Department for
Energy Security
& Net Zero

Evaluation of the reformed Renewable Heat Incentive

Synthesis of findings from the evaluation of the domestic RHI

Technical annex

BEIS/DESNZ Research Paper Series Number 2023/005

July 2023

Acknowledgements

This independent report was produced for BEIS by CAG Consultants, supported by Winning Moves and Wavehill.

We are grateful to all participants who agreed to be interviewed in research for this report.

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Glossary

Accreditation	A system that has submitted an application and 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.
Application effective date	The date from which an applicant can claim RHI payments for the renewable heat generated by their system.
Biomass	Refers to any fuel derived from organic matter generally wood, but also includes straw, grass and organic waste.
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.
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 eligibility of the application 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 most properties under the domestic RHI in which RHI payments were made on the basis of deemed (or estimated) rather than metered usage. The Energy Performance Certificate (EPC) was used to calculate a space and water heating demand, based on the characteristics of the building. That value of heat was then paid for by Ofgem (with various regulations in place, e.g. for maximum demand and minimum energy efficiency levels).
Full application	A completed application submitted to Ofgem with a relevant system already installed.
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 policies 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.
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.
MCS umbrella scheme	This is a contractual arrangement whereby an MCS-certified contractor (either an installer or a manufacturer) appoints a network of subcontractors, each of which undertakes specified work for the MCS contractor without being certified themselves. The scope of work undertaken by the subcontractors varies but typically includes site survey, sales activity,

	installation and sometimes commissioning of RHTs, with design work usually undertaken by the MCS contractor.
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 the Gas and Electricity Markets)	Ofgem is the regulator of the gas and electricity industries in Great Britain. Ofgem Delivery and Schemes (formerly known as E-serve) is Ofgem's delivery arm 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	Heat energy that comes from a natural source.
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). A COP is a measure of efficiency based on the proportion of useful energy given out compared with the amount taken to run the system. Therefore a system with a COP of 2 will produce twice the amount of thermal energy than electrical energy that it takes to run. Because the COP is calculated under laboratory conditions, seasonal adjustments are made to give its average performance across all times of the year to give us the SPF.
Self-build home	A new home commissioned by the potential user of the home, rather than by a third-party developer. The self-builder's input might vary from doing the actual building work to contracting the work to an architect or building company.
Shared ground loop (SGL)	This technology involves a large underground or underwater loop providing low-grade (low temperature) heat to multiple heat pumps in individual properties. Although SGLs often serve domestic properties, applications were made under the non-domestic RHI because this technology serves multiple properties. See Appendix D in the Technical Annex for more detail.
Solar thermal	Panels which convert solar energy to thermal energy.
Tariff band	The different rates paid per kWh of heat produced or biomethane injected depending on the size and type of installation.
Tariff degressions	The means of controlling the budget for the domestic RHI. The tariffs which can be paid to new applicants are lowered as more renewable heating systems are installed.
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 overcompensation, and if so, how and for which types of beneficiaries and contexts?

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

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 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 refinement of theories (sets of CMOs that were developed as part of the theoretical framework – see 'layer 4' in Appendix E for a description of these) ahead of each wave of fieldwork, which were then tested during the fieldwork and refined post-fieldwork. The CMO sets provided us with a framework through which to understand how different types of actors (consumers, installers, etc.) responded to the scheme and to the particular reforms that were the focus of each fieldwork wave (see footnotes in each of the qualitative methodology sections below).

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

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

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

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

	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’.

Interim applicant fieldwork

This research was conducted 2017-18.

Research questions

The following primary research question was agreed:

- How has the elongated period of reform implementation influenced applications to the RHI scheme?

Scope

Given the delay in the implementation of the RHI reforms, published in December 2016, BEIS were interested in exploring how successive RHI reform announcements in 2016 and 2017, and the way they were implemented, had influenced RHI applications for domestic heat pump installations.

A workshop was held with BEIS staff in September 2017 to further clarify the policy questions for this phase of the evaluation and to inform the design of the fieldwork. This confirmed that the focus of research with interim applicants should be:

- domestic heat pump applicants since April 2016, for ground source heat pumps and air source heat pumps
- domestic heat pump installers

It was noted that there were other groups that may have been significantly affected by the reform process (e.g. biomethane/biogas, large projects eligible for tariff guarantees) but it was agreed that these were best researched later in the evaluation, when more applications had come through and when the reforms had been more fully implemented.

Sampling

The sampling approach was directly related to the mechanisms being tested through the research. Data in the RHI applicant database were utilised to inform the design of each element of the sample, as outlined below.

Applicants for domestic heat pumps

For ASHPs, a heat demand limit of 20,000kWh was announced in December 2016 and implemented in September 2017. For GSHP, the limit was set at 30,000kWh. The RHI application data revealed spikes in the level of applications for both ASHPs and GSHPs in March 2017 and September 2017. The September 2017 spike was thought likely to have been driven by the rise in tariff levels and the heat demand limits which were implemented that month, so the March 2017 spike was the one which considered most likely to be associated with the reform announcements. To enable some understanding of the different drivers, the sample therefore included applications from both spikes.

In terms of ASHP applications, the data showed a higher proportion of applications which were significantly above the heat demand limit (25,000kwh+) from March 2016 onwards, and these applications were at their highest level (as a proportion of all ASHP applications) in September 2017

In terms of GSHP applications, the proportion of 35,000kwh+ applications had fluctuated considerably since the announcement of the heat demand limits in December 2016 but there was a very clear spike in these applications in September 2017.

Given these spikes in larger installations the sample focused on those applications which were above the heat demand limits, as these were the ones most likely to have been influenced by the introduction of the limits.

Table 2 provides an overview of the criteria applied in this part of the sample.

Table 2: Sampling criteria for domestic heat pump applications

Sample size	10
Sample frame	RHI application data
Sampling criteria	5 applicants who submitted their applications in March 2017 (based on tariff rate date), to explore whether the uncertainty regarding the reforms contributed to the spike in applications in that month. The above to be selected at random from within the following categories: - 3 ASHP applicants for a system 25,000 kWh+ est. annual generation - 2 GSHP applicant for a system 35,000 kWh+ est. annual generation to explore the impact of the proposed HDL reforms on applications significantly above the proposed HDLs. 5 applicants who submitted their applications between 1st and 19th September 2017 (inclusive) (based on tariff rate date) and who are significantly above the heat demand limits (i.e. 3 ASHP above 25,000 kWh, 2 GSHP above 35,000 kWh), to specifically explore the impact of the confirmed introduction of the heat demand limits on applicants for heat pumps significantly above the HDL.
Filters	Email and tel number present in the database Application status – approved Haven't opted out from further contact via the quant survey or only partially completed the quant survey

It proved challenging to recruit domestic applicants, particularly from the smaller number of GSHP applicants, and this led to the achieved sample being slightly different to the criteria above. The March sample therefore included four ASHP applicants and just one GSHP applicant.

Installers of domestic heat pumps

The installer sample was primarily constructed through asking applicants about their installer. It was felt that this would be useful in developing more of a ‘case study’ approach, allowing comparison of evidence provided by the applicant and installer of the same installation. This was then supplemented through sampling domestic heat pump installers from the MCS register.

The theory included reference to new installers entering the GB market to capitalise on the pre-reform market opportunities. The MCS register includes the date of registration, which allowed the identification of newly-registered installers of domestic heat pumps.

Whilst this generated a sample which included some companies who were newly-registered with the MCS, the research revealed that none of the companies were actually new to the market. They had either previously been registered with the MCS under a different name or had been operating in the market for some time but had only recently registered with the MCS.

We sought to overcome this in the research through asking the more established installers in our sample about the activities of others in the market.

Table 3 provides details of the installers included in the sample.

Table 3: Installer sample

Participant ID (installer)	No. of MCS-registered domestic installations	Source of contact	Install GSHP (Y/N)	Install ASHP (Y/N)	Domestic, Non-domestic or both
INST-HP-1	40	Applicant interview	Yes	Yes	Both
INST-HP-2	18	MCS	Yes	Yes	Both
INST-HP-3	284	MCS	Yes	No	Both
INST-HP-4	12	MCS	No	Yes	Domestic
INST-HP-5	10	Applicant interview	Yes	Yes	Domestic

Recruitment

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

- selection of initial sample to be contacted (as per the process described above)
- recruitment log developed to track communications to and responses from participants
- invitation email sent to applicants and installers 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

- follow-up telephone call after two working days of initial email, using agreed telephone script
- participants could opt-out at any time - no contact after opt-out
- maximum of four attempts at contact (two emails and two telephone calls – where voice messages are left this will count as one contact) with each potential participant - we did not attempt more than one contact per day per participant.
- new sample to be identified and contacted for each opt-out. Process to be followed as above

Data collection

The research involved semi-structured in-depth telephone interviews, conducted between December 2017 and February 2018. Interview length was approximately 45 minutes per interview.

Topic guides were developed for each participant type (domestic heat pump applicants, domestic heat pump installers). The topic guides were focused on the two theories being tested (the demand theory and the interim applicant theory).

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.

In advance of the interview, Interviewers were provided with basic information about the applicant 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
- participant background
- reasoning and contexts behind the following decisions:
    - to install a new heating system
    - to install a heat pump in particular
    - the timing of the installation
- role of the RHI subsidy in influencing the decision to install a heat pump
- role of the RHI reform announcements and their delayed implementation in influencing the nature or timing of the applicant’s application or installation
- installer details

- final reflections
- thank you and close

The main topics covered in the installer interviews were:

- introductions and consents
- business background and customer offer
- the role of the RHI reform announcements in influencing the installer's business activities to install a new heating system
- installer insights into how applicants were affected by the reform announcements and subsequent delays
- views on the future of the market
- final reflections
- thank you and close

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

Analysis

The analysis employed both Computer Assisted Qualitative Data Software Analysis (CAQDAS) and Excel spreadsheets. CAQDAS was used to code interview transcripts[4] and other data sources, including application data and survey evidence. The coded material was then exported to Excel. A framework was created within Excel to further code and analysis the evidence against CMOs against the two theories being tested, as well analysing other important evidence not covered in the theories. We analysed the extent of support for different CMOs in the framework and for potential refined or new CMOs (see Table 1 for an explanation of CMOs)[5]. 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

Key limitations of the research were:

- the research involved a relatively small sample of applicants and installers. The sample was not sufficiently diverse to get an in-depth understanding of the whole of the theory, i.e. the theory was not comprehensively tested, and the research full short of data saturation. For example, for a number of the CMO configurations identified we had findings from only one or two cases. Other mechanisms in the theory were not found in

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

[5] This involved identifying the outcome for each case and creating a tailored 'case-specific' CMO which aimed to capture the causal mechanism for that case and identified important contexts that triggered this. The tailored 'case-specific' CMOs were then reviewed across the sample, and compared to the initial theory, to find patterns and similarities between cases. The revised CMOs primarily comprised generalised versions of causal configurations (C to M and M to O linkages) that were well-evidenced in the 'case-specific CMOs'. However, the revised CMOs also included CMOs that clearly involved different causal mechanisms, even where few cases were observed. The revised theory aimed to identify which contexts were important in triggering specific causal mechanisms, leading to different outcomes.

our sample at all, but we did not have sufficient evidence to discount them. In our findings, therefore, we highlighted where we had less confidence in the theory and where there were gaps in the evidence.

- various challenges were encountered in developing the sample and recruiting interviewees. This led to some distinctions between sampling criteria and the achieved sample. A particular gap in the sample was in relation to installers who entered the British market during the interim period. No reliable sample frame was secured for this group, and this impacted on our ability to explore some aspects of the theory relating to installers.

- finally, some applicants were being interviewed 12 months after their installation had taken place and some of the interview questions were about decisions and actions which had taken place much earlier than the installation. In a small number of cases, this impacted on the applicant's ability to recall some of the details being requested in the interviews. This may also have affected the accuracy of their recall of some details. Similarly, in the installer interviews, some confusion was apparent regarding the timing and nature of the reforms and their relationship to tariff degressions. It should be noted however, that this was not simply an issue of recall but also reflected a lack of understanding on the part of some installers of the reform timelines and the distinctions between the reforms and the degressions.

Heat pump ‘evaluator’ fieldwork

This research was conducted 2018-19.

Research questions

The overall aim of this study was to understand why some consumers – termed heat pump ‘evaluators’ for the purposes of the research[6] - had not installed an RHI-eligible heat pump even when they have actively considered installing one.

In particular, for these consumers, the research sought to explore:

- what were the key (real and perceived) barriers to installing a heat pump for this group of consumers?
- to what extent did the (reformed) RHI act as an incentive, or disincentive, to installing a heat pump for this group?
- what would have enabled or incentivised this group to act differently?

Scope

At the outset of the fieldwork, a workshop was held with BEIS policy staff to discuss and agree the scope of the research. BEIS and the research team recognised that a key purpose of the domestic RHI was to incentivise consumers to install renewable heat technologies. Much of the research on the scheme had at that point focused on the reasons why consumers had gone ahead with renewable heat installations, but far less was understood about the reasons why some households with the potential to install a renewable heat technology did not end up doing so.

BEIS staff and the research team recognised that there was a spectrum of non-applicants that the research could potentially look at, from those not aware of renewable heat technologies at all, through to those who investigated in detail the feasibility of installing a renewable heating technology in their home. BEIS also highlighted that heat pumps were a technology of particular interest to them because of the high numbers of domestic applications for heat pumps and also their potential for supporting the transition to a low carbon economy beyond the RHI.

Sampling

As highlighted above, this research focused on domestic consumers who had reached the ‘alternatives evaluation’ stage of the customer journey for domestic heat pumps.

Specifically, the research focused on domestic consumers who had either:

- installed a new heating system (not eligible for RHI) but had actively considered a heat pump as part of the decision-making process, or
- had showed an active interest in installing a heat pump (e.g. had a quote, site visit or other meaningful interaction with heat pump installer, or had displayed other signs of active interest in heat pumps)

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[6] A heat pump evaluator is a consumer who had actively investigated installing a heat pump but had decided not to go ahead with the installation.

Table 4 sets the sampling criteria used for research.

Table 4: Sampling criteria

Sample size	30
Sampling criteria	Essential for all: Off-gas Preferably - had installed a new heating system (not eligible for RHI) but considered a heat pump as part of the decision-making process; alternatively – had shown active interest in installing a heat pump (e.g. had a quote, site visit or other meaningful interaction with heat pump installer, or had displayed other signs of active consideration of installing a heat pump) but did not proceed to installation. Post-reform consumers, i.e. their installation or their active interest was after 20th September 2017 Able-to-pay consumers (no need to screen for this as new heating system deemed sufficient indication) Potential additional criteria depending on sampling constraints: Those who enquired about RHI/heat pumps via 'formal' routes (e.g. ESAS) and those who did not Mix of ASHP and GSHP

Table 5 sets out the approach to sample frame development. The figures cited are based on our initial inspection of the ESAS data and scoping discussions with trade associations.

Table 5: Sample frame development

Sources of sample frame	Routes explored: Callers to Energy Saving Advice Service (ESAS) Installer databases – those who have enquired about heat pump installations but have not proceeded
Developing the sample frame – callers to ESAS	Initial analysis of ESAS data from 20th Sep 2017 onwards suggests: Reason for call was 'RHI' in 290 cases Of these, 51 match to an RHI application postcode (note this could include neighbours of applicants) 137 of the remaining agreed to recontact Mix of preferences for recontact – email/phone

	Screening of these to be conducted via telephone and online survey to ascertain fit with sampling criteria. Participation in screening survey to be incentivized, e.g. entry into prize draw.
Developing the sample frame – installer databases	Larger heat pump installers to be asked to contact those on their databases who enquired about a heat pump installation but did not proceed (as far as the installer is aware). It will be challenging to engage installers in this way so: Approaches made by trade associations (GSHPA and HPA) to a selection of their members who are most likely to respond favourably Initial conversation with the installers by CAG to explore their willingness to engage and explore views on feasibility of proposed approach Follow-up by Winning Moves team to get the screening survey link sent out Installers asked to contact customers to respond to the online screening survey or to tell the research team their telephone number so that the survey could be conducted via telephone. Prize draw (£250 prize) for all participants in screening survey

After a deeper review of these options, two routes to developing the sample frame were undertaken.

The first was through the Energy Saving Advice Service (ESAS) database. The approach was to filter down the database to enquiries made post 20th September and who had provided consent to be recontacted. As well those who had enquired about the RHI, we also included enquiries about renewable heating. Between 20th September 2017 and 29th June 2018[7], 225 enquiries were identified for the RHI or heat pump related issues and/or the reason for call was coded as Microgeneration, RHI or Domestic RHI tariffs. This equated to 208 unique contacts as some had contacted ESAS more than once. Winning Moves then conducted a screening survey (conducted online and via telephone) with people who met these criteria. There were 18 responses online, and then a further 71 were contacted (and fully screened) via telephone; 99 in total.

In the online set, 9 met the basic criteria to be asked if they were happy to be contacted by CAG. 8 agreed and shared details. In the telephone set, 39 met the basic criteria and were asked if they were happy to be contacted by CAG. 30 agreed and shared an email address and/or telephone number. All those who took part and completed the screening survey were entered into a prize draw to win £250 in high street shopping vouchers.

The second was through installers. Trade associations were approached as a first step to encourage their members to participate. Those trade associations then passed on details of member installers who had indicated that they would be prepared to assist with the recruitment. Each of these installers were then asked to email customers on their databases who had enquired about the installation of a heat pump but had not completed the purchase. They were sent suggested text for the email, including a link to the screening survey. To

[7] The ESAS service closed on the 29th of June 2018.

incentivise installers to assist with the recruitment in this way, all those who agreed to assist were given the opportunity to choose a charity to whom a £50 donation would be made on their behalf.

47 installers were contacted via email and telephone but only two indicated that they would be prepared to send out an email on our behalf. The poor response rate appears to have been caused by a number of factors including perceived GDPR-related constraints, the absence of relevant data and some installers simply being too busy to help.

Recruitment

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

- selection of initial sample to be contacted
- recruitment log developed to track communications to and responses from participants
- invitation email sent to customers 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
- follow-up telephone call after two working days of initial email, using agreed telephone script
- participants could opt-out at any time. No contact after opt-out
- maximum of four attempts at contact (two emails and two telephone calls – where voice messages are left this will count as one contact) with each potential participant. We did not attempt more than one contact per day per participant
- new sample to be identified and contacted for each opt-out. Process to be followed as above
- customers who completed a qualitative interview were sent a £30 shopping voucher

The screening survey with ESAS customers resulted in a sample frame of 38 people who fitted the sampling criteria and had agreed to participate in a qualitative interview. The installer route did not lead to any additional sample being identified because of a lack of responses to the screening survey (as highlighted above).

From the sample frame of 38, 29 subsequently agreed to take part in, and completed, a qualitative research interview for this fieldwork. This was one less than the target sample of 30. Of these:

- 7 had actively investigated installing either a ground source heat pump or an air source heat pump
- 6 had actively investigated installing a ground source heat pump only
- 16 had actively investigated installing an air source heat pump only

Data collection

The research involved undertaking semi-structured in-depth telephone interviews, conducted between December 2018 and January 2019. Interview length was approximately 30-40 minutes per interview.

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.

In advance of the interview, interviewers were provided with basic information about the participant from the screening survey. This enabled the interviewer to have an informed conversation with the applicant and reduce time collecting information the applicant had already provided.

The main topics covered in the applicant interviews were:

- introductions and consents
- participant background
- the heating system evaluation process, including trigger points and reasons for considering heat pumps
- factors influencing the participant's decision not to install a heat pump, including the reasons why they came to this decision
- the role of the RHI in their decision-making process about heating system choices
- final reflections
- thank you and close

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

Analysis

The analysis employed both Computer Assisted Qualitative Data Software Analysis (CAQDAS) and Excel spreadsheets. CAQDAS was used to code interview transcripts[8] and other data sources, including application data and survey evidence. The coded material was then exported to Excel. A framework was created within Excel to further code and analysis the evidence against CMOs against the two theories being tested, as well analysing other important evidence not covered in the theories. We analysed the extent of support for different CMOs in the framework and for potential refined or new CMOs (see Table 1 for an explanation of CMOs)[9]. The coding and analysis was undertaken by two researchers and was quality

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

[9] This involved identifying the outcome for each case and creating a tailored 'case-specific' CMO which aimed to capture the causal mechanism for that case and identified important contexts that triggered this. The tailored 'case-specific' CMOs were then reviewed across the sample, and compared to the initial theory, to find patterns and similarities between cases. The revised CMOs primarily comprised generalised versions of causal configurations (C to M and M to O linkages) that were well-evidenced in the 'case-specific CMOs'. However, the revised CMOs also included CMOs that clearly involved different causal mechanisms, even where few cases were observed. The revised theory aimed to identify which contexts were important in triggering specific causal mechanisms, leading to different outcomes.

checked for consistency by another research team member not directly involved in the coding and analysis process.

Limitations

Key limitations of the research were:

- potential sample bias - as highlighted above, we were unable to identify or recruit any sample via the installer route. All participants were therefore people who had used the ESAS service for advice about renewable heating options and/or the RHI. It is possible therefore that this narrowed the sample of those interviewed to a certain type of non-applicant (i.e. those inclined to phone a Government-supported telephone advice service may have possessed certain characteristics that other types 'heat pump non-applicants did not have). Nonetheless, the sample that was interviewed included a diverse set of participants in terms of demographics, heating evaluation experiences and the contextual factors that informed their decisions. This indicates the sampling approach yielded a sufficiently diverse participation population for the purposes of the research.

- participant recall - some applicants were being interviewed over 12 months after their heating system investigations and decisions had taken place. In a small number of cases, therefore, this impacted on the participants' ability to recall some of the details being requested in the interviews. This may also have affected the accuracy of their recall of some details. For example, there were instances of participants not being able to recall who gave them certain advice, how many installers they spoke to or what online research they had conducted. This limited the amount of detail that some interviewees were able to reveal about heating system evaluation processes.

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.

Note that SGLs were part of the non-domestic RHI, so findings related to SGLs can be found in the non-domestic RHI synthesis report, published separately. However, as this research also included findings in relation to technologies installed under the domestic RHI (domestic GSHPs and ASHPs), we drew on this research for the domestic synthesis RHI report too, hence the inclusion of this methodology section here.

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 6: 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[10] that serves as the heat source for multiple heat pumps in different properties (or different parts of the property). In these	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 of

[10] 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.

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	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[11]
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
- 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

[11] 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.

Table 7 provides more detail on the initial sampling framework.

Table 7: 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 Mixture of applicants: - post-reform (from 22 May 18) - 'interim' (14 Dec 16 – 21 May 18) - pre-reform (before 14 Dec 16)	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
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	Unknown	Purposively selected through	5

Respondent type	Criteria	Population size	Sample source	Target no. of interviews
	Not applied to RHI scheme		BEIS/CAG contacts	
SGL installers	Installers of SGL systems	Unknown	Identified through SGL applicant interviews	5

Source: Non-Domestic RHI Application Database and 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

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 8.

Table 8: 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[12]. 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[13]. 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 carry identifiers, which meant it was not possible to ascertain a quantitative view of the numbers of SGL applications over time

[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.

[13] This involved identifying the outcome for each case and creating a tailored 'case-specific' CMO which aimed to capture the causal mechanism for that case and identified important contexts that triggered this. The tailored 'case-specific' CMOs were then reviewed across the sample, and compared to the initial theory, to find patterns and similarities between cases. The revised CMOs primarily comprised generalised versions of causal configurations (C to M and M to O linkages) that were well-evidenced in the 'case-specific CMOs'. However, the revised CMOs also included CMOs that clearly involved different causal mechanisms, even where few cases were observed. The revised theory aimed to identify which contexts were important in triggering specific causal mechanisms, leading to different outcomes.

- 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 research 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

Domestic heat pump fieldwork

This research was conducted 2020-21.

Research questions

The research was designed to explore two areas of policy interest:

- experiences of purchasing, marketing & selling domestic heat pumps under the RHI scheme
- the impact of the RHI on the heat pump supply chain

It aimed to extend and deepen understanding of the customer journey for heat pumps, and of the market for heat pump installation, to inform policy on future support for heat pumps beyond the end of the domestic RHI scheme. The focus of this research was on the customer journey for owner occupiers rather than tenants or landlords in the private or socially-rented sectors[14].

To address these areas of policy interest, the research focused on three overarching questions and several sub-questions:

1. What were applicants' experiences of engaging with the supply chain when purchasing an RHI-supported heat pump?

- what was the customer journey from deciding to purchase a new heating system to having their heat pump installed? (incl. what advice/marketing received, installer search, why they chose the installer they did, system specification, etc)
- what was the influence of the RHI (and reforms) on their customer journey?
- what worked well and what worked less well when searching for an installer, discussing heating system options and specifying their system?
- how could the process of engaging with the supply chain have been improved during their heating system decision-making process?

2. How does the supply chain market heat pumps to consumers under the RHI?

- what methods (and why) are installers using to reach consumers?
- to what extent, and why, does the supply chain use the RHI (and reforms) to market heat pumps?
- what approach (and why) do installers take to giving advice to consumers?

3. What impact has the RHI (and RHI reforms) had on the heat pump supply chain's business and customer base?

- what influence has the RHI (and its reforms, including HDLs) had on supply chain business models, marketing and installations?

[14] In the 12 months to August 2020, owner occupiers represented 74.4% of applications for domestic RHI for heat pump installations, while social landlords represented 22.3% and private landlords represented 3.3%.

- what roles do MCS and Consumer Codes play in the way they operate? (focusing on relationship between the RHI and MCS)
- to what extent are installers doing many off-RHI installations? If so, why?
- how will the transition from the RHI to new scheme influence their approach to marketing to consumers?

Scope

It was agreed with BEIS that qualitative research with domestic heat pump applicants and heat pump installers should be supplemented by applicant survey research to further understand the experiences of purchasing domestic heat pumps under the RHI scheme.

Applicant survey research

Winning Moves carried out two activities to deepen the evaluation's understanding of domestic heat pump purchasing experiences.

- an exploration of existing survey monitoring data to understand customer experience of installing their heat pump
- a follow-up survey with those that reported in the monitoring survey that they were dissatisfied with ease of finding an installer

Existing survey monitoring data analysis[15]

This included analysis of existing survey data on:

- satisfaction with ease of finding a suitable installer
- difficulties faced in the process of installing the system
- how heat pump applicants found out about the RHI
- sources of information on renewable systems they used
- barriers to fixing any issues that came up since installing the system

Responses to these questions were analysed against date installed (e.g. pre and post reform), technology type installed and geographical location to understand if there were any patterns in experience[16]. The work included exploring Rural Urban Classification codes[17] and whether the property was on- or off-gas grid in addition to standard address fields for understanding any potential influences of geography.

This work drew on survey responses from Wave 28 and Wave 29 (i.e. those installing heat pumps between 1st March 2019 – 31st August 2019 and 1st September 2019 – 29th February

[15] Further detail on the applicant monitoring survey and heat pump satisfaction analysis can be found in the sections below.
[16] Full list of fields survey responses were cross-tabulated against included: On/off the gas grid, Technology type, Year of application, Pre/post reform (cut-off point: September 2017), UK Country, Region, Local authority (for most the sample size is very small), Town, Urban vs Rural, Type of area.
[17] https://www.gov.uk/government/collections/rural-urban-classification

2020 respectively)[18] and drew on 12,844 unweighted survey responses. Where possible statistical significance testing (e.g. chi square tests) was carried out on differences observed.

Follow-up survey

A follow-up survey with those that reported in the monitoring survey that they were dissatisfied with ease of finding an installer was issued to explore, further details on the difficulties they faced, methods used to identify potential installers and why they chose the installer they eventually appointed.

In total, 217 survey invitations were issued to sample reporting they were dissatisfied with the ease of finding a heat pump installer in Waves 28, 29 and 30[19]. In total 142 responded to the survey representing a 65.4% response rate. Of the 142 responding, 120 confirmed they had faced difficulties finding an installer (with 22 subsequently changing their opinion). Responses to the survey were cross-tabulated by available location data (e.g. on and off gird, region and nation)[20] and by technology type.

Sampling

Domestic heat pump applicants

The RHI applicant database was used as the main sampling frame, supplemented by some additional sampling from the applicant survey database to identify applicants who had difficulty finding an installer. The sampling criteria agreed with BEIS were that the domestic applicants should:

- focus on those who applied recently – between January and June 2020 - to help overcome potential recollection issues
- focus on owner occupiers (who are making a decision about their own property)
- include a mix of GSHPs and AHSPs applicants
- include a mix of on-gas and off-gas applicants
- include a geographical spread of customers, across England, Scotland and Wales
- include some customers who had difficulty in finding a suitable installer, as identified through the applicant survey

We analysed the June 2020 version of the application database. To ensure we had a sample of applicants who had installed heat pumps relatively recently, we based our analysis on domestic heat pumps commissioned within the period January 2020 to June 2020. Given that the COVID-19 pandemic impacted severely in the period March to June 2020, this meant that the research might have captured some impacts of the COVID-19 lockdown during 2020.

This gave us a starting sample population of 3,017 domestic RHI applications. Including only accredited applications reduced this sample to 1,927 applications, while limiting the population

[18] Wave 30 was not included in this initial analysis as it had not been completed at the time.
[19] Wave 28: 1st March 2019 – 31st August 2019, Wave 29: 1st September 2019 – 29th February 2020 and Wave 30: 1st March -31st August 2020. These waves were chosen to enhance recall – surveying earlier waves could have resulted in recall issues for applicants that had applied over two years before.
[20] Full list of fields survey responses were cross-tabulated against included: On/off the gas grid, Technology type, Urban/rural area, UK Country (a sample of over 20 was available only for England and Scotland – sample size for Wales were considered too small to explore in isolation/make comparisons with other countries)

to owner occupiers only, the sample size was further reduced to 1,493 (77% of the total accredited applications). Removing biomass and solar thermal applications left a sample of 1,411 applications and a total of 1,400 applicants (allowing for applicants who applied more than once in that period). Of these, 152 were GSHP applications and 1,259 were ASHP applications.

The sampling approach is set out in Table 9 . The large size of the sample population made it possible to successfully sample all of the groups we were hoping to. Within these interviews, we achieved a spread of interviews across the regions above, with more interviews from regions where more installations have taken place.

Table 9: Breakdown of interviews achieved with domestic heat pump applicants

No. of interviews:	GSHP applicants (applicant database)	GSHP applicants (expressed dissatisfaction with ease of finding an installer)[21]	ASHP applicants (applicant database)	ASHP applicants (expressed dissatisfaction with ease of finding an installer)	Total
Off-grid	3	1	15	2	21
On-grid[22]	2	1	9	2	14
Total	5	2	24	4	35

[21] Sampled from respondents to applicant survey (WAVE 30) who expressed dissatisfaction with the ease of finding a suitable installer.
[22] Some of the on-grid applicants were in locations specified in the application database as being 'on-grid' but did not have a gas connection at their property (e.g. because of the cost of getting a connection or because they preferred not to use gas).

Domestic heat pump installers

BEIS agreed that the interviews should focus solely on installers rather than trade associations because the aim of the research was to gather an in-depth understanding about how RHI had impacted on individual businesses. The sampling frame did not target manufacturers, but a few of the MCS-registered installers were found to be both manufacturers and installers of heat pumps. In sampling installers from the MCS database, the aim was to interview installers with a range of:

- organisation sizes (using the number of installations in the MCS database as a proxy for this)
- geographies
- type of heat pump installed (e.g. ASHP, GSHP or mix of both)

MCS provided a list of all MCS-accredited installers that had installed a heat pump (air source or ground source) in the previous 12 months (as of August 2020). The data available on these installers included contact data, MCS registration dates and the number of ASHP/GSHP installations in the previous 12 months. These figures show that the average number of heat pumps installed per installer in the 12 months to August 2020 was around 18.5. More than half (64%) of active MCS installers installed ASHP only over this period, while a further 33% installed both ASHP and GSHP during this period. Only 3% of active MCS installers installed GSHP only, and they installed a lower number of GSHP each during the 12-month period,

The breakdown of the final sample was drawn from MCS-certified installers that had installed heat pumps in the twelve months to August 2022. The aim was to interview between nine and eleven installers that had installed ASHP only during this period and eight installers that installed both GSHP and ASHP. But in practice, the sample of ASHP-only installers was smaller than anticipated, for reasons discussed in the recruitment section below. The sample of ‘large’, ‘medium’ and ‘small’ installers were marginally lower than planned but this was addressed by interviewing more installers in the ‘micro’ category.

Table 10: Final breakdown of interviews achieved with installers

No. of interviews:	Original sampling proposal	GSHP only installers	ASHP only installers	GSHP & ASHP installers	Final sample total
Proposed sampling total	20	1-3	9-11	8	20
Large installers	3	0	1	1	2
Medium installers	5	1	1	2	4
Small installers	6	1	1	3	5

Micro installers	6	1	2	5	8
Actual final total	n/a	3	5	11	19

In sampling installers, we aimed for a range of geographic locations across the devolved administrations and the different regions of England. In practice, we were able to recruit installer interviewees from almost every region (with the exception of the West Midlands).

Recruitment

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

- selection of initial sample to be contacted
- recruitment log developed to track communications to and responses from participants
- tailored invitation emails sent to applicants and installers in the sample
- the emails 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
- follow-up telephone call at least two working days after initial email, using agreed telephone script
- participants could opt-out at any time - no contact after opt-out
- maximum of four attempts at contact (two emails and two telephone calls – where voice messages are left this will count as one contact) with each potential participant - we did not attempt more than one contact per day per participant
- new sample to be identified and contacted for each opt-out. Process to be followed as above

No incentives were offered to potential respondents.

For the applicant sample, the large size of the population meant that we were able to meet all the sampling objectives agreed with BEIS. A total of 84 applicants were contacted, resulting in 35 interviews.

Table 11: Ratio of contacts to applicant interviews

Sub-sample of applicants	Number of applicants contacted	Number of applicants interviewed
On-grid GSHP	7	2

Off-grid GSHP	10	3
GSHP – dissatisfied with finding installer	7	2
On-Grid ASHP	22	9
Off-Grid ASHP	28	15
ASHP – dissatisfied with finding installer	10	4
Total	84	35

For the installer sample, recruitment was more challenging because the research was being undertaken at a time when the GHG-V was launching. Most installers, particularly those who installed ASHPs, were receiving high levels of enquiries from potential customers. We achieved 19 rather than 20 interviews with a slightly different balance between types of installer than originally planned. There was lower representation of ASHP-only heat pump installers than proposed, possibly because ASHP-only installers were receiving the highest level of enquiries relating to the GHG-V during the recruitment period and were least likely to respond positively to the recruitment process. However, the final sample provided some coverage of all the sub-categories that we aimed to cover, with a wide geographical spread.

Table 12: Ratio of contacts to installer interviews

No. of interviews:	Number of installers contacted	Number of installers interviewed
Installers who had installed ASHP only in 12 months to August 2020	29	5
Installers who had installed GSHP only in 12 months to August 2020	9	3
Installers who had installed both ASHP and GSHP in 12 months to August 2020	20	11
Total across all installer types	54	19

Data collection

The research involved undertaking semi-structured in-depth telephone interviews, conducted during September and October 2020. As noted above, this period coincided with the anticipated launch of the GHG-V scheme and then the final launch of the scheme on 30 September 2020. The COVID-19 pandemic affected the findings of the research, because of constraints faced by both applicants and installers in the preceding months, but data collection methods were not affected as these did not require face to face contact.

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 45-60 minutes per interview, depending on the respondent type.

In advance of the interview, interviewers were provided with basic information about the participant from the screening survey. This enabled the interviewer to have an informed conversation with the applicant and reduce time collecting information the applicant had already provided.

The main topics covered in the applicant interviews were:

- introductions and consents
- respondent background
- overview of the respondent's customer journey
- detailed exploration of the respondent's customer journey
- timescale from deciding to install a heat pump to completing installation
- triggers for exploring heat pump options
- sources of advice and information and factors affecting use of these
- factors influencing decision to install the heat pump
- how they chose an installer, and factors influencing this
- role of RHI in their customer journey
- aspects of the customer journey that went well or badly, and how this could have been improved
- final reflections
- thank you and close

The main topics covered in the supply chain interviews were:

- introductions and consents
- organisation background and 'offer' to customers
- installer insights into how their business delivers domestic heat pump services for customers (including marketing methods, use of RHI in marketing, approaches to customer advice and perspectives on MCS)
- other factors on their heat pump business (including factors influencing changes in business capacity for heat pumps over time)
- view on future of market (including end of domestic RHI scheme and introduction of the Clean Heat Grant (CHG)[23] and GHG-V, if applicable)

[23] Now known as the Boiler Upgrade Scheme (BUS).

- final reflections
- thank you and close

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

Analysis

The analysis employed both Dedoose, and Excel spreadsheets. Dedoose was used to code interview transcripts[24] and other data sources. A separate coding framework was developed for applicant interviews and installer interviews. Each interview transcript was coded against the relevant coding framework, with the coded data being, organised by topic and by participant.

To analyse the installer data, a framework was created within Excel to further code, organise and analyse the coded installer excerpts against CMOs. We analysed the extent of support for different CMOs in the candidate supply theory and the potential for refining existing, or developing new, CMOs (see Table 1 for an explanation of CMOs)[25]. The coding and analysis were quality checked for consistency by another research team member. Further thematic analysis was undertaken on other findings from installer interviews, including installer perspectives on the customer journey.

To analyse the applicant data, a customer journey matrix was created in Excel which summarised the main steps in the customer journey for each applicant. Further Excel files were used to analyse the main features of the customer journey for different types of applicants, using the excerpts relating to relevant codes in the applicant coding framework. Further thematic analysis was undertaken on other aspects of the applicant experience. As the objective of this research was not to test RHI demand theory, we agreed with BEIS that we would not undertake formal theory testing of demand CMOs for applicants in this research, but findings from the research will inform future revision of demand theory.

Limitations

Key limitations of the research were:

- the findings of this research were affected to some degree by the COVID-19 pandemic., although both applicants and installers reported that some installations had continued in spite of COVID-19-related restrictions
- the consumer research focuses on domestic applications by owner occupiers, because the main focus was on factors influencing the customer journey - across all domestic RHI technologies, owner occupiers represented 77% of accredited applications in the year to August 2020, with the remainder being homes owned by social landlords plus a few private landlords

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

[25] This involved identifying the outcome for each case and creating a tailored 'case-specific' CMO which aimed to capture the causal mechanism for that case and identified important contexts that triggered this. The tailored 'case-specific' CMOs were then reviewed across the sample, and compared to the initial theory, to find patterns and similarities between cases. The revised CMOs primarily comprised generalised versions of causal configurations (C to M and M to O linkages) that were well-evidenced in the 'case-specific CMOs'. However, the revised CMOs also included CMOs that clearly involved different causal mechanisms, even where few cases were observed. The revised theory aimed to identify which contexts were important in triggering specific causal mechanisms, leading to different outcomes.

- the GHG-V grant was launched during the fieldwork period and was receiving considerable attention from installers at the time of the fieldwork - this may have influenced their thinking about both the reformed RHI and the proposed CHG scheme
- ASHP-only installers were slightly under-represented in the installer sample, possibly because they were particularly affected by enquiries under the GHG-V schemes - this was addressed by increasing the sample of installers covering both ASHP and GSHP
- the installer sample included some manufacturers who were also involved in MCS-accredited installations, either directly or via sub-contractors

Assignment of Rights fieldwork

This research was conducted in 2022.

Research questions

BEIS asked CAG to conduct qualitative research to understand the reasons why AoR uptake was low and, in particular, to understand why the AoR didn't stimulate investors to promote AoR packages as much as first expected.

Based on this rationale, and the feedback from a scoping workshop with BEIS staff, the following research question was agreed:

- how, why and in what circumstances did the AoR reforms influence renewable heat finance offers to consumers?

In addition, six sub-questions were agreed:

- why and in what circumstances did investors register with Ofgem to provide assignment of rights offers?
- how, why and in what circumstances did investors promote assignment of rights offers?
- what were the barriers to promoting assignment of rights offers under the RHI?
- what could have stimulated more investors to promote assignment of rights offers?
- why did some social landlords decide to use AoR? What was their experience of using AoR packages?
- what were AoR investors experiences of negotiating the assignment of rights packages with RHI applicants?

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.

Sampling

The approach to fieldwork was twofold:

First, it was agreed that a set of four scoping interviews should be with key stakeholders (comprising representatives from the two consumer codes, BEIS and a heat pump trade association) with the aim of (a) refining the draft research approach, and (b) generating findings for the research.

Second, this was to be followed by a main fieldwork phase which would involve depth interviews with investors, potential investors, applicants and other stakeholders.

The scoping interviews supported the hypothesis from the scoping workshop that a key issue with the scheme was that AoR investors did not promote the scheme as much as first anticipated, leading to much lower uptake of AoR offers than first expected. Issues around the AoR scheme design, investor misperceptions about the heat pump market, the potential lack of returns involved in being an AoR investor and concerns around investor admin were all cited as barriers to investors entering and actively participating in the AoR market.

A sampling approach was therefore developed to gather data from investors as well as 'potential investors' (i.e. organisations that had actively considered becoming an investor but had decided not to go ahead). In addition, to provide a broader understanding of the AoR market, it was agreed that the research should also involve applicant interviews (to understand how AoR offers were marketed and how the process worked from an applicant perspective), as well as an interview with Ofgem, the scheme administrator (to understand more about AoR administrative processes). The initial sampling framework is set out below.

Table 13 – Initial sampling framework for the AoR research

	Investors	Potential investors	Stakeholders	AoR applicants
Sample population	28	Unknown	n/a	1316
Description	The only registered finance providers allowed to sell AoR packages	Financiers who had demonstrated some interest in registering as an investor but did not go ahead with registration	Representatives of organisations with key involvement in the design or implementation of the AoR scheme e.g., Ofgem, BEIS and the consumer codes	Householders and organisations that had applied to the RHI using the AoR option
Purpose	Key focus of research questions. To explore issues surrounding AoR promotion	To understand reasons why initially interested organisations didn't apply to become investors	To understand impact of scheme design and implementation on AoR promotion and take-up and gain wider industry views on AoR	To understand how the AoR was promoted to consumers and explore applicant experiences of using the AoR option
Target number of interviews	12	3	5	5

Sampling considerations	Ofgem provided a list of 28 investors. 15 of these were registered with HIES, 13 with RECC. Aim for spread of different types of investors e.g.: • at least 5 from each code • at least 4 installer investors • at least 2 financier investors	Might not be possible to source sufficient sample, so could increase investor or applicant interviews if so.	Purposive sampling, one representative each from: BEIS RECC HIES Heat Pumps Association (HPA) Ofgem	Aim for spread of applicants by tenure: • 2 social landlord applicants • 2 owner occupier applicants • 1 private landlord applicant
Source(s)	Ofgem	BEIS, HIES and RECC	BEIS/Ofgem	RHI application data

Recruitment

The final numbers of interviews for each respondent group was different to the targeted number, as highlighted in the table below.

Table 14 - Final sample composition

	Investors	**Potential investors**	**Stakeholders**	**AoR applicants**
Number of interviews	10	1	5	9
Sample breakdown	4 heat pump installers 2 renewable energy financiers 2 Community Interest Companies (CICs) 1 local authority 1 energy supplier	1 heat pump installer	A representative each from: • Ofgem • HIES • RECC • Heat Pump Association • BEIS	3 social landlords 4 owner occupiers 2 private landlords
Source(s)	Ofgem, for Ofgem-registered investors (assumes they can provide this)	BEIS, HIES and RECC	BEIS/Ofgem CAG contacts from previous rounds of research	Application data

There were a number of challenges during recruitment, resulting in a lower-than-targeted number of interviews for investors and potential investors:

- for investors, attempts were made to contact and recruit all 28 investors – only ten responded positively, with the remainder either non-contactable (e.g. because the organisation was longer in business or the contact details provided did not work), unresponsive, or unwilling to participate
- for potential investors, details of 8 organisations that had considered becoming investors were secured through liaison with the consumer codes – all 8 were approached for interview but, for the same reasons above, only one agreed to participate.

Working with the consumer codes, we also secured high-level evidence via email from ten potential investors on the reasons that they decided not to go ahead. This was used to supplement the findings from the single depth interview with the potential investor. Furthermore, additional interviews with applicants were undertaken to add a broader range of insight about the implementation of the AoR option.

Data collection

With the scoping interviews undertaken at the beginning of the research, the interviews happened in two waves:

- the 4 scoping interviews were conducted in March 2022
- the remaining 21 depth interviews took place in August and September 2022

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

The main topics covered in the stakeholder interviews were:

- introductions and consents
- organisation background
- extent to which the AoR reforms met their objectives
- the effectiveness of the design and implementation of the AoR option
- the reasons why uptake was lower than anticipated
- investor motivations and challenges in relation to promoting the AoR option
- final reflections

- thank you and close

The main topics covered in the investor interviews were:

- introductions and consents
- organisation background
- an exploration of the process of becoming an investor, including what worked well and less well about the registration process, and organisational motivations for registering
- experiences of being an investor, including the extent of the organisation's involvement in offering AoR packages, the impact of any promotion and marketing, and factors which helped or hindered AoR finance offers
- future plans
- final reflections
- thank you and close

The main topics covered in the potential investor interviews were:

- introductions and consents
- organisation background
- an exploration of the organisation's considerations in becoming an investor, including initial motivations for registering, what worked well and less well about the registration process
- reasons for deciding not to become an investor
- final reflections
- thank you and close

The main topics covered in the applicant interviews were:

- introductions and consents
- respondent background
- reasons for installing the new heating system(s)
- decisions about financing the new heating system(s)
- the role of the RHI and the AoR option in the decision to install a renewable heating system
- experiences of the AoR process
- final reflections

- thank you and close

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

Analysis

Qualitative data

A coding framework was developed informed by the candidate theory and the research questions, as well as the emerging findings from the fieldwork. Data from the interviews was then coded against this framework using Dedoose (a type of Computer Assisted Qualitative Data Analysis Software).[26] Each interview transcript was coded, with the coded material organised by topic. This data was then thematically analysed ahead of report writing.

An additional framework was then created within Excel to further code, organise and analyse the evidence against the hypotheses in the candidate theory. We analysed the extent of support for different hypotheses in the candidate theory and the potential for refining existing, or developing new, hypotheses[27].

Quantitative data

In addition to the analysis of qualitative data, high-level analysis of:

- RHI application data was undertaken to understand the number of AoR applications, tenure share for AoR applications and the number of AoR applications over time
- applicant survey data on applicant awareness and views on AoR was undertaken
- AoR investor data provided by Ofgem was undertaken to understand the numbers and types of organisations that registered to become investors

Limitations

Key limitations of the research were:

- only one interview was secured with a potential investor. This group was considered important for the research as it was anticipated they would be a key source of evidence about the reasons why organisations decided not to

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

[27] This involved identifying the outcome for each case and creating a tailored 'case-specific' CMO which aimed to capture the causal mechanism for that case and identified important contexts that triggered this. The tailored 'case-specific' CMOs were then reviewed across the sample, and compared to the initial theory, to find patterns and similarities between cases. The revised CMOs primarily comprised generalised versions of causal configurations (C to M and M to O linkages) that were well-evidenced in the 'case-specific CMOs'. However, the revised CMOs also included CMOs that clearly involved different causal mechanisms, even where few cases were observed. The revised theory aimed to identify which contexts were important in triggering specific causal mechanisms, leading to different outcomes.

register as investors and promote the AoR option. However, email evidence from potential investors, together with insight from the depth interviews with investors and wider stakeholders meant that the research nonetheless collected a good range of evidence about these issues

- the research was designed to understand the reasons why promotion and uptake of the AoR option was lower than expected. The research therefore necessarily involved an exploration of the barriers to uptake, and the report to some extent reflects this emphasis on identifying scheme-related issues and challenges. However, interviewees were also asked to consider what worked well about the AoR reforms and where successes were identified, these are also highlighted in the report

- participant recall may also have been an issue given that the fieldwork took place over four years after the AoR was introduced. There were some instances where research participants were not factually correct in their recollections of what happened in relation to the implementation of the AoR option. It is not clear, however, whether this was a recall issue, or whether this reflects a lack of clarity at the time (e.g. because of communication challenges) about what was actually happening

Detailed applicant monitoring

This appendix sets out the methodology used to conduct surveys with applicants[28] 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 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 was 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 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 around one third (30%) 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

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

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

Table 15: 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
Domestic waves 1-24. These waves pre-date this evaluation project and are not discussed in detail in this document.	Domestic	9 April 2014 - 30 March 2016	1 June 2014 and 15 July 2016
25	Domestic	1st April 2016 – 20th September 2017	November 2017 – January 2018
26	Domestic	21st September 2017 – 31st August 2018	October - November 2018
27	Domestic	1st September 2018 – 28th February 2019	April - May 2019
28	Domestic	1st March 2019 – 31st August 2019	October 2019 - January[29] 2020
29	Domestic	1st September 2019 – 29th February 2020	April 2020 – June 2020
30	Domestic	1st March 2020 – 31st August 2020	October – November 2020
31	Domestic	1st September 2020 – 28th February 2021	May-June 2021
32	Domestic	1st March 2021 – 31st August 2021	November-December 2021
33	Domestic	1st September – 31st March 2022	May-June 2022

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. 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 tariff rate 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

[29] Fieldwork period was extended to accommodate purdah.

criteria. Every unique applicant was invited to participate, and the tariff rate date range was used to select those that should be approached within each wave of monitoring.

For consistency with the previous monitoring work (Waves 1 – 24), Winning Moves approached only successful applications. For each survey wave, the sampling frame of 'successful' applications equates to approved applications in the timeframe to be covered in that wave.

The sampling frame for each survey wave was selected on the basis of tariff rate date. Waves 1-24 were implemented as a rolling census of domestic RHI applicants, which was conducted in monthly waves between May 2014 and April 2016. Wave 25 was conducted in October 2017, covering approved applications with a tariff rate date between 1st April 2016 and 20th September 2017. Wave 26 was conducted in October 2018 and covered approved applications with a tariff rate date between 21 September 2017 and 31 August 2018. Since then, Waves 27-33 have been conducted in six-monthly waves, each wave covering all approved applications with a tariff rate date within the six months preceding each wave.

As data collection for Wave 29 coincided with the coronavirus crisis (April 2020), the online survey was soft launched prior to being fully launched to ascertain whether response rates were likely to be affected by the concurrent lockdown measures. The soft launch involved sending the online domestic survey to 200 applicants. The results were encouraging, as response rates appeared to be similar or even higher than in previous waves. Thus, it was decided to fully launch the survey.

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, 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 16: Survey mode for each wave of the RHI accredited applicant survey by wave

Survey	Applicant group	Main survey mode	Telephone boost?
25	Domestic	Online	Yes
26	Domestic	Online	No
27	Domestic	Online	Yes
28	Domestic	Online	Yes
29	Domestic	Online	Yes
30	Domestic	Online	Yes

Survey	Applicant group	Main survey mode	Telephone boost?
31	Domestic	Online	No
32	Domestic	Online	No
33	Domestic	Online	Yes

Survey design

The surveys for Wave 25 onwards were adapted from the scripts used during the previous evaluation of the RHI. 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 17: Summary of the Wave 25 pilot by applicant group.

Metric	Domestic
Sample invited to participate in the pilot	346 applicants, randomly selected across dates of application and technology.
Number (and proportion) clicking on the link to access the survey	132 (51% of those that opened the email and 38% of the whole pilot sample) clicked the link to start the survey.
Number (and proportion) completing the survey	88 (25% of the whole pilot sample) completed the survey.
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.

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.

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
- inclusion of an incentive: entry to a prize draw for those who complete the survey
- 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 33[30]) 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
- 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 1-24. This is especially when considering that bounced and auto-

[30] 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.

junking of emails likely reduced the population of potential respondents. Response rates achieved for each online survey are as follows:

Table 18: The population and online response rate achieved in each wave.

Survey	Applicant group	Population[31]	Sample	Online survey response rate[32]
25[33]	Domestic	11,591	2,251	19%
26	Domestic	4,241	1,503	35%
27	Domestic	3,421	666	19%
28	Domestic	3,219	726	23%
29	Domestic	4,099	1,170	29%
30	Domestic	3,198	968	30%
31	Domestic	4,620	1,288	28%
32	Domestic	4,275	1,263	30%
33	Domestic	13,764	3,522	25%

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

[31] All accredited applications with an email in the database supplied by BEIS.
[32] 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.
[33] 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. However, analysis of response rates by application and accreditation date did not seem to bear out this hypothesis.

    - 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 domestic groups
    - 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
    - since Wave 29, data from all survey waves, and for all questions, have been amalgamated into a combined dataset
    - upon completion of each survey wave, the new data was being added to the combined dataset.
- 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 domestic survey, the weighting variables were:

- technology type
- property type
- floor space
- previous heating system
- number of occupants

In Waves 25-33, weights were calculated at the application level only.

However, historically, weights had been calculated at both the application and the applicant level. However, to avoid confusion, calculation of applicant weights was discontinued and there were no such weights for Waves 25-33.

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.

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.

All percentages reported on were based on weighted data, with sample sizes reported on the basis of unweighted data.

Accreditation date

For Waves 25-33, accreditation date was defined as respondents' tariff rate date. Tariff rate date is applied at point of application and is close to accreditation date.

Summary of work undertaken and number of responses

Table 19: 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	Domestic	11,591	2,251	19%	Yes	163	2,414	21%
26	Domestic	4,241	1,503	35%	No	n/a	1,503	35%
27	Domestic	3,421	666	19%	Yes	43	709	21%
28	Domestic	3,219	726	23%	Yes	59	785	24%
29	Domestic	4,099	1,170	29%	Yes	7	1,177	29%
30	Domestic	3,198	968	30%	Yes	49	1,017	32%
31	Domestic	4,620	1,288	28%	No	n/a	1,288	28%
32	Domestic	4,275	1,263	30%	No	n/a	1,263	30%
33	Domestic	13,764	3,522	25%	Yes	32	3,554	26%

* 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.

Limitations

- Self-selection bias. The sample consists of those applicants who opted for completing the survey. Self-selection might lead to the resultant sample being different from the population. This risk was mitigated by:
  - Monitoring discrepancies with regards to key demographics and boosting under-represented groups with follow-up telephone interviews
  - Weighting the sample to ensure it is aligned with the population with regards to key demographic characteristics
  - Offering a £250 voucher draw incentive to attract responses from less engaged applicants
- Applicants could only be approached once. As a result of this choice, which was made in order to reduce the burden on respondents, applicants with multiple applications could only be contacted once. This was particularly important for applications by social landlords, which accounted for approximately 20% of all applications. As these applications were submitted by a very small number of landlords, each of them accounting for a large number of applications, these applications are under-represented in the sample, which mainly consists of owners-occupiers
- Census approach. As the survey was intended to be a census of applicants, there was no random sampling of applicants. For that reason, no claims of statistical significance are made in the main report, despite the large sample size
- Timing of the survey. Applicants were approached within six months of their applications, ensuring that recall issues were not present. However, for certain topics, such as satisfaction with achieved temperature, it might have been too soon for them to comment on. The follow-up heat pump satisfaction survey, which recontacted respondents two years after their initial survey response, showed that satisfaction levels were equally high, confirming the validity of the initial responses too

Heat Pump Satisfaction Research

Introduction

As part of the evaluation, Winning Moves conducted analysis looking at heat pump satisfaction, which focused on the usage experiences of domestic RHI participants who had installed ASHPs and GSHPs.

Aims

The analysis sought to answer the following research question and sub-questions:

- What are the reasons for participants' satisfaction and dissatisfaction with heat pump performance?
    - To what extent do participants think their heat pumps provide sufficient heat? Why?
    - What are the reasons for performance satisfaction, where it exists, for different types of participants?
    - What are the reasons for performance dissatisfaction where it exists, for different types of participants?

The work explored participants' ASHP and GSHP usage experiences through:

1. Analysis of the RHI ongoing detailed applicant monitoring survey data, isolating those participants with an ASHP or a GSHP, to explore satisfaction with their heat pump at an early stage in their user journey (time point 1). This analysis examined to what extent satisfaction was associated with key demographics as well as with responses to other survey questions, such as attribution and reform influence.
2. An online follow-up survey issued to participants that have had an ASHP or a GSHP in place for at least two winters, the purpose of which was to explore participants' heat pump satisfaction, and reasons for satisfaction / dissatisfaction, at a more mature stage in their user journey (time point 2). The potential population for this research element included all participants with a heat pump installed between April 2016 and September 2018 who were willing to be contacted for future research.

The two combined work elements allowed us to understand whether and how heat pump satisfaction changed over time.

Analysis of ongoing monitoring survey data

Data source

Exploratory analysis was conducted on a sample composed of 12,925 domestic RHI participants with an ASHP or a GSHP who had already taken part in the monitoring survey. The analysis referenced two data sources:

- survey data collected via the ongoing monitoring survey of RHI participants between April 2014 and May 2019, i.e. survey waves 1-29 ('monitoring data') (n=12,925).

- information provided by the same participants at the application stage ('application data').

Monitoring data and application data was linked using their unique RHI number.

Various questions of relevance to the analysis requirements were captured in the monitoring survey, including: overall satisfaction; satisfaction with different aspects of the heating system, such as noise level, looks, or ease of adjusting the controls; internal temperature achieved by the heating system; faults with the system; and whether they had recommended it to others. Data relating to satisfaction was explored alongside demographic data from both the monitoring survey and application data to explore the profile of those reporting different levels of satisfaction. For further details on the applicant monitoring survey see the previous chapter on the detailed applicant monitoring.

Data analysis

Prior to analysis, the monitoring survey dataset was weighted using standard sampling weights from the ongoing monitoring survey as a strategy for correcting for differences between sample and the population in terms of i) technology type, ii) previous heating system, iii) floorspace, iv) property type.

Understanding differences in satisfaction pre and post reform

An additional aim was to explore applicant satisfaction prior and subsequent to reform of the RHI scheme to identify possible changes over the life of the scheme in satisfaction, as well as on the types of satisfied or dissatisfied participants. To do this, satisfaction data was cross-tabulated with a variable splitting data according to the pre- and post-reform periods i.e. the period prior and subsequent to 20th September 2017 when the first stage of reforms to the domestic RHI came into effect. Satisfaction scores for the two periods mentioned here were compared to identify notable changes.

Analysis of the heat pump satisfaction survey

Data collection

Participants responding to the ongoing monitoring survey who were willing to be contacted again for research purposes and where at least two winters had passed since installation (i.e. those with a heat pump installed prior to September 2018)[34] were issued a survey to evaluate their heat pump usage experiences. Table 20 summarises the number of invitations sent, number of responses received and the overall response rate.

[34] Note that the question about willingness to be contacted for future research was added into the questionnaire from April 2016 onwards. Therefore, the pool of potential participants for the usage experience online survey included all participants with a heat pump installed between April 2016 and September 2018 who were willing to be contacted for future research.

Table 20: Number of invitations, responses and the response rate

Number of invitations sent	2,330
Number of responses received	1,777
Response rate[35]	76.3%

Out of the 1,777 participants, 1,028 had their heat pump installed prior to the reform of the RHI scheme and 749 had their heat pump installed subsequent to the reform of the RHI scheme.

Survey responses received from the 1,777 participants were linked to their earlier responses to the ongoing monitoring survey to allow for analysis of changes in satisfaction over time. Data was linked using their unique RHI number. This was provided to Winning Moves in the monitoring data and kept as a unique reference number for all participants that were sent the survey.

Data analysis

Data was weighted using sampling weights to correct for differences between sample and the population in terms of i) technology type, ii) previous heating system, iii) floorspace, iv) previous fuel, and v) whether the application was associated with a new build. The population (N=10,502) were all RHI participants with an air source heat pump or a ground source heat pump with a tariff rate date between 1st April 2016 and 30th September 2018. The table below presents a comparison of the profiles of the heat pump satisfaction research population, and the survey weighted and unweighted sample:

[35] Calculated as: (Completed responses / invitations sent out) x 100

Table 21 Demographic comparison of the heat pump satisfaction research population and the survey sample

		Population		**Heat Pump Satisfaction survey (unweighted)**		**Heat Pump Satisfaction survey (weighted)**	
		Frequency	**Valid Percent**	**Frequency**	**Valid Percent**	**Frequency**	**Valid Percent**
Technology (from application data)	*ASHP*	8,181	77.9%	1,423	80.1%	8,181	77.9%
	GSHP	2,321	22.1%	354	19.9%	2,321	22.1%
	Total	**10,502**	**100.0%**	**1,777**	**100.0%**	**10,502**	**100.0%**
Previous heating system (from application data)	*Boiler*	5,252	50.0%	1,086	61.1%	4,996	47.6%
	Other	1,758	16.7%	287	16.2%	1,640	15.6%
	None	3,492	33.3%	404	22.7%	3,866	36.8%
	Total	**10,502**	**100.00%**	**1,777**	**100.0%**	**10,502**	**100.0%**
Floorspace from database (m^2)	*<100*	1,412	13.4%	287	16.2%	1,375	13.1%
	100-150	2,605	24.8%	484	27.2%	2,551	24.3%
	150-200	2,296	21.9%	414	23.3%	2,320	22.1%
	200-250	1,546	14.7%	242	13.6%	1,582	15.1%
	250<	2,643	25.2%	350	19.7%	2,673	25.5%
	Total	**10,502**	**100.0%**	**1,777**	**100.0%**	**10,502**	**100.0%**
	Detached house or bungalow	8,202	78.1%	1,357	76.4%	8,503	81.0%

Property type coded (from application data)	*Semi detached house or bungalow*	1,620	15.4%	322	18.1%	1,548	14.7%
	Flat/maisonette/terraced house	680	6.5%	98	5.5%	451	4.3%
	Total	**10,502**	**100.0%**	**1,777**	**100.0%**	**10,502**	**100.0%**
Grid Status	*On grid*	3,491	33.2%	701	39.4%	3,762	35.8%
	Off grid	7,010	66.8%	1,076	60.6%	6,740	64.2%
	Total	**10,501**	**100.0%**	**1,777**	**100.0%**	**10,502**	**100.0%**
Country	*England*	8,196	78.0%	1,379	77.6%	7,928	75.5%
	Scotland	1,575	15.0%	288	16.2%	1,896	18.1%
	Wales	731	7.0%	110	6.2%	678	6.5%
	Total	**10,502**	**100.0%**	**1,777**	**100.0%**	**10,502**	**100.0%**
Heat Demand (kw/h)	*Less than 10,000 kWh*	1,059	10.1%	153	8.6%	1,086	10.3%
	At least 10,000 kWh, but less than 15,000 kWh	2,437	23.2%	422	23.7%	2,540	24.2%
	At least 15,000 kWh, but less than 20,000 kWh	2,249	21.4%	387	21.8%	2,224	21.2%

	At least 20,000 kWh, but less than 25,000 kWh	1,657	15.8%	271	15.3%	1,536	14.6%
	At least 25,000 kWh, but less than 30,000 kWh	1,067	10.2%	204	11.5%	1,216	11.6%
	At least 30,000 kWh, but less than 35,000 kWh	618	5.9%	103	5.8%	580	5.5%
	At least 35,000 kWh, but less than 50,000 kWh	863	8.2%	162	9.1%	895	8.5%
	50,000 kWh +	552	5.3%	75	4.2%	425	4.0%
	Total	**10,502**	**100.0%**	**1,777**	**100.0%**	**10,502**	**100.0%**
Previous Fuel	*Electricity*	1,589	15.1%	273	15.4%	1,609	15.3%
	Gas	1,959	18.7%	449	25.3%	2,033	19.4%
	Oil / LPG	2,927	27.9%	560	31.5%	2,916	27.8%
	Other	295	2.8%	57	3.2%	296	2.8%
	First heating – i.e. no previous fuel	3,705	35.3%	414	23.3%	3,621	34.5%
	Unknown	27	0.3%	24	1.4%	27	0.3%
	Total	**10,502**	**100.0%**	**1,777**	**100.0%**	**10,502**	**100.0%**

Custom Built	*Yes*	2,732	26.0%	327	18.4%	2,880	27.4%
	No	7,770	74.0%	1,450	81.6%	7,622	72.6%
	Total	**10,502**	**100.0%**	**1,777**	**100.0%**	**10,502**	**100.0%**
Equipment cost (banded)	*Less than £8,500*	5,816	55.4%	595	41.8%	3,602	42.9%
	£8,500 to £14,999	3,412	32.5%	628	44.1%	3,458	41.2%
	More than £15,000	1,274	12.1%	200	14.1%	1,342	16.0%
	Total	**10,502**	**100.0%**	**1,423**	**100.0%**	**8,402**	**100.0%**
Total Cost (banded)	*Less than £8,500*	1,386	13.2%	167	9.6%	991	9.6%
	£8,500 to £14,999	5,152	49.1%	936	53.6%	5,122	49.8%
	More than £15,000	3,964	37.7%	643	36.8%	4,166	40.5%
	Total	**10,502**	**100.0%**	**1,746**	**100.0%**	**10,279**	**100.0%**

The population for the purpose of the heat pump satisfaction survey consisted of all applications with a tariff rate date up to 30/09/2018, which meant that, at the time of the survey (December 2020), the renewable heat technology had been installed in the property for at least two winters. As it was not possible to send the survey to any applications with a tariff rate date prior to 1/4/2016[36], i.e. in the period covered by the previous evaluation contract, earlier applications were also excluded from the population. Hence, the heat pump satisfaction research population consisted of all air and ground source heat pump applications with a tariff rate date between 1/4/2016 and 30/9/2018 (N=10,502).

A substantial part of the analysis was based around a key question in the heat pump satisfaction survey, which asked respondents to rate their overall satisfaction with their heat pump (selecting from the aforementioned five satisfaction options) and to then provide an open ended / free text explanation of that rating.

Analysis examining satisfaction levels over time was produced solely on the basis of responses from the 1,777 participants with an ASHP or a GSHP installed who had completed both the ongoing monitoring survey and the survey issued to participants with their heat pump in place for at least two winters. Differences in satisfaction over time were tested for statistical significance in Q[37], using Pearson's chi squared tests. The purpose of statistical significance testing was to determine whether possible differences found between two groups of participants may be due to chance or not.

For satisfaction metrics, the results were examined based on the most granular categories - 'very satisfied', 'fairly satisfied', 'neither satisfied nor dissatisfied', 'fairly dissatisfied' and 'very dissatisfied'. Analysis highlighted clear distinctions between the experiences of the different groups, particularly the 'very satisfied' and 'fairly satisfied' groups, with the latter often articulating at least some issues with their heat pump.

In addition to this, selected analysis and statistics showed and compared %s in the *overall* satisfied (i.e. 'very' + 'fairly' satisfied) and *overall* dissatisfied groups.

Limitations

- Self-selection bias. The sample consists of those applicants who suggested in the main survey that they would be happy to be recontacted. Self-selection might lead to the resultant sample being different from the population
- Due to the question on permitting recontact being included in the survey after April 2016, any applications with a tariff rate date before that point were not part of this exercise. Thus, views of applicants having had their heating systems installed for more than three winters are not reflected in this analysis

[36] In the survey waves prior to that date, there is no available information on whether survey respondents had consented to be re-approached in the future.
[37] Q is data analysis and reporting software.

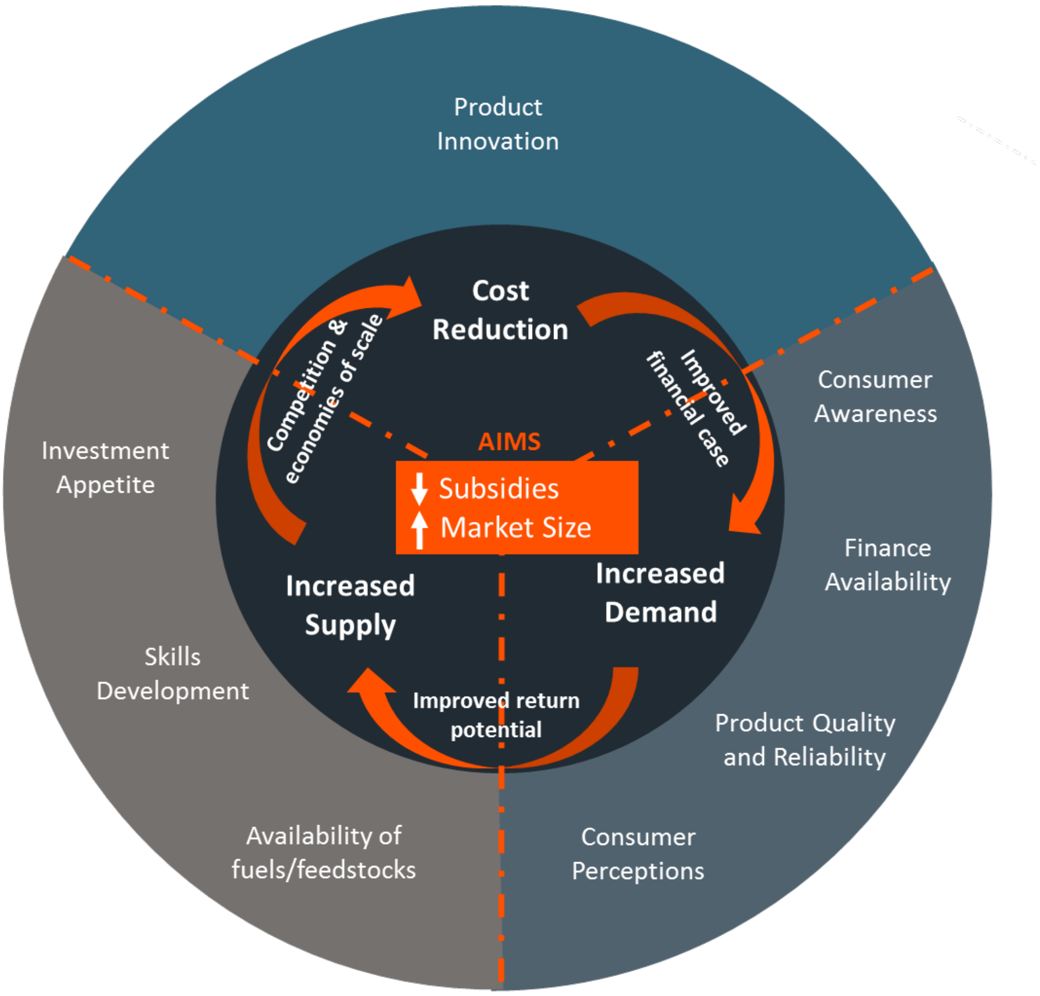
Sustainable Markets Assessment

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 22: 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
Other (combined for domestic and non-domestic)	Solar Thermal

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 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 below and its use in the synthesis report was appropriate to its level of robustness.

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 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 earlier in the scheme.

The cost data used in the SMA up to the final dashboard was presented in nominal terms, as inflation was low during the research period. For the final report, given the substantial rise in inflation this approach was revised to include real cost data[38].

Attachment 1 presents an example of the SMA Consultation Aide Memoire that was used for consultation with supply chain stakeholders and industry representatives (note: these covered both the domestic and non-domestic scheme). 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 23: 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 domestic installations, the installation date is determined based on the earlier of two reported dates (the reported application submission 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

[38] The final sustainable markets assessment was completed in. September 2022.

	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 24: 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. 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. Indicator findings sense-checked by CAG Consultants before being submitted to BEIS.

Table 25: Indicator B2

Indicator	Consumer complaints associated with renewable technologies
Data Source	RECC Complaints Data
Description of Indicator Analysis	This data drew on the number of complaints reported to the Renewable Energy Consumer Code. These complaints relate primarily to the installation of renewable heat technologies. The indicator expresses the number of complaints as a proportion of the number of annual accredited installations. Number of annual accredited installations is assessed in the same way as under indicator A1. Installations data for 2014 only covers the Apr-Dec period (when the RHI policy was live) and so 2014 RECC complaints figures have been adjusted accordingly.
Robustness of Data	Medium
Description of Robustness	The Renewable Energy Consumer Code is a subsidiary of the Renewable Energy Association and collects complaints data in a consistent way year on year. They focus on issues around the contract between the installer and consumer, including sale, installation and aftersales, but with the majority of complaints linked to the installation period. RHI installers are required to be members of a consumer code – of which RECC is the most common (although others exist e.g. HIES – home insulation and energy systems). The majority of RHI accredited

	installations are expected to be covered under the RECC consumer code. Expressing the indicator as a proportion of RHI annually accredited installations is a good proxy, however a) some of the products accredited by RHI in a given year will relate to products installed in the previous year, and b) RECC also applies for products installed outside of the RHI scheme (although market evidence suggests that RHI installations comprise the majority of the market).
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. Sense checking with findings from sector body / manufacturer consultation feedback undertaken by Hatch Regeneris / Wavehill

Table 26: Indicator C1

Indicator	Awareness amongst applicants of the range of alternative renewable heat technologies
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 that answered that they had considered more than one type of technology when deciding to make their RHI installation (whether conventional heating systems or renewable heating technologies). The domestic scheme applicant survey question asked "Which of these statements best describes how you selected your new heating system?" with options of: 1) I only considered renewable heating technologies, and just one type of renewable technology, 2) I only considered renewable heating technologies but explored more than one type of renewable technology, 3) I considered both conventional heating systems and renewable heating technologies, 4) Don't know. The indicator captured those that responded yes to either option 2) or 3).

	The indicator was based on responses over the previous 12-month period, compared with the preceding 12-month period. This data was collected in previous surveys, with exactly the same wording, allowing comparison over the full policy 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 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 27: Indicator C2

Indicator	General consumer awareness of renewable heat technologies
Data Source	BEIS Public Attitudes Tracker
Description of Indicator Analysis	This data was taken from the published raw data from the BEIS Public Attitudes Tracker Surveys The indicator drew on weighted responses to the following question: “How much, if anything do you know about the following types of renewable heating system...?" a) Air Source Heat Pumps b) Ground Source Heat Pumps c) Biomass boilers The indicator showed the proportion of those that gave any of the following responses "Know a lot", "Know a little about them", or "Aware of them but don't really know what they are". Note: data was updated in the third dashboard iteration (July 2019) to show weighted data rather than unweighted.
Robustness of Data	High

Description of Robustness	The data was drawn from general population surveys undertaken by BEIS with a representative sample of UK households
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.

Table 28: 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]. 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 29: 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 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 30: Indicator D3

Indicator	Proportion of applications using third party agreements
Data Source	RHI Applicant 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 indicator was based on the proportion of applicants that used assignment of rights to finance their installation. The indicator was based on responses over the previous 12-month period, compared with the preceding 12-month period.
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.

Table 31: Indicator E1

Indicator	Number of main equipment suppliers for each technology
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 For each update period, the indicator analysed a count of the manufacturers with 10% or more market share. This was assessed by the number of their products installed as part of accredited RHI applications in proportion to all installations by that technology type. The installation date was determined based on the earlier of two reported dates (the reported application submission date and the reported commissioning date). Only installations which were listed as 'accredited' or still under review were counted. An optimal range of 3-6 manufacturers with at least 10% market share was set on the basis that only 1-2 suppliers dominating the market would suggest limited strong competition, but too many smaller suppliers would suggest firms involved in the market may lack sufficient scale to invest in product/process innovation, marketing etc that could support market development.

Robustness of Data	Medium
Description of Robustness	Data came directly from Ofgem/BEIS Application Data A limited degree of cleansing was undertaken by Hatch Regeneris / Wavehill to establish number of firms with at least 10% market share for each technology.
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. Comparison to other external datasets e.g. BSRIA data was undertaken to sense check findings.

Supply indicators

Table 32: Indicator G1

Indicator	No. of MCS certified installers
Data Source	Microgeneration Certification Scheme Data
Description of Indicator Analysis	All domestic RHI installations were required to be installed by an MCS registered installer (or equivalent). The data for this indicator was provided by the Microgeneration Certification Scheme and includes a count of certified installers by technology type each month.
Robustness of Data	Medium
Description of Robustness	The data was provided by the Microgeneration Certification Scheme, using a consistent monitoring approach. There was a step change increase in installer numbers in Autumn 2014 and reduction in Spring 2015 which it was not possible to get a clear explanation for, from MCS.
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. Sense checking findings comparing against sector body consultations

Table 33: 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 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 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 were sense-checked by CAG Consultants before being submitted to BEIS.

Cost Indicators

Table 34: 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 domestic application data). The indicator produces a median cost per kW of installed capacity for each technology, for 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 35: 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)

Wavehill 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. Wavehill 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 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).

Key indicator data that was gathered at the level of individual RHI technologies to inform these indicator calculations, 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[39].

The introduction of reforms for the domestic scheme is assumed to be 22 September 2017 across all technologies. This is used to enable a before-after analysis of cost-effectiveness.

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. In particular, the payments can continue for seven years, while the heat generation would typically continue for longer than this.

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

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

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[40]. 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.

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. The impact of this is that the cost effectiveness indicators are not fully comprehensive of all installations, although costs and benefits for those installations included compare costs and benefits on a like for like basis in order to derive cost effectiveness indicators

The analysis would have taken account of any issues of non-compliance but no data was available from Ofgem to support this analysis. The impact of this was that the indicators may slightly over-estimate cost effectiveness, as it does not take account of any energy generation that was non-compliant with the scheme.

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 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 (i.e. a number lower than 0)
- those equal to 0 across all three indicators

[40] 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

- 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

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

Table 36: 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, dependent on the 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 / Wavehill, 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 37: 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 pre- and post-reform data, dependent on the 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 / Wavehill, 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 38: Heat Generated

Indicator	Heat generated
Source	RHI Payments Data (based on deemed data for domestic installations)
Description of Evidence Analysis	Raw data on heat generated was cleansed as outlined above. Data on the total heat generated to date split into pre- and post-reform data, dependent on the 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 Analysis and cleansing of data was undertaken by Hatch Regeneris / Wavehill, 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 39: 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 domestic applicant survey, these were: 1. Without the Renewable Heat Incentive (RHI), would any new heating system have been installed? 2. Without the Renewable Heat Incentive (RHI), would a different technology to the renewable heat technology have been chosen? 3. What technology type would / might have been chosen instead? If answer to (1) was yes (or was missing) and answer to (2) was yes, the counterfactual was the answer to (3) If answer to (1) was yes (or was missing) and answer to (2) was no, the counterfactual was the same as their installed RHT If answer to (1) was no, the counterfactual was their previous technology Responses were excluded if answer to (1) was yes and answer to (2) was missing Responses were excluded if answer to (2) was yes and answer to (3) was missing. The Core Counterfactual Assumption was based on the analysis above. This was used in two ways: Firstly, for the carbon abatement and air quality SCEA indicators, 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. Effectively, the carbon abatement and air quality outcomes were calculated relative to counterfactual technologies, so the ratio of ‘benefits’ to ‘subsidy costs’ automatically took account of additionality or ‘deadweight’. Secondly, for the installed capacity and renewable heat SCEA indicators, by drawing out an overall percentage (%) additionality based on the proportion of installations for which a non-RHT was the counterfactual technology. The overall additionality percentage was applied to these cost-effectiveness metrics (installed capacity and renewable heat generated) 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 was 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 remained 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. Domestic Survey – Max Deadweight Scenario: Q - Why did you decide to install a renewable heating system rather than a conventional heating system? If this question was answered and core analysis showed this as 'non-deadweight', the assessment was changed to 'deadweight' if response included none of the following: • recommended by a professional (e.g. plumber, architect or engineer) • in anticipation of/to claim the Renewable Heat Incentive • to save money • could get funding/grant Q - Why did you decide to install a renewable heating system rather than a conventional heating system? If this question was answered and core analysis showed this as 'non-deadweight', the assessment was changed to 'deadweight' if response included 'planning consent required' Q – What was the main heating system used to heat your home prior to installing RHT? If this question was answered and core analysis showed this as 'non-deadweight', the assessment was changed to 'deadweight' if they

	replied that the current main heating technology was ‘Central heating – a previous renewable heating installation’. Domestic Survey – Min Deadweight Scenario: Q - Why did you decide to install a renewable heating system rather than a conventional heating system? If this question was answered and core analysis showed this as ‘deadweight’, the assessment was changed to ‘non-deadweight’ if response included any of the following: • Recommended by a professional (e.g. plumber, architect or engineer) • In anticipation of/to claim the Renewable Heat Incentive • To save money • Could get funding/grant Q - Did any of the following prompt your decision to install a new heating system at that time? If this question was answered and core analysis showed this as ‘deadweight’, the assessment was changed to ‘non-deadweight’ if response included ‘Grant or funding became available at that time’ Q - How did you find out about the Renewable Heat Incentive (RHI) scheme? If this question was answered and core analysis showed this as ‘deadweight’, the assessment was changed to ‘non-deadweight’ if response included any of the following: • heating system manufacturer • an installer of renewable heating systems Q - Has the Renewable Heat Incentive (RHI) scheme made it easier to secure finance to install the renewable heat technology? If this question was answered and core analysis showed this as ‘deadweight’, the assessment was changed to ‘non-deadweight’ if response to this question was “Yes” 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 40: 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 kgCO2e 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 kgCO2e per kWh • Combined Heat and Power: 0.183 kgCO2e per kWh • Coal Boiler: 0.324 kgCO2e per kWh • Gas Boiler: 0.183 kgCO2e per kWh • LPG Boiler: 0.214 kgCO2e per kWh • Oil Boiler: 0.247 kgCO2e per kWh • Qatari LNG: 0.183 kgCO2e per kWh
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. CO2e emissions per kWh for each technology drew on HMT guidance. 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), depending on the 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.
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.
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 41: 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. Air quality damage costs per kWh for each technology drew 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), depending on the 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.
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 42: 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, using the same risk bandings as used in the CTA dashboard output. 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

Competition and Trade Assessment

This workstream analysed the extent to which the assumptions used in developing tariff levels for the RHI held in practice. Findings from that analysis were used to assess whether the tariff levels 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 impact of this is that this analysis was not able to fully test all of the BEIS assumptions and methods used in setting the tariff levels, to ascertain whether these meant that tariffs were set at an appropriate level. Instead, the analysis is based on testing some of the key assumptions used in modelling where these were able to be identified.

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:

- domestic Biomass (Dom Biomass)
- domestic Air Source Heat Pumps (Dom ASHP)
- domestic Ground Source Heat Pumps (Dom GSHP)

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. The impact of this adds to the earlier challenge, that this analysis has only enabled partial testing of the tariff setting methodology to ascertain whether the tariffs were set at an appropriate level

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). The impact of this was that there was variation in the robustness of evidence used to test the original tariff setting assumptions, meaning many of these findings could only be indicative, based on the robustness of evidence available.

Details of analysis

The indicators that this analysis could and did test are shown in Table 43.

Table 43: 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.
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 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 indicators by installation capacity size was conducted and presented in the dashboard, in order to assess whether the findings differed by size of installation. Typologies of size were defined for each of the RHTs by:

- Dom ASHP: RHT sizes have been categorised as:
    - Small = where RHT has an installed capacity less than or equal to 10kWth
    - Large = where RHT has an installed capacity greater than 10kWth
- Dom GSHP: RHT sizes have been categorised as:
    - Small = where RHT has an installed capacity less than or equal to 13kWth
    - Large = where RHT has an installed capacity greater than 13kWth
- Dom Biomass Boilers: RHT sizes have been categorised as:
    - Small = where RHT has an installed capacity less than or equal to 23kWth
    - Large = where RHT has an installed capacity greater than 23kWth

Table 44: 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 Domestic
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 domestic scheme, the data covered respondents from Wave 25 of the applicant survey. The indicator was based on the information provided by respondents to the following domestic RHI survey questions: • "Without the Renewable Heat Incentive (RHI), would any new heating system have been installed?" • "Without the Renewable Heat Incentive (RHI), would a different technology to the RHT have been chosen?" • "What technology type might have been chosen if the RHI was not available?" 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.
Robustness of Data	Medium
Description of Robustness	The applicant survey was carried out as part of the evaluation work which was sent to all RHI applicants. 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[41].

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

	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.

Table 45: 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 / Wavehill: 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 / Wavehill 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 / Wavehill, 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 46: 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 / Wavehill, 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 mean average 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[42] around in-situ efficiency for renewable heat technologies was incorporated.
Robustness of Data	High
Description of Robustness	Data came directly from Ofgem/BEIS Application Data.

[42] 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.

	Analysis and cleansing of data was undertaken by Hatch Regeneris / Wavehill, 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 / Wavehill sense checked findings against the median design efficiency of the top five products supported by each technology group through desk-based research.

Table 47: Fuel Price

Indicator	Fuel Price per kWh
Source of BEIS Modelling Assumptions	BEIS, Reformed RHI Impact Assessment, 2016
Basis of original assumptions	Dom Biomass - Sutherland Tables (providing comparative domestic heating costs data), referred to in BEIS, Reformed RHI Impact Assessment, 2016
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[43]. 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 the RHI Application Data, annual heat load, and by respondents to the following questions: • "On average, how frequently do you purchase biomass fuel?" • "Approximately how much do you pay per purchase (£)?" The fuel price per kWh was calculated by assessing annual spend using findings from the questions above and dividing this figure by deemed annual heat load (from the application data). The reported figure was then based on an average (mean) of the survey responses.

[43] 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

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. 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]. 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 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 internal research on the wood pellet market. That analysis covered approximately 60% of the ~500,000 tonnes/year UK domestic and commercial heating market.

Table 48: 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

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

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 / Wavehill, by removing the 5% highest and 5% lowest installed 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 / Wavehill, 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 49: 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 deemed use for domestic installations, set out in the BEIS application data. Consistent with BEIS recommendations and the internal approach, calculated heat load factor data was further cleansed by Hatch Regeneris / Wavehill, 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 / Wavehill, 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.

Quasi-experimental impact assessment

This section briefly presents the statistical methodologies employed in the quasi-experimental impact assessment of the impact of the domestic RHI reforms.

This includes the approach used to group the most similar participants based on a number of variables of interest (cluster analysis) and an econometric model following the logic of the Regression Discontinuity Design, which is used to assess the impacts of the reforms. This method estimates the impact of a policy by using a cut-off threshold to separate those affected by the policy from those not impacted. The method relies on the assumption that the individuals below and above a cut-off threshold are similar. If the only significant difference between the 2 groups is whether they received the intervention or not, any difference in the outcome of interest can be attributed to the policy. By comparing the value of the outcome of interest for the units above and below the cut-off threshold, the method estimates the impact of the policy, while considering other observable differences, if applicable.

These methodologies sought to answer the following evaluation questions:

- EQ1: What has been the impact of the reformed RHI (increased tariffs and heat demand limits) on the socio-demographic characteristics of the applicants and the characteristics of the properties where installation took place?
- EQ2: Have the impacts of the reformed RHI been uniform across technologies (biomass, ASHP and GSHP)?

Econometric model

The econometric model in this study is inspired by the logic of Regression Discontinuity Design (RDD). The RDD is based on separating the "treated" units, i.e. the applications affected by the policy reform, from the "control" units, i.e. the applications used as a comparison, according to the specific value (also called threshold or cut-off) of a given variable (the "forcing" variable, i.e. the variable determining whether a unit receives treatment or not).[45] In this study, the cut-off is based on the application timing, so that it separates the pre-reform period from the post-reform period.

The time periods of interest were calculated in the interim RHI quasi-experimental impact evaluation report. This analysis found that:

- for analysis focused on the tariff uplift reform, the pre-reform period includes up to 180 days before the announcement effect of the reform took place, 3rd March 2016, while the post-reform period goes from 14th December 2016 to 31st March 2022
- for analysis including the heat demand limits reform, either on their own or in conjunction with the tariff uplift reform, the pre-reform period includes up to 180

[45]An overview of the Regression Discontinuity Designs can be found in Chapter 6 of "*Mostly Harmless Econometrics: An Empiricist's Comparison*" by J. Angrist and J. Pischke.

days before 14th December 2016, while the post-reform period starts on 20th September 2017 and ends on 31st of March 2022

This implies that the cut-off period for higher tariffs policy is on 3rd March 2016 while for the heat demand limits it is on 14th December 2016. These are the timespans over which the announcement effect was estimated to take place. The reason for excluding these periods is to diminish the impact of the announcement effect.

The statistical method that is employed in this study evaluates the impact of the reformed RHI by comparing the applicants before and after the cut-off period. Estimation is carried out through a regression with a dummy variable modelling the impact after the cut-off period compared to impact before the introduction of the reform. The coefficient ρ on the dummy variables measures the impact of the policy on the "post-reform" units in comparison with the "pre-reform" units. In this analysis, the change in the outcome variable between the post- and pre-reform periods is labelled "change in constant" in the tables below.

As briefly introduced above, the outcome variable Y_i of interest in this study can be:

- numeric, as in the case of continuous variables such as floor space
- truncated numeric, i.e. continuous variables that can take on values only above/below a certain threshold, with this threshold being different from zero, such as gross heat demand
- binary as in the case of variables with only two fixed values (categories) such as ownership type
- categorical as in the case of variables with multiple fixed values (categories) such as property type

It should be noted that the estimation procedures and the interpretation of the results slightly change as a consequence of the nature of the variable. Care must be taken to note that:

- for the numeric outcome[46] variables, a linear regression after taking the logarithmic (natural base) of the variables is employed
    - this is a mainstay of econometric analysis justified by the fact that the logarithmic transformation reduces any concern with heteroscedasticity and helps interpretation of coefficients
    - this allows the coefficients to be interpreted as a change arising from a unitary increase in the related independent variable
- for the truncated numeric outcome variables, a truncated regression is employed - this implies a change in the estimation procedure as the parameters are estimated through the maximum likelihood method, but the interpretation of the coefficients remains the same as discussed in the point above.

[46] "Outcome variable" implies the dependent variable, i.e. that which is affected (or not) by unitary changes in independent variables within the model.

- for the binary outcome variables, binary logistic regression is employed to model the likelihood of the outcome variable being 1 or 0
    - the coefficients are transformed and interpreted as changes in the odds ratio[47]
    - this is defined as the ratio between the probability of a binary variable taking on a value of 1 and the probability of taking on a value of 0
    - as an example, if the change in odds ratio related to an independent variable is equal to 3, then this means that the probability of the binary variable taking on a value of 1 is 3 times higher than the probability of it taking on a value of 0 after a unitary change in the independent variable
    - if the change in odds ratio related to an independent variable is less than 1, as an example 0.50, then this means that the probability of the binary variable taking on a value of 1 is only 0.50 time as likely as the probability of it taking on a value of 0 after a unitary change in the independent variable
    - the odds ratio represents the odds that the outcome (e.g., installing ASHP) occurs as a result of a specific status of a variable (e.g., being a homeowner) compared to the odds of the outcome occurring in the opposite position (e.g., being a landlord)
    - the change in the odds ratio means how this ratio changes after the reform with respect to the pre-reform period
- finally, a multinomial logistic regression is employed for the categorical outcome variables. This is a generalisation of logistic regression, so that one of the categories is chosen as a reference. The other categories are assessed against it in a binary logistic framework. As in the logistic case in the point above, the coefficients can be transformed and interpreted as changes in the odds ratio.

Cluster analysis

Cluster analysis was employed to assess the impact of the RHI reforms upon the typology of applicants across a number of characteristics by partitioning a collection of units, i.e. applicants. Cluster is a statistical term to indicate groups of units which are as similar as possible with regard to the variables used in the analysis[48]. This was completed in two steps. Firstly, successful applicants were grouped according to a combination of the variables of interest to create mutually exclusive groups so that one

[47] The coefficient of the logit model is the logarithm of the odds ratio. To convert it to the odds ratio, we need to use the exponential function, $exp(coefficient) = odds\ ratio$. In general, this is how one can interpret the results of the logit model in this study: (1) if the estimated coefficient (log odds ratio) is any positive value, e.g. 0.3, then the odds ratio is bigger than one, $exp(coefficient) > 1$. So the interpretation would be "… more likely …"; (2) if the estimated coefficient (log odds ratio) is any negative value, e.g. -2.3, then the odds ratio is smaller than one, $exp(coefficient) < 1$. So the interpretation would be "… less likely …"; (3) if the estimated coefficient (log odds ratio) is zero, then the odds ratio is one, $exp(coefficient) = 1$. So the interpretation is "… the same as …" or "there is no change in …".

[48] A summary of the clustering methods can be found in Chapter 14 of Hastie T., Tibshirani R. and J. Friedman (2013) "*The Elements of Statistical Learning*".

applicant could belong to only one of the groups. This was a modelling device to abstract away from the complexity of describing the characteristics of applicants or group applicants. Typologies of applicants were built by aggregating together, through cluster analysis, those that are most similar in terms of a set of variables from scheme dataset and the survey dataset, i.e. gross heat demand, annual generation intensity, floor space and income band. Cluster membership was identified by using an index measuring the dissimilarity between the values in each applicant of the variables mentioned above. As the set of variables used for clustering are both numeric and ordinal, Gower distance was used as the dissimilarity measure and the Partitioning Around Medoids (PAM) method was used as the algorithm to cluster the data. Both methods are well suited to handle mixed-type variables. The number of clusters was selected by looking at the homogeneity in the clustered observations.

After identifying the clusters of applicants, the relative change in the occurrence of the clusters following the introduction of the RHI reforms was assessed using the econometric framework described above. Here, multinomial logistic regression was used to model the likelihood of applicants falling in a specific cluster compared to a cluster used as baseline. The cluster with the smallest properties and lowest level of demand was selected as the baseline cluster. This approach was used to assess whether the reformed scheme had an impact on any change in the composition of the clusters occurring at the introduction of the RHI by assessing its influence of the reform on the likelihood of an applicant falling in a specific cluster.

Limitations of the analysis

This study has implemented an econometric model following the logic of the regression discontinuity design to assess the impact of the reforms on specific variables of interest describing the socio-demographic characteristics of applicants and the characteristics of the properties where installations took place. The main limitation of this study is related to the fact that when using time as the variable separating the units which are part of the reformed scheme (treated units) from those in the pre-reformed scheme (control units), results may be influenced by the ability of applicants to choose which scheme they want to apply to, a choice which is influenced by the relative costs and benefits. It violates the assumption that the units cannot influence whether they are treated or not, which is needed to evaluate the policy's causal effect. Thus, as pre-agreed with BEIS, in order to mitigate this limitation, we estimated the effect of the announcement on the number of applications with the implicit assumptions that the ability of applicants to choose which scheme (reformed or pre-reformed) they want to apply to would manifest itself as an unusually high or low number of applications for each specific RHI technology. There is also the risk that a change in external factors or other aspects of the reform, such as the Assignment of Rights, may impact the results in the study, especially when having to leave a long period between the sample for the pre-reformed and the reformed scheme.

Appendix C: Tariff Levels

Table 50: Tariff levels

Technology type	Date of accreditation	Tariff Rate 2021/22 (p/kWh)	Adjusted by
Biomass	between 1 January 2017 and now	7.01	CPI
Biomass	between 1 July 2016 and 31 December 2016	5.08	CPI
Biomass	between 1 April 2016 and 30 June 2016	5.65	CPI
Biomass	between 1 January 2016 and 31 March 2016	5.9	RPI
Biomass	between 1 October 2015 and 31 December 2015	7.38	RPI
Biomass	between 1 July 2015 and 30 September 2015	8.19	RPI
Biomass	between 1 April 2015 and 30 June 2015	10.25	RPI
Biomass	between 1 January 2015 and 31 March 2015	12.79	RPI
Biomass	between 9 April 2014 and 31 December 2014	14.22	RPI
ASHP	between 15 December 2016 and now	10.92	CPI
ASHP	between 1 April 2016 and 15 December 2016	8.18	CPI
ASHP	between 01 April 2015 and 31 March 2016	8.37	RPI
ASHP	between 9 April 2014 and 31 March 2015	8.52	RPI
GSHP	between 15 December 2016 and now	21.29	CPI
GSHP	between 01 April 2016 and 15 December 2016	21.05	CPI
GSHP	between 09 April 2014 and 31 March 2016	21.91	RPI
Solar Thermal	between 01 April 2016 and now	21.49	CPI
Solar Thermal	between 09 April 2014 and 31 March 2016	22.38	RPI

Appendix D: 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 Domestic Applicant Survey

Table 51: [MATCHED SAMPLE FROM THE APPLICANT SURVEY AND THE HEAT PUMP SATISFACTION SURVEY] How satisfied overall are you with your RHT?

	%
Very satisfied	53.4%
Fairly satisfied	30.6%
Neither satisfied nor dissatisfied	3.5%
Fairly dissatisfied	3.6%
Very dissatisfied	2.7%
Too early to say	6.2%
Total	100.0%
Unweighted base	n = 1730

*Base: heat pump satisfaction survey respondents excl. 'don't know'

Table 52: [SINCE APRIL 2014] What is the household's approximate total income before tax and any other deductions?

	%
£0 to £10,399	2%
£10,400 to £20,799	8%
£20,800 to £31,199	13%
£31,200 to £41,599	11%
£41,600 to £51,999	11%
£52,000 to £103,999	22%

£104,000 to £129,999	4%
£130,000 or over	7%
Prefer not to say	22%
Total	100%
Unweighted base	n = 26539

* Base: All respondents excluding refusals / not answered

Table 53: [SINCE MAY 2016] What was the main heating system used to heat your home prior to installing RHT? (Please select any that apply)

	Technology (from application data)				
	ASHP (%)	Biomass (%)	GSHP (%)	Solar thermal (%)	Total (%)
Central heating – Oil	29.4%	40.4%	34.2%	22.1%	30.2%
Central heating - Gas (mains)	26.1%	5.0%	10.1%	44.2%	23.9%
Central heating - LPG/Other bottle gas	5.6%	5.4%	4.7%	3.8%	5.4%
Central heating - Electric boiler	2.8%	3.1%	1.6%	1.1%	2.5%
Central heating – a previous renewable heating installation	2.8%	5.0%	4.1%	5.0%	3.1%
Fixed room heaters - electric (including storage or Economy 7)	12.0%	15.2%	8.4%	6.1%	11.4%
Fixed room heaters - solid fuel (open fire/enclosed oven)	6.1%	18.8%	6.6%	5.7%	6.7%
No heating system previously in place	14.8%	12.4%	30.7%	12.1%	16.7%
Don't know	**	**	**	2.0%	**
Other (please specify)	5.3%	7.9%	4.2%	2.3%	5.2%

New build or barn conversion	3.8%	**	6.9%	1.1%	3.9%
Unweighted bases	n = 10801	n = 593	n = 1727	n = 465	n = 13586

* Base: All respondents excluding refusals / not answered; multiple response
** Denotes a percentage under 0.5%

Table 54: [SINCE APRIL 2014] Satisfaction with RHT overall

	%
Very satisfied/satisfied	83%
Neither	4%
Very dissatisfied/dissatisfied	5%
No answer	9%
Total	100%
Unweighted base	n = 26594

*Base: All respondents excluding refusals / not answered

Table 55: [SINCE APRIL 2014] % very satisfied/satisfied per type of technology

	2014	2015	2016	2017	2018	2019	2020	2021	2022
ASHP	88%	82%	85%	81%	82%	80%	82%	82%	79%
Biomass	83%	74%	82%	89%	89%	91%	79%	93%	87%
GSHP	93%	89%	86%	88%	87%	82%	87%	90%	76%
Solar Thermal	90%	85%	92%	90%	81%	86%	91%	92%	83%
Unweighted base	n = 26594								

*Base: All respondents excluding refusals / not answered

Table 56: [SINCE SEPTEMBER 2017] Has the RHT had any faults, required any unexpected maintenance or repairs since installation?

	Technology (from application data)				
	ASHP (%)	Biomass (%)	GSHP (%)	Solar thermal (%)	Total (%)

Yes, but was covered by installer/manufacturer warranty/contract	26.8%	32.3%	32.2%	18.5%	27.4%
Yes, and has incurred an additional cost	2.2%	4.3%	2.5%	6.3%	2.4%
No	69.7%	62.2%	64.2%	73.6%	68.9%
Don't know	1.2%	1.2%	1.1%	1.6%	1.2%
Unweighted bases	n = 9337	n = 373	n = 1282	n = 233	n = 11225

*Base: All respondents excluding refusals / not answered

Table 57: [SINCE APRIL 2014] Were any of the following difficulties faced in the overall process of installing the RHT in the home?

	Technology (from application data)				
	ASHP (%)	Biomass (%)	GSHP (%)	Solar thermal (%)	Total (%)
No difficulties were faced in the overall process of installing the RHT	56.1%	53.2%	52.0%	67.8%	56.1%
Lack of information or advice	8.3%	9.2%	8.0%	5.4%	8.1%
Unclear information or advice	13.3%	12.2%	12.5%	8.1%	12.7%
Not clear who to go to for advice	9.7%	11.7%	11.4%	8.2%	10.0%
Unsure which technology to choose	7.2%	10.9%	9.1%	7.5%	7.8%
Difficulties accessing a loan	2.3%	4.8%	2.0%	0.6%	2.4%
Finance package not available	3.4%	4.2%	5.2%	2.7%	3.7%
Storage space	7.5%	5.5%	6.6%	3.3%	6.9%
Difficult to integrate renewable heat technology with existing heating system	4.7%	4.1%	4.3%	3.4%	4.5%

Disruption caused by installation	15.6%	16.5%	21.3%	7.0%	15.9%
Required survey or engineer report before installation of the system	11.2%	6.9%	8.0%	5.9%	10.0%
Identifying or finding an installer	10.6%	13.0%	14.4%	11.0%	11.3%
Lack of trusted, local installers	12.1%	14.0%	14.7%	9.4%	12.4%
Sourcing suppliers of fuel/feedstock	0.6%	4.2%	**	0.6%	0.9%
Objections from family and friends	1.4%	1.2%	1.0%	**	1.2%
Objections from neighbours	1.5%	1.1%	1.1%	**	1.3%
Don't know	1.6%	**	0.7%	0.8%	1.3%
Other (please specify)	9.8%	3.9%	11.1%	5.2%	9.1%
Unweighted bases	n = 15266	n = 4288	n = 4003	n = 2889	n = 26446

*Base: All respondents excluding refusals / not answered; multiple response
** Denotes a percentage under 0.5%

Table 58: [SINCE APRIL 2014] Were any of the following difficulties faced in the overall process of installing the RHT in the home?

	%
No difficulties were faced in the overall process of installing the RHT	56%
Lack of information or advice	8%
Unclear information or advice	13%
Not clear who to go to for advice	10%
Unsure which technology to choose	8%
Difficulties accessing a loan	2%
Finance package not available	4%
Storage space	7%

Difficult to integrate renewable heat technology with existing heating system	5%
Disruption caused by installation	16%
Required survey or engineer report before installation of the system	10%
Identifying or finding an installer	11%
Lack of trusted, local installers	12%
Sourcing suppliers of fuel/feedstock	1%
Objections from family and friends	1%
Objections from neighbours	1%
Don't know	1%
Other (please specify)	9%
Total	100%
Unweighted base	n = 26446

*Base: All respondents excluding refusals / not answered; multiple response

Table 59: [SINCE MAY 2016] Reform influence summary variable

	%
Unaware of the reforms	60%
Not influenced	22%
Don't know influence	2%
Probably influenced	16%
Unweighted base	n = 4623

*Base: All respondents excluding refusals / not answered

Table 60: [SINCE MAY 2016] Reform influence summary variable by [SINCE APRIL 2014] Technology (from application data)

	Technology (from application data)	

	Technology (from application data)				
	ASHP (%)	Biomass (%)	GSHP (%)	Solar thermal (%)	Total (%)
Unaware of the reforms	62%	48%	55%	63%	60%
Not influenced	22%	31%	18%	18%	22%
Don't know influence	2%	1%	2%	1%	2%
Probably influenced	14%	19%	25%	18%	16%
Unweighted bases	n = 3172	n = 354	n = 754	n = 343	n = 4623

*Base: All respondents excluding refusals / not answered

Table 61: [SINCE APRIL 2014] How was the installation of the RHT funded?

	%
Savings	78%
Personal loan	11%
Finance agreement (where a third party funds all/part of the installation in return for all/part of the RHI payment)	1%
Other finance agreement, e.g. from manufacturer or installer	1%
Mortgage or remortgage	9%
Scottish or Welsh Government Scheme	4%
Renewable Heat Premium Payment (RHPP)	4%
Local authority scheme	0%
No upfront cost	0%
Would prefer not to say	1%
Other (please specify)	4%
Unweighted base	n = 26556

*Base: All respondents excluding refusals / not answered; multiple response

Table 62: [SINCE APRIL 2014] What is the household's approximate total income before tax and any other deductions?

	%
£0 to £20,799 (%)[49]	10%
£20,800 to £51,999 (%)[50]	35%
£52,000 to £130,000 or over (%)[51]	33%
Prefer not to say (%)	22%
Total	100%
Unweighted base	26,539

*Base: All respondents excluding refusals / not answered

Table 63: [SINCE APRIL 2014] Floorspace from database (m^2) by income levels under or over £52,000

	Under £52,000	Over £52,000	Prefer not to say	Total
<100	22%	10%	16%	17%
100-150	31%	20%	22%	25%
150-200	23%	23%	21%	22%
200-250	12%	18%	15%	15%
250<	12%	28%	26%	21%
Total	100%	100%	100%	100%
Unweighted bases	n = 11778	n = 8520	n = 6241	n = 26539

*Base: All respondents excluding refusals / not answered

[49] This grouped the component values of all responses in the following income ranges: £0 to £10,399 (%) + £10,400 to £20,799 (%)
[50] This grouped the component values of all responses in the following income ranges: £20,800 to £31,199 (%) + £31,200 to £41,599 (%) + £41,600 to £51,999 (%)
[51] This grouped the component values of all responses in the following income ranges: £52,000 to £103,999 (%) + £104,000 to £129,999 (%) + £130,000 or over (%)

Table 64: [SINCE APRIL 2014] Previous heating system (from application data) by income levels under or over £52,000

	Under £52,000	Over £52,000	Prefer not to say	Total
Boiler	62%	64%	57%	61%
Other	19%	15%	16%	17%
None	19%	21%	27%	21%
Total	100%	100%	100%	100%
Unweighted bases	n = 11715	n = 8452	n = 6188	n = 26355

*Base: All respondents excluding refusals / not answered

Table 65: [SINCE APRIL 2014] On or off the gas grid (from application data) by income levels under or over £52,000

	Under £52,000	Over £52,000	Prefer not to say	Total
On grid (%)	38%	37%	35%	37%
Off grid (%)	62%	63%	65%	63%
Total (%)	100%	100%	100%	100%
Unweighted bases	n = 11764	n = 8512	n = 6235	n = 26511

*Base: All respondents excluding refusals / not answered

Table 66: [SINCE APRIL 2014] Property type coded (from application data) by income levels under or over £52,000

	Under £52,000	Over £52,000	Prefer not to say	Total
Detached house or bungalow	72%	79%	80%	76%
Semi detached house or bungalow	18%	13%	13%	15%

Flat/maisonette/terraced house	10%	8%	8%	9%
Total	100%	100%	100%	100%
Unweighted bases	n = 9807	n = 7335	n = 5270	n = 22412

*Base: All respondents excluding refusals / not answered

Table 67: [SINCE APRIL 2014] Region (from application data) by income levels under or over £52,000

	Under £52,000	Over £52,000	Prefer not to say	Total
East	12%	13%	13%	12%
East Midlands	10%	9%	10%	10%
London	1%	2%	1%	1%
North East	3%	3%	2%	3%
North West	5%	5%	5%	5%
Scotland	19%	15%	16%	17%
South East	10%	16%	14%	13%
South West	16%	15%	16%	16%
Wales	8%	5%	6%	7%
West Midlands	6%	6%	6%	6%
Yorkshire and the Humber	9%	7%	7%	8%
Unknown	3%	3%	3%	3%
Total	100%	100%	100%	100%
Unweighted bases	n = 11778	n = 8520	n = 6241	n = 26539

*Base: All respondents excluding refusals / not answered

Table 68: [MERGED DATA bar LEGACY] Attribution categories by [SINCE APRIL 2014] What is the household's approximate total income before tax and any other deductions?

	£0 to £20,799 (%)[52]	£20,800 to £51,999 (%)[53]	£52,000 to £130,000 or over (%)[54]	Prefer not to say (%)	Total (%)
Would not have installed a new heating system without the RHI	41%	36%	36%	30%	35%
Would have chosen a non-RHT without the RHI	11%	11%	12%	11%	11%
Would have chosen a different RHT without the RHI	2%	2%	4%	3%	3%
Made no difference - would have installed the same heating system anyway	21%	26%	25%	26%	25%
Don't know	25%	25%	22%	30%	25%
Total	100%	100%	100%	100%	100%
Unweighted bases	n = 1884	n = 6680	n = 6257	n = 4202	n = 19023

*Base: All respondents excluding refusals / not answered

[52] This grouped the component values of all responses in the following income ranges: £0 to £10,399 (%) + £10,400 to £20,799 (%)

[53] This grouped the component values of all responses in the following income ranges: £20,800 to £31,199 (%) + £31,200 to £41,599 (%) + £41,600 to £51,999 (%)

[54] This grouped the component values of all responses in the following income ranges: £52,000 to £103,999 (%) + £104,000 to £129,999 (%) + £130,000 or over (%)

Table 69: [MERGED DATA bar LEGACY] Attribution categories by [SINCE APRIL 2014] On or off the gas grid (from application data)

	On grid (%)	Off grid (%)	Total (%)
Would not have installed a new heating system without the RHI	37%	34%	35%
Would have chosen a non-RHT without the RHI	11%	12%	12%
Would have chosen a different RHT without the RHI	3%	3%	3%
Made no difference - would have installed the same heating system anyway	25%	26%	25%
Don't know	24%	26%	25%
Total	100%	100%	100%
Unweighted bases	n = 6955	n = 12506	n = 19461

*Base: All respondents excluding refusals / not answered

Table 70: [MERGED DATA bar LEGACY] Attribution categories by [SINCE APRIL 2014] New Build

	No	Yes	Total
Would not have installed a new heating system without the RHI	39%	15%	35%
Would have chosen a non-RHT without the RHI	12%	11%	12%
Would have chosen a different RHT without the RHI	3%	5%	3%
Made no difference - would have installed the same heating system anyway	22%	42%	25%
Don't know	25%	27%	25%
Total	100%	100%	100%
Unweighted bases	n = 16694	n = 2421	n = 19115

*Base: All respondents excluding refusals / not answered

Data tables from the Heat Pump Satisfaction Survey

Table 71: [HEAT PUMP SATISFACTION SURVEY] How satisfied overall are you with your RHT?

	%	Unweighted bases
Very satisfied	65.9%	n = 1115
Fairly satisfied	25.9%	n = 459
Neither satisfied nor dissatisfied	3.1%	n = 61
Fairly dissatisfied	3.1%	n = 57
Very dissatisfied	2.0%	n = 38
Total	100.0%	n = 1730

*Base: heat pump satisfaction survey respondents excl. 'don't know'

Data tables from Subsidy Cost-Effectiveness Assessment

Table 72: Domestic RHI subsidy cost per unit of benefit, by technology- whole scheme, based on analysis up to May 2022.

	Heat pumps	Biomass	Solar thermal	All technologies
Programme Data				
Number of accredited installations	85,326	12,117	8,720	106,163
Number of installations included in SCEA analysis	69,581	10,643	5,187	85,411
Capacity installed for those in SCEA analysis (MW)	915	318	26	1,258
Renewable heat generation for whole scheme (Twh)	5.4	2.8	0.08	8.3
Carbon abatement for whole scheme (thousands of tonnes CO_2e)	750	543	8	1,301
Subsidy Cost Effectiveness Indicators				

Mean annual subsidy cost per kW of installed capacity (£)	235	223	176	234
Subsidy cost per MWh of renewable heat generated (£)	134	166	344	151
Subsidy cost per tonne of CO2e abated (£)	592	590	2,085	598
Value of Air Quality damage costs saved to date per £ of subsidy invested (£)	0.06	-0.15	0.01	-0.03

Source: Subsidy Cost-Effectiveness Assessment, Wavehill. Heat generation and carbon abatement estimates were calculated based on a sample of 80% of RHI applications for which full cost and benefit data was available, and then scaled up to represent the whole scheme.

Table 73: Cumulative heat generation and carbon abatement to end May 2022

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 – Pre reform	220	128	633	0.05
Heat Pumps – Post-Reform	245	150	513	0.07
Biomass – Pre reform	229	167	594	-0.15
Biomass – Post reform	180	132	491	-0.10
Solar Thermal – Pre reform	172	344	2,101	0.01
Solar Thermal – Post reform	193	346	1,934	0.01
All technologies – Pre-Reform	230	151	619	-0.05
All technologies – Post-Reform	240	149	515	0.06

Source: Subsidy Cost-Effectiveness assessment, Wavehill.

Data tables from Quasi-Experimental Impact Assessment

Table 74 Estimated impacts using scheme data arising from introducing tariff uplifts in the case of ASHPs installed in properties with gross heat demand smaller than 20,000 kWh.

Outcome variable	Estimated impact	Percentage change / change in odds ratio	Number of observations	Model
Floor space	0.12**	13%	35,190	Log linear regression
Annual generation intensity	0.19**	21%	28,074	Log linear regression
Gross heat demand	636*	5%	28,074	Truncated linear regression
Gross heat demand density	-0.03	-3%	28,074	Log linear regression
SPF	0.52**	15%	28,074	Linear regression
Owner Occupiers	2.64**	14	34,827	Binomial logit[55]
Detached	0.65**	1.92	34,827	Multinomial logit[56]
Semi-detached	0.69**	2	34,827	Multinomial logit[56]

Note: This table presents the estimated impact on each outcome variable of the tariff uplift in the case of ASHPs with gross heat demand below 20,000 kWh. The estimated impact is measured by the coefficient on the dummy variable indicating that an application took place after the introduction of the reform. Changes in the odds ratio are reported for the cases where a binomial logit or a multinomial logit is used, i.e. owner occupiers, detached and demi-detached. Percentage change is reported in all other cases. (**) and (*) indicate that the results are significant at the 99% and 95% confidence levels, respectively. The natural logarithm transformation is used in the log linear regression.

Table 75 The results for change in constant coefficient that represents the impact of the introduction of heat demand limits – biomass

Dependent variable	Estimated impact	Percentage change / change in odds ratio	Number of observations	Model

[55] The respondents not being owner occupiers were used as the baseline category. In the scheme data, "Ownership Type" has 3 categories: "Owner", "Private Landlord" and "Social Landlord". However, due to very few instances of the "Social Landlord" category a, "Private Landlord" and "Social Landlords" were grouped together to form the new category "Landlord." The variable therefore became binary.
[56] The category flats, maisonettes and terraced houses was used as baseline category.

Floor space	-0.10**	-10%	1,661	Log linear regression
Annual generation intensity	-0.05	-5%	1,413	Log linear regression
Gross heat demand	-5,572**	-16%	1,413	Truncated linear regression
Gross heat demand density	-0.05	-5%	1,413	Log linear regression
Owner occupiers	6.00**	400	1,661	Binomial logit[55]
Detached	-0.74**	0.48	1,661	Multinomial logit[57]
Semi-detached	-0.55**	0.58	1,661	Multinomial logit[57]

Note: This table presents the estimated impact on each outcome variable of the tariff uplift and heat demand limits in the case of biomass boilers. The estimated impact is measured by the coefficient on the dummy variable indicating that an application took place after the introduction of the reform. Changes in the odds ratio are reported for the cases where a binomial logit or a multinomial logit is used, i.e. owner occupiers, detached and demi-detached. Percentage change is reported in all other cases. (**) and (*) indicate that the results are significant at the 99% and 95% confidence levels, respectively. The natural logarithm transformation is used in the log linear regression.

Table 76 Estimated impacts using survey data arising from introducing tariff uplifts in the case of ASHPs installed in properties with gross heat demand smaller than 20,000 kWh.

Dependent variable	Estimated impact	Change in odds ratio	Number of observations	Model
Household with at least one member older than 55 years old	-0.79**	0.45	5,470	Binomial logit[58]
Household income II (£31,200 to £51,999)	-0.17**	0.85	4,460	Multinomial logit[59]
Household income III (£52,000 to £103,999)	-0.38**	0.69	4,460	Multinomial logit[59]
Household income IV (above £104,000)	-0.36**	0.70	4,460	Multinomial logit[59]
To claim RHI payments	-0.94**	0.39	5,596	Binomial logit[60]

57 The category flats, maisonettes and terraced houses was used as baseline category.
58 The respondents belonging to households with at least one member older than 55 years old were used as the baseline category.
59 The category household income I (up to £31,199) was used as baseline category.
60 The respondents not including RHI payments as a reason to apply to the RHI were used as the baseline category.

Financial savings	0.11	1.12	5,596	Binomial logit[61]
Increase efficiency	0.16	1.17	5,596	Binomial logit[62]
Rising energy prices	0.28	1.33	5,596	Binomial logit[63]
Grant availability	-0.66*	0.52	5,596	Binomial logit[64]
Environmental concerns	0.29	1.33	5,596	Binomial logit[65]
Reducing emissions	-0.26	0.77	5,596	Binomial logit[66]

Note: This table presents the estimated impact on each outcome variable of the tariff uplift in the case of ASHPs with gross heat demand below 20,000 kWh. The estimated impact is measured by the coefficient on the dummy variable indicating that an application took place after the introduction of the reform. When assessing the impact of household income, band I is dropped as it used as baseline against which the impact of the other band is measured. (**) and (*) indicate that the results are significant at the 99% and 95% confidence levels, respectively.

Table 77 Estimated impacts using scheme data arising from introducing tariff uplifts in the case of GSHPs installed in properties with gross heat demand bigger than 30,000 kWh.

Dependent variable	Estimated impact	Percentage change/change in odds ratio	Number of observations	Model
Floor space	-0.01	-0.8%	2,603	Log linear regression
Annual generation intensity	0.05	5.4%	1,800	Log linear regression
Gross heat demand	-6,601	-15.4%	1,800	Truncated linear regression
Gross heat demand density	-0.15**	-14.0%	1,800	Log linear regression
SPF	0.00	0.0%	1,800	Linear regression
Owner occupiers	6.89**	982	2,135	Binomial logit[55]

[61] The respondents not including financial savings as a reason to apply to the RHI were used as the baseline category.
[62] The respondents not including increased efficiency as a reason to apply to the RHI were used as baseline category.
[63] The respondents not including rising energy prices as a reason to apply to the RHI were used as baseline category.
[64] The respondents not including grant availability as a reason to apply to the RHI were used as baseline category.
[65] The respondents not including environmental concerns as a reason to apply to the RHI were used as baseline category.
[66] The respondents not including reducing emissions as a reason to apply to the RHI were used as baseline category.

Detached	-0.62**	0.5	2,135	Multinomial logit[67]
Semi-detached	0.04	1.0	2,135	Multinomial logit[67]

Note: This table presents the estimated impact on each outcome variable of heat demand limits in the case of GSHPs with gross heat demand over 30,000 kWh. The estimated impact is measured by the coefficient on the dummy variable indicating that an application took place after the introduction of the reform. Changes in the odds ratio are reported for the cases where a binomial logit or a multinomial logit is used, i.e. owner occupiers, detached and demi-detached. Percentage change is reported in all other cases. (**) and (*) indicate that the results are significant at the 99% and 95%, confidence levels, respectively. The natural logarithm transformation is used in the log linear regression.

Table 78 Estimated impacts using scheme data arising from the introduction of tariff uplifts and heat demand limits in the case of ASHPs installed in properties with gross heat demand bigger than 20,000 kWh.

Dependent variable	Estimated impact	Percent change / change in odds ratio	Number of observations	Model
Floor space	-0.10**	-9%	13,817	Log linear regression
Annual generation intensity	0.15**	17%	11,591	Log linear regression
Gross heat demand	-1,075	-4%	11,591	Truncated linear regression
Gross heat demand density	0.05	5%	11,591	Log linear regression
SPF	-0.05	-2%	11,591	Linear regression
Owner occupiers	6.11**	449	13,817	Binomial logit[55]
Detached	-0.48**	0.62	13,817	Multinomial logit[68]
Semi-detached	-0.61**	0.54	13,817	Multinomial logit[68]

Note: This table presents the estimated impact on each outcome variable of tariff uplifts and heat demand limits in the case of ASHPs with gross heat demand above 20,000 kWh. The estimated impact is measured by the coefficient on the dummy variable indicating that an application took place after the introduction of the reform. Changes in the odds ratio are reported for the cases where a binomial logit or a multinomial logit is used, i.e. owner occupiers, detached and demi-detached. Percentage change is reported in all other cases. (**) and (*) indicate that the results are significant at the 99%, and 95% confidence levels, respectively. The natural logarithm transformation is used in the log linear regression.

[67] The category flats, maisonettes and terraced houses was used as baseline category.
[68] The category flats, maisonettes and terraced houses was used as baseline category.

Table 79 Estimated impacts using survey data arising from introducing tariff uplifts and heat demand limits in the case of ASHPs installed in properties with gross heat demand bigger than 20,000 kWh.

Dependent variable	Estimated impact	Change in odds ratio	Number of observations	Model
Household with at least one member older than 55 years old	-0.20	0.82	5,470	Binomial logit[58]
Household income II (£31,200 to £51,999)	-0.38**	0.69	2,939	Multinomial logit[69]
Household income III (£52,000 to £103,999)	-0.00	1.00	2,939	Multinomial logit[69]
Household income IV (above £104,000)	-0.48**	0.62	2,939	Multinomial logit[69]
To claim RHI payments	-0.01	0.99	3,710	Binomial logit[60]
Financial savings	-0.21	0.81	3,710	Binomial logit[61]
Increase efficiency	0.34	1.40	3,710	Binomial logit[62]
Rising energy prices	-0.07	0.93	3,710	Binomial logit[63]
Grant availability	-0.01	0.99	3,710	Binomial logit[64]
Environmental concerns	0.57	1.77	3,710	Binomial logit[65]
Reducing emissions	0.25	1.28	3,710	Binomial logit[66]

Note: This table presents the estimated impact on each outcome variable of the tariff uplifts and heat demand limits in the case of ASHPs with gross heat demand above 20,000 kWh. The estimated impact is measured by the coefficient on the dummy variable indicating that an application took place after the introduction of the reform. When assessing the impact of household income, band I is dropped as it used as baseline against which the impact of the other band is measured. (**) and (*) indicate that the results are significant at the 99% and 95% confidence levels, respectively.

[69] The category Household income I (up to £31,199) was used as baseline category.

Appendix E: 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 80 – is a high-level 'if, then, because' statement summarising the aims of the RHI reforms, to inform the evaluation as a whole.

Table 80: Layer one of the theoretical framework for the evaluation of the reformed RHI

If … the Government subsidises renewable heat generation through to 2029, via applications to the RHI scheme up to 2022, 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 domestic RHI's four main areas of influence. These theories, set out in realist terms as 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[70], 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 domestic RHI, in what contexts and why?
- supply theory – who and what aspects of RHT supply were influenced by the domestic RHI, in what contexts and why?
- usage theory – who and what aspects of RHT usage were influenced by the domestic RHI, in what contexts and why?
- fuel theory – for biomass boilers, who and what aspects of fuel and feedstock supply were influenced by the domestic RHI, in what contexts and why?

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

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)
- each of the 'layer 3' CMOs in the 'generic' demand, supply, usage and fuel theory, including new CMOs suggested by the 'layer 4' theory

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

The wider mapping was used to inform periodic reviews and refinement of the generic mid-level theory and assessments of the high-level theory, taking into account the frequency with which different CMOs were observed, the contexts that were linked to different mechanisms and to which specific CMOs (even if not frequently observed) revealed different causal linkages between Contexts and Mechanisms, or between Mechanisms and Outcomes. The final assessments of these two levels of theory for the 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)
- this synthesis of findings on the 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 domestic RHI scheme.

The attachments below present:

- an overall assessment of the 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 domestic RHI has contributed to different outcomes in relation to the demand, supply and usage of RHTs, and the supply of fuel for these RHTs

Overall Assessment of the Domestic RHI's Contribution to High-level Theory

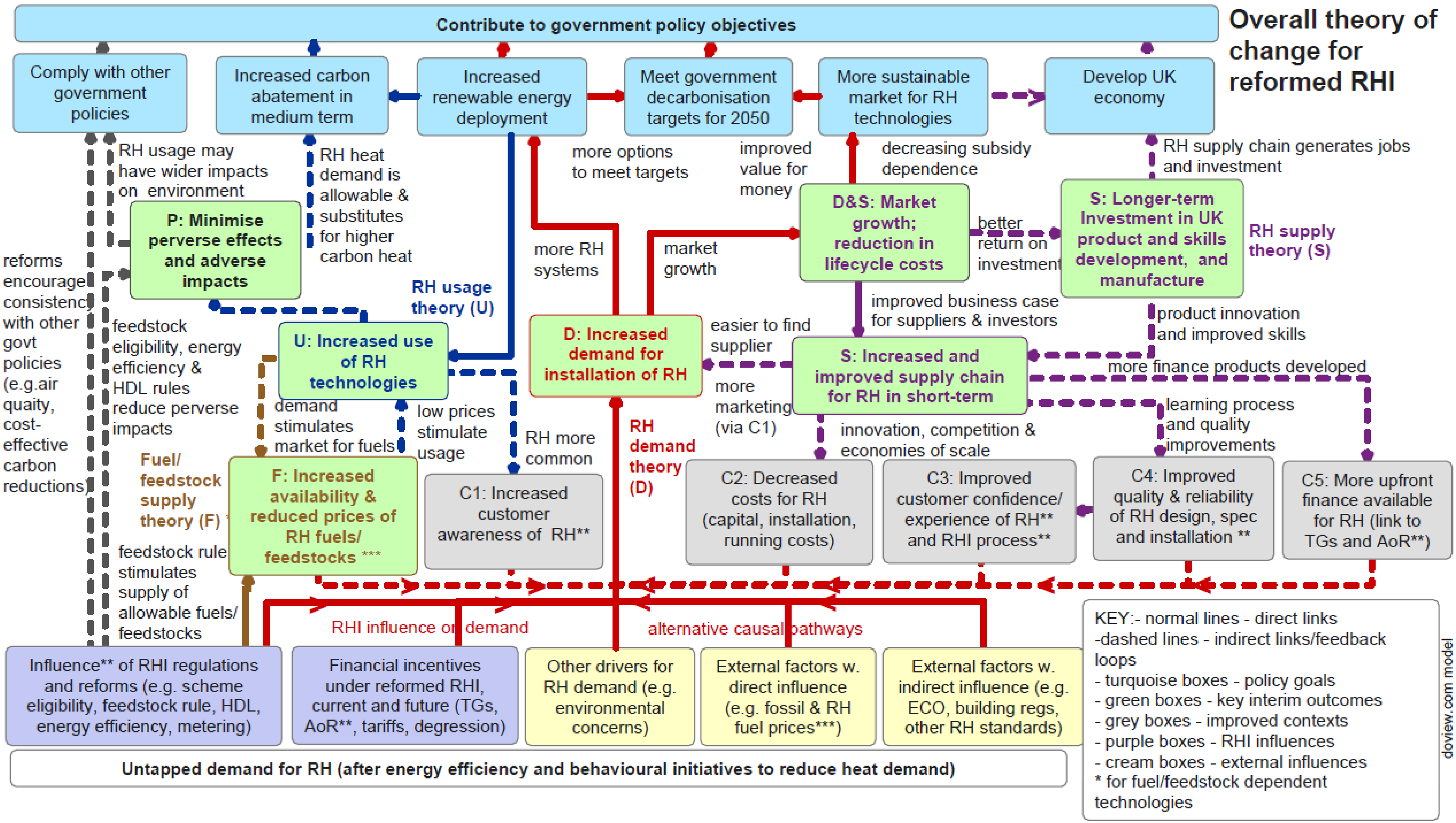
This section presents the overall 'policy map' (or high-level theory of change) for the domestic reformed RHI, which was developed in the early stages of the evaluation.

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
- the high-level theory diagram was used to identify key elements of the 'system' which BEIS sought to understand in more detail. In consultation with BEIS, more detailed realist theory was developed for four sub-systems: RH demand theory, RH usage, RH supply and RH fuel supply. Each of the sub-systems was described in terms of realist CMOs, presented in the next sub-section, which aim to describe how the causal linkages in the high-level theory diagram work. On the high-level theory diagram, 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, which was informed by the logic model that formed part of the Sustainable Markets Assessment (as presented in Appendix B)
    - RH fuel 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

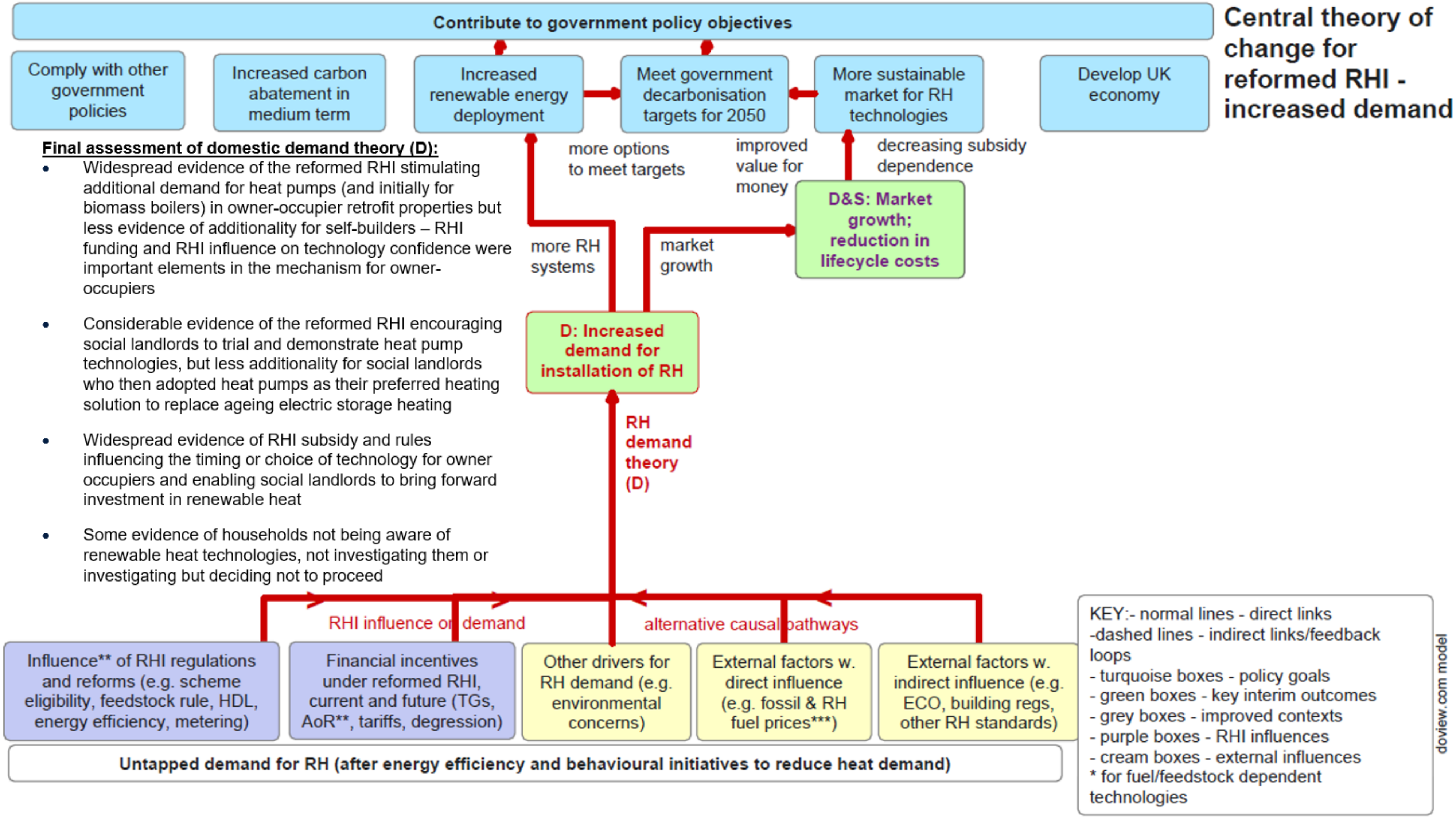
A brief 'walk through' of the Theory of Change is presented after the diagrams.



Central theory of change for reformed RHI - increased demand

Final assessment of domestic demand theory (D):

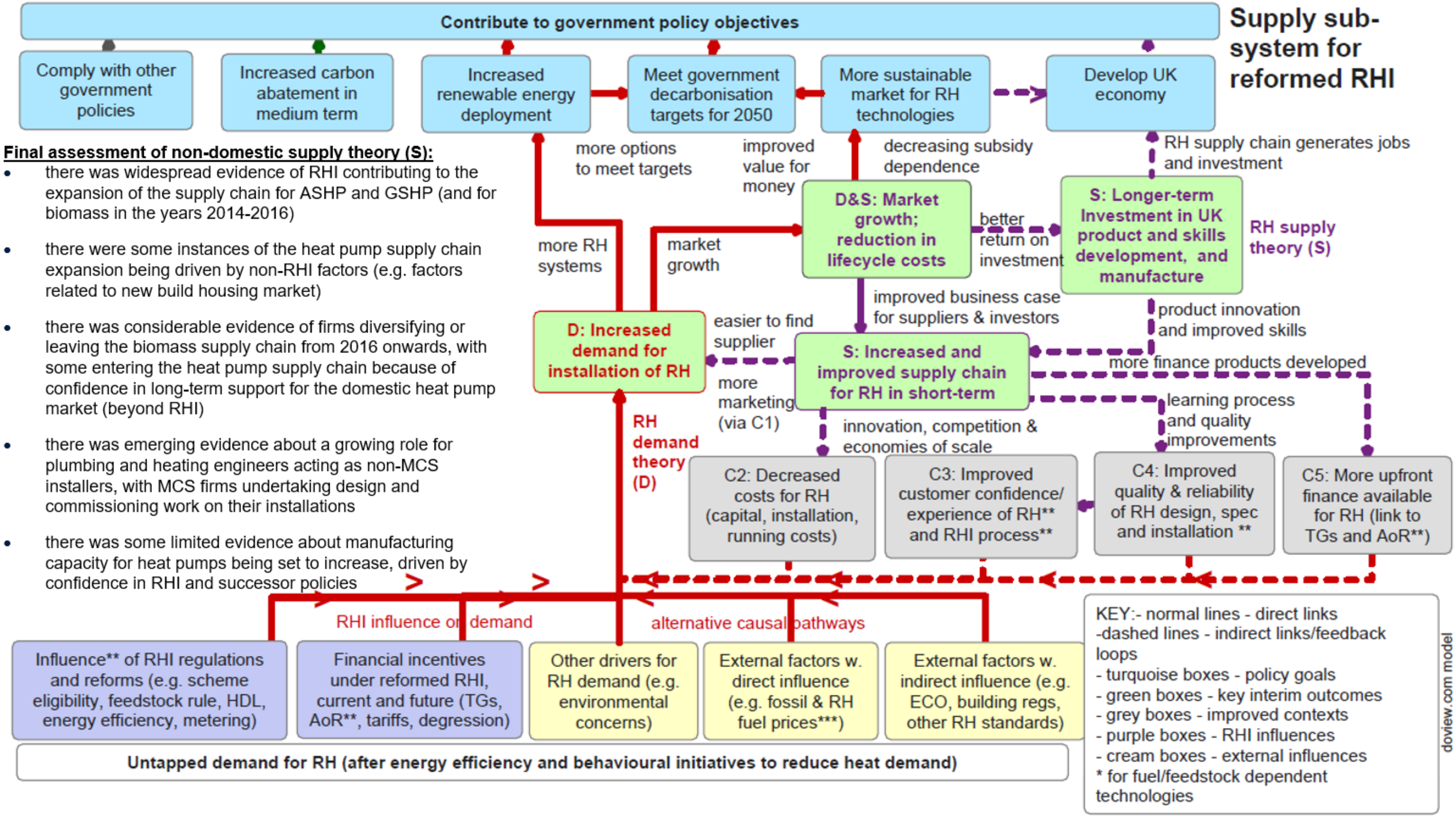
- Widespread evidence of the reformed RHI stimulating additional demand for heat pumps (and initially for biomass boilers) in owner-occupier retrofit properties but less evidence of additionality for self-builders – RHI funding and RHI influence on technology confidence were important elements in the mechanism for owner-occupiers
- Considerable evidence of the reformed RHI encouraging social landlords to trial and demonstrate heat pump technologies, but less additionality for social landlords who then adopted heat pumps as their preferred heating solution to replace ageing electric storage heating
- Widespread evidence of RHI subsidy and rules influencing the timing or choice of technology for owner occupiers and enabling social landlords to bring forward investment in renewable heat
- Some evidence of households not being aware of renewable heat technologies, not investigating them or investigating but deciding not to proceed



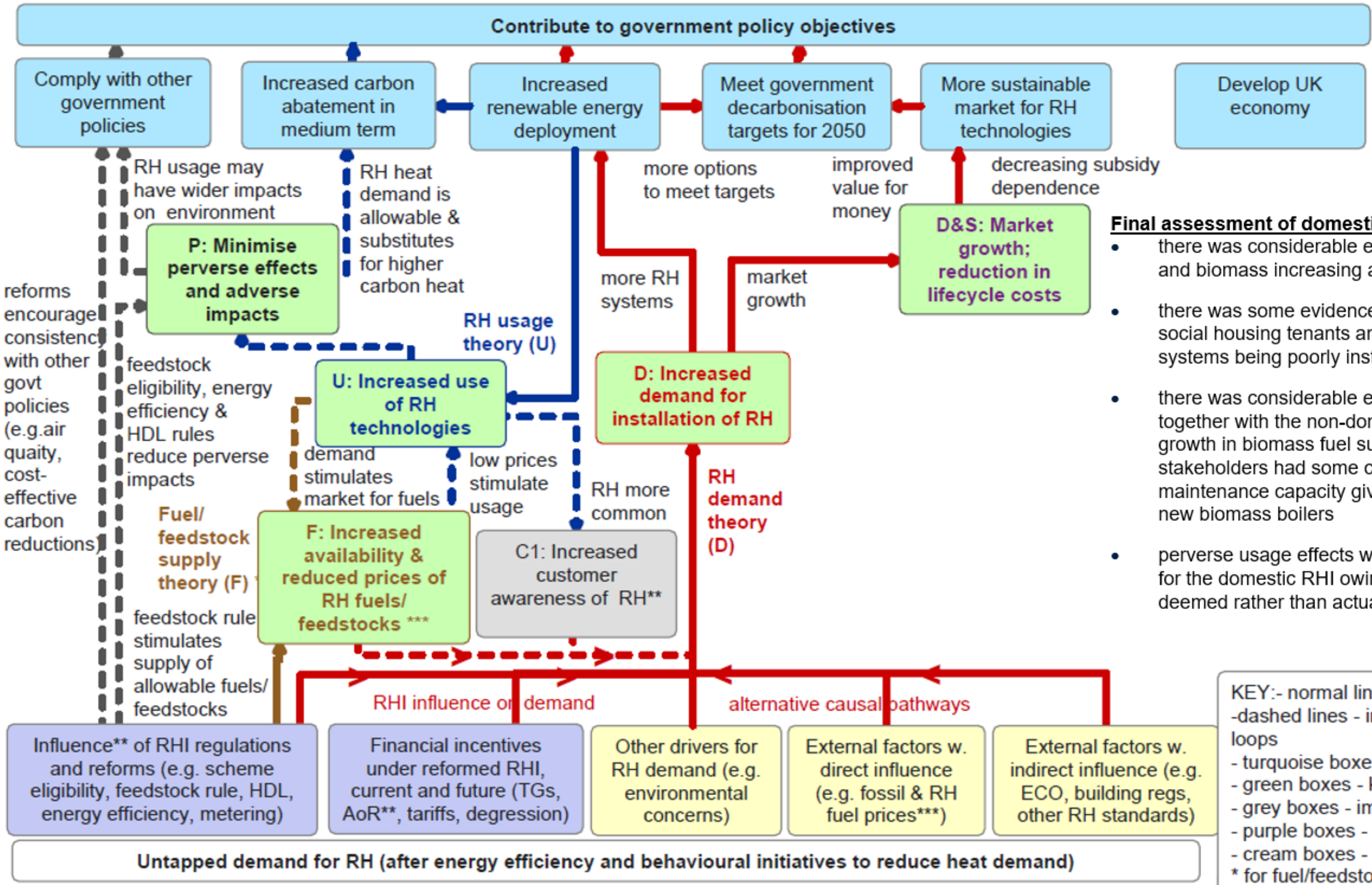
Supply sub-system for reformed RHI

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

- there was widespread evidence of RHI contributing to the expansion of the supply chain for ASHP and GSHP (and for biomass in the years 2014-2016)
- there were some instances of the heat pump supply chain expansion being driven by non-RHI factors (e.g. factors related to new build housing market)
- there was considerable evidence of firms diversifying or leaving the biomass supply chain from 2016 onwards, with some entering the heat pump supply chain because of confidence in long-term support for the domestic heat pump market (beyond RHI)
- there was emerging evidence about a growing role for plumbing and heating engineers acting as non-MCS installers, with MCS firms undertaking design and commissioning work on their installations
- there was some limited evidence about manufacturing capacity for heat pumps being set to increase, driven by confidence in RHI and successor policies



Fuel supply and wider impacts theory for reformed RHI



Final assessment of domestic usage (U) and fuel theory (F):

- there was considerable evidence of usage of heat pumps and biomass increasing as expected
- there was some evidence of comfort-taking by fuel poor social housing tenants and evidence of some heat pump systems being poorly installed or specified
- there was considerable evidence of the domestic RHI, together with the non-domestic RHI, stimulating early growth in biomass fuel supply, although supply chain stakeholders had some concerns about fuel supply and maintenance capacity given the decline in the market for new biomass boilers
- perverse usage effects were not observed to be a problem for the domestic RHI owing to payments being based on deemed rather than actual heat demand

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 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 domestic RHI was that:

- there was widespread evidence of the reformed RHI stimulating additional demand for heat pumps (and initially for biomass boilers) in owner occupier retrofit properties but less evidence of additionality for self-builders – RHI funding and RHI influence on technology confidence were both important elements in the mechanism for owner occupiers
- there was considerable evidence of the reformed RHI encouraging social landlords to trial and demonstrate heat pump technologies, but less additionality for social landlords who then adopted heat pumps as their preferred heating solution to replace ageing electric storage heating
- there was widespread evidence of RHI subsidy and rules influencing the timing or choice of technology for owner occupiers and enabling social landlords to bring forward investment in renewable heat
- there was also some evidence of households not being aware of renewable heat technologies, not investigating them or investigating but deciding not to proceed

Theory for the 'supply sub-system' of the reformed 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 the introduction of the AoR reforms)

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

- there was widespread evidence of RHI contributing to the expansion of the supply chain for ASHP and GSHP (and for biomass in the years 2014-2016)
- there were some instances of the heat pump supply chain expansion being driven by non-RHI factors (e.g. factors related to new build housing market)
- there was considerable evidence of firms leaving the biomass supply chain and diversifying into fuel or entering the heat pump supply chain from 2019 onwards, with confidence in long-term support for the heat pump (beyond RHI) being an important 'pull' factor
- there was emerging evidence about a growing role for plumbing and heating engineers acting as non-MCS installers, with MCS firms undertaking design and commissioning work on their installations
- there was some limited evidence about manufacturing capacity for heat pumps being set to increase, driven by confidence in RHI and successor policies

Theory for 'RH usage and fuel supply' for the reformed 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 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)
- as domestic RHI payments were made on the basis of deemed heat demand rather than actual heat demand, there was little incentive for perverse effects (e.g. inflation of heat demand) either before or after the reforms

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 boilers was expected to be affected by the reformed 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

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.

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

- there was considerable evidence of usage of heat pumps and biomass increasing as expected (i.e. renewable heat demand increasing)
- there was some evidence of comfort-taking (i.e. increased thermal comfort) by fuel poor social housing tenants, which would tend to reduce carbon abatement, but overall the policy did save carbon
- there was also some evidence of heat pump systems being poorly installed or specified
- there was considerable evidence of the domestic RHI, together with the non-domestic RHI, stimulating early growth in biomass fuel supply, although supply chain stakeholders had some concerns about fuel supply and maintenance capacity given the decline in the market for new biomass boilers
- perverse usage effects were not observed to be a problem for the domestic RHI owing to payments being almost always based on deemed rather than actual heat demand

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

Initial and revised generic CMOs for reformed domestic RHI

This section presents realist 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, as developed during the scoping phase of the evaluation. This is referred to as the 'initial realist theory'. For each area of theory, this is followed by the revised set of CMOs or 'revised realist theory'. These CMOs have been revised in the light of the mapping and synthesis of evidence across all the evaluation workstreams, as described above and 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 central Government's overall policy goals for the reformed RHI (as set out at the top of the overall policy map above).

Desirable	Neutral	Undesirable

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

- limited evidence (for a specific technology e.g. ASHP, GSHP, biomass)
- considerable evidence (for a specific technology e.g. ASHP)
- widespread evidence across both heat pumps and biomass

None of the qualitative research was targeted at demand or supply of solar thermal technologies so they are not included in this theory review.

Where there was no evaluation evidence for specific CMOs in the initial theory, these initial CMOs have been omitted from the revised theory. The CMOs have not been renumbered in the revised theory, in order that the relationship between the initial and revised CMOs should remain clear. This means that, where a CMO has been omitted from the revised theory, the numbering is not sequential.

CMOs in demand theory are prefixed with 'D' and numbered from 1 onwards (e.g. D1, D2 etc), while supply theory CMOs are prefixed 'S', usage theory CMOs with 'U' and fuel theory CMOs with 'F'. Where an initial CMO has been refined into multiple sub-CMOs in the revised theory, these are denoted with lower case letters (e.g. D1 in the initial theory has been refined into sub-CMOS D1a and D1b.

Each mechanism (M) is triggered by different contexts (C): so CMOs that apparently conflict with each other were actually observed for different groups, in different contexts. A few of the CMOs (e.g. those relating to RHI influence of the timing and scale of demand for RHTs) may be observed alongside other 'additionality' CMOs, and are clearly marked as such.

Table 81: 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) • 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)	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
		• 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 • Desire to make use of readily available biomass or waste feedstock	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)
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	Desirable	As above, plus one or more of: • More than one RH technology looks feasible	I/we would have invested in RH anyway but the details of RHI subsidy and rules influenced our choice of	Decide to proceed with a particular technology, at a particular scale or at a particular time because of RHI

Name	Desirability	Contexts	Mechanism	Outcome
choice, scale or investment timing'		• Flexibility in terms of scale/timing • Upcoming change in RH rules	technology, scale or timing	incentives and/or change in rules (possibly feedback to supply system contexts (S); 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 • Problems accessing capital/finance OR • Unwilling to invest OR • Not enough time for RH choice (e.g. emergency boiler replacement) 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
		• 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 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 82: 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
D1a - owner occupier retrofit – 'Increase in genuine demand[71] for RH which is additional (i.e. largely attributable to reformed RHI)'	Desirable	Widespread evidence for AHSP and GSHP throughout the domestic RHI (and for biomass during 2014-2016, prior to tariff degressions)	• Both rural/off-gas grid location AND on-gas grid locations (provided the latter was associated with strong environmental concerns) • Trigger point for new heating system in existing home (e.g. expanding, refurbishing, need to replace heating system) • Awareness of, and confidence in, heat pumps or biomass boilers • Access to trusted, informed RH adviser and installer	RHI subsidy makes it worthwhile for me to invest in this RH system now, rather than an alternative heating system AND RHI-supported growth in the market gives me confidence that this will meet my future heating needs acceptably compared to alternatives	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)[72]

[71] Genuine demand means demand that does not involve perverse effects (e.g. creating unnecessary heat demand in order to claim RHI).
[72] 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
			• Made aware of RHI through RH marketing by potential installers or recommendations from other users • Other contexts favourable for at least one RHT (e.g. for heat pumps - well insulated property(ies), appropriately-sized radiators and possibly underfloor heating – or upgrading possible to provide these; for biomass – availability of storage space, self-supply or confidence in fuel supply) • RH impacts acceptable to neighbours/planning authority • Attractive balance between costs/benefits/risks/ hassle, given relative capital and running		

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			costs of RH and other heating options – influenced by predicted RHI tariffs, fossil fuel and electricity prices, biomass fuel costs (where relevant) - 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 • Applicant has access to savings, bank loan or can extend mortgage • Applicant is willing to invest in a new heating system at this time		

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
D1b - technology trials by social landlords – 'Increase in genuine demand[73] for RH which is additional (i.e. largely attributable to reformed RHI)'	Desirable	Considerable evidence for ASHP and emerging evidence for shared ground loop GSHP (no evidence for biomass)	• Rural/off-gas grid locations AND other locations not suitable for gas (e.g. apartment blocks) • Strong environmental commitment • Strong commitment to reducing fuel poverty amongst social housing tenants • Concern that solid fuel, biomass systems and older electric storage heating systems are not generally suitable for vulnerable tenants • Trigger for investment (e.g. asset management system suggests refurbishment and new heating system	RHI funding enables us to make the financial case for trialling and demonstrating heat pump technologies, leading to this becoming our preferred heating solution for certain types of properties that are unsuitable for gas, where we would otherwise have installed modern electric storage heating	Social landlord adopts this technology as their preferred heating solution for specific types of properties that are unsuitable for gas heating (positive feedback to supply system contexts via market growth – D&S on overall policy map)[75]

[73] Genuine demand means demand that does not involve perverse effects (e.g. creating unnecessary heat demand in order to claim RHI).
[75] 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
			are due for this property; action triggered by complaint from, or concerns about, the tenant) • Awareness of, and sufficient confidence in, heat pump technology to embark on trial installations • Heat pump technologies exist that are suitable for social housing properties, and for operation by social housing tenants • Social housing quality standards require low carbon heating system, now or in foreseeable future (e.g. the Energy Efficiency Standard for Social Housing 2		

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			(EESSH2) in Scotland)[74] • Access to trusted, informed RH adviser and installer • Aware of RHI opportunities through marketing by potential installers or recommendations from other social landlords • Other contexts favourable for heat pumps (e.g. well insulated properties, appropriately-sized radiators and/or underfloor heating – or upgrading possible to provide these)		

[74] In Scotland, the Energy Efficiency Standard for Social Housing 2 (EESSH2) aims to maximise the number of homes in the social rented sector attaining EPC level C by 2020 and EPC level B by 2032. [74] Scottish Government (2019), *The Energy Efficiency Standard for Social Housing (EESSH2) Scottish Government Guidance for Social Landlords (Revised February 2019)*, February 2019. Available at: https://www.gov.scot/publications/energy-efficiency-standard-social-housing-eessh-scottish-government-guidance-social-landlords-revised-february-2019/ [Accessed 20 May 2020]

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• RH impacts acceptable to neighbours/planning authority • Attractive balance between costs/benefits/risks/ hassle, given relative capital and running costs of RH and those of alternative heating systems that would also meet required heating standards – influenced by predicted RHI tariffs, fossil fuel and electricity prices - perceived benefits include environmental/carbon and fuel poverty considerations • RHI subsidy forms a key part of the social landlord's financial considerations as to whether to install RHT		

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Social landlord has access to capital, loan or other sources of funds to meet upfront costs • Social landlord wants a 'preferred heating system' to facilitate maintenance and spares arrangements • Social landlord is willing to invest in heat pump system at this time		
D2a – self builders - 'Increased genuine demand for RH which is non-additional (i.e. would probably have gone ahead anyway without reformed RHI)'	Neutral	Considerable evidence for ASHP and GSHP (and also biomass during the period 2014-2016)	As above, plus: • New, self-build property • Environmental motivations • Planning requirements or building regulations relating to new build property (e.g. Future	I would probably have installed a renewable heating system in my self-build property anyway, because of my environmental motivations and planning requirements, even without RHI. RHI revenue is nice	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	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			Homes Standard[76], and the New Build Heat Standard in Scotland)	to have but represents a relatively small part of the overall budget for this major project.	
D2b – preferred solution for social landlords - 'Increased genuine demand for RH which is non-additional (i.e. would probably have gone ahead anyway without reformed RHI)'	Neutral	Considerable evidence for ASHP and emerging evidence for shared ground loop GSHPs	As for D1b above, but: • Landlord has already trialled and demonstrated heat pump technologies successfully • Tenants have become familiar with heat pump technologies and report improvements in comfort and decreases in bills relative to electric storage heating systems	We have now adopted ASHP (or shared ground loop GSHP) as our preferred solution for specific types of property, and would continue to install this technology in the absence of the domestic RHI. Our early decisions were influenced by RHI (see D1b), but this solution	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)

[76] The consultation on the 'Future Homes Standard' by the Ministry of Housing, Communities and Local Government ran from October 2019 to February 2020. The consultation document is available at: https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings [Accessed 22 May 2020]

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Social housing quality standards require low carbon heating system, now or in foreseeable future (e.g. the Energy Efficiency Standard for Social Housing 2 (EESSH2) in Scotland)[77] • Social landlord has adopted heat pumps as their preferred solution for certain types of housing	has now become established.	
D3 - mixed motives for owner occupiers/self-builders - 'Increased genuine demand for RH which is partly additional (i.e. some RHI influence on decision to proceed)'	Desirable	Considerable evidence for ASHP and GSHP (and also biomass during the period 2014-2016)	Mix of contexts from D1a and D2a: • Fairly strong environmental commitment	I invested in a well-specified RH system or a mixture of reasons: the subsidy helped me to decide to go ahead but it's difficult to	Potential applicant decides to proceed with a well-specified RH system now that is partly attributable to RHI scheme (positive feedback to supply system contexts via market

[77] In Scotland, the Energy Efficiency Standard for Social Housing 2 (EESSH2) aims to maximise the number of homes in the social rented sector attaining EPC level C by 2020 and EPC level B by 2032. [77] Scottish Government (2019), *The Energy Efficiency Standard for Social Housing (EESSH2) Scottish Government Guidance for Social Landlords (Revised February 2019)*, February 2019. Available at: https://www.gov.scot/publications/energy-efficiency-standard-social-housing-eessh-scottish-government-guidance-social-landlords-revised-february-2019/ [Accessed 20 May 2020]

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Property suitable for RH technology • Alternative heating options are expensive and/inconvenient to run or install (e.g. oil, LPG)	say what would have happened in the absence of RHI. RHI-supported growth in the market may have contributed to our confidence that the system will meet my future heating needs acceptably compared to alternatives.	growth – D&S on overall policy map)
D4a - RHI influenced timing or technology choice for owner occupiers - '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 influence across ASHP, GSHP and biomass	As above, plus some of these contexts: • More than one RHT looks feasible • Flexibility in terms of timing • Upcoming change in RH rules, upcoming tariff degression risks	I would have invested in RH anyway but the details of RHI subsidy and rules influenced my timing or choice of technology (for example: TIMING:	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)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			or upcoming end of domestic RHI • Post-reform tariffs for ASHP and GSHP are more favourable than for biomass • Experience of changes to previous renewables schemes (such as tariff degressions in the Feed-in-Tariff scheme)[78] • Social landlord channels RHI receipts back into housing department budget	applicant brought forward investment to avoid heat demand limits, to reduce the risk of tariff degression or to meet end of scheme deadline; 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.)	
D4b –social landlords bring forward investment - 'Increased genuine demand for RH which may not be	Desirable	Limited evidence for ASHP and	As above, plus some of these contexts:	We would have invested in RH anyway, over time, but RHI	Social landlord proceeds with RH investment earlier than they otherwise would

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

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
additional, but RHI influences investment timing' (not mutually exclusive from other CMOs)'		GSHP (not biomass)	• Flexibility in terms of timing • Upcoming change in RH rules, upcoming tariff degression risks or upcoming end of domestic RHI • Social landlord channels RHI receipts back into housing department budget, extending the budget for further investment	subsidy has encouraged and enabled us to do more, faster	(possibly feedback to supply system contexts - see overall policy map)
D5 – investigated but didn't proceed - 'No increase in genuine demand for RH - don't proceed with renewable heating system at this time'	Undesirable	Considerable evidence for ASHP, GSHP and biomass (primary data sources are the decline in applications for biomass; non-applicant research for heat pumps; and heat	Some of these contexts are present: • Time pressure to install new heating system (e.g. failure of existing system) • Adviser or installer not trusted, not well-informed about RH or not readily available within desired timescale	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) too slow OR insufficiently reliable, OR not feasible, OR too risky, 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
		pump installations being lower than anticipated by BEIS)	• Supply chain constraints for RHT or supporting works (e.g. likely delays in sourcing equipment) • RHI scheme and/or technologies perceived to be complex • Planning barriers to RHT installation • Expensive upgrades required to property to make it suitable for RHT • Lack of confidence in RHT or reservations about its performance • Concerns about running costs or maintenance of RHT • Unattractive balance between costs, benefits, risks, hassle, given RH capital and running costs	have too low a rate of return OR to involve too much upfront spending (OR to require costly external finance) relative to my other options	

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			compared to alternative system (e.g. electricity or fossil fuels) • Unwillingness or inability to access capital/finance (or high cost of finance) • Unwilling to invest at this time • For biomass: good quality biomass supplies not readily available or highly priced • For biomass: no space for biomass storage		
D6 – not eligible for RHI - 'Increased genuine demand for RH which is not eligible for RHI'	Neutral	Considerable evidence for ASHP and limited evidence for shared ground loop GSHPs	• New build properties (other than self-build) • Non-MCS accredited heat pumps • Building regulations for new housing	This RH investment is not eligible for RHI but, even without RHI, it is the best option to meet building regulations for	Decide to proceed with a well-specified RH system, without RHI (feedback to supply system contexts, but not attributable to reformed RHI)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			require low carbon heating solution	this new build property	
D7 – not worth the hassle of claiming RHI - 'Increased genuine demand for RH but RHI not claimed'	Neutral	Limited evidence for heat pumps	• Wealthy home owners • Heat pump installed as part of major refurbishment or self-build project • Environmental motivations • Building regulations require low carbon heating solution	It makes sense for me to install a heat pump as part of this major refurbishment or self-build project, but claiming RHI is not worth the hassle.	Decide to proceed with a well-specified RH system, without RHI (feedback to supply system contexts, but not attributable to reformed RHI)
D8 - 'aware but did not actively consider RHT or investigate'	Undesirable	Limited, indirect evidence (e.g. BEIS Public Attitudes survey)	Aware of RHTs, but some of these contexts apply: • Time pressure to install new heating system (e.g. failure of existing system) • Not aware how to find trusted adviser or installer	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	Potential applicant proceeds with a non-RHT without actively considering an RHT (no feedback to RHT supply theory in overall policy map)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential applicants	Outcome
			• Negative feedback from earlier experiences or other users • Assumptions about unsuitability, high cost, complexity or poor performance of RHTs • Unwilling to invest at this time • Aware of RHT but not aware of RHI scheme	were not suitable for us.	
D9 - 'not aware of what RHTs can offer'	Undesirable	Limited, indirect evidence (e.g. BEIS Public Attitudes survey)	• Not aware of what RHTs can offer	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 RHT supply theory)

Table 83: 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 but not because of reformed RHI'	Neutral	• Existing skills and capacity in RH • Strong commitment to renewable heat • Strong CSR values	We're primarily attracted to RH by social values rather than profitability, and already offer extensive RH capacity	Increase in capacity may not be attributable to RHI

Name	Desirability	Contexts	Mechanism	Outcome
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)
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

Name	Desirability	Contexts	Mechanism	Outcome
				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)
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	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)

Name	Desirability	Contexts	Mechanism	Outcome
		• 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)		
S8 - 'Shrinkage in RH capacity attributable to reformed RHI'	Undesirable	Previously active in supplying some element of RH market RHI reforms adversely affect their business contexts (e.g. too risky, rules too difficult to meet, too much competition)	I/we are withdrawing from the RH market or reducing our capacity, primarily because of the RHI reforms	Decision to reduce/withdraw from RH supply or services that is primarily attributable to RHI scheme (negative feedback to contexts for demand theory)

Table 84: 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	Widespread evidence for ASHP and GSHP (and for biomass in years 2014-2016)	• Confidence in ongoing Government support for this RHT market, for several years ahead • Aware of RHI (and reforms) and successor policies (e.g. Boiler Upgrade Scheme) • 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 • 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
S2 – 'expand RH supply chain but not because of reformed RHI'	Neutral	Some evidence for heat pumps	• Installers/manufacturers who take a long-term view of the heat pump market, beyond RHI • Installers/manufacturers targeting the new build housing market or commercial market, rather than existing housing stock	We see good potential in the heat pump market that are not dependent on RHI.	Potential suppliers expand short to medium-term capacity, but not attributable to RHI (positive feedback to contexts for demand theory in overall policy map)
S3 – 'enter RH supply chain because of improvements to RH market, supported by RHI'	Desirable	Considerable evidence for heat pumps from 2019 onwards	As above plus: • 'Push' factors (such as downturn in solar PV market at end of Feed-in-Tariff; decline in domestic or non-domestic biomass market post-degression) encourages firms to look for new opportunities • 'Pull' factors (e.g. improvements to RHTs, awareness, costs and reliability, confidence in future Government support for heat pump market during and beyond RHI scheme)	'Push' and 'pull' factors, together with confidence in long-term support to the market from RHI and successor policies, make us ready to enter the installation or manufacture supply chain for heat pumps	New companies enter specific elements of the RH supply chain, offering selected services to potential applicants (positive feedback to contexts for demand theory)

Name	Desirability	Level of evidence	Contexts	Mechanism for potential suppliers	Outcome
			• Improved demand contexts and increased demand (D) • Capability to offer services within the RH supply chain		
S4 – 'enter RH supply chain because of demand from customers'	Desirable	Limited evidence for heat pumps	• Plumbing and heating engineers • Not MCS accredited - MCS accreditation involves a cost in terms of money and time. • Capable of installing but not designing or commissioning heat pump systems • Links to MCS accredited body via an 'umbrella scheme' operated by an installer or manufacturer	Our existing customers want us to install heat pumps and we can do this by linking up with an MCS accredited body. This will gradually build our skills in heat pump installation and maintenance, but it's not currently worthwhile for us becoming MCS accredited for these services.	New companies enter the supply chain for heat pumps and are upskilled in heat pump installation.
S5a – 'improvements in RHT or supply chain largely attributable to reformed RHI'	Desirable	Limited evidence for heat pumps (e.g. performance improvements	Mix of the contexts above PLUS • Confidence in stability of RHI policy and tariff levels to 2022, and longer term growth in RH market beyond 2022 (premised on confidence in policies such as the Boiler Upgrade Scheme (BUS) and its successors)	RHI and successor policies give us the confidence to make a long-term investment in RH capacity (e.g. product development or innovation, research,	Potential suppliers decide to expand/improve long-term capacity for RH supply or services that is primarily

Name	Desirability	Level of evidence	Contexts	Mechanism for potential suppliers	Outcome
		for ASHP; smaller units developed for GSHP)	• Technical capability for innovation in heat pump design	manufacture, premises)	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 heat pumps	• Existing skills and capacity in RH • Strong commitment to renewable heat • Reluctance to premise business strategy on RHI support (e.g. because of ideological opposition to subsidies or because of long-term view of RHT market) • Confidence in RHT markets that are not eligible for, or less dependent on, RHI (e.g. because of changes to other funding or regulations)	We have confidence to make a long-term investment in RH capacity (e.g. product development or innovation, research, manufacture, premises) because of other factors (e.g. support for heat networks from other sources; changes to building standards) even without RHI support	Potential suppliers decide to expand/improv e long-term capacity for RH supply or services that is not attributable to RHI scheme (positive feedback to contexts for demand theory)

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 biomass suppliers after 2014-2016	• Reduction in demand for biomass installations after domestic and non-domestic RHI degressions of 2014-2016, coupled with other policy factors affecting multi-technology installers (e.g. degressions in the Feed-in-Tariff scheme for renewable electricity) • Heat demand limits further reduce potential for biomass installations in large domestic off-gas properties • Tariff rebasing for biomass does not bring tariffs back to pre-degression levels • MCS accreditation involves a cost in terms of money and time.	I/we are withdrawing from the RH market or reducing our capacity, primarily because of RHI degressions in the biomass market, combined with heat demand limits for large properties – the tariff rebasing introduced by reforms was insufficient to reverse this. It's no longer worthwhile for us to be MCS accredited for these services.	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 biomass	• Business takes a strategic approach to RH market • The business has the capability to diversify into other aspects of RH market (e.g. equipment supply, equipment maintenance or fuel supply, domestic market) or 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 diversify 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)

Table 85: 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 (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)

Name	Desirability	Contexts	Mechanism	Outcome
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 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)

Name	Desirability	Contexts	Mechanism	Outcome
U6 - 'Problems using RH system owing to fuel problems'	Undesirable	• 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; 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 86: Revised usage theory

Name	Desirability	Level of evidence	Contexts	Mechanism for accredited RHI applicant	Outcome
U1- 'Increased usage of RH systems, as expected, attributable to RHI'	Desirable	Widespread evidence for ASHP, GSHP and biomass boilers	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 deemed heat demand, 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)

Name	Desirability	Level of evidence	Contexts	Mechanism for accredited RHI applicant	Outcome
U2- ‘Higher than expected usage of RH, owing to comfort-taking’	Neutral	Some evidence for ASHP; limited evidence for GSHP	• ASHPs serve social housing properties previously at risk of fuel poverty • Social housing tenants previously had ageing electric storage systems with Economy 7 or similar tariffs • Social housing tenants well-briefed and supported in using heat pump systems	Social housing tenant enjoys higher level of comfort and lower bills because of RHI-supported replacement of ageing electric storage heating with modern ASHP or shared ground loop GSHP, and being switched to a more favourable tariff	Heat demand for this accredited applicant is higher than previous levels but energy bills are still reduced (possible negative feedback to carbon/cost-effectiveness outcomes, depending on extent of comfort-taking)
U3- ‘Unexpected usage of RH system, owing to installation or specification problems’	Undesirable	Some evidence for heat pump systems	Some of the following contexts apply: • System poorly specified or installed • Energy efficiency of building is poor	Our RH system works but is less efficient or more hassle than expected, so our heating is inadequate and/or our heating costs are higher than we expected	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
			• User(s) poorly briefed on how to use system		

Table 87: 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)
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	Expand capacity for, improve quality of, reduce cost of or extend area of RH fuel or feedstock supply for use in

Name	Desirability	Contexts	Mechanism	Outcome
			us to use our supply of RH fuels or feedstock in our own RHI system	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, attributable to RHI'	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 or increased competition from imports) so we are reducing our supply of certain RH fuels/feedstocks	Decrease in supply of certain fuel/feedstocks attributable to RHI (negative feedback to contexts for RH demand (F), RH usage (U) and linkages to other wider impacts (P))
F5 – 'No increase in	Undesirable	AT LEAST ONE of the following contexts fails:	Despite RHI support and	No increase in supply of RH fuels

Name	Desirability	Contexts	Mechanism	Outcome
fuel/ feedstock supply, despite RHI'		• 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)	reforms, it's not worth us supplying increased volumes of fuels or feedstocks, or supplying these at reduced cost	and feedstocks (no positive feedback to contexts for RH demand (F), RH usage (U), and no influence on wider impacts (P))

Table 88: Revised RH fuel and feedstock theory

Name	Desirability	Level of evidence	Contexts	Mechanism for fuel suppliers	Outcome
F1- 'Increased supply of good quality fuel, attributable to reformed RHI'	Desirable	Considerable evidence for biomass (particularly prior to biomass degressions in 2014-2016)	• Aware of RHI (and reforms) • Ready access to fuel supply • RH market appears to be profitable for us, compared to other potential outlets for these fuels • RH fuels supply fits corporate values • Relevant skills/client base for RH fuel supply • Confident in consistency of fuel supply source • Confident in customer appeal of these fuels • Confident in stability of RHI policy and tariff levels to 2021, and longer term growth in RH market • Increase in demand for biomass systems (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 supply these fuels at reduced cost	Potential fuel suppliers expand capacity for, improve quality of, reduce cost of or extend area of RH fuel supply (positive feedback to contexts for demand (F), but possible impacts on alternative markets for fuels and wider environment (P)

Name	Desirability	Level of evidence	Contexts	Mechanism for fuel suppliers	Outcome
F3- 'Increased good quality supply, not attributable to reformed RHI'	Neutral	Limited evidence for biomass	• External factors lead to increase in biomass supply (e.g. winter storms increase the supply of wood)	We're expanding RH fuel supply because of other external factors drivers, not RHI	Potential fuel suppliers increase supply of or quality of certain fuels but not attributable to RHI (positive feedback to demand theory (F), but not attributable to RHI)
F4- 'No increase in good quality fuel supply, despite RHI'	Undesirable	Limited evidence for biomass	Some of the following contexts apply: • Increased regulations constrain the economics of fuel supply • Insufficient confidence in Government support for biomass market in longer term to invest in fuel supply increase • External factors affect biomass supply in UK	Despite RHI support and reforms, it's not worth us supplying increased volumes of fuels, 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 (no feedback to contexts for RH demand (F) or RH usage (U), and no influence on wider impacts (P))

This publication is available from: www.gov.uk/government/publications/reforms-to-the-domestic-renewable-heat-incentive-evaluation.

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