hypothesised CMOs. For example, CMOs D8 and D10 were developed during an earlier round of synthesis, related to awareness of and investigation of RHTs, but have been omitted from the revised theory because there was no evidence to support them for the non-domestic RHI.

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• They did not ask their technical adviser/supplier about RHT options • Technical adviser/supplier did not mention RHTs (possibly lacking RHT skills/knowledge themselves) Other possible negative contexts: • Perceive RHTs as new and untested • Lack of access to information on RHTs • Lack of environmental motivations/supply chain pressures • Possibly - perceive RHTs as unsuitable for their facility		

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Possibly - perceive RHTs as too expensive, even with RHI • Possibly - perceive RHTs as unreliable • Possibly - perceive RHTs as a hassle to run • Possibly - lack of confidence in financial benefits of RHI • Possibly - negative stories about RHTs from peers		
D11. 'Not aware of what RHTs can offer'	Undesirable	Not known - the evaluation did not target research at this group	Positive contexts: • Off-gas grid • Access to capital/finance • Possibly – considering investment in new,	We were not aware of RHTs so went ahead with a non-RHT system	Potential applicants proceed with a non-RHT system without considering RHTs at all (no feedback to

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			refurbished or expanded facilities • Negative contexts: • Not aware of RHTs • Lack of environmental motivations/supply chain pressures • Technical suppliers/advisers did not mention RHTs (possibly lacking RHT skills/knowledge themselves)		RHT supply theory)

Table 65. Initial supply theory

Name	Desirability	Contexts	Mechanism	Outcome
S1 - 'Expand RH supply chain in short to medium-term because of reformed RHI'	Desirable	Some or all of: • Aware of RHI (and reforms) • RH market appears to be profitable for us • RH fits our corporate values • Already have experience/capacity of installing/supplying some RH technologies in some areas • Relevant skills/client base for installation/supply of some RH technologies in some areas • Confident in appeal of these RH technologies to customers • Confident in stability of RHI policy and tariff levels to (say) 2020 • Access to training/skilled labour • Increased demand (D) for RH	With RHI support for the market, including RHI reforms, there's now a good business case for us to invest in new or increased capacity to supply RH in short to medium-term (e.g. training, kit, staff, marketing effort, finance)	Expand short to medium-term capacity for, improve quality of or extend area of RH installation, supply, finance (positive feedback to contexts for demand theory)
S2 – 'Expand RH supply chain	Neutral	• Existing skills and capacity in RH	We're primarily attracted to RH by	Increase in capacity may not

Name	Desirability	Contexts	Mechanism	Outcome
but not because of reformed RHI'		• Strong commitment to renewable heat • Strong CSR values	social values rather than profitability, and already offer extensive RH capacity	be attributable to RHI
S3 - 'Enter RH supply chain because of improvements to RH market, supported by RHI'	Desirable	As above plus: • Previously under confident or unaware of RH technologies and their suitability for customers • Improved demand contexts and increased demand	Improvements to RH technology, awareness, costs and reliability, supported by RHI, make us ready to recommend certain RH technologies to our customers where we would not previously have done so	Heating professionals recommend RH and invest as necessary to support this recommendation (positive feedback to contexts for demand theory)
S4 – 'Enter RH supply chain because of demand from customers'	Desirable	As above plus: • Customers asking about RH technologies (increased demand (D)) • Competitors offer some RH options	We need to offer RH options to our customers to remain competitive in the marketplace	Heating professionals decide to invest in capacity to offer RH to customers (positive feedback to contexts for demand theory)

Name	Desirability	Contexts	Mechanism	Outcome
S5 – 'Improvements in RH technology or supply chain largely attributable to reformed RHI'	Desirable	Mix of the contexts above PLUS Confident in stability of RHI policy and tariff levels to 2020, and longer term growth in RH market beyond 2020	RHI gives us the confidence to make a long-term investment in RH capacity (e.g. product development, research, manufacture, premises)	Decision to expand/improve long-term capacity for RH supply or services that is primarily attributable to RHI scheme (positive feedback to contexts for demand theory)
S6 - 'Supply chain expansion or improvement (short or long term) partly supported by reformed RHI'	Desirable	Mix of the contexts above (e.g. strong commitment to environment and RH already, but business case for RH supply and/or customer pull also important)	I/we are expanding short or long-term RH capacity or offer for a mixture of reasons, but the market influence of the reformed RHI has contributed to this decision	Decision to expand/extend RH supply or services in short or long-term that is partly attributable to RHI scheme (positive feedback to contexts for demand theory)

Name	Desirability	Contexts	Mechanism	Outcome
S7 - ‘No expansion or improvement in supply chain despite reformed RHI’	Undesirable	AT LEAST ONE of the following contexts fails: • Not aware of RH opportunities OR • Don’t see RH as profitable market for us OR • Business faces uncertainties OR • RH doesn’t fit corporate values OR • No relevant experience or skills/client base for certain RH technologies OR • Not confident in appeal of some RH technologies to customers OR • Not confident in stability of RHI policy, tariff levels OR growth in RH market beyond 2020 OR • Can’t source training/labour at acceptable cost OR • Don’t see increase in demand (D)	Despite RHI support and reforms, it’s not worth us investing in (or expanding existing) capacity for installation, supply, finance products or manufacturing capacity for this RH technology in this area at this time	No increase in supply capacity for some RH technologies and in some areas (no positive feedback to contexts for demand theory)
S8 - ‘Shrinkage in RH capacity attributable to reformed RHI’	Undesirable	Previously active in supplying some element of RH market	I/we are withdrawing from the RH market or reducing our capacity, primarily	Decision to reduce/withdraw from RH supply or services that is

Name	Desirability	Contexts	Mechanism	Outcome
		RHI reforms adversely affect their business contexts (e.g. too risky, rules too difficult to meet, too much competition)	because of the RHI reforms	primarily attributable to RHI scheme (negative feedback to contexts for demand theory)

Table 66. Revised supply theory (with feedbacks to contexts (C) for demand theory (D))

Name	Desirability	Level of evidence	Contexts	Mechanism for potential suppliers	Outcome
S1 - 'Expand RH supply chain in short to medium-term because of reformed RHI'	Desirable	Considerable evidence for a few technologies and multiple evidence sources (primarily observed for ASHP, GSHP, biomass and CHP)	Some or all of: • Aware of RHI (and reforms) • RH market appears to be profitable for us • RH fits our corporate values • Already have experience/capacity of installing/supplying some renewable heat technologies in some areas • Relevant skills/client base for installation/supply of some renewable heat technologies in some areas • Confident in appeal of these renewable heat technologies to customers • Confident in stability of RHI policy and tariff levels to (say) 2020 • Access to training/skilled labour • Increased demand (D) for RH	With RHI support for market demand, including RHI reforms, there's now a good business case for us to invest in new or increased capacity to supply RH in short to medium-term (e.g. training, kit, staff, marketing effort, finance)	Potential suppliers expand short to medium-term capacity for, improve quality of or extend area of RH installation, supply, finance (positive feedback to contexts for demand theory in overall policy map)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential suppliers	Outcome
S3[53] - 'Enter RH supply chain because of improvements to RH market, supported by RHI'	Desirable	Limited evidence for a few technologies (primarily observed in biomass market (pre-reform) and heat pump market (post-reform))	As above plus: • Previously under confident or unaware of renewable heat technologies and their suitability for non-domestic customers • Improved demand contexts and increased demand (D) • Capability to offer services within the RH supply chain	Improvements to RHT, awareness, costs and reliability, enabled by long-term RHI support to the market, make us ready to recommend certain renewable heat technologies to non-domestic customers where we would not previously have done so OR has enabled us to develop a niche within the RH supply chain (e.g. consultancy, third-party ownership models)	Heating professionals recommend RH and potential customers invest as necessary to support this recommendation OR new companies enter specific elements of the RH supply chain, offering selected services to potential applicants (positive feedback to contexts for demand theory)

[53] The numbering of CMOs is not sequential because there was no evidence for some of the CMOs in the initial theory. For example S2 and S4 were omitted from the revised theory because there was no evidence to support them.

Name	Desirability	Level of evidence	Contexts	Mechanism for potential suppliers	Outcome
S5a - 'Improvements in RHT or supply chain largely attributable to reformed RHI'	Desirable	Limited evidence for a few technologies (primarily observed in biomass market and GSHP markets)	Mix of the contexts above PLUS • Confident in stability of RHI policy and tariff levels to 2020, and longer term growth in RH market beyond 2020	RHI gives us the confidence to make a long-term investment in RH capacity (e.g. product development or innovation, research, manufacture, premises)	Potential suppliers decide to expand/improve long-term capacity for RH supply or services that is primarily attributable to RHI scheme (positive feedback to contexts for demand theory)
S5b - 'Improvements in RHT or supply chain that were not attributable to reformed RHI'	Desirable	Limited evidence for a few technologies (primarily GSHP,	• Existing skills and capacity in RH • Strong commitment to renewable heat • Reluctance to premise business strategy on RHI support (EITHER because of ideological opposition to subsidies, OR because of long-term view of RHT market)	We have confidence to make a long-term investment in RH capacity (e.g. product development or innovation, research, manufacture,	Potential suppliers decide to expand/improve long-term capacity for RH supply or services that is not attributable to

Name	Desirability	Level of evidence	Contexts	Mechanism for potential suppliers	Outcome
		biogas, biomethane)	• Confidence in RHT markets that are not eligible for, or less dependent on, RHI (e.g. because of changes to other funding or regulations)	premises) because of other factors (e.g. support for heat networks from other sources; changes to building standards) even without RHI support	RHI scheme (positive feedback to contexts for demand theory)

S7- 'No expansion or improvement in supply chain despite reformed RHI'	Undesirable	Widespread evidence across multiple technologies (observed for ASHP, GSHP, WSHP, biomass and CHP, biogas, biomethane)	The following contexts are present: • Aware of end of non-domestic RHI in March 2021 AND • Business faces uncertainties OR • Not confident in successor policies to non-domestic RHI OR not confident in growth in RH market beyond 2021 OR don't see increase in non-domestic demand (D) OR • See more opportunities in domestic RHI market and divert supply resources to domestic supply chain Plus possibly: • Can't source training/labour at acceptable cost OR • Not aware of RH opportunities OR • Don't see RH as profitable market for us OR RH doesn't fit corporate values OR • No relevant experience or skills/client base for certain Renewable heat technologies OR	Despite RHI support and reforms, it's not worth us investing in (or expanding existing) capacity for installation, supply, finance products or manufacturing capacity for this RHT in this area at this time because the business case is not predicted to be sufficiently attractive over a sufficiently long time period	Potential suppliers decide not to increase supply capacity for some renewable heat technologies and in some areas (no feedback to contexts for demand theory)

			• Not confident in appeal of some Renewable heat technologies to customers OR • New technology developments (e.g. for large heat pumps) emerged too late for non-domestic RHI support to have much impact on the supply chain		

Name	Desirability	Level of evidence	Contexts	Mechanism for potential suppliers	Outcome
S8 -'Shrinkage in RH capacity attributable to reformed RHI (or pre-reform degressions)'	Undesirable	Considerable evidence for a few technologies (primarily observed for biomass and biomass CHPH)	The following contexts are present: • Previously active in supplying some element of RH market • RHI reforms and successive degressions and upcoming end of non-domestic RHI adversely affect their business contexts (e.g. too risky, rules too difficult to meet, too much competition) OR adversely affected by the end of non-domestic RHI in March 2021 • Business faces uncertainties OR • Not in a position to meet demand supported by successor policies to non-domestic RHI OR • Not aware of successor policies to non-domestic RHI OR • Other non-RHI factors lead to shrinkage of the non-domestic RH supply chain (e.g. COVID-related factors; closure of Renewable Obligation Certificate scheme)	I/we are withdrawing from the RH market or reducing our capacity, primarily because of the RHI reforms and other changes in the RHI scheme, including the end of the non-domestic scheme	Potential suppliers decide to reduce/withdraw from RH supply or services that appear primarily attributable to RHI scheme (negative feedback to contexts for demand theory)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential suppliers	Outcome
S9 -'Suppliers mitigate impacts of RHI changes by diversifying'	Neutral	Considerable evidence for a few technologies (primarily biomass; plus some evidence of diversification from non-domestic heat pumps into domestic heat pumps)	The following contexts are present: • Business takes a strategic approach to RH market AND • Has capability to diversify into other aspects of RH market (e.g. equipment supply, equipment maintenance or fuel supply, domestic market) OR • Has capability to diversity into non-renewable heat technologies (e.g. gas boilers, renewable electricity, batteries, electric vehicle chargers)	I/we will retain our presence in the RH market but also diversify to protect our business from RHI uncertainties	Existing suppliers decide to diversity into other elements of RH supply chain, increasing services to some parts of the supply chain but decreasing them in other parts to usage and fuel theory, depending on type of diversification observed)

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Table 67: Initial usage theory

Name	Desirability	Contexts	Mechanism	Outcome
U1 - 'Increased usage of RH systems, as expected, attributable to RHI'	Desirable	• Well-specified and installed system • Property is energy efficient • User(s) well-briefed in how to use system • RH substitutes for higher carbon heat • RH fuel available and competitively priced compared to alternatives • RH technology performs well	Our RH system is working well and we are claiming RHI to match actual (or deemed) heat demand	Carbon savings and financial benefits generated by RH are as anticipated, or better than expected, over time Positive feedback to demand contexts and carbon/cost-effectiveness outcomes (wider impacts may be mixed)
U2 - 'Higher than expected usage of RH, owing to genuine need'	Desirable	• Heat demand previously suppressed (e.g. fuel poor OR concern for environment)	We choose to use more heat now because (a) it's renewable OR (b) it's cheaper to use than our old system	Heat demand is higher than anticipated, and carbon savings lower, but for bona fide reasons

Name	Desirability	Contexts	Mechanism	Outcome
				(Positive feedback as above)
U3 - 'Increased usage of RH systems, not attributable to RHI	Neutral	• As above, but RHI not claimed • System may or may not be eligible for RHI	We use our RH system but do not claim RHI, because ineligible OR because not worth the hassle	Carbon savings not attributable to RHI support (Positive feedback as above)
U4 - 'Inappropriate use of RH systems'	Undesirable	• Well-informed customer with EITHER • ill intent OR • need to increase profit from RH system (e.g. not because cost-effective)	Our RH system is working well but we artificially increase our heat demand to get more RHI subsidy (e.g. opening windows)	Actual carbon savings are lower than expected, because of deemed (or actual) heat demand being higher than it would be without RHI (Negative feedback to

Name	Desirability	Contexts	Mechanism	Outcome
				demand contexts, and potentially perverse effects (P) on carbon/cost-effectiveness outcomes (wider impacts may be mixed))
U5 - 'Unexpected usage of RH system, owing to installation or specification problems'	Undesirable	• User(s) poorly briefed on how to use system or • System poorly specified or installed or • Energy efficiency of building is poor or • Technology doesn't fit expectations	Our RH system works but is less efficient or more hassle than expected, so our heating is inadequate or we boost it with other heat source(s), despite RHI incentives	Actual carbon savings and comfort levels are lower than expected, while user costs may be higher (Negative feedback as above)
U6 - 'Problems using RH	Undesirable	• RH fuel becomes expensive or difficult to obtain	We use our RH system less than anticipated, or not at	Actual carbon savings stop or are lower than

Name	Desirability	Contexts	Mechanism	Outcome
system owing to fuel problems'		• Negative contexts relating to fuel (F)	all, and boost it with other heat sources (where available), despite RHI incentives	expected; comfort lower than expected but user costs higher effectiveness) (Negative feedback as above)
U7 -'Usage problems lead to replacement of system'	Undesirable	• RH system fails OR • does not meet user needs OR • too much hassle OR • becomes uneconomic to run or repair (e.g. because RHI payment period ends)	Our RH system is no longer workable or economic to run/repair, so we are replacing it, despite RHI incentives	No further carbon savings relative to alternative. (Negative feedback as above)

Table 68. Revised usage theory[54]

Name	Desirability	Level of evidence	Contexts	Mechanism for accredited RHI applicant	Outcome
U1- 'Increased usage of RH systems, as expected, attributable to RHI'	Desirable	Considerable evidence for a few technologies (primarily biomass and CHP, ASHP, GSHP – does not apply to biomethane which generates gas not heat)	The following contexts apply: • Well-specified and installed system • Property is energy efficient • User(s) well-briefed in how to use system • RH substitutes for higher carbon heat • RH fuel available and competitively priced compared to alternatives • RHT performs well	RHI payments, based on metered heat generation[55], support expected usage of our RH system, at the levels we expected	Carbon savings and financial benefits generated by RH for this accredited applicant are as anticipated, or better than expected, over time (positive feedback to demand contexts and carbon/cost-effectiveness outcomes - wider impacts may be mixed)

[54] Biomethane is not included in this table because the technology generates gas for injection into the gas grid instead of generating heat.
[55] Except for domestic properties on shared ground loops, for which heat demand is deemed.

Name	Desirability	Level of evidence	Contexts	Mechanism for accredited RHI applicant	Outcome
U2- 'Higher than expected usage of RH, owing to new business opportunities premised on RHI or comfort-taking opportunities'	Neutral	Limited evidence for a few technologies (primarily biomass, CHP and ASHP/GSHP)	• Business case for new business opportunity or business expansion was premised on RHI support for renewable heat AND • Heat demand would not exist without RHI support (i.e. usage is not substituting for use of fossil fuels) OR • Non-domestic RHI used by social landlord (or similar body) to support RHT serving multiple domestic properties previously at risk of fuel poverty	We choose to invest in a business or domestic heating opportunity which increases our heat demand because RHI enables us to access low cost renewable heat	Heat demand for this accredited applicant is higher than anticipated, with lower than expected carbon savings (possible negative feedback to carbon/cost-effectiveness outcomes, depending on comfort-taking and/or the nature of new business opportunities)

Name	Desirability	Level of evidence	Contexts	Mechanism for accredited RHI applicant	Outcome
U4- 'Inappropriate use of RH systems'	Undesirable	Considerable evidence for a few technologies – but improved by reforms (primarily biomass)	• Well-informed customer with EITHER • Ill intent OR • Need to increase profit from RH system (e.g. because not cost-effective or because viability is marginal on Tier 2 tariff)	Our RH system is working well but we artificially increase our heat demand to get more RHI subsidy (e.g. unnecessary drying of fuel; unnecessary heating of spaces)	Actual carbon savings for this accredited applicant are lower than expected, because of deemed (or actual) heat demand being higher than it would be without RHI (negative feedback to demand contexts, and potentially perverse effects (P) on carbon/cost-effectiveness outcomes - wider impacts may be mixed)
U5- 'Unexpected usage of RH system, owing to installation or specification problems'	Undesirable	Considerable evidence for a few technologies (primarily biomass, ASHP, GSHP, WSHP)	• User(s) poorly briefed on how to use system OR • System poorly specified or installed OR • Energy efficiency of building is poor OR	Our RH system works but is less efficient or more hassle than expected, so our heating is inadequate or we boost it with other heat source(s), despite RHI incentives.	Actual carbon savings and comfort levels are lower than expected, while user costs may be higher than expected. (negative feedback as above)

Name	Desirability	Level of evidence	Contexts	Mechanism for accredited RHI applicant	Outcome
			• Technology doesn't fit expectations OR • RHT not easy to control OR • Tariff tiering constrains RHT usage (e.g. not cost effective to run on Tier 2 tariff)		
U6- 'Problems using RH system owing to fuel problems'	Undesirable	Limited evidence for a few technologies (primarily biomass)	• RH fuel becomes expensive or difficult to obtain • Negative contexts relating to fuel (F)	We use our RH system less than anticipated, or not at all, and boost it with other heat sources (where available), despite RHI incentives	Actual carbon savings stop or are lower than expected for this accredited applicant; usage lower than expected but user costs higher than expected (negative feedback as above)

Name	Desirability	Level of evidence	Contexts	Mechanism for accredited RHI applicant	Outcome
U7- 'Usage problems lead to replacement of system'	Undesirable	Limited evidence for a few technologies (primarily biomass)	• RH system fails OR • Does not meet user needs OR • is too much hassle OR • becomes uneconomic to run or repair (e.g. because RHI payment period ends)	Our RH system is no longer workable or economic to run/repair, so we are replacing it with a non-renewable system, despite loss of RHI incentives	No further RHI payments or carbon savings relative to alternative heating system for this accredited applicant (negative feedback as above) – unless the system is sold to another user on a secondhand basis, with its associated entitlement to RHI

Table 69. Initial RH fuel and feedstock theory

Name	Desirability	Contexts	Mechanism	Outcome
F1 - 'Increased fuel or feedstock supply, attributable to reformed RHI'	Desirable	Some or all of: • Aware of RHI (and reforms) • Ready access to fuel/feedstock supply • RH market appears to be profitable for us, compared to other potential outlets for these fuels/feedstocks • RH fuels/feedstocks supply fits corporate values • Relevant skills/client base for RH fuel/feedstock supply • Confident in consistency of fuel/feedstock supply source • Confident in customer appeal of these fuels/feedstocks • Confident in stability of RHI policy and tariff levels to 2020, and longer term growth in RH market • Increase in demand for fuel/feedstock based RH (D)	With RHI support for the market, including RHI reforms, there's now a good business case for us to supply increased volumes of RH fuels or feedstock, or supply these fuels/feedstocks at reduced cost	Expand capacity for, improve quality of, reduce cost of or extend area of RH fuel or feedstock supply (positive feedback to contexts for demand, particularly (F), but possible impacts on alternative markets for fuels/feedstock and wider environment (P)

Name	Desirability	Contexts	Mechanism	Outcome
F2 - 'Increased self supply'	Desirable	As above but: • Potential investor in/user of RH system using own supply	With RHI support for the market, including RHI reforms, there's now a good business case for us to use our supply of RH fuels or feedstock in our own RHI system	Expand capacity for, improve quality of, reduce cost of or extend area of RH fuel or feedstock supply for use in own RH system (may contribute to other positive/negative impacts as above via (F) and (P)
F3 - 'Increased supply, not attributable to reformed RHI'	Neutral	• Already strong commitment, skills and capacity for supplying RH fuels/feedstock • Other drivers (e.g. waste policy)	We're expanding RH fuel/feedstock supply because of other policy drivers, not RHI	Increase in supply of certain fuel/feedstocks but not attributable to RHI (no feedback attributable to RHI)
F4 - 'Decreased fuel/ feedstock supply,	Undesirable	• Already strong commitment, skills and capacity for supplying RH fuels/feedstock • Other drivers (e.g. waste policy)	The influences of reformed RHI have adversely changed our market (e.g. through a fall in feedstock prices	Decrease in supply of certain fuel/feedstocks attributable to RHI (negative feedback to contexts for RH demand (F), RH

Name	Desirability	Contexts	Mechanism	Outcome
attributable to RHI’			or increased competition from imports) so we are reducing our supply of certain RH fuels/feedstocks	usage (U) and linkages to other wider impacts (P))
F5 -’No increase in fuel/ feedstock supply, despite RHI’	Undesirable	AT LEAST ONE of the following contexts fails: • Not aware of RH opportunities OR • Don’t see RH market as profitable for fuels/feedstocks compared to alternative uses • RH supply doesn’t fit corporate values OR • Insufficient skills or client base for RH fuel/feedstock supply OR • Not confident in appeal of fuels/feedstocks to customers OR • Not confident in stability of RHI policy, tariff levels OR growth in RH market beyond 2020 • No increase in demand for fuel/feedstock based RH (D)	Despite RHI support and reforms, it’s not worth us supplying increased volumes of fuels or feedstocks, or supplying these at reduced cost	No increase in supply of RH fuels and feedstocks (no positive feedback to contexts for RH demand (F), RH usage (U), and no influence on wider impacts (P))

Table 70. Revised RH fuel and feedstock theory

Name	Desirability	Level of evidence	Contexts	Mechanism for fuel suppliers	Outcome
F1- 'Increased supply of good quality fuel or feedstock, attributable to reformed RHI'	Desirable	Considerable evidence for a few technologies (primarily biomass)	Some or all of: • Aware of RHI (and reforms) • Ready access to fuel/feedstock supply • RH market appears to be profitable for us, compared to other potential outlets for these fuels/feedstocks • RH fuels/feedstocks supply fits corporate values • Relevant skills/client base for RH fuel/feedstock supply • Confident in consistency of fuel/feedstock supply source • Confident in customer appeal of these fuels/feedstocks • Confident in stability of RHI policy and tariff levels to 2021, and longer term growth in RH market • Increase in demand for fuel/feedstock based RH (D)	With RHI support for the market, including RHI reforms, there's now a good business case for us to supply increased volumes of good quality RH fuels or feedstock, or supply these fuels/feedstocks at reduced cost	Potential fuel suppliers expand capacity for, improve quality of, reduce cost of or extend area of RH fuel or feedstock supply (positive feedback to contexts for demand (F), but possible impacts on alternative markets for fuels/feedstock and wider environment (P)

Name	Desirability	Level of evidence	Contexts	Mechanism for fuel suppliers	Outcome
F2 -'Increased self-supply'	Desirable	Considerable evidence for a few technologies (primarily biomass)	As above but: • Potential investor in/user of RH system using own supply	With RHI support for the market, including RHI reforms, there's now a good business case for us to use our supply of RH fuels or feedstock in our own RHI system	Potential fuel suppliers expand capacity for, improve quality of, reduce cost of or extend area of RH fuel or feedstock supply for use in own RH system (may contribute to other positive/negative impacts as above via (F) and (P)
F3- 'Increased good quality supply, not attributable to reformed RHI'	Neutral	Limited evidence for a few technologies (primarily straw)	All of: • Already strong commitment, skills and capacity for supplying RH fuels/feedstock • External factors (e.g. increased demand from biomass power stations)	We're expanding RH fuel/feedstock supply because of other external factors drivers, not RHI	Potential fuel suppliers increase supply of or quality of certain fuel/feedstocks but not attributable to RHI (positive feedback to demand theory

Name	Desirability	Level of evidence	Contexts	Mechanism for fuel suppliers	Outcome
					(F), but not attributable to RHI)
F4-'Decreased supply of good quality fuel/ feedstock, despite to RHI'	Undesirable	Limited evidence for a few technologies (primarily biomass)	All of: • Already strong commitment, skills and capacity for supplying RH fuels/feedstock • Other drivers (e.g. waste policy; quality standards for wood fuel)	External factors have adversely affected our market, despite the influence of the reformed RHI, so we are reducing our supply of or quality of certain RH fuels/feedstocks	Decrease in supply of or quality of certain fuel/feedstocks by existing fuel suppliers despite RHI (negative feedback to contexts for RH demand (F), RH usage (U) and linkages to other wider impacts (P))

Name	Desirability	Level of evidence	Contexts	Mechanism for fuel suppliers	Outcome
F5-'No increase in good quality fuel/ feedstock supply, despite RHI'	Undesirable	Considerable evidence for a few technologies (primarily biomass and biomethane/ biogas)	AT LEAST ONE of the following contexts is present: • Not aware of RH opportunities OR • Don't see RH market as profitable for fuels/feedstocks compared to alternative uses OR • RH supply doesn't fit corporate values OR • Insufficient skills or client base for RH fuel/feedstock supply OR • Not confident in appeal of fuels/feedstocks to customers OR • Not confident in stability of RHI policy, tariff levels or growth in RH market beyond 2020 OR • No increase in demand for fuel/feedstock based RH (D) OR • External factors (e.g. COVID-19 constraints; bark beetle influence on woodchip imports) OR	Despite RHI support and reforms, it's not worth us supplying increased volumes of fuels or feedstocks, improving quality or supplying these at reduced cost	Existing and potential fuel suppliers decide not to increase the supply of, or quality of, RH fuels and feedstocks (no feedback to contexts for RH demand (F) or RH usage (U), and no influence on wider impacts (P))

Name	Desirability	Level of evidence	Contexts	Mechanism for fuel suppliers	Outcome
			• Competition from major users of biomass (e.g. power stations) OR • Competition from use of biomass as feedstocks for biogas and biomethane		

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