Department for
Energy Security
& Net Zero

Evaluation of the Green Homes Grant Voucher Scheme (GHGV)

Outcome and economic evaluation – Technical Annex

Ipsos with BRE, Energy Saving Trust and UCL

Research Paper Number 2023/028

June 2023

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Annex 1: Methodological approach to the final impact and economic outcome evaluation

This Annex provides an overview of the evaluation scope, analytical approach, data and limitations of the evaluation of the Green Homes Grant Voucher Scheme (GHGVS).

A.1.1 Evaluation scope

This report focussed on the evaluation questions listed in the evaluation matrix in Table A1.1 below. The evaluation matrix sets out the core evaluation questions, sub-questions developed by the evaluation team, and the extent to which these have been covered in this report. This report focuses on the final assessment of the outcome and economic evaluation questions. Process evaluation questions have been fully covered in the process evaluation report[1] (February 2022) and the interim outcome and economic evaluation report[2] (August 2022). The interim outcome and economic evaluation also covered several outcome and economic evaluation questions, as detailed in Table A.1.1 below.

Table A.1.1: Final outcome and economic evaluation scope (evaluation matrix)

Evaluation questions	Sub-evaluation questions	Where covered in the Report
Additionality / complementarity How did the voucher scheme interact with other BEIS schemes? What was the extent of participation in multiple schemes Were similar installers used for other stimulus schemes? To what extent were installations delivered	Interaction: Were the same houses / consumers eligible for GHGVS + other schemes (if so, which)? What conditions underpinned multi-programme eligibility? To what extent were applicants aware of the ability to apply to 1+ and did they understand how to do this? Multiple scheme participation: What were the implications (+ve/-ve) of multi-programme eligibility? How many homes actually benefitted from 1+ scheme and what was the scale in GBP? Installer overlap: What was the overlap in terms of installers working across	Chapter 3 of the interim outcome evaluation

[1] Evaluation of the Green Homes Grant Voucher Scheme (GHGV): Process Evaluation Report. BEIS, 2022. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1131110/green-homes-grant-vouchers-phase-1-process-evaluation-report.pdf

[2] Evaluation of the Green Homes Grant Voucher Scheme (GHGV): Interim Outcome and Economic Evaluation Report. BEIS, 2022. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1131112/green-homes-grant-vouchers-phase-2-interim-outcome-report.pdf

Evaluation questions	Sub-evaluation questions	Where covered in the Report
which were not possible through other policies?	GHGVS + other schemes? What were the implications (+ve/-ve) of this? Additionality: Are there any installations which have been possible through GHGVS, but not others and/or more prominent in GHGVS than others? What are they and what are the explanations?	
Energy, carbon and bills savings How effectively has the scheme delivered energy, carbon and bills savings?	Have participating households seen a reduction in their energy consumption post-installation? Why?[3] Bearing in mind fluxes in electricity and gas markets, what would have been the effects of the measures on bills without the flux in prices? Which households have seen the greatest reduction? Why? Which types of installations have seen the greatest reduction in energy consumption, carbon and bills savings? Why? What does the above tell us about the targeting of the scheme and any opportunities that were maximised / could have been better optimised?	Chapter 6 of this report, except for considerations of scheme targeting, which is covered in Chapters 3 and 4 of the process evaluation and Chapter 2 of the interim outcome evaluation.
Improved health and well-being and/or warmer homes How effectively has the installation of energy efficiency / low-carbon heating measures led to property occupants improved health and well-being and/or warmer homes?	To what extent are the measures likely to have reduced the risk of mould in houses? To what extent are the measures likely to have made homes warmer? To what extent are the installations completed through the scheme likely to have led to improvements in the health of participating households? Which profile of applicant, household and installation are more likely to have seen an improvement in their health? What is the difference in outcome for classified	Chapter 7 of this report

Evaluation questions	Sub-evaluation questions	Where covered in the Report
	fuel poor (proxy assessment) vs. classified non-fuel-poor? How do these findings compare to benefiting households' perceptions of improved health? What factors appear to be driving (a) modelled health outcomes, and (b) perceived health outcomes? What are the barriers to improved health (modelled / perceived)?	
Consumer demand for installation of homes and low-carbon heating measures How effectively has the scheme driven consumer demand for installation of homes and low-carbon heating measures? What have we learned about consumer preferences from the choice of primary and secondary measures in combination with any additional unrelated building work?	How effective was the scheme in attracting consumers to install measures which wouldn't have otherwise had them installed? How, if at all, does this differ by household profile and by type of measure? What can the scheme data (and consultations with applicants) tell us the factors driving applications for primary vs. secondary measures? What are applicants (and other stakeholders)' views on the scheme's distinction between secondary and primary measures – what (if any) effect did this have on applicant participation, installation choice, satisfaction with the scheme, and outcome (e.g. energy efficiency)? What do households who have participated in the scheme say about their interest in / willingness to install future measures? Does this differ for applicants (in general) vs. those who have had installations completed, and by installation type?	Chapter 4 of the interim outcome evaluation and Chapter 11 of this report
Fuel poor and low-income customers How effectively has the scheme engaged low-income households,	How does the proportion of fuel poor households applying for the scheme compare to the proportion of fuel poor households nationally?	Chapter 5 and Annex 5 of this report

Evaluation questions	Sub-evaluation questions	Where covered in the Report
including those at risk of fuel poverty?	What measures did fuel poor households request? Did this differ at all from other applicants? To what extent are the measures implemented likely to have taken households classified as fuel poor out of fuel poverty?	
Supply Chain Outcomes How effectively has the scheme supported the creation or preservation of FTE jobs involved directly and indirectly in delivering? How effectively has the scheme driven the development of skills needed to meet Net Zero? Did the scheme contribute to the creation of long-term growth in the energy efficiency / low-carbon heating supply chain?	Jobs: Did participating firms recruit new employees as a result of participating in / in preparation for the scheme? Did they retain these jobs? Did the scheme have any (+ve / -ve) effect on job retention / loss? What are the employment figures for firms before and after the schemes start and closure, as compared to a counterfactual analysis? Skills: To what extent did participating installers participate in training? Through what mechanisms did the scheme encourage and/or enable training? What were the reasons for non-participation in training? What were the barriers to training? Considering these findings all together, what value (if any) did the scheme training programme offer? Could anything have been done differently / better? Business growth: What are the growth figures for firms before and after the schemes start and closure, as compared to a counterfactual analysis? Based on qualitative data and an analysis of the variables between participating firms (within the results) what factors appear to have driven these results?	Jobs: Chapter 9 and Annex 7 of this report Skills: Chapter 5 of the process evaluation and Chapter 5 of the interim outcome evaluation. The skills training competition was evaluated separately. Business growth: Chapter 9 of this report and Chapter 8 of the interim outcome evaluation
Quality To what extent did the scheme deliver energy efficiency installations which were high quality?	What does the scheme data tell us about quality? What do auditors report on the overall quality of installations within the scheme? To what extent does the profile of installations complete support this?	Chapter 8 of this report

Evaluation questions	Sub-evaluation questions	Where covered in the Report
	What do applicants perceive to be the quality of the installations completed? What do these findings tell us about the effectiveness of the scheme in supporting higher quality installations? To what extent were the results likely to have been driven by scheme design?	
Fraud and Gaming To what extent has the scheme been affected by fraud and gaming?	What does the scheme data tell us about fraud and gaming? Is there sufficient data to profile which types of household / consumer might have been more / less likely to be a victim of the fraud? Do applicants report (further) instances of fraud and gaming? How were instances of this dealt with and what were the scheme mechanisms for prevention, reporting and dealing with fraud and gaming? What do these findings tell us about the effectiveness of the scheme in mitigating against fraud and gaming? To what extent were the results likely to have been driven by scheme design?	Chapter 4 of the process evaluation and Chapter 7 of the interim outcome evaluation
To what extent did the scheme deliver energy efficiency installations which represented good value for money?	What is the average cost of installing measures in homes applying and redeeming vouchers under the scheme? How does this vary by measure or property type? What benefits have been achieved by GHGVS? What costs are incurred by the different actors involved in the scheme? Have there been differences in costs and benefits between the different subgroups of participants?	Chapter 10 of this report

A.1.2 Analytical approach

A.1.2.1 Overarching approach

For each anticipated outcome of this outcome evaluation, we have assessed: (a) actual change – i.e., whether anticipated outcomes occurred, and (b) whether these were caused by the scheme (attribution / contribution). This is reflected in the structure of Chapters 5 to 11 (except Chapter 10: Value for Money) which describe how the scheme intended to achieve each outcome (as per the Theory of Change (ToC)); evidence of a change in the outcome area over the time period of the scheme; and an exploration of the scheme's contribution to the observed change.

To support our analysis, and to ensure as robust an analysis as possible, we applied a four-step approach to the outcome evaluation.

Step 1: Iterative understanding the ToC and it's causal hypotheses. This step also had the following sub-steps:

1. The evaluation team participated in a ToC workshop, conducted in November 2020 and led by BEIS. The workshop was attended by 10-20 policy officers from BEIS working on the Green Economic Stimulus package. The ToC built upon the strategy and hypotheses set out by the department.

2. As part of the process evaluation final report, produced in August 2021, Ipsos conducted a review of the scheme ToC. We reviewed the ToC assumptions against the findings of the process evaluation to assess validity. We found that some of the assumptions were valid, but that others had proven to be invalid.

3. At the interim stage of the outcome and economic evaluation, we presented this understanding to BEIS policy stakeholders via (a) a presentation of the process evaluation findings, and (b) a ToC workshop, in which we presented six outcome pathways[4] and their associated assumptions. These outcome pathways were based around those identified by BEIS at the beginning of the evaluation as reflecting the scheme's intended benefits. We posed questions to BEIS and thus derived additional assumptions and hypotheses to test. We followed up this workshop with interviews with three BEIS policy officers and one TrustMark representative to further understand these in detail. On this basis we set our framework for investigation (see Table A1.1 above) and developed the data collection and analysis tools.

4. The final presentation of the ToC and outcome pathways in this report follow a slightly different structure to the pathways as presented and discussed in the ToC workshop. It has been updated to reflect the evaluation findings which have revealed more nuances to GHGVS ToC.

Step 2: Outcome-specific analysis. Different techniques described briefly below in the next subsection ('approaches to outcome assessment') were used to measure the distinct outcomes of the scheme.

Step 3: Triangulation. For several of the workstreams (quality, benefits to households, market outcomes), several strands of research (e.g. scheme data analysis, TrustMark data analysis, survey data and qualitative interviews) provided evidence that informed the outcome

[4] Energy efficiency, growth of the low-carbon heat market and consumer behaviour, fuel poverty, increased employment and improved skills, quality, and fraud and gaming.

assessment. Where this was the case, we triangulated the evidence. To ensure a joined-up robust analysis, we held several internal analysis meetings (between Ipsos, UCL and EST) to draw agreement on the findings.

Step 4: Developing causal explanations and lessons for future policymaking. To understand why and how the scheme does / does not contribute to different outcomes and to explain any variations within our findings according to type of applicant, installer and/or measure, we cross-compared evidence and dug into the literature to contextualise our findings. To do this we optimised the expertise we have within our team to consider explanations and further elaborated the nuances of the ToC and its assumptions and their validity.

A.1.2.2 Approaches to outcome assessment

Coverage of fuel-poor households: Annex 5 details the methodology used to analyse the scheme's coverage of fuel-poor households and its impact on fuel poverty. The analysis was conducted by BRE, drawing on an analysis of scheme data and modelling. The results of this are covered in Chapter 5 of the main report.

Consumer demand: Consumer's interest in, and demand for, the scheme is based upon qualitative interviews with scheme's applicants and further analysis of the wave 1 and wave 2 applicant surveys. This is covered in Chapter 11 of the main report.

Energy, carbon and bills savings: A regression analysis of the scheme's effects on energy, carbon and bills savings was conducted by UCL, using smart meter data from participating households (see Annex 4 for further detail). This was triangulated with applicants' reports on their energy consumption behaviour (including comfort taking) and perceptions of energy savings, as gathered through depth interviews and the applicant survey.

Property occupant health and well-being: Analysis of this outcome was carried out using modelling and estimates to be developed by UCL using the Health Impact of Domestic Energy Efficiency Measures (HIDEEM) model. The model uses data on indoor environmental changes (such as changes to indoor temperature and ventilation following a new installation in the house) to determine the effect on household occupant health. This is explained in further detail in Annex 3. Findings on occupant health and wellbeing from either the qualitative or quantitative primary research was also triangulated with the analysis from the modelling.

Jobs: Analysis of the scheme's effects on jobs was assessed via an econometric analysis of businesses who performed installations under the scheme (the treatment group), with similar companies that did not participate into GHGVS (the control group). This is explained in further detail in Annex 7. Where relevant, findings on occupant health and wellbeing from either the qualitative or quantitative primary research was also used to triangulate the analysis.

Analysis of quality of installations: This was conducted based upon an analysis of TrustMark lodgement and audit data, triangulated with data from qualitative interviews with certification bodies and auditors as well as interviews with relevant BEIS policy officers and TrustMark and findings from the wave 2 survey of applicants. This strand was led by EST.

A.1.2.3 Strengths and limitations of the analytical approach

Table A.1.2: Strengths and limitations of each analytical approach taken

Strand	Strengths and limitations
Overarching	It was only possible to robustly quantify impacts – i.e. with reference to an appropriate counterfactual scenario – for the analysis of the scheme's impacts on jobs and energy, carbon and bill savings. The data collected for the evaluation through surveys and depth interviews may also be subject to recall and self-selection bias. Not all survey results presented are statistically significant, but have been reported for completeness. Where this is the case we have highlighted this in footnotes in the Report. It is particularly the case for the TrustMark statistics on compliance presented in sections 8.2.2 and 8.2.3, and for the presentation of the survey findings on onward behaviour in Chapter 11.
Fuel poverty analysis	The extent to which the scheme reached those likely to be in fuel poverty was assessed by modelling building performance information with income after housing costs (AHC) data gathered through the wave 1 applicant survey. It was not possible to assess the AHC for 23% of occupants completing the wave 1 survey (i.e. 760 of the 3,365 participants applying for the property in which they lived), and up-to-date EPC data was also not available through the scheme (EPC assessment was not a prerequisite for participation). EPCs were therefore modelled using the BRESMI method, which requires less detailed inputs for each dwelling characteristic than would be made using a full EPC survey. As a result, there are limitations on the accuracy of both the EPC and the AHC assessment, and therefore on the overarching fuel poverty assessment.
Energy savings analysis	A strength of the evaluation is that we have been able to triangulate evidence from a matched control analysis of energy consumption before and after treatment for 2,428 households (and 2,831 measures) with survey data and depth interview data on reported consumption behaviour. However, for some of the measures, the sample available was too small to generate any statistically significant findings, which – in these cases – limits the findings. The energy savings analysis does not systematically account for the potential effects of post-COVID-19 changes in occupancy patterns, energy use, and base-levels of home warmth due to increased home occupancy during and immediately post-COVID-19.
Health impact analysis	The lack of actual EPC data that limited the fuel poverty modelling also limited the health impact analysis. Further, whilst PAS requirements mandated that installations met minimum ventilation requirements, the health impacts assessment did not independently assess ventilation, and this lack of data on ventilation limits the strength of the modelling. Barriers to improved health were not systematically investigated through the applicant survey nor the depth interviews, due to the need to focus on other

Strand	Strengths and limitations
	questions more critical to the evaluation within the budget of the evaluation and in keeping with research ethics around proportionality. We can provide some analysis of barriers to health derived from the literature, and analysis of the qualitative research findings, though the latter will be somewhat speculative since this was not a targeted question to the applicants interviewed. Perceptions of changes in health post-installation, as reported in depth interviews and/or the applicant survey may be subject to recall bias.
Quality analysis	The TrustMark audit dataset includes missing inspection question information. The number of inspections conducted per Government scheme varies considerably, which affects the robustness of the comparative analysis.
Jobs impact	The scheme was designed to provide a temporary (rather than an on-going) stimulus to employment and economic activity. This is problematic in the context of the administrative data available on the employment and turnover of firms – which arrives with variable lags making it challenging to isolate short term changes in firm performance. The absence of post-scheme data makes it challenging to determine how far those jobs might have been sustained for a longer period.
CBA	The cost benefit analysis draws only on energy savings outcomes data for around 60% of all measures installed as part of the scheme due to a lack of incomplete data as drawn from ECO3 (see Annex 2 for more information).
Consumer demand for the scheme	It was not within the scope of the evaluation to develop a full cross-scheme analysis of deadweight costs (i.e. the extent to which the programme spend was additional, or consumers would have installed measures anyway). Quantitatively rigorous methods to assess deadweight have been applied as part of the analysis of energy savings and of jobs impacts. Our qualitative analysis of additionality / deadweight suggests that applicants for measures which tend to be less expensive and / or require less intrusive work in the home were more likely to state that they would have installed the measure without the scheme than applicants for measures that tend to cost more and / or require more intrusive work in the home.

A.1.3 Approach to data collection

A.1.3.1 Summary of data sources and data collection methods

Table A.1.3 overleaf provides an overview of all data sources which contributed to the evidence base for this report. Primary data collection took place during two phases: for the process evaluation January to August 2021, and for the outcome evaluation January to August 2022.

All interviews undertaken lasted 45-60 minutes and were conducted via Microsoft Teams or telephone.

Table A.1.3: Data sources for this report

Source	Type of data covered	Volume of data
Secondary data sources		
Scheme data	Number and profile of applicants, households (incl. building type), installers & applications/ installations (incl. by type).	Data on all applicants and installers participating in the scheme and the number and nature of measures installed
Smart meter data	Energy consumption (electricity and gas)	2,428 applicants who had at least one measure installed (matched to the same number of comparable households sharing their smart meter data with the Smart Energy Research Lab at UCL, representing a control group of households who did not install a measure using a GHGVS voucher)
Fuel Poverty modelling	Fuel Poverty modelling	A modelling of fuel poverty status before and after a GHGVS measure installation for 2,477 households
ONS data Business Structure Database	Company information like turnover, number of employees	Information on the employment size of 777 business delivering installations under GHGVS
TrustMark data	Quality of installations Participation into the scheme	Data for 1,221 TrustMark audits of GHGVS installations carried out between October 2020 and January 2022
Primary data sources		
Qualitative interviews with applicants (homeowners, landlords, tenants)	How became aware of scheme, reasons for participation, confirming & understanding experience of customer journey, COVID-19 effects/other barriers, additionality/free-rider effects, likelihood to install similar measure in	61 applicants interviewed during the process evaluation January to August 2021 (41 homeowner-occupiers, 15 landlords, 1 tenant and 4 applying on behalf of other people), 30 applicants interviewed during the outcome evaluation (January to August

Source	Type of data covered	Volume of data
	future, satisfaction with the installation, energy bills savings.	2022) – comprised of: 15 homeowner-occupiers, 15 landlords),
Qualitative interviews with non-applicants	Awareness of the scheme, views on the relevance of the scheme, barriers to (and potential motivations for) application.	18 non-applicants interviewed during the process evaluation January to August 2021
Qualitative interviews with installers	How became aware of scheme, reasons for participation, confirming & understanding experience of installer journey (incl. training and accreditation), COVID-19 effects/other barriers. Effects of the scheme on jobs, skills development, firm growth.	17[5] installers interviewed during the process evaluation January to August 2021 10 installers interviewed during the outcome evaluation January to August 2022
Qualitative interviews with manufactures	Effects of GHG scheme on service offering, amount of business incoming, growth, business capacity, turnover, staffing and skills; viewpoints on scheme effects on quality and energy efficiency market.	11 manufacturers interviewed during the process evaluation January to August 2021 10 manufacturers interviewed during the outcome evaluation January to August 2022
Qualitative interviews with certification bodies	Effects of GHG scheme on service offering, amount of business incoming, growth, business capacity, turnover, staffing and skills; viewpoints on scheme effects on quality and energy efficiency market.	8 certification bodies interviewed during the process evaluation January to August 2021 8 certification bodies interviewed during the outcome evaluation January to August 2022
Qualitative interviews with training providers	Effects of GHG scheme on service offering, amount of business incoming, growth, business capacity, turnover, staffing and skills; viewpoints on scheme effects on quality and energy efficiency market.	6 trainers interviewed during the process evaluation January to August 2021 8 trainers interviewed during the outcome evaluation January to August 2022

[5] 16 installers were interviewed qualitatively between February and May 2021. One additional installer was interviewed on the 11/08/2021, who was recruited through the quantitative survey.

Source	Type of data covered	Volume of data
Qualitative interviews with auditors	Effects of GHG scheme on service offering, amount of business incoming, growth, business capacity, turnover, staffing and skills; viewpoints on scheme effects on quality and energy efficiency market.	5 auditors interviewed during the process evaluation January to August 2021 10 auditors interviewed during the outcome evaluation January to August 2022
Qualitative interviews with TrustMark	The quality systems underpinning GHGVS.	2 representatives interviewed during the process evaluation January to August 2021 3 representatives interviewed during the outcome evaluation January to August 2022
Qualitative interviews with BEIS officials	The design of the scheme, delivery challenges and scheme achievements.	9 officers interviewed during the process evaluation January to August 2021 3 officers interviewed during the outcome evaluation January to August 2022
Telephone survey with installers	The impact of the scheme on demand for their products, employment and business.	218 installers, conducted during the process evaluation January to August 2021
Online survey of applicants	Applicants experience with the scheme and installations.	3,606 applicants ('wave 1 applicant survey') during the process evaluation January to August 2021 1,726 applicants who participated in the "wave 1 applicant survey", provided consent to be recontacted, and had an installation completed in their property ('wave 2 applicant survey') conducted during the outcome evaluation January to August 2022

A.1.3.2 Sampling approach for qualitative data collection

Qualitative interviews were conducted with four different audiences, the sampling approach for each group is detailed below.

Applicants – process evaluation

A total of 41 homeowner-occupiers, 15 landlord applicants, four not owning the property but 'applying on behalf of others', and one tenant were interviewed from a sample of 1,677 applicants drawn from the scheme data supplied by BEIS. Ipsos aimed for a mix of demographics, region, application stage, measure installed and property type within the sample (see Table A.1.4 overleaf). The target for number of homeowner-occupiers and landlords was met, but only one tenant[6] was interviewed due to the number of tenants attracted by the scheme having been low. People ‘applying on behalf of someone’ were most often those people applying for a relative or someone they cared for who was less able to compete the form themselves.

Table A.1.4: Qualitative interview sample characteristics - applicants (process evaluation)

	Homeowners	Landlords	Applied on behalf/tenants
Scheme Type			
Low income	16	2	2
Main scheme	25	13	3
Property type			
Bungalow Detached	2	-	-
Flat	-	2	-
Detached	22	3	2
Mid-Terrace	2	-	
Semi-Detached	15	9	3
Terraced house	-	1	
Region			
Midlands	14	5	-
North	8	5	3
South	18	5	2
South East	1	-	-
Measure type			
Air Source Heat Pump	9	5	2
Biomass boiler	1	-	-
Cavity Wall Insulation	6	2	-
External Solid Wall Insulation	6	3	-

[6] Possible reasons behind the lack of tenants in the data are detailed in section A.1.5.

	Homeowners	Landlords	Applied on behalf/tenants
Flat Roof Insulation	1	1	-
Loft Insulation	6	2	1
Pitched roof insulation	-	-	1
Room-in-roof	1	-	-
Solar Thermal	10	1	1
Under-floor insulation: Suspended floor	1	1	-
Gender			
Male	22	10	5
Female	19	5	-
Age			
36-45	5	-	-
46-55	9	5	-
56-65	15	7	1
66+	12	3	4
Total	41	15	5

Applicants – outcome evaluation

A total of 16 homeowner-occupiers and 15 landlord applicants were interviewed from a sample of 16,623 applicants (16,067 homeowners and 556 landlords) drawn from the scheme data supplied by BEIS. Interviewees were selected based on the type of installation applied for, date of installation, property type, property age and geographical location (see Table A.1.5). Interviewees were not purposively sampled as to age or gender, though only people aged over 40 were reached, both because higher numbers of these applied to the scheme.

Table A.1.5: Qualitative interview sample characteristics – applicants

	Homeowners	Landlords
Gender		
Female	6	9
Male	10	6
Age		

	Homeowners	**Landlords**
40-50	2	2
51-60	3	0
61 +	11	13
Installation type		
Installation in progress	1	0
Air source heat pump	4	2
Double/triple glazing	4	1
Internal solid wall insulation	2	1
Room in roof insulation	3	5
Solar thermal	2	2
External wall insulation	0	2
Flat roof insulation	0	1
Loft insulation	0	1
Property type		
Detached	3	0
Semi-detached	9	1
Semi-Detached/Terrace	1	0
Terraced	3	8
Flat	0	1
Other	0	5
Property age		
1900-1929	4	6
1930-1949	1	0
1950-1966	2	2
1976-1982	1	0
1991-1995	1	0
2007-11	1	0
N/A	1	0
Not on list	2	7
Pre 1900	2	0
Pre-1900	1	0
Geography		
Midlands	5	6
North of England	6	0
South of England	5	5
Other	0	4
Installation date		
Q1 2021	5	0
Q2 2021	0	4
Q3 2021	7	7
Q4 2021	4	4
Total	16	15

Ipsos targeted households who had had the following measures for depth interview in the outcome evaluation:

- Internal solid wall insulation
- Air source heat pump

- Solar thermal
- Room-in-roof insulation
- Double/triple glazing

The rationale for this was to ensure evidence on these criteria were collected:

- The level of disruption, in terms of the installation (see Table A.1.6)
- The level of technical know-how / guidance to use it afterwards
- Cost
- Scale of labour required – i.e. person-days (vs. easy-to-install)

This was to test assumptions around:

- Any difference in experience depending on level of disruption
- Consumers' ability to manage measures post-installation
- The extent to which costs affected behaviour

Table A.1.6 sets out our ex-ante understanding (based upon expertise within the team) of the relative level of disruption, 'technical difficulty' of usage, cost and level of effort of labour required to install each measure. The analysis is based upon ex-ante understanding acquired from outside of this evaluation and has not been updated to reflect the findings of e.g. the research into costs and benefits and installation experience gathered for this report.

Table A.1.6: Level of disruption – installations

	Level of disruption	How technical is it to use afterwards	Cost	Scale of labour to implement
Internal solid wall insulation	High	Low	High	High
External solid wall insulation	Low	Low	High	Medium
Cavity wall insulation	Low	Low	Low	Low
Under-floor insulation (solid floor)	Medium	Low	Medium	Medium
Under-floor insulation (suspended floor)	Low	Low	Low/Medium	Low/Medium
Loft insulation	Low	Low	Low	Low
Flat roof insulation	Low	Low	Low	Low
Pitched roof insulation	Low	Low	Low	Low
Room-in-roof insulation	Medium	Low	Low	Medium
Insulating a park home (assume external wall insulation)	Low	Low	High	Medium/High
Air source heat pump	Medium/High	Medium	High	Medium/High
Ground source heat pump	High	Medium	High	High
Solar thermal (liquid filled flat plate or evacuated tube collector)	Medium	Medium	Medium/High	Medium/High
Biomass boiler	Medium	Medium	Medium/High	Medium/High
Draught proofing	Low	Low	Low	Low

	Level of disruption	How technical is it to use afterwards	Cost	Scale of labour to implement
Double or triple glazing	Medium/High	Low	High	Medium/High
Secondary glazing	Medium	Low	Medium	Medium
Energy efficient replacement doors	Low/Medium	Low	Medium	Low/Medium
Hot water tank thermostat	Low	Low	Low	Low
Hot water tank insulation	Low	Low	Low	Low

Installers – process evaluation

We aimed to reach a total of 15-20 installers for the purposes of the process evaluation to understand their experience of the scheme, these were sample from different sources. Twelve contacts willing to speak to the evaluation team were provided by the certification body Cavity Insulation Guarantee Agency (CIGA) and a further nine from MSC. In addition, contacts for 20 installers were provided by EST through their networks / web-searching. To reduce potential biases related to convenience sampling and to achieve greater variation among the installers recruited, some contacts were drawn from scheme data and one contact from the installer quantitative survey. In total, 17 interviews were conducted with the profile as per Table A.1.7.

Table A.1.7: Qualitative interview sample characteristics – installers (process evaluation)

Installer Characteristic	Count
Company size	
<10	5
<25	6
25-50	4
50-100	1
100-250	1
Company structure	
Delivery through own staff only	12
Delivery through subcontractors (in addition to staff)	4
Delivery through subcontractors only	1
Service coverage	
National	5
North	1
North East	1
North West	1
South East	2
South West	3

Installer Characteristic	Count
South	1
East	1
No info	2
Company base	
National	0
North	1
North East	1
North West	1
South East	6
South West	2
South	1
East	1
Wales	2
No info	2
Measure type	
Air source heat pump	3
Biomass boiler	5
Cavity wall insulation	7
External solid wall insulation	2
Flat roof insulation	2
Loft insulation	7
Pitched roof insulation	2
Room-in-roof	1
Solar thermal	5
Under-floor insulation: Suspended floor	3

Installers – outcome evaluation

We aimed to reach a total of 10 installers to understand their experience of installations, the impact of the scheme on jobs and skills' development. These were sampled from the scheme data from a total of 925 enrolled companies. The sampling criteria were:

- Region: to include a spread across North, Midlands, South
- Insulation type: even split between insulation and low-carbon heat installers
- Certifications obtained: installers that obtained any certification to participate in the scheme

The profile of the installers interviewed in during the outcome evaluation is presented in Table A.1.8.

Table A.1.8: Qualitative interview sampling characteristics – installers (outcome evaluation)

Installer Characteristic	Count
Company size	**Information not collected**
Company structure	**Information not collected**
Service coverage	
Midlands	3
North of England	2
South of England	5
Measure type	
Air source heat pump	1
Air source heat pump, solar thermal (liquid filled flat plate or evacuated tube collector)	1
Cavity wall insulation, loft insulation, air source heat pump, hybrid heat pump	1
Pitched roof insulation	1
Solar thermal (liquid filled flat plate or evacuated tube collector)	1
Solid wall insulation (internal or external)	2
Solid wall insulation (internal or external), cavity wall insulation, under-floor insulation (solid floor, suspended floor), loft insulation, flat roof insulation, pitched roof insulation, room-in-roof insulation	1
Under-floor insulation (solid floor, suspended floor), Insulating a park home	1
Under-floor insulation (solid floor, suspended floor), loft insulation	1
Certifications gained in order to participate in GHGVS	
TM registration	3
TM registration, MCS	1
TM registration PAS 2030: 2017	1

Installer Characteristic	Count
TM registration, MCS PAS 2030: 2017 PAS 2030: 2019 PAS 2035: 2019	1
TM registration, MCS PAS 2030: 2017 PAS 2030: 2019 PAS 2035: 2019	1
TM registration PAS 2030: 2019	2
TM registration PAS 2035: 2019	1
Total	**10**

Wider supply chain – process evaluation

A total of 20 interviews with representatives from manufacturers, certification bodies, auditors and training providers were scheduled for the process evaluation. Participants were posed questions on their organisational context, recent demand for products and services, recently added products and services, changes in workforce, skills and innovation, prospects of business growth, and views on the scheme.

Manufacturers (11 interviews): A diverse mix of manufacturers was recruited covering all four measure sub-categories defined in the scheme (i.e. insulation, heat pumps and solar thermal, heating controls, and windows and doors) and all sizes of businesses (i.e. SME and large). Manufacturers were selected through a combination of EST's existing business database and online searches. Businesses were requested to put forward senior employees with an understanding of business strategy and the ability to speak on behalf of the business.

Certification bodies (8 interviews): This included a balance of TrustMark and MCS certification providers. They varied in the length of time they have been certifying and the number of members. Areas of specialism were also diverse, including measures such as insulation, biomass, electrics, windows, doors, roofing, and energy assessment.

Training providers (6 interviews): These providers varied in the work packages they delivered and the length of time they had been training. All training providers were delivering training exclusively for energy efficiency and renewable energy measures.

Auditors (5 interviews): Their recruitment was quite challenging as very few quality inspections had been conducted on the measures installed at the time of these interviews.

Wider supply chain – outcome evaluation

Fieldwork for this phase of the evaluation was conducted between mid-January and 4th March 2022. Interviewees were recruited by EST, who directly emailed and phoned suitable participants within the industry to invite them to take part in an interview. Interviewees were identified through a combination of EST's existing business database as well as online research. A diverse range of interviewees were considered for an interview to ensure each category of participants ranged in specialism, organisation size and experience. Although most interviewees did not participate in GHGVS process evaluation, there were some who provided feedback in this earlier round of interviews in 2021. These interviewees were approached again due to the limited sample size of the population.

A semi-structured telephone interview, ranging in length from 20 minutes to over an hour, was conducted with each respondent. Questions varied depending on which category the interviewee belonged to, but each group was asked about the interviewee's organisational context and experience, description and demand of their products and services, scheme influence on employment and business and any other impacts that the scheme had on their business that had not already been discussed.

Interviews were recorded and transcribed manually. The raw qualitative data was analysed in NVivo by coding the main themes across all interviewees in each group type.

Training providers (8 interviews): Respondents delivered training for numerous different work packages: heat pumps and solar thermal, heating, and hot water controls, retrofit assessor and retrofit coordinator training, insulation and non-fabric measures.

Auditors (9 interviews): Although they all inspect a wide range of installations examining different types of measures, certain auditors also had specific areas of specialism, including heating, insulation and ventilation, though they were not limited to these types of inspections. The number of audits personally undertaken by each interviewee under GHGVS ranged from five to over 1,500.

Certification bodies (7 interviews): They covered a variety of specialisms including heating sector registration, audit inspection, PAS 2030 certification, retrofit coordination certification, window energy rating, competent person scheme, training, and renewable certification, MCS and TrustMark. All certification bodies interviewed have been operating in the renewable energy, energy efficiency and low-carbon heat sector for at least one decade.

Manufacturers (11 interviews): Respondents covered a variety of products including insulation, heat pumps, biomass, solar PV, and hot water, glazing, ventilation systems, heat recovery and building management systems. The manufacturers interviewed had been in the renewable energy, energy efficiency and low-carbon heat sector for between 20 and 50 years.

Furthermore, to supplement quality analysis, EST collected quantitative audit data from TrustMark. This data constitutes the outcomes of all site audits conducted by Trustmark for the scheme. It covers all questions and their respective outcomes for each audit.

Installer survey

The installer survey was conducted by telephone. All installers listed in GHGVS who had provided consent to be contacted for the research were included in the sample for the research; 791 records were issued for fieldwork.

The questionnaire was developed by Ipsos, in consultation with BEIS and other partners (to ensure that data met the needs of different parts of the evaluation). The survey was ‘soft launched’ and reviewed after the first nine interviews were complete: including collating feedback from the interviewers and reviewing survey data. Briefing notes were made available to help interviewers to deal with participant comments and queries. The average interview length was 24 minutes.

A total of 218 interviews were completed with installers, with the soft launch running from 10 to 12 May 2021, and the main phase of fieldwork from 1 June to 6 July 2021. Because of a lack of suitable profile data in the installer database, the installer data is presented unweighted.

Applicant survey (wave 1)

The applicant survey employed a push-to-web method. This entails contacting applicants by post to invite them to complete a survey online. Those who cannot complete online complete the survey by telephone). Sampled applicants received a written invitation at the applicant address which contained a request to visit the survey website to complete the survey online. Access to the survey was controlled by password, which was provided in the invitation letter. Participants who were unable to complete the survey online were invited to call the survey helpline and request to complete the interview by telephone. All applicants were offered a £10 shopping voucher as a thank you for completing the survey. A total of 3,606 applicants completed the survey.

The sample for the applicant survey was drawn from the scheme data. To be eligible to complete the survey, applicants had to have:

- Applied for at least one Green Homes Grant voucher
- Consented to be re-contacted for the research
- An applicant status in one of the following categories:
    - In progress
    - Grant application incomplete
    - Grant application completed
    - Grant application update received
    - Eligibility verification
    - Request sent – grant application incomplete
    - Landlord
    - Park home
    - Application received

The sample was drawn from an anonymised version of the scheme data. With an anticipated response rate of around 20%, and a target of 3,000 interviews, a total sample of 15,506 was selected (assuming 8% of addresses would be unusable e.g. empty, applicant moved, away/on holiday through fieldwork period, etc.). The sample was stratified by key variables including scheme type (main vs. low income), applicant type (owner-occupier, landlord, other), property type (house vs. flat vs. park home) and measure (aiming for a minimum of 100 completed interviews per primary measure, and a minimum of 50 interviews per secondary measure). In the event, all eligible addresses were issued for landlords and those applying for vouchers for some measures (heat pumps, biomass boilers) with the aim of achieving the target number of interviews. For other applicants, a random sample was drawn following stratification by property type (house vs. flat), scheme type (main vs. low income), number of measures for which vouchers were applied, and region. A total sample of 17,331 records was drawn.

After the sample was drawn, it was sent to BEIS where addresses and contact details for applicants were appended. Following cleaning of addresses, and other quality checks, a total sample of 15,506 was issued for fieldwork.

It was originally envisaged that three reminder mailings would be required to reach the target of 3,000 completed interviewers. However, after just the first invitation, the target number of interviews was reached for most analysis groups. The survey was left open until the communicated end date to allow anyone wishing to still respond to do so. The only sub-groups with shortfalls in response were landlords, and applicants for vouchers for biomass boilers. To increase the response rates among these two groups, the non-responders in these categories were sent a further reminder letter asking them to take part.

The questionnaire was developed by Ipsos, in consultation with BEIS and the evaluation's consortium partners (to ensure that the survey data met the needs of different parts of the evaluation, including the cross-cutting evaluation). The average interview length was 20 minutes.

In total, 3,606 participants completed the survey, including 3,365 owner-occupiers, 177 landlords and 64 participants who had applied on behalf of others. This represents a total response rate of 23%. Fieldwork ran from 10th July to 5th August 2021, though most interviews were completed within the first week of fieldwork (2,227 completes were received by 15th July). The target number of interviews for applicants for biomass boilers was reached (n=59 against a target of 50), though despite targeted reminders we fell slightly short of the target number of interviews with landlords (n=177 against a target of 200).

Data were weighted to the profile of the applicant database by key variables including scheme type, applicant type, property type and region. The impact of the weighting was slight, and the final effective sample size was 88%.

Applicant survey (wave 2)

The wave 2 applicant survey was open to responses from 31st May – 11th August 2022. It was conducted targeting wave 1 applicant survey participants who had consented to recontact and had successfully redeemed a voucher. The rationale behind this was so that they could provide their views on installation and post-installation experience of their home.[7] Of the 3,606 wave 1

[7] Information on voucher redemption was drawn from scheme data obtained from BEIS, dated to February 2022.

participants, 2,734 (76%) provided consent for recontact and 2,167 (60% of the wave 1 survey participants) had redeemed their voucher.

Of this sample, Ipsos reached a total of 1,726 completions for the wave 2 survey, representing a response rate of 80%. Most survey participants (92%) were those who lived in the property that had been renovated (‘occupiers’), a further 5% were landlords, and 3% were people who had applied to the voucher scheme on behalf of someone else.

Table A.1.9 Profile of survey respondents

	Occupiers	Landlords	Those applying on someone else’s behalf	Total
Number of responses	1,584 (92%)	89 (5%)	53 (3%)	1,726

Base: 1,726 wave 2 survey respondents

Like for the first wave of the survey, Ipsos used a push-to-web methodology. Through this method, participants are contacted by post to invite them to complete a survey online. In both waves, each participant first received a letter that invited them to complete the survey either online, or, if they preferred, through a telephone interview (which they would have to arrange by calling a number). All who took part completed the survey online. Ipsos received no requests for telephone interviews.

The initial invitation letter was followed up with three subsequent reminder letters, sent at approximately two-week intervals, to participants who had not completed the survey since the previous letter.

Access to the online survey was controlled by password. Passwords were provided to participants in the invitation (and reminder) letters. Participants were offered £10 vouchers as an incentive for taking part.

A.1.3.3 Strengths and limitations of the primary data

The approach to sampling and fieldwork and the effect this may have had on bias within our findings is set out below.

Applicants

The evaluation was able to reach nearly all the target numbers for stakeholder groups to be covered, with the Scheme Administrator being the only exception. Further, the evaluation gathered data from a largely representative spread of regions, measures, building types and demographics covered in the installer and applicant qualitative research.

Qualitative research with applicants for the process evaluation was completed between mid-January 2021 to June 2021.[8] It covered a total of 41 homeowners, 15 landlords, four non-homeowners ‘applying on behalf of others’,[9] as well as one tenant. For the wave 2 qualitative

[8] Fieldwork ran to the 22nd March 2021, but then had to pause for six weeks to abide by the rules of purdah that take place around local and national government elections.

[9] This mainly comprised family members living outside of the property applying on behalf of those living in it (who were unable to apply for it on their own).

research with applicants, a total of 30 people (15 landlords and 15 homeowners) whose installation had been successfully installed were recruited for interview (applicants who had not had an installation were screened out of the research). These qualitative research participants were selected from the scheme data supplied by BEIS. At both phases, Ipsos aimed for a mix of demographics, region, application stage, measure installed and property type within the sample.

The difference in timing and context between the waves of applicant research (which applies as well to the two waves of the applicant surveys conducted) is important to note interpreting the findings in this report. Applicants participating in the first wave of (process evaluation) research were much less likely to have had an installation completed and those who had been successful in completing an installation represented a minority, less likely to have faced challenges with the installation. Several interviews with applicants also took place before the closure of the scheme. The closure - and the implications this created for households wishing to install measures within an agreed timeline or who had initially intended to apply for further measures under the scheme - have clearly coloured some of the views of those applicants interviewed after this event. For example, whether an installation was completed at the time of interview had an impact on applicants' responses to the wave 1 applicant survey.[10] As part of the theory-based approach taken to the outcome evaluation, this context is taken into account in developing our findings and conclusions.

Another aspect of context we have considered in interpreting the findings of this phase of the evaluation are the sharp increase in energy prices and the associated collapse of domestic energy providers that occurred in the winter of 2021-2022. This may have impacted consumer energy behaviours and their perspectives on energy consumption and therefore shaped the findings of the wave 2 qualitative research (which investigated the impact of the new measures on energy behaviours and perceptions of energy savings and home thermal performance).

Finally, we consider that the sample of responses to both the applicant survey and qualitative research may represent some element of self-selection bias, in which participants with a particularly negative or positive experience of the scheme may have felt more inclined to participate in fieldwork than those with more neutral experiences. This is because the qualitative research demonstrates a high number of partially negative experiences under the scheme. However, given that the scheme did face significant delivery challenges and high levels of applicant and installer dissatisfaction have been reported within other sources such as the National Audit Office Report of September 2021 and in the media, it is fair to assume that these experiences are representative.

Installers and wider supply chain

As part of the process evaluation qualitative research with 16 installers were carried out between mid-January 2021 and mid-February 2021. The survey of installers was conducted from the 1st June to 6th July 2021. Fieldwork with auditors, trainers, certification bodies and training providers was conducted from mid-January 2021 to May 2021. One additional

[10] See Evaluation of the Green Homes Grant Voucher Scheme (GHGV): Process Evaluation Report (BEIS, 2022), section 3.9, page 35. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1131110/green-homes-grant-vouchers-phase-1-process-evaluation-report.pdf

interview with installers was conducted after the quantitative survey, in the first week of August 2021. All wave 2 qualitative research with these stakeholder groups was conducted in January and February 2022.

As with the applicant consultations, the data collected for the outcome evaluation has not been to the same scale as the data collected amongst installers for the process evaluation (for which a survey, as well as qualitative interviews, was conducted).

Also as with the applicant research, the policy context at the point of each interview had a bearing on the views of the research participants, particularly in relation to their satisfaction with and views on GHGVS and other government schemes, but also their views on the effects of training, quality of installations and the home improvement market. As with the applicant research, we have taken this context and the influence it is likely to have on participant views and experiences into account in developing our analysis and conclusions.

A.1.4 Analysis of secondary data

Over the three phases of the project, the evaluation of GHGVS comprised several secondary analysis strands covering several different topics. Each strand is presented in a separate annex.

Cost benefit and complementarity analysis

A Cost Benefit Analysis (CBA) was included in this evaluation to assess GHGVS' value for money. This analysis was performed by UCL and was delivered in three tranches. During phase 1 of the project (the process evaluation) the CBA methodology was scoped, interim results from the CBA were delivered in March 2022 at the end of the interim phase. Finally, an updated version of this analysis has been produced for this final report, using the latest cut of the scheme data[11]. Full details on the CBA methodology and its limitations are detailed in Annex 2.

Health impact analysis

An assessment of GHGVS health impacts was provided for this final report. The analysis was performed by UCL in the last quarter of 2022 using the final cut of the scheme data and the Health Impact of Domestic Energy Efficiency Measures (HIDEEM) model. Full details on the health impact methodology and its limitations are detailed in Annex 3.

Energy, carbon, and bills savings analysis

The energy, carbon, and bills savings analysis was also conducted by UCL for this report using the final cut of the scheme data. The analysis provides estimates of the energy, carbon and bills savings of households that received a GHGVS installation (the treatment group) compared to similar households with no measures installed (the control group). The comparison group was sourced from the UCL's Smart Energy Research Laboratory (SERL). Full details on the energy, carbon and bills savings methodology and its limitations are detailed in Annex 4.

[11] The last cut of the scheme data refers to December 2021.

Fuel poverty analysis

The analysis on fuel poverty was conducted by BRE. A first version of the Fuel Poverty Analysis was delivered as part of the interim outcome evaluation using a combination of the scheme data and the wave 1 applicant survey. The final version of this piece of analysis was ran in the final quarter of 2022 and relied on the latest cut of scheme data. Full details on the Fuel Poverty methodology and its limitations are presented in Annex 5.

Quality of installations

An assessment of the quality of installations was delivered by EST, using audit and lodgement data supplied by TrustMark. The work was split, with initial results delivered as part of the interim outcome and economic evaluation report and updated and finalised for the final evaluation of impacts presented in this report. Full details on the quality of installations methodology and its limitations are presented in Annex 6.

Impacts on jobs analysis

During phase 3, Ipsos carried out an analysis of the job creation impacts of GHGVS, to explore how far demand stimulated by the provision of subsidies encouraged firms to create new jobs. The analysis used longitudinal data on the employment and turnover of firms delivering measures through GHGVS. Further analysis was completed to explore how far (a) GHGVS led to any further productivity gains by encouraging firms to redeploy furloughed workers in a productive capacity and (b) the net economic effects of GHGVS by examining impacts on local unemployment levels. Full details on the are presented in Annex 7.

Annex 2: Cost-Benefit Analysis (Value for Money)

This Annex sets out in detail the methodology used for the CBA and provides additional analytical results (where not incorporated into the main body of the report (Chapter 10)).

Value for Money (VfM) is a balanced judgement about finding the best way to use public resources to deliver policy objectives (HM Treasury, 2022).[12] CBA is a method often used to assess VfM when it is possible to monetise the main benefits associated with an intervention.

This CBA sought to understand how the societal benefits derived from implementing the scheme compared to the costs associated with providing the scheme grants. For the participating households, it sought to understand how participation costs compared with the benefits gained. It has compared the discounted benefits (valued in monetary terms) of GHGVS to the discounted costs in the form of Net-Present Value (NPV) and Benefit-Cost Ratio (BCR) from societal and households' perspective. In doing so it answers the following evaluation questions.

- What is the average cost of installing measures in homes applying and redeeming vouchers under the scheme? How does this vary by measure or property type?
- What benefits have been achieved by GHGVS?
- What costs are incurred by the different actors involved in the scheme?
- Have there been differences in costs and benefits between the different subgroups of participants?

A.2.1 Methodology

A.2.1.1 Data sources

Energy consumption

Information on the changes in annual energy consumption savings (kWh) associated with the measures installed under GHGVS was taken from two sources:

- Estimates of expected energy savings per measure and property type as calculated for ECO3 by Ofgem which are based on deemed scores.[13] The estimates are available for 10 measures installed the scheme and cover about 60% of completed measure installations as of 7th December 2021.
- Estimates of the average effect on electricity and gas energy savings associated with measures installed under GHGVS. UCL derived these estimates using smart meter gas and electricity consumption data collected from 2,428 households participating in

[12] The Green Book: Central Government Guidance on Appraisal and Evaluation. HM Treasury, 2022. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063330/Green_Book_2022.pdf
[13] ECO3 deemed scores, Ofgem, 2018.

GHGVS who consented to provide UCL with access to their smart meter data. The energy changes were estimated for air source heat pump, loft insulation, external solid wall Insulation, pitched roof insulation, and cavity wall insulation. The sample is limited to limited to households from which smart meter data was collected and have gas central heating. This covers about 3.4% of measures installed under the scheme as of 7th December 2021.

Health benefits

Information on changes in NHS spending associated with the measures installed under GHGVS was sourced from the output of the health impact analysis conducted by UCL as part of this evaluation. The estimates were based on the HIDEEM model and are available for most of the measures installed under the scheme. We deflated the changes in NHS spending using the GDP deflator.[14]

Cost

The main cost used in the analysis was the installation cost of measures which was sourced from the scheme delivery data, the majority of which have been implemented in 2021.[15] Other cost types used in the analysis include:

- The cost related to the time allocated by households to liaise with the installers, preparation of the building for installations, clean-up, and other related costs (hassle cost to the household of the installation). GHGVS scheme delivery data does not contain information on hassle costs, so we sourced this information from the ECO3 impact report.[16] This is available for five measures installed under GHGVS[17] and constitutes about 2% of installation costs, on average.[18] We, therefore, computed the hassle costs to the household associated with the installation of the remaining GHGVS measures used in the analysis as 2% of their installation costs.
- The cost associated with the time and resources devoted by scheme administrators to set up the application process, go through the applications, and award grants, among other activities, while ensuring that monitoring and fraud-prevention systems were in place (administration and programme management costs). According to NAO (2021),[19] BEIS was expected to spend £50.5 million (representing 20% of the total amount spent on vouchers) on administrative and program costs over the financial years 2020/21 and 2021/22. We computed the administration and programme management costs as 20% of the installation cost for the subset of the whole spending used in this analysis.
- The cost associated with training of installers (training cost). NAO (2021) attributes £7.3 million (2% of the total amount spent on vouchers) to training for installers. Thus, we

[14] The reference year is 2021. The data can be accessed from https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal
[15] We used the variable 'quote_amount' collected by the scheme data to reflect the installation cost of measures installed up to 07/12/2021.
[16] Energy Company Obligation ECO: 2018 – 2022: Final Stage Impact Assessment. BEIS, 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/749638/ECO_3_Final_Stage_IA__Final.pdf
[17] The available hassle (hidden) costs per installation are the following: £115 for cavity wall insulation, £145 for loft insulation, £235 for external solid wall insulation and £200 for air source heat pump.
[18] The median is about 2% of installation cost.
[19] Green Homes Grant Voucher Scheme Report – Value for Money. National Audit Office, 2021. https://www.nao.org.uk/reports/green-homes-grant/

computed the training cost as 3% of the installation cost for the subset of the whole spending used in this analysis.

Since the benefits were monetised based on prices available in the 2021 reference year, the total costs were adjusted to reflect the same reference year.

Other data

As GHGVS scheme data does not include information on the lifetime of the measures, we used the estimated figures from the Ofgem ECO3 energy savings data except for pitched roof insulation.[20] The lifetime score for a measure is associated with its expected savings over its lifetime.[21]

A.2.1.2 VfM approach

For the analysis, we monetised the following societal benefits: energy savings, NHS spending savings or 'comfort taking' (when relevant),[22] carbon savings and air quality improvements; and to individual households: energy bills savings and comfort taking. The costs analysed for society comprise the cost of installation, the hassle cost to the household of the installation, the administrative and programme management costs, and the training costs for installers.

Societal value of energy use

Although many policies have objectives other than energy use, they will include energy use as part of the wider impact (HM Treasury, 2022).[23] Therefore, changes in energy use should be quantified and valued within the evaluation. This applies also to GHGVS, which has the dual aim of facilitating post-pandemic economic recovery and decreasing carbon emissions towards the UK's target for net zero by 2050. Valuation of energy use is based on HM Treasury (2022) and its supplementary guidance (BEIS, 2023).[24] Net changes in energy use, associated with energy efficiency measures installed as part of GHGVS, are calculated using Ofgem estimates for similar ECO3 measures and based on GHGVS specific energy estimates.

Policy interventions increasing energy efficiency and facilitating heat decarbonisation have an impact on energy consumption and related costs. Financial savings from increasing energy efficiency might however be used to raise consumption, an outcome known as direct rebound effect and related to increased comfort from warmer buildings and associated welfare gains. Net energy changes in this case are obtained by subtracting the rebound effect from the expected savings from the intervention.

Net energy changes are valued based on the social cost of energy, the long run variable cost (LRVC) of energy supply. The LRVC reflects the production and supply costs of energy which

[20] The ECO3 measures table published by Ofgem does not have information on the lifetime for pitch roof insulation. We therefore used 42 years given it is internal insulation.

[21] The lifetime of each technology can be found at: https://www.ofgem.gov.uk/publications-and-updates/eco3-measures-table

[22] This relates to spending some of the energy savings to raise the temperature of the home. To avoid double counting, comfort taking was included in the societal CBA solely for measures where the corresponding health benefits were unavailable. This is because increased comfort via higher temperature could lead to improved health outcomes leading to reduced health expenditure. The relevant measures are heating controls, park home insulation, room-in-roof insulation, and under-floor insulations (both solid and timber).

[23] The Green Book: Central Government Guidance on Appraisal and Evaluation. HM Treasury, 2022. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063330/Green_Book_2022.pdf

[24] Valuation of energy use and greenhouse gas (GHG) emissions: Supplementary guidance to the HM Treasure Green Book on Appraisal and Evaluation in Central Government. BEIS, 2023. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1129242/valuation-of-energy-use-greenhouse-gas-emissions-for-appraisal.pdf

vary according to the amount of energy supplied.[25] The supply costs vary over time and according to the type of fuel and the sector being supplied (Data Tables 9-13 of the accompanying spreadsheet to BEIS (2023).[26] The value of energy use is expressed as follow, where Δ indicates change in the variable of interest:

$$value\ of\ energy = \Delta \mathrm{E} \times LRVC.$$

By including the value of energy savings in the VfM analysis, one can capture social benefits both in the long run and short run. In the short run, they release energy for alternative uses. In the long run, the LRVC can be reduced due the decreased energy demand so that the construction of new plants can be prevented (BEIS, 2018).[27]

Value of increased comfort (direct rebound effect)

As comfort taking (direct rebound effect) increases the welfare of the users of affected homes, it should be quantified and valued in the VfM analysis. In this study, this effect is estimated at 15% of energy savings,[28] and its valuation is based on the retail price of energy, as this captures the gain in welfare. This means that the rebound effect (RE) is given by 15% of the expected energy changes $(E(\Delta \mathrm{E}))$ estimated by Ofgem for similar ECO3 measures. Given that GHGVS specific energy estimates based on the smart meter data are net energy savings, we computed their RE as follows:

$$(\Delta \mathrm{E} + RE)\ \times 15 = 100 \times RE \Rightarrow$$

$$RE = \frac{\Delta \mathrm{E} \times 15}{85}$$

The computed RE is multiplied by the retail price of energy found in Data Tables 4-8 of the accompanying spreadsheet to BEIS (2021), so that

$$value\ of\ RE = \mathrm{RE} \times \text{retail price}.$$

Societal value of changes in GHG emissions

The quantification of GHG emissions changes $(\Delta\ \mathrm{GHG})$ is based on net energy changes and emissions factors (Data Table 1 and 2a of the accompanying spreadsheet to BEIS (2021)). Valuation of changes in GHG emissions is calculated by multiplying the changes in GHG (CO_2e) by the value of carbon. Carbon prices 〚$(£/\mathrm{tCO2e})$〛) are retrieved from Data Table 3 of the accompanying spreadsheet to BEIS (2023). The value of changes in GHG emissions is expressed as follow:

$$value\ of\ GHG = \Delta\ \mathrm{GHG}\ \times\ value\ of\ carbon.$$

[25] The valuation of energy use is based on the LRVC instead of retail fuel prices, as the latter includes fixed costs, carbon costs and taxes which reflect transfers.

[26] The data can be accessed from https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

[27] Energy Company Obligation ECOd: 2018 – 2022: Final Stage Impact Assessment. BEIS, 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/749638/ECO_3_Final_Stage_IA__Final.pdf

[28] The Green Deal and Energy Company Obligation Impact Assessment. DECC, 2011. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/43000/3603-green-deal-eco-ia.pdf

Societal value of air quality

Air pollution can have adverse health impacts, and direct long-term environmental impacts. As policy intervention targeting the reduction of emissions have an impact on air pollution, changes in air quality are expected to be part of the appraisal work and incorporated in the VfM analysis. Air quality effects are estimated by applying ‘activity costs’ given the estimated changes in fuel. Activity costs or damage costs (2021 p/kWh) for specific types of fuel can be found in the supplementary guidance to HM Treasury (2022). More specifically, Data Table 15 of the accompanying spreadsheet to BEIS (2023) provides air quality damage costs from primary fuel use – both in terms of national averages and domestic values (inner conurbation, small urban, medium urban, big urban, rural). The estimates for national averages are used and discounted using the health discount rate. The changes in the value of air quality are provided by:

$$\text{value } of\ air\ quality = \Delta E \times activity\ costs$$

A.2.1.3 Assumptions

The CBA involved the following assumptions:

1. The CBA is implemented at the societal level to produce an overall and technology-specific net-present value (NPV) reflecting the social / government position.
2. The appraisal period reflects the different lifetime of the measures as different measures have different periods over which the impacts are expected to materialise.
3. The counterfactual against which the costs and benefits of the scheme are evaluated is based on the ‘no policy’ option.
4. The computation of the NPV involves the discounted net cash flows (R) over the period of appraisal t, assuming the discount rate (r) being equal to 3.5% for the first 30 years and 3% for years 31 to 75 (the social time preference rate, following guidance from the Green Book),

$$NPV\ (i, N) = \sum_{t=0}^{N} \frac{R_t}{(1+r)^t}.$$

The CBA was conducted separately using Ofgem energy estimates for ECO3 measures and the estimated average net energy consumption changes associated with selected GHGVS based on smart meter data (as discussed in section A.2.1.1).

A.2.1.4 CBA based on Ofgem estimates for ECO3

The implementation of the CBA based on Ofgem estimates for ECO3 measures involved the following steps:

1. Obtaining the average annual energy savings per technology and property type.
2. Obtaining mean installation costs per technology and property type based on GHGVS scheme data.
3. For each technology, obtaining a weighted average of energy savings and installation cost based on the property types (i.e., bungalows detached,

bungalows mid-terrace, bungalows end-terrace/semi-detached, detached, end-terrace, flat, maisonette, mid-terrace, semi-detached).[29]

4. Using the weighted average of energy savings as the basis for the quantification and monetisation of the sum of the discounted benefits (energy savings, carbon savings, comfort taking (if relevant) and air quality).
5. Discounting and deflating health benefits.
6. Using the weighted average of installation cost to produce an estimate for hassle costs to households (when relevant), administration and programme management cost, and training cost.
7. Computing the NPV for each technology.
8. Computing the NPV for the scheme (based on the installed measures under consideration).

We also compared the main costs incurred by the households, i.e., the financial contribution to the installation and hassle cost when relevant for the installed measures, against the main benefits enjoyed by them, i.e., energy savings reflected in bills savings and health benefits or comfort taking (whenever applicable). Quantification of energy savings is done as in the baseline CBA with the exception that net energy changes are valued based on the retail price of energy, rather than the LRVC, to reflect changes in energy bills directly applicable to households. We compared the costs and benefits through BCRs, with the first analysis (Table A.2.6) focusing on different technologies across property types; and the second analysis (Table A.2.7) focusing on the means of participation across technologies, i.e., the route that households have followed to participate in the scheme (low-income route vs. main route). In the latter, computation of BCR is expected to be higher (therefore implying that benefits outweigh costs to a greater extent) for the households using the low-income route compared to those using the main route, as their financial contribution to the installations is lower.

A.2.1.2.5 CBA based on GHGVS energy estimates

The implementation of the CBA based on GHGVS energy estimates involved the following steps:

1. Using the annual estimated average net electricity and gas consumption changes (kwh) as the basis for the quantification and monetisation of the sum of the discounted benefits (energy savings, carbon savings and air quality).
2. Discounting and deflating health benefits.
3. Obtaining mean installation costs per technology based on GHGVS scheme data.
4. Using the average installation cost to produce an estimate for hassle costs to households (when relevant), administration and programme management costs, and training costs.
5. Computing the NPV for each technology.

In addition, we computed the CBA from the perspective of the households as discussed in the previous section but only at the level of technology (Table A.2.10).

[29] We computed the weighted average because the savings are available for different property types.

A.2.2 Limitations

While the analysis implemented is in line with established best practices,[30] there were some data limitations that affect its robustness.

- The CBA did not cover all the measures installed under the scheme because of data unavailability. Thus, the results should be interpreted with caution. Specifically, the ECO3 energy estimates cover about 60% of the measures installed under the scheme as of 7th December 2021, most of them being insulation measures and excludes low-carbon measures. The extent to which exclusion of low-carbon measures biases the results depends on whether their benefits outweigh their costs. If the benefits outweigh the costs, then the overall CBA results are downward biased.
- Also, GHGVS-specific energy estimates cover about 64% of the measures installed as of 7th December. These estimates are based on a sample of 2,428 households (6% of households with at least one completed measure installation as of this date) who consented to provide UCL with access to their smart meter data. While the composition of measures installed in these households are similar to those of the full population, the energy estimates are likely not representative of the full population because the sample was not drawn randomly from the full population. Thus, the findings of the CBA may not be representative of the entire population.
- There are other potential benefits of the scheme not monetizable, and therefore not included in this CBA. These include improved security of energy supply and the potentially reduced cost of meeting peak energy demand; decreases in the long-run variable cost of energy supply from reduced demand for energy; benefits to the aesthetics and value of property arising from an increased quality of installations; the benefits of increased understanding of energy efficiency technologies and amongst homeowners and landlords.
- Hassle costs to installers for the time allocated to issue quotes, and to households for the time taken to complete the application were not monetised as part of the analysis due to the non-availability of data. However, these costs are expected to be very small compared to the summative costs already included in the analysis, therefore the impact of not including them is also expected to be minimal.
- Installation costs incurred by installers (e.g., labour and material costs), were not included in the scheme data made available to us and they were therefore also not included in the CBA.

[30]We followed the guidance in The Green Book: Central Government Guidance on Appraisal and Evaluation. HM Treasury, 2022). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063330/Green_Book_2022.pdf

A.2.3 Results

A.2.3.1 Installation costs in homes redeeming vouchers under the scheme

External solid wall insulation has the highest average cost compared to other insulation measures, without significant variation across average property types, except for flats for which the cost has been typically lower. Loft insulation was most costly for detached bungalows but was most-commonly installed in detached and semi-detached houses. Cavity wall insulation was most-commonly installed under the scheme in detached houses and within this housing type also had the highest average cost.

With the exception of solar thermal, low-carbon heating measures had the highest average cost compared to other measures installed under the scheme. Ground source heat pumps had the highest average cost compared to other measures and was most costly for detached houses. Air source heat pumps had the second highest average cost compared to other measures with minimal variation across property types. Table A.2.1 presents the average cost per technology and property type for insulation measures while Table A.2.2 presents that of low-carbon heat and secondary measures.

Table A.2.1. Average installation costs per technology and property type according to GHGVS data (insulation measures)

Property Type	Cavity Wall Insulation £	Internal Solid Wall Insulation £	External Solid Wall Insulation £	Flat Roof Insulation £	Under-floor Insulation Timber £	Under-floor Insulation Solid £	Loft Insulation £	Roof-in-Room Insulation £	Pitched roof insulation £	Park Home Insulation £
Bungalow detached	1,454 (524)	5,852 (9)	10,114 (241)	7,556 (51)	3,054 (94)	3,322 (2)	1,450 (687)	6,295 (32)	6,107 (313)	
Bungalow mid-terrace	985 (7)	5,656 (11)	8,940 (129)	6,563 (4)	2,345 (22)	5,292 (1)	1,099 (41)	6,348 (6)	4,191 (51)	
Bungalow semi-detached, end-terrace	1,107 (174)	6,653 (23)	9,319 (240)	6,125 (30)	2,473 (61)	2,625 (2)	1,033 (233)	6,151 (26)	4,875 (196)	
Detached	1,887 (1668)	6,877 (72)	11,360 (530)	7,098 (170)	2,806 (355)	3,609 (16)	1,233 (2,553)	6,907 (113)	5,206 (1,062)	
End-terrace	1,378 (232)	6,223 (139)	10,361 (949)	5,877 (79)	2,342 (149)	3,624 (6)	952 (528)	6,173 (61)	4,329 (898)	
Flat	1,016 (95)	6,016 (73)	7,118 (129)	6,723 (24)	2,649 (25)	-	1,163 (169)	6,671 (24)	4,324 (39)	
Maisonette	1,052 (8)	6,397 (11)	7,002 (4)	25,607 (7)	3,484 (3)	-	1,161 (25)	-	5,221 (6)	
Mid-terrace	980 (319)	5,819 (468)	9,080 (3,019)	5,516 (123)	2,170 (370)	3,554 (16)	939 (1,009)	5,900 (192)	4,303 (1243)	
Semi-detached	1,339 (1,306)	6,453 (251)	10,172 (3,904)	5,777 (322)	2,306 (737)	3,072 (17)	1,017 (2,299)	6,500 (259)	4,442 (2195)	
Single park home[31]										6,271 (88)
Double park home[32]										6,458 (332)
All property types[33]	1,522 (4,333)	6,131 (1,057)	9,814 (9,145)	6,353 (810)	2,430 (1,816)	3,429 (60)	1,119 (7,544)	6,385 (713)	4,630 (6,003)	6,419 (420)

Note: Average cost figures in £, based on number of properties in parentheses.

31 'Single' park homes are roughly 12 metres long and 3 meters wide (36m2).
32 'Double' park homes are roughly 12 meters long and 6 meters wide (72m2).
33 Weighted-average cost.

Table A.2.2. Average installation costs per technology and property type according to GHGVS data (low-carbon heat and secondary measures)

Property Type	Air source heat pump £	Ground source heat pump £	Hybrid heat pump £	Solar Thermal £	Biomass boiler £	Heating Controls £	Window Glazing £	Secondary glazing £	Draught proofing £	Energy efficient replacement doors £
Bungalow detached	13,566 (440)	20,708 (4)	10,082 (59)	6,596 (380)	5,182 (1)	722 (41)	3,092 (31)	2,834 (2)	-	2,297 (44)
Bungalow mid-terrace	10,834 (18)	-	9,986 (18)	6,573 (54)	-	677 (24)	1,987 (11)	4,570 (1)	-	2,051 (26)
Bungalow semi-detached, end-terrace	10,516 (87)	-	9,992 (66)	6,513 (164)	-	591 (53)	1,764 (20)	1,716 (1)	1,421 (1)	1,896 (38)
Detached	12,052 (1,519)	20,975 (19)	10,281 (66)	6,771 (1,832)	10,328 (4)	958 (181)	2,938 (94)	1,364 (1)	604 (2)	2,178 (142)
End-terrace	10,814 (241)	11,400 (2)	10,001 (104)	6,991 (924)	-	724 (134)	3,247 (112)	2,416 (3)	315 (1)	2,151 (148)
Flat	10,390 (48)	-	9,906 (11)	7,293 (13)	-	848 (9)	3,101 (13)	2,908 (2)	-	1,391 (8)
Maisonette	10,463 (6)	-	9,995 (1)	5,995 (1)	-	790 (3)	4,863 (2)	-	270 (1)	2,612 (2)
Mid-terrace	10,675 (300)	12,900 (1)	9,933 (176)	6,952 (1,494)	-	771 (262)	2,720 (218)	1,986 (6)	482 (6)	2,044 (339)
Semi-detached	11,211 (1,135)	20,344 (3)	9,968 (365)	6,844 (2,339)	10,616 (1)	769 (424)	2,975 (331)	2,968 (10)	861 (4)	1,985 (414)
All property types	11,724 (3,794)	19,934 (29)	10,009 (900)	6,845 (7,201)	9,518 (6)	783 (1,131)	2,909 (832)	2,615 (26)	636 (15)	2,054 (1,161)

Note: Average cost figures in £, based on number of properties in parentheses.

Table A.2.3. Average installation cost for the smart meter data sample used in the CBA

Measure	N	Installation cost
Air source heat pump	263	14,344
Cavity wall insulation	310	2,070
External solid wall insulation	308	12,351
Loft insulation	458	1,490
Pitched roof insulation	306	5,579

A.2.3.2 Ofgem estimates for ECO3

Property Type

The CBA based on the ECO3 energy estimates indicates that benefit cost ratio (BCR) of the scheme is greater than one, meaning the benefits derived exceed the costs from the society's perspective, suggesting good scheme value for money. There are however differences across technologies. Cavity wall insulation, heating controls, and room-in-roof insulation provided the greatest societal BCR. External solid wall insulation was one of the inefficient technologies from a VfM perspective due to its relatively high installation cost. By excluding the set of the most cost inefficient EWI measures installed in two property types (mid-terraced and semi-detached), we obtain a relatively higher BCR. Table A.2.4 overleaf presents the costs and benefits and BCRs for each of the ten measure types considered in this CBA analysis. Table A.2.5 presents the comparison of the net benefit/cost depending on whether EWI is included or not in the CBA, as explained above, and the corresponding BCRs.

The social benefits are driven mostly by carbon savings and air quality improvements. Table A.2.6 shows the contribution of the individual benefits to the total social benefits for each of the ten measure types. Internal and solid wall insulation have the same percentage contributions because their weighted average ECO3 energy savings are similar. The same argument applies to underfloor insulation (both solid and suspended floor) and roof-in-room insulation.

Table A.2.4. Societal costs and benefits (based on ECO3 estimates), appraisal period 2021-2063 (2021 prices) - Net benefit/cost

Measure Type	*N*	Lifetime	Benefits £	Costs £	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Cavity wall insulation	4,333	42	43,819,629	8,609,671	35,209,958	5.1
Internal solid wall insulation	1,057	36	9,477,062	8,100,848	1,376,214	1.2
External solid wall insulation	9,145	36	89,950,220	112,547,515	-22,597,295	0.8
Flat roof insulation	810	20	8,352,720	6,431,400	1,921,320	1.3
Loft insulation	7,546	42	23,445,422	11,485,012	11,960,410	2.0

Measure Type	*N*	Lifetime	Benefits £	Costs £	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Park home insulation	420	30	1,075,620	3,370,080	-2,294,460	0.3
Roof-in-room insulation	713	42	10,413,365	5,666,924	4,746,441	1.8
Under-floor insulation: Solid floor	60	42	198,840	257,280	-58,440	0.8
Under-floor insulation: suspended floor	1,816	42	9,165,352	5,518,824	3,646,528	1.7
Heating controls	1,131	12	3,931,356	1,108,380	2,822,976	3.5
Window glazing	832	20	4,433,728	3,025,152	1,408,576	1.5
All	27,863	-	204,263,314	166,121,086	38,142,228	1.2

Table A.2.5. Costs and benefits, appraisal period 2021-2063 (2021 prices) – Net benefit/cost comparison based on EWI treatment

CBA type	Measure Type	N	Benefits £	Costs £	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Baseline (all 10 measures included)	**EWI (all)**	9,145	89,950,220	112,547,515	-22,597,295	0.8
Baseline (all 10 measures included)	**All measures**	27,863	204,263,314	166,121,086	38,142,228	1.2
Excluding most inefficient EWI measures	**EWI (partial)**	2,222	27,021,742	28,354,942	-1,333,200	1.0
Excluding most inefficient EWI measures	**All measures**	20,940	141,334,836	81,928,513	59,406,323	1.7

Table A.2.6. Contribution of individual benefits to total social benefits by measure

Measure Type	Energy savings (% of total benefits)	NHS spending savings / 'comfort taking' if relevant[34] (% of total benefits)	Carbon savings (% of total benefits)	Air quality improvements (% of total benefits)
Cavity wall insulation	23.6%	0.5%	45.7%	30.2%
Internal solid wall insulation	24.5%	0.6%	45.0%	29.9%
External solid wall insulation	24.5%	0.6%	45.0%	29.9%
Flat roof insulation	28.2%	0.1%	43.3%	28.4%
Loft insulation	23.6%	0.4%	45.7%	30.2%
Park home insulation	23.7%	7.9%*	41.0%	27.4%
Roof-in-room insulation	22.0%	7.4%*	42.5%	28.1%
Under-floor insulation: Solid floor	22.0%	7.4%*	42.5%	28.1%
Under-floor insulation: suspended floor	22.0%	7.4%*	42.5%	28.1%
Heating controls	29.2%	9.0%*	37.5%	24.3%
Window glazing	28.2%	0.4%	43.1%	28.3%
All	24.3%	1.4%	44.7%	29.6%

*Indicates measures where the corresponding health benefits were unavailable

A.2.3.3 Costs and benefits to participating households

On average, the benefits of having one or more measure installed under GHGVS outweighed the costs at the individual household level. However, the monetary value of installing different technologies varied by type of household. Bungalows tended to have a lower BCR compared to other property types for about half of the technologies implemented. Conversely, they have a very high BCR compared to other properties in the case of under-floor insulation (solid floor) and roof to room insulation, making these types of measure very cost-efficient for this specific property type.

The group of flat and maisonette also tended to have a lower BCR compared to other property types for about half of the technologies implemented, while detached houses have a relatively high BCR for cavity wall insulation. The group of end-terrace, mid-terrace and semi-detached properties have a high BCR compared to other properties in the case of solid wall insulation

[34] Comfort taking was included in the CBA solely for measures where the corresponding health benefits were unavailable. The relevant measures whose corresponding health benefits were unavailable are heating controls, park home insulation, room-in-roof insulation, and under-floor insulations (both solid and timber).

(both external and internal). For park home insulation, single park homes have a relatively high BCR compared to double park homes.

For households accessing the scheme via the low-income route, the benefits of participation outweighed the costs for all types of property. This was also the case most of the households using the main route to participate in the scheme, except for those installing external solid wall insulation and park home insulation, for whom a net loss was observed.

In terms of differences across technologies, heating controls, under floor insulation and internal solid wall insulation provided the greatest benefit-to-cost ratio for households entering the scheme via the low-income route. For households participating via the main route, roof-in-room insulation, cavity wall insulation and heating controls provided the highest benefit-to-cost ratio.

Table A.2.7. Private benefit-to-cost ratios per technology and property type

Measure type and property type	*N*	Main Benefits £ (bills savings + comfort taking	Main Costs £ (Household contribution + hassle cost)	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Cavity wall insulation					
Bungalows	705	2,331,435	346,155	1,985,280	6.7
Detached	1,665	12,917,070	1,137,195	11,779,875	11.4
End / Mid / Semi[35]	1.854	7,723,764	871,380	6,852,384	8.9
Flat / Maisonette[36]	103	217,021	42,951	174,070	5.1
External solid wall insulation					
Bungalows	610	2,218,570	1,363,350	855,220	1.6
Detached	529	6,057,579	2,386,848	3,670,731	2.5
End / Mid / Semi	7,862	40,402,818	12,618,510	27,784,308	3.2
Flat / Maisonette	133	398,468	362,824	35,644	1.1

[35] Group of end-terrace, mid-terrace and semi-detached properties.
[36] Group of flats and maisonette.

Measure type and property type	***N***	**Main Benefits £ (bills savings + comfort taking**	**Main Costs £ (Household contribution + hassle cost)**	**Value of benefits compared to costs £ (Net benefit/cost)**	**Benefit-to-cost ratio (BCR)**
Flat roof insulation					
Bungalows	85	727,515	131,070	596,445	5.6
Detached	170	1,447,550	323,510	1,124,040	4.5
End / Mid / Semi	524	2,706,460	512,472	2,193,988	5.3
Flat / Maisonette	30	206,580	196,200	10,380	1.1
Internal solid wall insulation					
Bungalows	43	131,580	21,113	110,467	6.2
Detached	72	824,472	91,440	733,032	9.0
End / Mid / Semi	854	3,932,670	254,492	3,678,178	15.5
Flat / Maisonette	84	271,572	121,800	149,772	2.2
Loft insulation					
Bungalows	961	2,036,359	423,801	1,612,558	4.8
Detached	2,549	5,263,685	1,172,540	4,091,145	4.5
End / Mid / Semi	3,834	4,777,164	1,292,058	3,485,106	3.7
Flat / Maisonette	194	348,036	89,628	258,408	3.9
Park home insulation					
Double park	331	461,083	279,364	181,719	1.7
Single park	88	101,200	47,696	53,504	2.1
Roof-in-room insulation					

Measure type and property type	*N*	Main Benefits £ (bills savings + comfort taking	Main Costs £ (Household contribution + hassle cost)	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Bungalows	63	590,247	48,699	541,548	12.1
Detached	113	1,063,782	162,607	901,175	6.5
End / Mid / Semi	511	3,254,048	392,959	2,861,089	8.3
Flat / Maisonette	24	214,560	29,280	185,280	7.3
Under-floor insulation: Solid floor					
Bungalows	5	10,820	570	10,250	19.0
Detached	16	42,032	2,768	39,264	15.2
End / Mid / Semi	38	44,536	3,762	40,774	11.8
Under-floor insulation: Suspended floor					
Bungalows	176	526,592	88,176	438,416	6.0
Detached	355	1,340,480	203,060	1,137,420	6.6
End / Mid / Semi	1,250	2,581,250	410,000	2,171,250	6.3
Flat/Maisonette	28	58,128	16,912	41,216	3.4
Heating controls					
Bungalows	118	188,800	2,242	186,558	84.2
Detached	181	601,463	10,679	590,784	56.3
End / Mid / Semi	817	1,557,202	13,072	1,544,130	119.1
Flat / Maisonette	12	14,484	156	14,328	92.8
Window Glazing					

Measure type and property type	*N*	Main Benefits £ (bills savings + comfort taking	Main Costs £ (Household contribution + hassle cost)	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Bungalows	61	141,154	17,446	123,708	8.1
Detached	94	435,408	53,110	382,298	8.2
End / Mid / Semi	657	2,079,405	274,626	1,804,779	7.6
Flat / Maisonette	15	27,630	3,075	24,555	9.0

Table A.2.8. Benefit-to-cost ratios per means of participation and technology

Measure Type	Means of participation	N	Main Benefits £ (bills savings + comfort taking)	Main Costs £ (household contribution + hassle cost)	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Cavity wall insulation	Low Income	551	2,662,432	64,467	2,597,965	41.3
Cavity wall insulation	Main	3,776	20,526,336	2,333,568	18,192,768	8.8
Internal solid wall insulation	Low Income	821	3,930,127	18,062	3,912,065	217.6
Internal solid wall insulation	Main	232	1,230,064	470,728	759,336	2.6
External solid wall insulation	Low Income	6,755	35,031,430	5,458,040	29,573,390	6.4
External solid wall insulation	Main	2,379	14,050,374	11,274,081	2,776,293	1.2
Flat roof insulation	Low Income	486	2,996,190	135,594	2,860,596	22.1
Flat roof insulation	Main	323	2,092,071	1,027,463	1,064,608	2.0
Loft insulation	Low Income	2,093	3,281,824	307,671	2974153	10.7
Loft insulation	Main	5,445	9,147,600	2,668,050	6,479,550	3.4
Park home insulation	Low Income	276	368,460	9,384	359,076	39.3
Park home insulation	Main	143	193,765	317,746	-123,981	0.6

Measure Type	Means of participation	N	Main Benefits £ (bills savings + comfort taking)	Main Costs £ (household contribution + hassle cost)	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Roof-in-room insulation	Low Income	461	3,273,100	75,604	3,197,496	43.3
Roof-in-room insulation	Main	250	1,849,750	558,000	1,291,750	3.3
Under-floor insulation: Solid floor	Low Income	50	79,700	-	-	-
Under-floor insulation: Solid floor	Main	9	17,676	7,092	10,584	2.5
Under-floor insulation: suspended floor	Low Income	892	2,129,204	8,920	2,120,284	238.7
Under-floor insulation: suspended floor	Main	917	2,376,864	709,758	1,667,106	3.3
Heating controls	Low Income	1,043	2,156,924	2,086	2,154,838	1,034
Heating controls	Main	85	205,615	24,650	180,965	8.3
Window glazing	Low Income	733	2,368,323	222,832	2,145,491	10.6
Window glazing	Main	94	315,652	125,208	190,444	2.5

A.2.3.4 GHGVS energy specific estimates

Table A.2.9 (overleaf) presents the societal costs and benefits for each of the five measure types for which estimation of energy consumption changes with smart meter data was possible for gas-heated households. As can be seen, the BCR for cavity wall insulation, external solid wall insulation and loft insulation are qualitatively similar to those presented in Table A.2.4 although they differ in magnitude. The cost associated with the installation of air-source heat pumps outweighs the societal benefits in the sample of installations used in the analysis. This is partly due to high installation cost. Table A.2.10 shows the contribution of the individual benefits to the total social benefits for each of the five measure types.

Table A.2.9. Societal costs and benefits, appraisal period 2021-2063 (2021 prices) - Net benefit/cost

Measure Type	N	Lifetime	Benefits £	Costs £	Value of benefits compared to costs £ (Net benefit/cost)	Benefit-to-cost ratio (BCR)
Cavity wall insulation	310	42	647,590	641,700	5,890	1.01
External solid wall insulation	308	36	989,912	3,804,108	-2,814,196	0.26
Loft insulation	458	42	698,450	682,420	16,030	1.02
Pitched roof insulation	306	42	443,700	1,707,174	-1,263,474	0.26
Air source heat pump	263	15	2,112,942	3,772,472	-1,659,530	0.56

Table A.2.10. Percent contribution of individual benefits to total social benefits by measure

Measure Type	Energy savings (% of total benefits)	NHS spending savings (% of total benefits)	Carbon savings (% of total benefits)	Air quality improvements (% of total benefits)
Cavity wall insulation	23.1%	2.5%	44.8%	29.6%
External solid wall insulation	24.2%	1.7%	44.5%	29.6%
Loft insulation	23.5%	0.8%	45.5%	30.1%
Pitched roof insulation	23.5%	0.9%	45.5%	30.1%
Air source heat pump	2.8%	0.4%	57.2%	39.6%

A.2.3.5 Cost and benefits to participating households

Table A.2.11 shows the cost and benefits from the household’s perspective for the five measures. Loft insulation provided the greatest benefit-to-cost ratio for households followed by cavity wall insulation and pitched roof insulation. The BCR for air-source heat pump is less than one partly due to the observed increase in electricity consumption associated with the installation of air-source heat pumps.

Table A.2.21 Private benefit-to-cost ratios by technology

Measure Type	***N***	**Main Benefits £ (bills savings + comfort taking)**	**Main Costs £ (household contribution + hassle cost)**	**Value of benefits compared to costs £ (Net benefit/cost)**	**Benefit-to-cost ratio (BCR)**
Cavity wall insulation	309	335,265	185,709	185,709	1.8
External solid wall insulation	307	532,952	767,500	-234,548	0.69
Loft insulation	458	369,148	186,864	182,284	1.98
Pitched roof insulation	306	234,396	179,010	55,386	1.31
Air source heat pump	263	154,644	1,247,146	-1,092,502	0.12

Annex 3: Health Impact Analysis

By using health impact assessment modelling, it is possible to evaluate the potential impact of energy efficiency measures. Note that health impact assessment is a theoretical assessment and models the potential of the impacts of an intervention on health, rather than the actual impact the intervention has had.

This analysis seeks to quantify potential health improvements associated with the installation of measures through GHGVS in terms of impacts on the reduction in the cost of heating a home, either in the form of improvement in welfare (e.g. thermal comfort), or potential reduction in ill health and the associated costs on health services.

The analysis of the effects generated by GHGVS installations on indoor environmental conditions and occupants' health was performed using the Health Impact of Domestic Energy Efficiency Measures (HIDEEM) model developed for BEIS and using information provided by BEIS on the GHG Voucher scheme recipients.

A.3.1 Health impact assessment method

Change in household warmth and any corresponding health and well-being impacts were estimated using the Health Impact of Domestic Energy Efficiency Measures (HIDEEM) model. The HIDEEM model was developed by UCL and the London School of Hygiene and Tropical Medicine and is integrated into the National Household Model (NHM) as health impact module (NHM-Health) for BEIS.

HIDEEM is an exposure-determinant and health impact model that uses household-level information to quantify change in indoor environmental exposures and health outcomes through establish pathways. The underlying housing stock within the model is the English Housing Survey (EHS). The model comprises (i) a building physics model of English houses that quantifies indoor winter temperatures, exposures to particle pollution, tobacco smoke, radon, mould growth and energy demand in relation to the energy performance of the dwelling; and (ii) a model of the resulting health impacts based on a combination of life table methods and directly modelled changes in disease prevalence.

The health impact assessment using HIDEEM requires knowledge of the basic dwelling features and energy performance to predict the potential baseline indoor environmental quality (IEQ). To estimate changes in IEQ, GHGVS scheme data was used, including key features of the dwelling and measures installed (see below). The scheme data was then matched to extract representative dwellings from the EHS for the purpose of modelling the potential health impacts.

Other household determinants of potential health impact include age and sex, and these should be controlled for to estimate the effect of changes in IEQ. Where such information was not available from the scheme data, an approximation using a sample of households from the EHS was used to provide a range of impacts.

A.3.1.1 Health Impact of Domestic Energy Efficiency Measures model

For this GHGVS evaluation, a standalone version of the HIDEEM model is used to estimate the potential health impact of a selection of energy efficient measures installed in dwellings. The HIDEEM method works by calculating the changes in indoor environmental exposure of wintertime temperature and mould risk related to changes to the energy performance of the dwelling. The model can also estimate changes in air pollution (i.e. PM2.5 (indoor and outdoor sourced), environmental tobacco smoke, radon). However, due to data limitations on ventilation characteristics and before/after energy performance measurements, along with the uncertainty of where PAS 2035 was applied within the scheme, indoor air quality changes were not estimated except for mould risk, measured as the percentage change in risk of mould severity index being greater than 1 and relates to risk of asthma.[37]

Exposure to a change in the range of experienced wintertime temperature can modify the risk of developing a host of cardiovascular and respiratory diseases. [38] Dwelling energy efficiency measures for which health impacts were estimated comprise changes to the fabric performance, including loft, cavity wall and solid wall insulation, double-glazing replacement, along with boiler upgrade and gas central heating system installation.[39]

The model used the environmental changes of indoor temperature following a new installation in the dwelling to determine the effect on household occupant health (measured in QALYs using households representative of those living in dwellings similar to those participating in GHGVS), and then converting this health impact into the impact on health sector spending. The change in health sector spending use disease specific change in risks to changes in disease treatment costs, which are drawn from NHS disease treatment spending data.[40]

The quantification of health impacts based on the HIDEEM involved the following steps:

1. Identifying dwelling characteristics for scheme participants that could be used to define the housing stock on which to sample from the EHS; namely dwelling age and type.
2. Characterising the scheme's energy efficiency interventions applied within the HIDEEM modelling framework; adjusting and updating any relevant features of the HIDEEM model according to the scheme specification. The interventions included were: solid wall insulation, cavity wall insulation, draught proofing, glazing, heat pumps, roof insulation.
3. Running the model using the input data and corresponding EHS sampling to estimate the impacts of the scheme interventions on a change from the baseline estimated indoor environmental conditions (e.g. cold and mould risk). The change in exposure then drives an average change in relative risk, which creates a change in estimated health impact using the QALY, among the sample of households used to represent the scheme recipients.

[37] Fisk WJ, Lei-Gomez Q, Mendell MJ. Meta-analyses of the associations of respiratory health effects with dampness and mold in homes. Indoor Air 2007;17:284–96.
[38] Wilkinson, P., Landon, M., Armstrong, B., Stevenson, S., & McKee, M. (2001). Cold comfort: The social and environmental determinants of excess winter death in England, 1986-1996. Joseph Rowntree Foundation.
[39] Hamilton, I., Milner, J., Chalabi, Z., Das, P., Jones, B., Shrubsole, C., Davies, M., & Wilkinson, P. (2015). Health effects of home energy efficiency interventions in England: A modelling study. BMJ Open, 5(4). https://doi.org/10.1136/bmjopen-2014-007298
[40] Milner, J., & Hamilton, I. G. (2014). Evidence review and economic analysis of excess winter deaths and illnesses: Economic modelling report. National Institute for Health and Care Excellence. http://www.nice.org.uk/Guidance/InDevelopment/GID-PHG70/Documents

4. Calculating change in healthcare costs from the QALY by converting this health impact to the impact on health sector spending.

The model outputs an evaluation of the ex-ante impact of the energy efficiency measures on estimated changes in indoor environmental conditions and the impact on mortality and morbidity, and associated changes in healthcare expenditure.

Estimating the potential health benefits associated with GHGVS required characterising the dwellings energy performance from the available scheme data and drawing a sample of households from the EHS that represent those who live in dwellings similar to GHGVS recipients and using the HIDEEM model to calculate the effect of the introduction of a selection of energy efficiency measures that could change the indoor environmental conditions. This included developing both an intervention and comparison of a pre-intervention state for the target households. The analysis also needed to account for uncertainty in the sample related to occupancy, underlying health conditions, and existing environmental conditions within the dwellings.

The above modelling assumptions mean that the results cannot be used to estimate the health impact for any specific household but are instead indicative of the potential health impacts of the broader scheme population.

A.3.2 Scheme data used in the health impact assessment

The scheme data provided a set of dwelling attributes and energy performance characteristics needed for the health impact analysis. The dwellings characteristics and energy performance data were derived from the scheme data for those taking part in GHGVS. The set of key variables used comprised:[41]

- Dwelling type (e.g., bungalow, detached house, semi-detached house, terraced house, and flats).
- Dwelling age (e.g., pre-1900; 1900-1929; 1930-1949; 1950-1966; 1967-1975; 1976-1982; 1983-1990; 1991-1995; 1996-2002).
- Scheme type (i.e. low income; main).
- Measures: cavity wall insulation; external solid wall insulation; internal solid wall insulation; loft insulation; roof insulation; floor insulation; park home insulation; double or triple glazing; draught proofing; secondary glazing; heat pump (air, ground, hybrid); biomass boiler; solar thermal; electric storage heating; heating controls; hot water tank insulation; hot water tank thermostat; external energy efficient doors; solar PV; energy efficient lighting).

The following variables were not included[42]:

[41] These variables are not included because the HIDEEM model does not evaluate newer homes or modular constructions due to the underlying data on temperature containing no such dwellings.

[42] Some measures are not used for determining any potential health impacts due to the lack of a mechanism to change indoor temperatures due to efficiency improvement (i.e. hot water tanks, heating controls, doors, PV, or lighting), or due to the lack of data on how IEQ changes from installations (i.e. biomass boilers, solar thermal, electric storage). Other measures, such as heat pumps are only assumed to improve the temperature-related energy performance to a maximum threshold and are therefore modelled as a proxy improvement.

- Dwelling Type: park homes are not included in the analysis due to a lack of data used in the modelling for changes in indoor environmental change from retrofits.
- Dwelling Age: Post-2002 dwellings are excluded from changes in health impacts related to temperature changes due to both higher performance levels and lack of data used in the modelling for changes in indoor environmental change from retrofits.
- Measures: biomass boiler; solar thermal; electric storage heating; heating controls; hot water tank insulation; hot water tank thermostat; external energy efficient doors; solar pv; energy efficient lighting). These measures are not used for determining any potential health impacts from certain types of efficiency improvement having no clear mechanism to change temperature (i.e. hot water tanks, heating controls, doors, PV, or lighting), or due to the lack of data on how IEQ changes from installations (i.e. biomass boilers, solar thermal, electric storage). Some measures, such as heat pumps are only assumed to improve the temperature-related energy performance to a maximum threshold and are therefore modelled as a proxy improvement.

Combined, these dwelling attributes and energy efficiency measures are the basis of the dwelling IEQ change and the corresponding estimated change in health outcomes.

A.3.3 Data limitations

The health impact analysis is subject to the following limitations:

- The full input data points used by the HIDEEM model were not available from the scheme data and therefore several assumptions were made in order to mitigate against these limitations and to estimate household environmental changes.
- The lack of a measure of the change in energy performance of the dwelling from a baseline level to a modified level (e.g. Energy Performance Certificate (EPC) before/after installation) meant that assumptions in temperature change were derived from associations with the retrofit measure and not from the change in overall performance, though they are related. For example, an unfilled cavity wall will have a higher heat loss than a filled cavity and therefore a higher risk of low indoor temperatures during wintertime conditions.
- To estimate the dwelling indoor temperature baseline condition, the modelling assumed that the intervention was not present prior to the scheme and therefore all interventions are considered as additive from the baseline. The modelling used the dwelling type, age, and knowledge of added interventions to determine the baseline and modified performance levels for driving the indoor temperature calculation. The HIDEEM modelling used data from existing studies to underpin these assumptions (Hamilton, 2015).
- Data about the age and sex of the household occupants were also unavailable. These would be used to further tailor the impacts for individual household typologies. Instead, an average estimate of households that reside in the dwelling types were drawn from the EHS to estimate the change in health related to the change in IEQ. The potential

improvement in health relates to both the underlying vulnerability of the household and the duration of the effect, i.e. how long someone can benefit from the change.

- A lack of data on ventilation remains an important limitation of the health impact assessment. However, this limitation is mitigated by the PAS requirements under the scheme, which mandated that installations met minimum ventilation requirements; as such the scheme did have measures in place to ensure mould risks were minimised.[43]

A.3.4 GHGVS health impact assessment results

The analysis below shows the results of the HIDEEM modelling for GHGVS applicants. The analysis is shown with two timespans, one showing the impact of the interventions over a 5-year period to illustrate short term impacts, and the second over a 42-year period to illustrate longer term impacts that span a relevant human health period.

Table A.3.1 shows the change in indoor environmental conditions for households of GHGVS applicants who had at least one energy efficiency installations completed as of 7th December, 2021. The change in indoor temperature related to relevant measures, i.e. fabric and heating system measures, shows modest changes in indoor temperature, ranging around 0.1-0.3 ºC during wintertime conditions.

The positive environmental exposure changes have a corresponding modest positive benefit for health. The change in health over a period of 5 years amounts to around 158 QALYs (Table A.3.1), and around 1,309 QALYs after 42 years (Table A.3.2). When these QALYs are converted to health care contacts, the change in QALYs results in a change in the number of people seeking medical services, and health-related expenditure for that disease. When considering the impact these environmental exposure changes have on health sector expenditure for treatment of temperature related disease, the impacts amount to a total scheme level estimate of £143,000 after 5 years and £2,305,000 after 42 years.

[43] All measures within the GHGVS must meet the minimum ventilation requirements of PAS 2030:2017 section A5 and tables A4/5/6. Ventilation requirements must be satisfied and evidenced in full for the installation to be PAS compliant. It is recognised under PAS 2030:2017 ventilation requirements are recommendations, yet under the TrustMark GHGVS requirements, these are mandatory requirements. In all cases where the installation of a insulation measure is undertaken, the property must have ventilation requirements completed in line with either PAS 2030:2017 or as per the requirements of PAS 2035:2019 and PAS 2030:2019 depending upon the installation methodology used.

Table A.3.3 – Results of the health impact analysis for GHGVS recipients over 5 years

	Count	Base Temperature (SIT[44])	Change in SIT	Modified Temperature (SIT)	Change in Mould Risk	Change in Mortality and Morbidity QALYs over 5 years	Change in NHS spending over 5 years
Cavity wall insulation	3,805	17.9	0.2	18.1	-0.3	33.5	-£30,135
Draught proofing	13	17.9	0.1	17.9	2.5	0.0	-£19
Glazing	670	17.5	0.1	17.7	-0.3	3.0	-£2,849
Heat pumps	3,443	17.7	0.2	18.0	-0.5	27.6	-£27,301
Roof insulation	11,464	17.7	0.1	17.7	-0.1	24.6	-£22,497
Solid wall insulation	7,602	17.7	0.3	18.0	-0.6	70.0	-£60,251
Grand Total	26,997					158.6	-£143,053

[44] SIT is the indoor temperature and is standardised to conditions at 5ºC outdoors, i.e. standardised indoor temperature (SIT).

Table A.3.4 – Results of the health impact analysis for GHGVS recipients over 42 years

	Count	Base Temperature (SIT)	Change in SIT	Modified Temperature (SIT)	Change in Mould Risk	Change in Mortality and Morbidity QALYs over 42 years	Change in NHS spending over 42 years
Cavity wall insulation	3,805	17.9	0.2	18.1	-0.3	276.8	-£479,756
Draught proofing	13	17.9	0.1	17.9	2.5	0.2	-£298
Glazing	670	17.5	0.1	17.7	-0.3	24.0	-£41,503
Heat pumps	3,443	17.7	0.2	18.0	-0.5	215.1	-£391,683
Roof insulation	11,464	17.7	0.1	17.7	-0.1	201.7	-£348,216
Solid wall insulation	7,602	17.7	0.3	18.0	-0.6	591.3	-£1,044,259
Grand Total	26,997					1,309.1	-£2,305,715

Based on the above analysis and keeping in mind the limitations of the input data, GHGVS shows a likely in improvements in wintertime indoor temperatures and a related reduction of mould risk from warmer air for households installing measures under the scheme.

The results show that the change in temperature is modest at the household level but would correspond to a positive change in health and could reduce health sector spending in temperature-related disease treatments.

These estimates reflect the data limitations wherever possible to provide an average effect, whose estimate can be improved on with further health specific data (e.g. age and sex of households).

Overall, however, the scheme is likely to have provided health benefits to participating households where the interventions are highly likely to result in an improvement in temperatures and reduction in mould risk.

Annex 4: Energy, Carbon and Bills savings analysis

This report provides estimates of the average effect on electricity and gas savings, and carbon and bill savings, of measures installed as part of GHGVS. This analysis has been conducted using smart meter gas and electricity consumption data collected from:

- A total of 2,428 households participating in GHGVS, who consented to provide UCL with access to their smart meter data ('treatment group'), and
- Similar smart meter and linked contextual data from the ~13,000 households participating in the SERL Observatory ('control group').

Smart meter data was collected from the treatment group before and after the installation of an energy efficient and/or low-carbon heating measure under GHGVS. In order to understand whether observed changes in energy consumption amongst the treatment group could be attributed to GHGVS measure, UCL compared the energy consumption patterns of the treatment group to those of the control group over the same time period through the use of linear regression models.

The outcome variable in the regression model was the average daily electricity, or gas, consumption of homes in a 12-month evaluation period, running from September 2021 to August 2022. The majority of GHGVS measures were installed between March and August 2021. The model controlled for the pre-baseline energy use of each household, based on a three-month period from December 2020 to February 2021, as well as a range of household-level building, appliance, and occupant characteristics.

A.4.1 Methodology

A.4.1.1 Recruitment

The recruitment of GHGVS applicants to collect smart meter data for this evaluation was conducted as part of a separate BEIS-funded project. BEIS provided UCL with GHGVS scheme data in late September 2021. The scheme data recorded UPRNs,[45] information regarding consent for contact for further research and an evaluation ID which could be linked to a separate file containing details of GHGVS application and the measures installed through the scheme. UCL created a list of approximately 21,000 UPRNs associated with households that consented to contact for further research and who had at least one measure installed under the scheme at the time of sampling. The DCC[46] register was then queried for information about DCC-enrolled smart meters associated with these UPRNs. This is the same process used to recruit participants to the SERL Observatory, which has been approved by UCL ethics and is compliant with GDPR and the Smart Energy Code. UPRNs with a smart electricity meter that was commissioned at least 90 days before the date of the completed retrofit measure were identified and the addresses associated with these UPRNs were found using OS

[45] Unique Property Reference Number
[46] Data Communications Company – the GB smart meter communication network.

AddressBase.[47] There was no filtering based on the type of retrofit measure that the participants had installed. Ultimately invitations to participate in the research were sent to 6,862 addresses.

Recruitment and consent took the following steps:

- Initial contact via a letter posted to a recipient of a GHG measure at a meter's registered address. The first wave of recruitment letters were sent in late October 2021. Recipients were offered a £10 voucher if they agreed to take part in the study.
    - Non-responsive recipients were sent a reminder letter 13 days after the first mailing.
    - Recipients who were still non-responsive were sent a final reminder 13 days after the second mailing and this included paper/mailing options for sign up and survey completion.
- Participants opted in by logging on to a web portal using a link and unique code provided in the letter.
    - Consent was obtained at this point.
    - The online survey was completed at this point (see below for more information about the survey).
- There were paper/mail options for those unable/unwilling to respond online.
- Once UCL obtained consent (and any authentication processes was completed as required by the Smart Energy Code), smart meter data was collected via the DCC and linking to contextual data (e.g. the survey, EPC data etc.).

The deadline for taking part in the research was 13th December 2021. By this date 2,428 applicants had completed the survey, including 355 who signed up by post. The survey response rate was 35.8%; this is exceptionally high compared to the average SERL Observatory sign up rate of about 10%. This unusually high response rate suggests that those who sought a Green Homes Grant Voucher and agreed to participate in further research may already be keen to engage with issues around domestic energy use.

GHGVS applicants provided consent for their smart meter data to be accessed for the purpose of the evaluation, including up to 12 months before the participation start date (drawing on the historic data that is stored on smart meters), and for these data to be linked to the following contextual data for the evaluation:

- Information on the household's energy saving and heating behaviours, characteristics of the building they occupied where the measure was installed, appliances in the home, and occupant demographic variables. This was collected through a survey conducted by UCL. The questions were identical to those used in the SERL Observatory survey[48].
- Pre-measure EPC rating, which was collected via the Government's open data API,[49] This is publicly available data and can be used for scientific research purposes in the

[47] A database of all GB addresses
[48] Consent form – Smart Energy Research Lab. UCL, Smart Energy Research Lab, not dated. https://doc.ukdataservice.ac.uk/doc/8666/mrdoc/pdf/serl_main_recruitment_survey_copy.pdf
[49] Energy Performance of Buildings Data: England and Wales. DLUHC, 2023. https://epc.opendatacommunities.org/

public interest. Consent to process EPC data was also obtained from the applicants (the EPC data processed is that which is made publicly available by DLUHC via https://epc.opendatacommunities.org/).

- Information on the measure installed, as well as the start and end dates of the installation, taken from GHGVS scheme data.

All data from the participants were stored within the UCL 'Data Safe Haven', a secure research lab which enables virtual access for ONS Accredited Researchers working on a project approved by UCL ethics and the SERL Data Governance Board.

A.4.1.2 Profile of GHGVS applicant households analysed for energy consumption

Of the 2,428 GHGVS households for which smart meter data was analysed, 1,321 (54%) had applied through the main scheme, and 1,107 (46%) through the low-income scheme. Amongst the households in the treatment group used in the analysis, 2,831 measures were installed by 7th December 2021. This represents ~6% of all measure installations that were completed under the scheme by this date (see Table A.4.1).

Table A.4.5. Households and installations in GHGVS. All figures are for measure installations completed as of 7th December 2021.

Part of the treatment group used in this analysis	Number of households with at least one installation	% of households	Number of installed measures	% of installed measures (%)
Yes	2,428	6%	2,831	6%
No	40,317	94%	46,009	94%
Total	42,745	100%	48,840	100%

Figure A.4.1 shows the distribution over time by date of completion of installation of measures for the treatment group used in the analysis. It shows that the majority of measures were installed in the households of this group between March and August 2021.

Figure A.4.1: Completed installations over time.

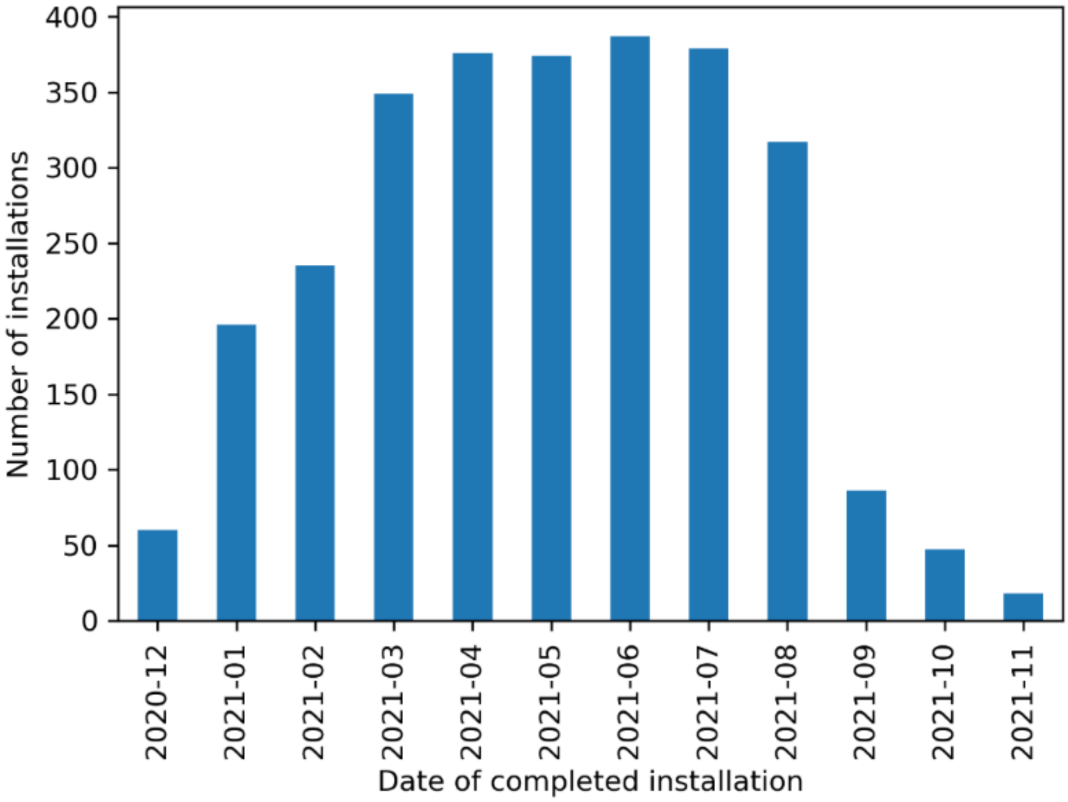

Table A.4.2 provides a breakdown by measure group and measure type of the total number of installations that were completed in all GHGVS households and in the treatment group as of 7th December 2021. The table shows that a similar proportion of insulation measures, low-carbon heating and secondary measures were installed in the sample drawn for this energy analysis as for the overall population of GHGVS applicants. Table A.4.2 shows that smart meter data was collected and analysed for about 6% of all households who installed measures using GHGVS vouchers, except for windows and doors, where the sample represents only 4% of all GHGVS applicants who had the measure installed. This means that from a measure perspective, GHGVS sample used in this analysis is fairly representative of the wider GHGVS population. If the sample was drawn randomly from the population, then sample-level estimates could be taken to be unbiased estimates for the population. However, this is not the case. The sample should therefore be assumed to be affected by selection bias, and estimates based on the sample should be assumed to be biased.

The most common measure group installed in the properties of the treatment group used in this analysis was insulation (68% of installations), followed by low-carbon heat (26%). Some of the most common individual measures were loft insulation (19%), solar thermal (14%), cavity wall insulation (13%), pitched roof insulation (13%), external solid wall insulation (12%) and air source heat pump (10%), followed by under-floor insulation suspended floors (6%), then windows and doors and heating controls (both at 3%).

Table A.4.6. Proportion of completed installations by measure group and measure type

Columns (A) refer to all GHGVS applicants who had a measure installed ('full population'). Columns (B) refer to GHGVS applicants who had measures installed *and* who consented to share their smart meter data with UCL for the evaluation ('treatment group').

Measure	Number of installations (A)	% of all GHGV installations (A)	Number of installations (B)	% of all installations in treatment group (B)	% of all GHGV installations (B/A*100)
Primary Measures	**45,565**	**93%**	**2,670**	**94%**	**6%**
Insulation	**33,238**	**68%**	**1,940***	**68%**	**6%**
Cavity wall insulation	4,435	9%	376	13%	8%
External solid wall insulation	9,562	20%	350	12%	4%
Flat roof insulation	845	2%	51	2%	6%
Internal solid wall insulation	1,088	2%	18	0.6%	2%
Loft insulation	7,757	16%	551	19%	7%
Park home insulation	609	1%	15	0.5%	2%
Pitched roof insulation	6,222	13%	372	13%	6%
Room-in-roof insulation	769	2%	43	2%	6%
Under-floor insulation: Solid floor	66	0.1%	10 or fewer*	<0.4%*	<15%*
Under-floor insulation: Suspended floor	1,885	4%	157	6%	8%
Low-carbon heat	**12,330***	**25%**	**740***	**26%**	**6%**
Air source heat pump	3,924	8%	290	10%	7%

Measure	Number of installations (A)	% of all GHGV installations (A)	Number of installations (B)	% of all installations in treatment group (B)	% of all GHGV installations (B/A*100)
Biomass boiler	10 or fewer*	0.01%	10 or fewer*	<0.4%*	-*
Ground source heat pump	30*	0.1%	10 or fewer*	<0.4%*	<34%*
Hybrid heat pumps	955	2%	50*	2%	5%
Solar thermal	7,413	15%	397	14%	5%
Secondary Measures	**3,275**	**7%**	**160**	**6%**	**5%**
Double/triple glazing	856	2%	40*	1%	4%
Draught proofing	16	0.03%	10 or fewer*	<0.4%*	<63%*
Energy efficient replacement doors	1,217	3%	47	2%	4%
Secondary glazing	27	0.1%	10 or fewer*	0.07%	7%
Heating controls	1,159	2%	72	3%	6%

Notes: Columns (A) refer to all GHGVS applicants who had a measure installed ('full population'). Columns (B) refer to GHGVS applicants who had measures installed *and* who consented to share their smart meter data with UCL for the evaluation ('treatment group'). This covers measure installations completed as of 7th December 2021. To prevent statistical disclosure, counts of less than 10 have been adjusted and presented as '10 or fewer', and the total for the group and for the next smallest count within that group have both been rounded to the nearest 5 to prevent the count being inferred. Percentages have also been adjusted accordingly. All adjusted figures are indicated with *.

A.4.1.3 Use of SERL Observatory data

SERL is an ongoing UKRI-funded research project, with one of its aims being to collect smart meter and linked contextual data from over 13,000 participants, who have consented for their data to be used for research into the public good that has been approved for access to the data via SERL's governance procedures.[50] Approval was obtained from UCL ethics and the SERL Data Governance Board to use this data as a control group for GHGVS evaluation. To enable comparative analysis as part of the evaluation, the same contextual data was collected

[50] For a detailed description of the dataset, see Webborn E, Few J, McKenna E, Elam S, Pullinger M, Anderson B, Shipworth D, Oreszczyn T. The SERL Observatory Dataset: Longitudinal Smart Meter Electricity and Gas Data, Survey, EPC and Climate Data for over 13,000 Households in Great Britain. *Energies*. 2021; 14(21):6934. DOI: 10.3390/en14216934.

for both samples (control and treatment), except for scheme data which was only available for GHGVS participants.

A.4.1.4 Data preparation

Both the treatment dataset (GHGVS smart meter dataset) and the control dataset (the SERL Observatory dataset) were prepared following these steps:

1. GHGVS smart meter data was cleaned by flagging anomalous individual smart meter readings (e.g. with incorrect time stamps, or unrealistically large values) as invalid – only the remaining, 'valid', readings were used in further steps of analysis. This made GHGVS smart meter data equivalent in content and structure to the SERL Observatory dataset, described in Elam et al. 2022.[51] This was so that the treatment and control home data were both of equal data quality and format, so that the remaining stages of data preparation and analysis, described below, could be undertaken.
2. The energy consumption in kilowatt hours (kWh) for each home for each day of the trial was then calculated using only the valid smart meter readings (i.e. those that were not flagged as anomalous in step 1 above), for both the treatment and control households. This was calculated separately for gas consumption and for net electricity consumption (i.e. the household's import from the electricity grid minus its export, if any).
3. For each household and fuel type, daily energy usage was calculated based on half-hourly smart meter readings, where all 48 readings (or 46/50 on days when clocks changed) were available and valid. When this was not the case, the daily smart meter reading was used instead, if available and valid. For electricity data for homes with microgeneration, such as rooftop solar photovoltaic panels (identified based on their having one or more electricity export readings during the trial period), daily readings were not used in the absence of complete half-hourly data for a given day, as only the half-hourly readings include export data. This follows the approach developed by Few et al (2022).[52]

An 'evaluation period' of September 2021 to August 2022 was defined, during which the impact of interventions on household energy use would be evaluated. This period was selected as the full year before the timestamp of the most recent available data in the SERL Observatory dataset (31 August 2022). By assessing consumption over a full year, the team were better able to estimate the average effects of interventions over a year.

Previous energy use is a strong predictor of future energy use, so gas and net electricity use for a pre-baseline period (December 2020 to February 2021) was also calculated to act as a control variable. Although the pre-baseline period would ideally also consist of a full year prior to the installation of equipment, both recruitment timings and the availability of only 12 months of smart meter data prior to the date of consent to participate meant that few homes had smart meter data available for analysis prior to December 2020. For this reason, this was set as the

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[51] Elam, S., Webborn, E., Few, J., McKenna, E., Pullinger, M., Oreszczyn, T., Anderson, B., Ministry of Housing, Communities and Local Government, European Centre for Medium-Range Weather Forecasts, Royal Mail Group Limited. (2022). *Smart Energy Research Lab Observatory Data, 2019-2022: Secure Access*. [data collection]. *6th Edition.* UK Data Service. SN: 8666, DOI: 10.5255/UKDA-SN-8666-6.

[52] Few, Pullinger, McKenna, Elam, Webborn and Oreszczyn (2022) Smart Energy Research Lab: Energy use in GB domestic buildings 2021. Variation in annual, seasonal, and diurnal gas and electricity use with weather, building and occupant characteristics. (SERL Statistical Reports: Volume 1), https://serl.ac.uk/key-documents/reports/.

starting date for the pre-baseline period. Considering that GHGVS installations began in November 2020 initially at low rates, a date of 28 February 2021 was selected for the end of the pre-baseline period. This provided a suitably long period upon which to estimate pre-baseline energy use (three months), but which was short enough that few recruited homes had to be omitted from further analysis (due to their installations commencing during the pre-baseline period).

Each household's daily mean gas and net electricity use in kWh was calculated as follows:

- Pre-baseline (December 2020 to February 2021): The mean of the available daily values over the period.
- Evaluation period (September 2021 to August 2022): The mean of the available daily values was calculated for each quarter of the evaluation period for each home and fuel. The mean for the full year was then calculated from the mean of the weighted quarterly means, i.e. the sum of the means for each quarter multiplied by the number of days in that quarter, then divided by 365. The formula is presented in the equation below, where y_h is the evaluation period mean daily energy use for household *h* for the given fuel (electricity or gas), *Q* is the quarters of the evaluation period, $\bar{E}_{hQ}$ is the mean electricity or gas use for the given home and quarter and D_Q is the number of days in that quarter. Using the mean of the weighted quarterly means, rather than the simple mean of the available data for the full year, helps improve the estimated value in any cases where data availability varies substantially over the year.

$$y_h = \frac{\sum_{Q=1}^{4} \bar{E}_{hQ} D_Q}{365}$$

A.4.1.5 Data analysis

Selection of data

All households in the treatment and control group samples were included in the regression models, with the following exceptions:

- Treatment group households whose installations began during the pre-baseline period, i.e. before March 2021, or finished after the start of the evaluation period, i.e. after August 2021.
- Households for which more than 80% of clean daily readings were missing for the pre-baseline period or for any individual quarter of the evaluation period. Estimates of daily mean energy use were considered unreliable if more than this level of data were missing. This filtering was done separately per fuel, i.e. exclusion from the gas analysis did not automatically mean exclusion from the electricity analysis and vice versa.
- Households, on a per-fuel basis, identified as having outlier data, identified using an Interquartile Range (IQR) method.
- For regressions relating to the measure level, rather than measure group, households with more than one measure installed.

Table A.4.7. The reduction in the number of observations in each step of the data preparation

Data selection step	Number of treated households after this step	Number of control households after this step
Initial count, before any data selection steps	total: 2,428	gas: 8,055
	total: 2,428	electricity: 10,834
Selecting period	gas: 1,393	gas: 8,055
	electricity: 2,024	electricity: 10,834
Merging datasets and missing observations	gas: 974	gas: 3,576
	electricity: 1,434	electricity: 4,701
Removing outliers	gas: 960	gas: 3,438
	electricity: 1,310	electricity: 4,600

Regression models

The effects on gas and net electricity consumption of different types of intervention funded through GHGVS during the evaluation period were estimated through a series of linear regression models, described below. A fixed evaluation period was used to assess the impact of the interventions, from September 2021 to August 2022, as detailed above. The fixed evaluation period, along with the inclusion of a geographic region variable in the regression model, controlled for a range of geographic and time-dependent variables, notably local climate variables including temperature, irradiance (the solar energy reaching the ground per unit time and area), precipitation, wind speed, and similar, as well as COVID household occupancy effects, so that they did not need to be included in the regression model. A wide range of other variables were considered for inclusion in the model to control for their impacts on energy use. The team used machine learning (LASSO regression) to identify which of these variables affected energy consumption. The team then controlled for these factors in the final regression models. The inclusion of these variables in the model increased the sensitivity of the model to detect changes in energy use that could be attributed to GHGVS measures.

The formulae of the regression models are set out below.

$$y_{i1} = \alpha + \beta y_{i0} + \sum_{m=1}^{M-1} \gamma_m Measure_{im} + \sum_{r=1}^{R-1} \delta_r Region_{ir} + \sum_{a=1}^{A-1} \eta_a Age_{ia} + X'\psi + \epsilon_{i1} \qquad (1)$$

$$\begin{aligned} y_{i1} = \alpha + \beta y_{i0} + \sum_{m=1}^{M-1} \gamma_m Measure_{im} + \sum_{r=1}^{R-1} \delta_r Region_{ir} + \sum_{a=1}^{A-1} \eta_a Age_{ia} + \sum_{m=1}^{M-1}\sum_{r=1}^{R-1} \theta_{m,r} Measure_{im} \times Region_{ir} \\ + \sum_{m=1}^{M-1}\sum_{a=1}^{A-1} \kappa_{m,a} Measure_{im} \times Age_{ia} + X'\psi + \epsilon_{i1} \qquad (2) \end{aligned}$$

- In this study, the outcome variables (y_{i1}) are daily mean net electricity and gas usage during the evaluation period. The models were run separately for each combination of the following: For electricity usage and for gas usage.
- At the level of the measure groups (such as *low-carbon heat, LCH)*, and at the measure level (such as *air source heat pump*).
- For homes which, during the pre-baseline period, had gas central heating, and those which had electric central heating.
- Without interaction terms between the measure/measure group and building age and region (specification 1 above), and with those terms (specification 2 above).

Thus, overall, there are sixteen sets of results according to the dependent variable, the $Measure_{im}$ variable in the specification that can take group or individual measures, the selection of households by heating fuel, and whether or not interaction effects with region and age band of the building were included. We also controlled in the models for pre-baseline period daily mean energy (gas or electricity) use (y_{i0}), in addition to occupant and dwelling characteristics at the property level selected through the LASSO approach (X).

The full list of variables implemented in the model to capture the unbiased estimators with their data sources is included in Table A.4.3 below. The list of the variables' names are mostly available in the online appendix of McKenna et al. 2022.[53] Table A.4.3 shows the variables in the SERL survey data, Table A.4.4 presents the variables in the EPC data, and Table A.4.5 contains the variables in the scheme data.

Table A.4.3. Variables included in the SERL survey data

Associated survey question number	Description	Categories
A301	Type of central heating - None	Yes, No
A302	Type of central heating - gas, gas boiler	Yes, No
A303	Type of central heating - electric storage heaters	Yes, No
A304	Type of central heating - electric radiators	Yes, No
A305	Type of central heating - other electric	Yes, No
A306	Type of central heating - oil	Yes, No
A307	Type of central heating - solid fuel	Yes, No
A308	Type of central heating - biomass	Yes, No
A309	Type of central heating - district or community	Yes, No
A310	Type of central heating - other	Yes, No
A901	Do you adjust your heating - When especially cold	Yes, No

[53] McKenna, E., Few, J., Webborn, E., Anderson, B., Elam, S., Shipworth, D., Cooper, A., Pullinger, M. and Oreszczyn, T., 2022. Explaining daily energy demand in British housing using linked smart meter and socio-technical data in a bottom-up statistical model. Energy and Buildings, 258, p.111845. Available at: https://www.sciencedirect.com/science/article/pii/S0378778822000160#s0190

Associated survey question number	Description	Categories
A902	Do you adjust your heating - Because of children, infants, babies	Yes, No
A903	Do you adjust your heating - Visitors	Yes, No
A904	Do you adjust your heating - Pets	Yes, No
A905	Do you adjust your heating - Stress	Yes, No
A906	Do you adjust your heating - Working at home	Yes, No
A907	Do you adjust your heating - None of these	Yes, No
A12_Taps_GB	Tap water heated (Gas Boiler)	Yes, No
A12_Taps_EH	Tap water heated (Electrical Heater)	Yes, No
A12_Taps_SWH	Tap water heated (Solar Water Heater)	Yes, No
A12_Taps_Other	Tap water heated (Other)	Yes, No
A12_Taps_NA	Tap water heated (Not applicable)	Yes, No
A12_Taps_DK	Tap water heated (Don't Know)	Yes, No
A12_Shower_GB	Shower water heated (Gas Boiler)	Yes, No
A12_Shower_EH	Shower water heated (Electrical Heater)	Yes, No
A12_Shower_SWH	Shower water heated (Solar Water Heater)	Yes, No
A12_Shower_Other	Shower water heated (Other)	Yes, No
A12_Shower_NA	Shower water heated (Not applicable)	Yes, No
A12_Shower_DK	Shower water heated (Don't Know)	Yes, No
B9	When was your accommodation built	Before 1900, 1900 to 1929, 1930 to 1949, 1950 to 1975, 1976 to 1990, 1991 to 2002, 2003 onwards
B1001	Appliances in accommodation - Kitchen - Electric Oven	Yes, No
B1002	Appliances in accommodation - Kitchen - Gas Oven	Yes, No
B1003	Appliances in accommodation - Kitchen - Electric Hob	Yes, No
B1004	Appliances in accommodation - Kitchen - Gas Hob	Yes, No
B1005	Appliances in accommodation - Kitchen - Dishwasher	Yes, No
B1006	Appliances in accommodation - Kitchen - Fridge or fridge-freezer	Yes, No

Associated survey question number	Description	Categories
B1007	Appliances in accommodation - Kitchen - Separate stand alone freezer	Yes, No
B1008	Appliances in accommodation - Laundry - Combined clothes washer dryer	Yes, No
B1009	Appliances in accommodation - Laundry - Washing machine	Yes, No
B1010	Appliances in accommodation - Laundry - Tumble dryer	Yes, No
B1011	Appliances in accommodation - Consumer electronics - Laptop, computer	Yes, No
B1012	Appliances in accommodation - Consumer electronics - TV	Yes, No
B1013	Appliances in accommodation - Cooling - air conditioning unit	Yes, No
B1014	Appliances in accommodation - Cooling - cooling fan	Yes, No
C2_sum	Number of occupants from C2 responses	continuous

Table A.4.4. Variables included in the EPC data

Variable name	Description	Categories
localAuthority	Local authority to find the region	
constructionAgeBand	The construction age band of a dwelling	Before 1900, 1900 to 1929, 1930 to 1949, 1950 to 1975, 1976 to 1990, 1991 to 2002, 2003 onwards
builtForm	The built form of a dwelling	Detached, semi-detached, mid-terrace, end-terrace
propertyType	The property type	House, Bungalow, Flat, Maisonette, Park home
totalFloorArea	Total floor area of a dwelling	Numeric
numberHabitableRooms	The number of habitable rooms in a dwelling	Numeric
numberHeatedRooms	The number of heated rooms in a dwelling	Numeric
tenure	The tenure status	Owner-occupied, rental (private), rental (social)
currentEnergyEfficiency	Energy efficiency of a dwelling	numeric
windowsEnergyEff	Energy efficiency of windows in a dwelling	Very poor, poor, average, good, very good

Variable name	Description	Categories
wallsEnergyEff	Energy efficiency of walls in a dwelling	Very poor, poor, average, good, very good
lightEnergyEff	Energy efficiency of lights in a dwelling	Very poor, poor, average, good, very good
energyTariff	The type of energy Tarrif in a dwelling	Single, dual, off-peak 10 hours, off-peak 7 hours
CurrentEnergyRating	Energy rate of a dwelling	A, B, C, D, E, F, G

Table A.4.5. Variables included in the scheme data

Variable name	Description	Categories
Measure Group	Measures are categorised in four groups	insulation, low-carbon heat, heating controls and insulation, windows and doors
Measure Name	The installed measures available for households in smart meter data	air source heat pump, heat pumps, solar thermal, cavity wall insulation, external solid wall insulation, internal solid wall insulation, loft insulation, under-floor insulation, flat roof insulation, pitched roof insulation, room-in-roof insulation, park home insulation, heating controls, energy efficient replacement doors, other windows and doors
Completion date	The date that installation is completed in a property	date (dd/mm/yyyy)

The variables of interest for this specification were the measure name (or measure group), as well as its interaction terms with the region, i.e. the geographic location, of the home in which the measure was installed[54] ($Measure_{im} \times Region_{ir}$), and its interaction with the age band of construction of the property ($Measure_{im} \times Age_{ia}$). Using the interaction terms, we verified whether there was any difference in the impact on energy use of installing a measure under GHGVS considering the geographical location of the household and the dwelling age band.

Therefore, the average impact of any given measure (or measure group) "m" was captured by γ_m in the models that exclude the interaction terms (specification 1 above). Any difference in those impacts in region "r" and property with age band "a" are given by the terms $\gamma_m + \theta_{m,r}$ and $\gamma_m + \kappa_{m,a}$, respectively, in the models that include those interaction terms (specification 2 above). These indicate statistically significant differences between a given region or age band

[54] The team controlled for the interaction terms of the geographical location of households and type of measure (measure group) to consider the differences in the effect of each type of measure (measure group) on energy use in different regions. Besides, it also considers the potential differences in the quality of installation of each measure (measure group) in the different areas.

compared to a reference category. Further information on how the LASSO approach regulated the model is included in the next section.

Regularisation parameter

Before we used the LASSO approach to estimate the effects, we needed to determine the regularisation parameter, which has a key role in selecting independent variables for the estimation among all the variables that we fed to the model. To do that, we used a 5-fold cross-validation approach with grid searching over 500 values between zero and one. We also considered two metrics to find the optimum value for this regularisation parameter, R^2 and the negative root mean squared error (negative RMSE). We provide the optimum values for the regularisation parameter in the LASSO regression based on the level of measures (group and individual) and fuel (gas and electricity).

Counterfactual scenario

We present the results as the change in the energy use (estimated coefficient) and as a percentage of a counterfactual scenario (what would have happened if the installation did not take place). The counterfactual scenario is computed as follows:

1. We first computed the average post-intervention energy consumption (kWh/day) for each measure. Table A.4.6 presents the average gas and electricity usage in the post-intervention period.
2. We then add the estimated coefficient of the different measures and groups of measures to their respective average energy usage (computed in the previous step), when the intervention had a negative effect on energy use.
3. When the intervention led to an increase in energy use, we subtract the estimated coefficient from the average energy use.

It is likely that some households that installed air source heat pumps removed their gas meters after the intervention to avoid the payment of standing charges.[55] This means that such homes had missing gas data during the evaluation period. As such, during the evaluation period homes that had ASHPs installed and subsequently had zero gas usage are systematically missing from the dataset.

By omitting these gas-meter-removal installations from the sample, the average post-installation gas usage is higher than with their inclusion. As a result, estimated energy savings for households which had installed air source heat pumps were counterintuitively low; the initially reported findings suggested that ASHP installations only led to a reduction in gas use over the trial period of 20.5 kWh/day, equivalent to a decrease in gas use of 53% (which does not align with the residual gas use typical households would be expected to use following an ASHP installation).

To corroborate this intuition, we compared the proportion of missing gas data for households installing ASHPs against households installing other measures. Again, we found that the proportion of cases with valid gas readings during the evaluation period among households with ASHP installations was substantially lower than average.

To reduce/eliminate the resultant bias in the reported energy savings for heat pumps, we assumed that the difference in the proportion of cases with valid gas usage data was

[55] See e.g. https://octopus.energy/blog/disconnecting-your-gas-supply/

attributable to systematically missing data, and recalculated relevant percentage changes by imputing a post-treatment gas use of zero for a proportion of households in the sample.

The proportion of households we imputed was calculated as the difference between the proportion of cases missing gas data for ASHP households versus a weighted average of the same proportion for households installing other measures.[56, 57] The adjusted estimates are more in keeping with expectations.

In summary, the analysis followed the following steps:

1. Calculate the total number of properties with gas usage for each measure (including air source heat pump): tot_gas
2. Calculate the total number of properties with electricity usage for each measure: tot_elec
3. Calculate the ratio of tot_gas over tot_elec: tot_gas2tot_elec_ratio
4. Calculate the weighted average of tot_gas2tot_elec_ratio among all measures except air source heat pump based on tot_elec[58]
5. Calculate the difference between the tot_gas2tot_elec_ratio for air source heat pump and the weighted average in step 4: adj_coef = 0.53
6. Multiply tot_elec by adj_coef for air source heat pump: $152 \times 0.53 \cong 81$
7. Recalculate the average gas usage for treated households with air source heat pump[59]:

$$\frac{41 \times 4.3 + 81 \times 0}{41 + 81} = 1.4 \text{ kWh}$$

8. Recalculate the average gas usage for treated households with low-carbon heat:

$$\frac{144 \times 22.4 + 81 \times 0}{144 + 81} = 14.3 \text{ kWh}$$

56 We define the proportion of missing gas data relative to the proportion of missing electricity usage time-series data, given that there may be other drivers of missing data across multiple variables in the SERL dataset.
57 Note that we did not re-estimate the model coefficients using imputed data, but only the reported energy savings relative to a counterfactual scenario. The model coefficient, which we continue to report in the regression output tables, likely represents the lower bound estimate of gas savings achieved by ASHP installations.
58 The weighted average of this ratio for all the EE and LC measures except ASHP is 0.8, and the average of this ratio for ASHP is 0.27. It could be seen there is a big difference among ASHP and the rest of the measures that could be due to removing the gas meter after ASHP installation.
59 In the dataset the average of the post-intervention gas usage for households installed ASHP is 4.3 kWh.

Table A.4.6. Average gas and electricity usage per day for households in SERL observatory and GHGVS smart meter data

Group	Average Gas Usage	Average Electricity Usage
SERL Observatory	28.4 kWh	7.4 kWh
GHGVS	28.2 kWh	10.7 kWh
Measure level		
GHGVS (with air source heat pump)	1.4* kWh	19.6 kWh
GHGVS (with external solid wall insulation)	29.9 kWh	8.5 kWh
GHGVS (with cavity wall insulation)	31 kWh	9.3 kWh
GHGVS (with loft insulation)	32 kWh	8.1 kWh
GHGVS (with pitched roof insulation)	26.2 kWh	8.1 kWh
Measure group level		
GHGVS (with insulation)	29.6 kWh	8.5 kWh
GHGVS (with insulation + low-carbon heat)	30.9 kWh	12.1 kWh
GHGVS (with heating controls and insulation + low-carbon heat)	32.9 kWh	10.2 kWh
GHGVS (with heating controls and insulation + low-carbon heat + insulation)	35.5 kWh	11.9 kWh

* Starred figures were adjusted using the aforementioned approach.

A.4.1.6 Conversion of energy savings to carbon and bill savings

We followed guidance from HM Treasury (2022)[60] and its supplementary guidance (BEIS, 2021)[61] to convert the energy estimates to bills and carbon savings.

[60] The Green Book: Central Government Guidance on Appraisal and Evaluation. HM Treasury, 2022). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063330/Green_Book_2022.pdf

[61]Valuation of energy use and greenhouse gas (GHG) emissions: Supplementary guidance to the HM Treasure Green Book on Appraisal and Evaluation in Central Government. BEIS, 2023. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1129242/valuation-of-energy-use-greenhouse-gas-emissions-for-appraisal.pdf

Bill Savings

The impact on bills was computed based on net energy consumption changes (kWh/day) and inflation adjusted retail energy prices for the domestic sector (real 2021 p/kWh). The retail prices were sourced from the updated Data Tables 9-13 of the accompanying spreadsheet to BEIS (2023).[62]

Carbon savings

The quantification of greenhouse gas (GHG) emissions changes (Δ **GHG**) was based on net energy consumption changes, long run electricity marginal emissions factors for the domestic sector and natural gas GHG emission factors (Data Tables 1 and 2a of the accompanying spreadsheet to BEIS (2021)) as follows:

$$\Delta \text{ GHG} = \sum_{i=1}^{n} \Delta \text{ fuel use}_i \; x \text{ emission factor}_i$$

A.4.2 Results

A.4.2.1 Energy savings

This section presents the average effects identified through this study on household mean daily gas or net electricity use over the full-year evaluation period, from September 2021 to August 2022, of the different measures and groups of measures installed in gas- or electrically-heated homes[63] through GHGVS. We present the results as the change in the energy use (estimated coefficient) and as a percentage of a counterfactual scenario (what would happen if the installation did not take place), which is mentioned in the methodology section.

$$\frac{|Estimated\ Coefficient^{64}|}{Average\ Energy\ Use^{65} + (-1 \times Estimated\ Coefficient)} * 100$$

Table A.4.7 presents a summary of the results as a percentage of counterfactual scenario. The details of the estimated coefficients could be found in Table A.4.8 to Table A.4.11.

[62] We used the 2022 scenario B domestic retail gas price (7.36 in 2021 p/kWh) and 2022 central domestic retail electricity price (30.73 in 2021 p/kWh). The data can be accessed from https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

[63] 'Gas heated homes' includes homes that installed a heat pump and which underwent a fuel-switch as a result.

[64] The details of the estimated coefficients could be found in Table A.4.8 to Table A.4.11.

[65] This refers to the treated household's average energy consumption in the post installation period as shown in Table A.4.6

Table A.4.7. The impact expressed as a percentage of what could happen without intervention for gas and electricity usage – homes with gas central heating

Group	Average impact on gas usage	Average impact on electricity usage
Measure level		
GHGVS (with air source heat pump)	$\frac{26.8}{1.4+26.8}$ = 95% reduction	$\frac{6.2}{19.6-6.2}$ = 46.3% increase
GHGVS (with external solid wall insulation)	$\frac{3.3}{29.9+3.3}$ = 9.9% reduction	-
GHGVS (with cavity wall insulation)	$\frac{1.9}{31+1.9}$ = 5.8% reduction	-
GHGVS (with loft insulation)	$\frac{1.4}{32+1.4}$ = 4.2% reduction	-
GHGVS (with pitched roof insulation)	$\frac{1.3}{26.2+1.3}$ = 4.7% reduction	-
Measure group level		
GHGVS (with insulation)	$\frac{2.7}{29.6+2.7}$= 8.4% reduction	$\frac{0.35}{8.5-0.35}$ = 4.3% increase
GHGVS (with insulation + low-carbon heat)	-	$\frac{3.4}{12.1-3.4}$ = 39.1% increase
GHGVS (with heating controls + low-carbon heat)	-	$\frac{2.2}{10.2-2.2}$ = 27.5% increase
GHGVS (with heating controls + low-carbon heat + insulation)	-	$\frac{2.5}{11.9-2.5}$ = 26.6% increase

Table A.4.8 and Table A.4.9 present estimates of energy savings in kWh/day for homes with gas central heating that were found to be statistically significant at the 10% level (p-value<0.1). This indicates that there is a 90% probability that the observed results are not down to statistical chance, and are actual effects of the interventions, assuming all model assumptions are valid. Table A.4.10 and Table A.4.11 present additional results of interaction effects between region and measure/measure group that were found to be statistically significant for electricity and gas, respectively, at the 10% level, for the same homes with gas central heating.

No measures or measure groups were found to have statistically significant impacts on electricity or gas use during the evaluation period for households with electric central heating, and no further interaction effects with region or building age were statistically significant for either gas or electric central heating. No measures in the secondary measures group were found to be statistically associated with changes in energy use during the evaluation period. More detailed regression model results can be found in the supplementary data files that accompany this analysis.

Insulation

The results show that, on average for gas centrally-heated homes, insulation measures (when aggregated as a group in proportion to the levels each individual measure was installed in the sample) correlate with an increase in electricity use over the post-installation evaluation period of 0.35 kWh/day for electricity (95% confidence interval: 0.12-0.59 kWh/day) and a reduction in gas use of 2.66 kWh/day (95% confidence interval: 1.72-3.25 kWh/day). This is equivalent to an increase of 4.3% in electricity use and a reduction of 8.4% in gas use compared to the counterfactual scenario as it presented in Table A.4.6 and A.4.7.

At the measure level, external solid wall insulation, cavity wall insulation, loft insulation, and pitched roof insulation are correlated with changes in gas usage over the post intervention period for gas-centrally heated homes. The impact of the external solid wall insulation was a reduction in gas use, of 3.29 kWh/day (95% confidence interval: 1.88-4.69 kWh/day). This is equivalent to a reduction of 9.9% compared to the counterfactual scenario as it presented in Table A4.6 and A4.7. The effects of cavity wall insulation, loft insulation, and pitched roof insulation on gas usage are 1.9 kWh/day (95% confidence interval: 0.31-3.5 kWh/day), 1.41 kWh/day (95% confidence interval: 0-2.86 kWh/day)[66], and 1.34 kWh/day (95% confidence interval: 0-2.9 kWh/day)[67], respectively, which are equivalent to a reduction of 5.8%, 4.2%, and 4.7%, respectively, compared to the counterfactual scenarios as presented in Table A4.6 and A4.7.

No other individual insulation measures had a statistically significant effect on electricity or gas use over the evaluation period for gas centrally-heated homes. Either the effects were too small to be detected or there were too few homes in the treatment group for the study to be able to detect the effects of these measures using this approach. This means that gas usage may have reduced even though the study is not able to draw conclusions on this.

There were no statistically significant differences in the energy saving estimates of insulation measures associated with electrically heated homes, nor of insulation measures associated with building age or region for gas or electrically heated homes. This again means that any effects that may have been present were too small to be detected in this study given the number of homes in each of these categories.

Low-carbon heat

The low-carbon heat measure group consists of heat pumps (mainly air source heat pumps and hybrid heat pumps) and solar thermal. As the low carbon heating measure group includes both heat pumps and solar thermal, the aggregated estimates do not have a meaningful interpretation, as it combines two disparate measures with very different savings impacts.[68] As a result, aggregated estimates are not presented here.

[66] This interval is only related to reduction as according to 95% CI (which could be found in Table A.4.9), the upper bound is 0.034.

[67] This interval is only related to reduction as according to 95% CI (which could be found in Table A.4.9), the upper bound is 0.216.

[68] Solar thermal systems use energy from the sun to warm water for storage in a hot water cylinder or thermal store. Because the amount of available solar energy varies throughout the year, a solar water heating system won’t provide 100% of the hot water required throughout the year; a conventional boiler or immersion heater is normally used to make up the difference. Larger solar hot water arrays can also be arranged to provide some contribution to heating your home. However, the amount of heat provided is generally very small (less than 10% of the home’s heating requirement), so it is not usually considered worthwhile. Most solar hot water systems are just designed to provide the hot water you use for bathing, showering and hot taps.

A decrease in gas use combined with an increase in electricity use would be expected of a household switching from using a gas boiler for space and water heating to using an electric heat pump – this is because gas boilers use gas as a fuel, while heat pumps use electricity. Therefore, if a gas boiler is removed and replaced with a heat pump, the logical result will be that gas consumption will reduce while electricity use will increase. Indeed, this fuel-switching effect is observed in the data for air source heat pumps at the measure-level. These were found to correspond with a reduction in gas use over the trial period of 26.83 kWh/day (95% confidence interval: 23.39-30.28 kWh/day) and increase in electricity use of 6.17 kWh/day (95% confidence interval: 5.19-7.17 kWh/day). This is equivalent to a decrease in gas use of 95%[69] and increase in electricity use of 46% compared to the counterfactual scenarios as presented in Table A.4.6 and A.4.7.

There were also statistically significant ($0.0<p<0.1$) regional differences in increase in gas use amongst the low-carbon heat measure group over the evaluation period (see Table A.4.11). Measures outside the South East area were associated with an average decrease in gas use of 6.89 kWh/day (95% confidence interval: 5.29-8.5 kWh/day), while measures located in the South East were associated with a larger decrease in gas use over the evaluation period of 12.9 kWh/day.

For the average impact of low-carbon heat measures on electricity usage, the variation among the regions is more than the impact on gas usage over the evaluation period (see Table A.4.10). While the average impact on electricity usage is an increase of 2.68 kWh/day (95% confidence interval: 2.18-3.19 kWh/day), the measures located in the South East and Yorkshire and the Humber were associated with larger increases in electricity use over the evaluation period of 4.35 kWh/day and 3.57 kWh/day, respectively. These effects were smaller for the measures located in the Wales and West Midlands on electricity use over the evaluation period (0.89 kWh/day and 1.4 kWh/day, respectively). Moreover, at the measure level, the impact of ASHP on electricity usage in North East is 2.34 kWh/day higher than the average effect, which means an increase of 8.51 kWh/day for the ASHP measure in this region. There are several potential drivers of these regional differences, including differences in climate and regional differences in the distribution of building characteristics, methods of installation or use of heat pumps, etc. Further research would be required to investigate the reasons for the observed interaction effects with region.

There were no other statistically significant differences in the energy saving estimates of low-carbon heat associated with building age or region.

There were 397 solar thermal measures included within the treatment group sample. However, these were not associated with a statistically significant change in gas or electricity use over the trial period. Solar thermal systems are designed to use solar energy to heat a dwelling's hot water and would be expected to be associated with a reduction in gas or electricity consumption (depending on the existing fuel used to heat the dwelling's hot water). To look closely at the effect of the solar thermal measure, we employed the same analysis (as the LASSO approach) but only using data for households that installed solar thermal measure and the control group. The purpose of this approach was to rule out any possible effect of the shrinkage factor (which is the parameter used in LASSO methodology that reduces overfitting of the model to the training data) on the estimated coefficient of the solar thermal measure in

[69] The decrease in gas usage is not 100% because it is likely the households use gas for other activities such as cooking.

the main model. However, the result of this further analysis supported the previous conclusion that the solar thermal measure had no significant effect on energy use.

A.4.2.4 The effects of combined installations of measure groups among Heating Controls and Insulation, low-carbon heat and Insulation measure groups

We evaluate the combined effects of measure groups when there were more than one measure groups had installed in a property as part of GHGVS. We found statistically significant results for three combinations on electricity usage in homes that initially had gas central heating: (1) Insulation + low-carbon heat, (2) Heating Controls and Insulation + low-carbon heat, and (3) Heating Controls and Insulation + low-carbon heat + Insulation. The results are presented in Table A.4.6.

Homes that initially had gas central heating and had Insulation + low-carbon heat measure group interventions showed a statistically significant increase in electricity use of 3.45 kWh/day (95% confidence interval: 2.18-4.71 kWh/day), and no statistically significant change in gas use. Such homes that had Heating Controls and Insulation + low-carbon heat measure group interventions showed a statistically significant increase in electricity use of 2.16 kWh/day (95% confidence interval: 1.14-3.18 kWh/day). Finally, homes that installed Heating Controls and Insulation + low-carbon heat + Insulation measure groups together experienced an average increase of 2.53 kWh/day (95% confidence interval: 1.06-3.99 kWh/day) in their electricity usage. This impact is 0.96 kWh/day higher than average in Yorkshire and the Humber, which means properties in this region experienced a 3.49 kWh/day increase in their electricity usage after installing a combination of measures in Heating Controls and Insulation + low-carbon heat + Insulation measure groups.

Table A.4.8. The results of LASSO regression using specification (1) for households with gas central heating – impact on electricity use

Variables	Estimated coefficient (Electricity kWh/day)	CI: [0.025	CI: 0.975]	p-value Measure group
Measure group				
Insulation	0.35	0.116	0.591	Insulation
Insulation + low-carbon heat	3.446	2.179	4.714	Insulation + low-carbon heat
Heating controls and insulation + low-carbon heat	2.159	1.141	3.177	Heating controls and insulation + low-carbon heat
Heating controls and insulation + low-carbon heat + insulation	2.527	1.061	3.993	Heating controls and insulation + low-carbon heat + insulation
Individual measure				
Air source heat pump	6.171	5.189	7.165	

Table A.4.9. The results of LASSO regression using specification (1) for households with gas central heating – impact on gas use

Variables	Estimated coefficient (Gas kWh/day)	CI: [0.025	CI: 0.975]	p-value
Measure group				
Insulation	-2.660	-3.382	-1.938	0.000
Individual measure	-2.641	-4.029	-1.252	0.000
External solid wall insulation	-3.289	-4.694	-1.883	0.000
Cavity wall insulation	-1.904	-3.499	-0.309	0.019
Loft insulation	-1.414	-2.862	0.034	0.056
Pitched roof insulation	-1.344	-2.904	0.216	0.091
Air source heat pump	-26.834	-30.275	-23.392	0.000

Table A.4.10. Additional results of Lasso using specification (2), including interaction effects between measure groups and region/building age, for households with gas central heating – impact on electricity use.

Variables	Estimated coefficient (Gas kWh/day)	CI: [0.025	CI: 0.975]	p-value
Measure group				
Low-carbon heat × South East	1.665	0.407	2.924	0.01
Low-carbon heat × Wales	-1.890	-3.612	-0.168	0.031
Low-carbon heat × West Midlands	-1.275	-2.727	0.177	0.085
Low-carbon heat × Yorkshire and the Humber	0.885	0.005	1.764	0.049
[Heating controls and insulation + low-carbon heat + insulation] × Yorkshire and the Humber	0.959	0.229	1.689	0.01
Individual measure				
Air source heat pump × North East	2.344	0.359	4.329	0.021

Table A.4.11. Additional results of Lasso using specification (2), including interaction effects between measure groups and region/building age, for households with gas central heating – impact on gas use.

Variables	Estimated coefficient (Gas kWh/day)	CI: [0.025	CI: 0.975]	p-value
Measure group				
Low-carbon heat × South East	-6.028	-10.697	-1.358	0.011

A.4.2.2 Bill and carbon savings

This section translates the estimates of statistically significant energy savings presented in the previous section into bill and carbon savings using the method described in above. A positive value indicates a saving i.e., a reduction in bills or carbon emissions, while a negative value means an increase in bills or carbon emissions.

Table A.4.12 presents the average bill savings for measures that were evaluated as producing statistically significant energy savings, while Table A.4.13 presents the average greenhouse gas emissions savings, expressed as tonnes of carbon dioxide equivalent, for the same measures. Table A.4.14 and Table A.4.15 present bill and carbon savings, respectively, for the insulation group of measures. These were associated with statistically significant energy savings. Figures in the text below refer to these tables.

Table A.4.12. Average bills savings (2021 £/year) by fuel and measure (households with gas central heating).

Measure	Gas bill savings (£/year)	Electricity bill savings (£/year)	Total bill savings (£/year)
Air source heat pump	721	-692	29
External solid wall insulation	88	na	88
Cavity wall insulation	51	na	51
Loft insulation	38	na	38
Pitched roof insulation	36	na	36

Table A.4.13. Average carbon savings (tCO_2e/year) by fuel and measure (households with gas central heating).

Measure	Gas carbon savings (tCO_2e/year)	Electricity carbon savings (tCO_2e/year)	Total carbon savings (tCO_2e/year)
Air source heat pump	1.8	-0.6	1.2
External solid wall insulation	0.2	na	0.2
Cavity wall insulation	0.1	na	0.1
Loft insulation	0.1	na	0.1
Pitched roof insulation	0.1	na	0.1

Table A.4.14. Average bills savings (2021 £/year) by fuel for insulation group (households with gas central heating).

Measure group	Gas bill savings (£/year)	Electricity bill savings (£/year)	Total bill savings (£/year)
Insulation	71	-40[70]	31

[70] This result is counterintuitive, and we believe most plausibly arises due to noise in the data.

Table A.4.15. Average carbon savings (tCO_2e/year) by fuel for insulation group (households with gas central heating).

Measure group	Gas carbon savings (tCO_2e/year) [71]	Electricity carbon savings (tCO_2e/year)	Total carbon savings (tCO_2e/year)
Insulation	0.2	-0.03	0.17

Insulation

For gas heated homes, external solid wall insulation was found to generate a statistically significant reduction in gas use which lead to average bill savings of £88/year and average carbon savings of 0.2 tCO2e/year.

When aggregated as a group, Insulation measures led to average gas savings of £71/year and electricity savings of £-40/year (a total of £31/year), whilst carbon savings were on average 0.2 tCO2e/year for gas and -0.03 tCO2e/year for electricity (a total of 0.17 tCO2e/year). These figures are determined by the mix of insulation measures installed across the sample of GHGVS applicants with gas heated homes and for whom smart meter data was analysed.

Low-carbon heat

The only low-carbon heat measures that were found to generate a statistically significant reduction in energy use were heat pumps. For homes that were previously gas-centrally heated, air source heat pumps were associated with average gas bill savings of £721/year and an increase in electricity costs for households of £692/year, overall resulting in an average net saving in energy bills of £29/year. The net carbon savings associated with an air source heat pump were overall positive at 1.2 tCO2e/year, due to a gas carbon saving of 1.6 tCO2e/year and an electricity carbon saving of -0.6 tCO2e/year.

A.4.3 Discussion

The average effects on bills and carbon savings presented above are highly dependent on the relative prices and carbon intensities of a unit of gas and a unit of electricity, and as such the future bill savings and carbon savings of these measures are likely to change substantially as prices and carbon intensities change. In particular, the carbon savings associated with any measure that affects electricity usage will increase as the carbon intensity of electricity decreases as part of the ongoing process of decarbonising electricity generation. This will impact on the net carbon benefit of air source heat pumps in particular, as these increase average electricity usage substantially. Average changes in bills will be shaped by factors such as changes in market prices, and government and regulator interventions, such as changes to the energy price guarantees and energy taxes.

[71] These results should be interpreted with caution because the lack of statistical significance in gas usage could be attributed to the limited sample size available for the analysis, rather than indicating that low carbon heat measures do not result in gas savings.

Annex 5: Fuel Poverty analysis

One of the aims of GHGVS was to reach fuel poor households who may be struggling to afford to adequately heat their homes, either because they have low incomes, energy inefficient homes, or a combination of the two.

The objective of this analysis was to identify GHGVS recipients likely to be fuel poor prior to the installation of the GHG energy efficiency installations (Phase 1) and the proportion of households who were taken out of fuel poverty as a direct result of the dwelling improvements funded by the scheme (Phase 2).

A.5.1 Phase 1 – Pre-installation fuel poverty status

In order to understand whether the scheme has been successful in reaching these people, for the process evaluation, BRE modelled the proxy fuel poverty status of households who successfully applied for the scheme.[72]

The current definition of fuel poverty being used in England is the Low Income, Low Energy Efficiency (LILEE) metric. Under this definition, households are fuel poor if:

- They have a Fuel Poverty Energy Efficiency Rating (FPEER)[73] of band D or below and;
- The household income after housing costs and fuel costs falls below a set income threshold (defined as 60% of the national AHC-equivalised income).

BRE combined data collected through GHGVS with their proprietary SAP model to model the likelihood of a household being in fuel poverty, prior to and following any installation of measures through the scheme. More information on how GHGVS data was modelled is given below. A full list of the data sources used for model inputs is included below.

A.5.1.1 Methodology

The proxy fuel poverty indicator comprises two components: (i) the income of the household and (ii) the energy efficiency rating of the dwelling. If a household falls below both the income threshold (defined as 60% of the AHC-equivalised income[74]) and the modelled energy efficiency threshold (defined as EPC band D or below), then they will be flagged as likely to be fuel poor. The energy efficiency threshold of band D or below has been chosen to align with

[72] For Phase 2 of the fuel poverty analysis, BRE modelled the direct effects of the GHGV installation measures on the fuel poverty status of households in order to quantify how many households would be expected to be taken out of fuel poverty as a direct result of the energy measures funded by GHGV. The Phase 2 modelling approach and findings are covered later in this report.

[73] The FPEER methodology is based on the Government's Standard Assessment Procedure (SAP) for assessing the energy performance of domestic properties while taking into account the impact of policy interventions (e.g. Warm Homes Discount) that directly affect household energy costs. Like SAP, the methodology gives an energy efficiency rating from 0 (lowest) to 100 (highest). This rating can be translated into an energy efficiency 'Band' from G (lowest) to A (highest), rather like the SAP rating being used to generate an overall energy efficiency Band (again from G to A) for EPCs. As a general rule, the EPC band will be a good proxy for the FPEER band.

[74] AHC means 'income after housing costs'. Housing costs include mortgage and/or rent on the property. Equivalisation is an adjustment to take into account variations in the size and composition of the household.

the LILEE fuel poverty definition, whilst still providing a good proxy of whether a household has high fuel bills, as defined under the Low Income, High Cost (LIHC[75]) fuel poverty definition.

Derivation of Income

The wave 1 applicant survey collected income information which was used to calculate the household's equivalised AHC income. This measure was only considered for applicants who were responding to the survey in relation to a voucher application for a property in which they lived. No assessments were made of AHC income for properties for which applications were made by landlords or those applying on behalf of others. This means that a total of 241 (unweighted) properties were excluded from the analysis (177 landlord properties and 64 where the application was made on behalf of others). This resulted in a total of 3,365 participants being asked about AHC income.[76]

Respondents who had applied for measures for the property in which they lived were asked to estimate the amount of money they have left after accounting for housing costs. They were asked whether their household income after housing costs was above or below a threshold which was based on the number of children (aged 13 or younger) and adults (aged 14 and over) in the household. The threshold[77] was calculated as follows, based on 2018 household incomes:

> *Income threshold = 13,927[78] x (0.58 + (0.42 x (number of adults in household – 1)) + (0.2 x number of children in household))*

The calculation was embedded in the survey script and fed in the appropriate income threshold into the relevant question. The question asked:

[If household owns property with mortgage/Once your household has paid your mortgage] [If household part rents/part owns property (shared ownership)/Once your household has paid your mortgage and the rental on your property] [If household rents property (private or social rent)/Once your household has paid your rent] [All others/Once your household has paid any housing costs], would you say the money you have left each month is more than <threshold >, or less than this?

It was not possible to assess the AHC income for 28% (1,001 participants) of all respondents to the wave 1 applicant survey, as follows:

- 241 who were not asked because not applicable to them (177 landlords, 64 making an application on behalf of others); and
- 760 who applied for the property in which they lived, but who did not provide an answer to the relevant questions in the survey (i.e. unable to assess household structure, did not know or preferred not to answer the question about AHC equivalised income).

[75] The Low Income High Costs (LIHC) indicator is a measure of fuel poverty in which a household is considered to be fuel poor if: (a) They have required fuel costs that are above average (the national median level); and (b) Were they to spend that amount, they would be left with a residual income below the official poverty line. The LIHC definition is a relative indicator as it compares households to the national median fuel costs and income – thereby reflecting contemporary trends.

[76] Figure A.5.1 provides a detailed breakdown of survey responses and respective base sizes of relevant sub-questions to this section.

[77] Fuel poverty uses equivalised income with factors consistent with the Department for Work and Pension poverty analysis. This reflects that a large household will need a larger income to service the same level of costs.

[78] 60% of the AHC Income in the 2018 dataset.

Overall, this means that AHC income was not assessed for 23% of occupants completing the wave 1 survey (i.e. 760 of the 3,365 participants applying for the property in which they lived). The proportion of occupants for which it was not possible to assess AHC income, and therefore for which the survey data is likely to under- or over-estimate levels of fuel poverty, was higher amongst the following groups (vs. 23% of occupants on average):

- Older participants (33% of those aged 75 or older vs. 20% of under 35s).
- Ethnic minorities (31% of those from ethnic minority communities vs. 19% of white participants).
- Those applying for properties in London (27%), West Midlands (27%), and East of England (25%).
- Those applying through the low-income scheme (24%, vs. 22% applying through the main scheme).
- Those applying for insulation measures (24%) or secondary measures (26%), compared with 20% applying for low-carbon heating measures. Levels were particularly high for those applying for wall insulation (25%), and draught proofing, glazing or replacement doors (27%).

Derivation of Energy Efficiency Rating

Up-to-date EPC data was not available for households participating in the GHGV scheme. For this reason, the Energy Efficiency Rating of the dwelling had been modelled for each of the households surveyed (prior to and following any installations through the scheme), following the RdSAP[79] methodology. This is the same method used in the creation of EPCs. The modelling has allowed for a SAP rating to be calculated which can then be converted into an EPC band, between A and G, for each dwelling in the sample, where A represents very low fuel cost (high energy efficiency) and G represents very high fuel costs (low energy efficiency). Dwellings with a modelled EPC band of D or below will be classed to have a ‘low energy efficiency’, and occupants living in these dwellings will be flagged as likely to be fuel poor, if their income also falls below the income threshold. Since the rating here has been based on RdSAP, it does not take into account the impact of policy interventions (e.g. Warm Homes Discounts), potentially leading to a small number of households being classed as fuel poor that would not have been if such policy interventions were able to be taken into account in the calculations.

To perform a true RdSAP (EPC) calculation, a lot of detailed information regarding the physical characteristics of the dwelling and energy efficiency measures is required. It is not feasible to acquire this level of information for dwellings being improved as part of GHGV scheme. There was limited information available to BRE regarding the physical characteristics of the dwellings and BRE have therefore used their ‘Simple SAP’ stock model to produce SAP ratings, which itself consists of two separate models: the BRESMI model and the Baseline model. The BRESMI model allows for an RdSAP calculation to be performed with much fewer inputs than would be normally required, by utilising in-built imputation procedures. The Baseline model applies statistical modelled distributions to infer building characteristics, where key inputs are unknown.

[79] A Reduced data version of a standard SAP calculation, Reduced data SAP (RdSAP).

Despite the various sources of input data specified, some of the critical data inputs were not available for each household. Where data were missing, BRE's model (the Baseline model) imputed the values using statistical modelling techniques (see Imputation methodology section below for more details). This imputation process uses data from the English Housing Survey to determine the likely distribution of building characteristics, given a specific dwelling archetype and geographical location. The scale of this imputation is discussed in the 'assumptions and limitations' section. This provides an estimation of building characteristics across the whole sample but is not accurate when focusing in on specific dwellings.

After all the required data inputs were collated or imputed for each household in the sample, an RdSAP calculation was performed to determine the dwelling's modelled EPC band.

Of the 2,605 households for whom AHC income questions were assessed (i.e. excluding landlords, those applying on behalf of others, and those not providing a valid answer to the AHC income questions), there were only 128 properties for which it was not possible to provide an EPC. The lack of matching came about because it was not possible to match the Unique Property Reference Number (UPRN) for the property during the EPC modelling process: many of these were park homes.

Determining the Fuel Poverty status

The information collected from the wave 1 applicant survey on income was combined with the modelled EPC rating to create the proxy Fuel Poverty status. If a household had an equivalised AHC income of below the income threshold, and a modelled EPC band of D or below, then the household was classified as likely to be in fuel poverty.

As noted above, this is only a proxy fuel poverty status, which has been developed to represent the LILEE fuel poverty definition,[80] currently in use in England. Differences in the data collection process, the model used to calculate an EPC band, and the method of combining income and energy efficiency metrics means that the actual fuel poverty status of each household (were it to be calculated using the official LILEE method) may differ. Despite the slight differences, EPCs are a very good proxy for FPEER ratings.

Amongst occupier applicants[81], it was possible to assess the fuel poverty status of 74% of the total sample (2,477 participants unweighted). This breaks down as follows:

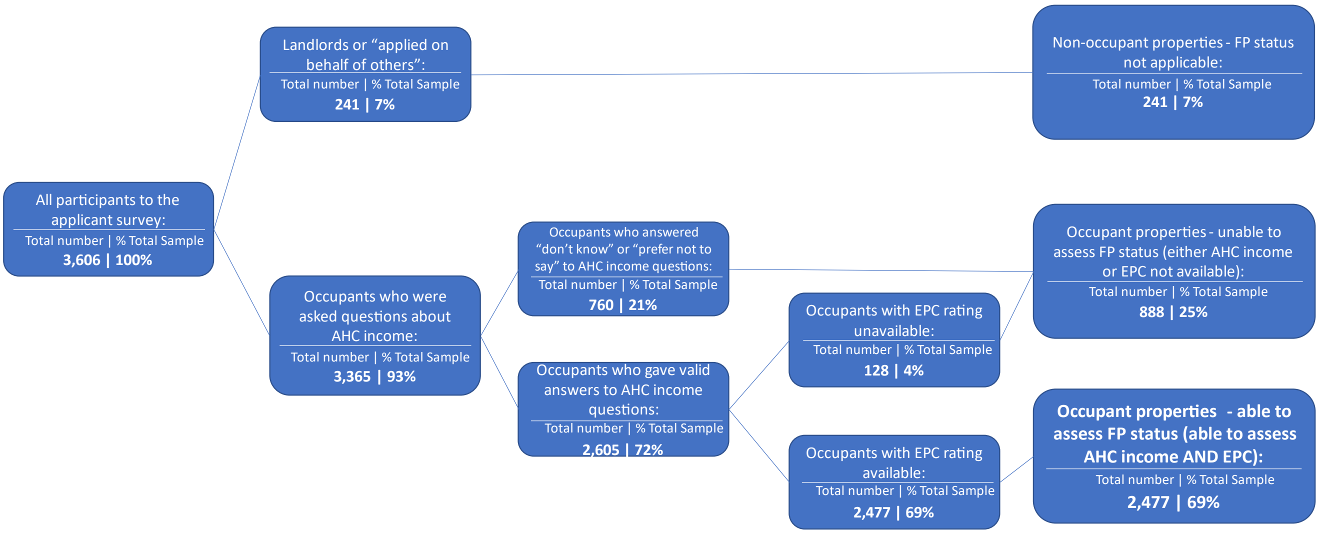
Table A.5.1: Breakdown of Fuel Poverty status of occupier applicants

Whether AHC income and/or EPC available	Number of occupier households	% of all occupier households
Able to assess fuel poverty status		
AHC income and EPC both available	2,477	74%
Not able to assess fuel poverty status		
AHC income but no EPC	128	4%
EPC but no AHC income	720	21%
No EPC and no AHC income	40	1%
Total	**3,365**	**100%**

[80] Due to the correlation between the energy efficiency of a dwelling and the associated cost for heating the property, this proxy indicator can also be used to represent the Fuel Poverty status under the previously used LIHC (Low Income, High Cost) definition.
[81] Base: all who applied for a voucher for their current home n=3,365

The following chart provides a detailed breakdown of survey responses and respective base sizes of relevant sub-questions related to the assessment of AHC-income.

Figure A.5.1 Process for establishing valid occupant properties for which fuel poverty status could be assessed



Groups amongst the occupier applicants for whom fuel poverty status was less likely to be assessed include:

Survey participants who did not provide data on AHC income

- Older applicants (37% of those aged 75 or over), linked to lower proportions in older age groups providing valid answers to questions on AHC income: given that older people are less likely to be assessed as fuel poor in national estimates[82], these lower levels of assessment in the wave 1 applicant survey may lead to an overestimate of the prevalence of fuel poverty within the applicant survey data.
- Applicants from ethnic minority communities (32%, vs. 22% of white applicants), again linked to lower proportions providing valid answers on AHC income. Ethnic minorities are more likely to be assessed as in fuel poverty in national estimates, so this may lead to an underestimate of fuel poverty within the wave 1 applicant survey data.
- Applicants in London (30%), West Midlands (29%), and East of England (27%).

Survey participants who did not provide data on EPCs

- Those applying for vouchers for park homes (73%), or flats (34%) vs. 24% of those applying for vouchers for houses. The high proportion for whom fuel poverty status could not be assessed amongst those applying for park homes is because of low levels of EPC matching on park homes. There is no estimate of fuel poverty level for park homes in national data, and the picture for flats is more mixed, with converted flats more likely than average to be assessed as fuel poor, but purpose-built flats less likely. On balance, given the prevalence of different housing stock in England, these levels of missing data will not greatly impact on overall (total level) estimates.

[82] Annual Fuel Poverty Statistics in England, BEIS, 2022 (2020 data), Section 3.2.2. https://www.gov.uk/government/statistics/annual-fuel-poverty-statistics-report-2022

Taken together, these results suggest that there may be some biases in the overall assessment of fuel poverty status, driven by higher levels of missing data for input variables to the fuel poverty assessment. The fuel poverty statistics for England,[83] where 13% of respondents were estimated to be in fuel poverty in 2019, suggest that some in these groups are more likely to be in fuel poverty such as ethnic minority households (20% nationally), and those in the West Midlands (18% nationally), whilst others are less likely to be in fuel poverty such as households with the oldest member being aged 75 or over (9% nationally), and those in purpose-built flats (11% nationally), etc.). It is therefore unclear the extent to which these biases have led to an overestimate or an underestimate of fuel poverty status for these groups of occupier applicants for the purposes of this evaluation.

A.5.1.2 Methodological assumptions and limitations of the evidence

Imputation methodology

Up-to-date EPC data was not available for the majority of GHGVS dwellings. It was therefore necessary for BRE to model the energy efficiency of the dwellings based on the limited data available and use the BRESMI model as described in the section 'Derivation of Energy Efficiency Rating' above. Where data was not available for certain dwelling characteristics these needed to be imputed using baseline data which was based on population distributions.

Excluding the UPRN, nineteen key variables feed into the BRESMI model. Of these, three variables in particular were largely imputed from the baseline model: hot water tank insulation, solar hot water, and photovoltaics. For hot water tank insulation 2,461 households (99%) had the data imputed from the baseline model, as none of the datasets provided information on this.

All 2,477 households had information about solar thermal hot water systems imputed from the baseline model. Due to the infrequency of solar hot water systems, and to be conservative, the baseline model assumes that no household had these systems.

For photovoltaics, the data for 1,803 households (73%) was obtained from the baseline model. Due to the infrequency of photovoltaics, and to be conservative, the baseline model assumed that a household does not have photovoltaics. The wave 1 applicant survey was the only dataset that provided any information on solar hot water and photovoltaic, but the questions did not distinguish between the two, so where an applicant said they did or didn't have one of these systems, it was assumed they meant photovoltaic, as this is much more common. All other variables had less than half of their data imputed from the Baseline model.

Excluding the solar hot water variable, all but two households had at least one variable imputed from the baseline model, this variable most likely being hot water tank insulation. Over half, 1,323 households (54%), had 3 or less variables imputed from the baseline model.

Due to the imputation method used in this analysis, only aggregated data analysis can be considered as robust. Data from the Baseline model should only be used and analysed collectively; small groups or individual households should not be relied on for accurate data.

[83] Fuel Poverty Statistics England, BEIS, 2021 (2019 data). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/966471/Fuel_poverty_detailed_tables_2019_data_LILEE.xlsx

A.5.1.3 Data quality

There were many problems with data quality, some of which have already been discussed above. A further major issue was the lack of data consistency across the datasets used in the modelling process: the scheme data, Trustmark, EPC, and wave 1 applicant survey datasets. Even some of the simple variables, such as dwelling type values, differed across datasets. The analysis conducted relied on the priority list of data sources described in Appendix A that sets out which dataset should be ‘trusted’ for each variable.

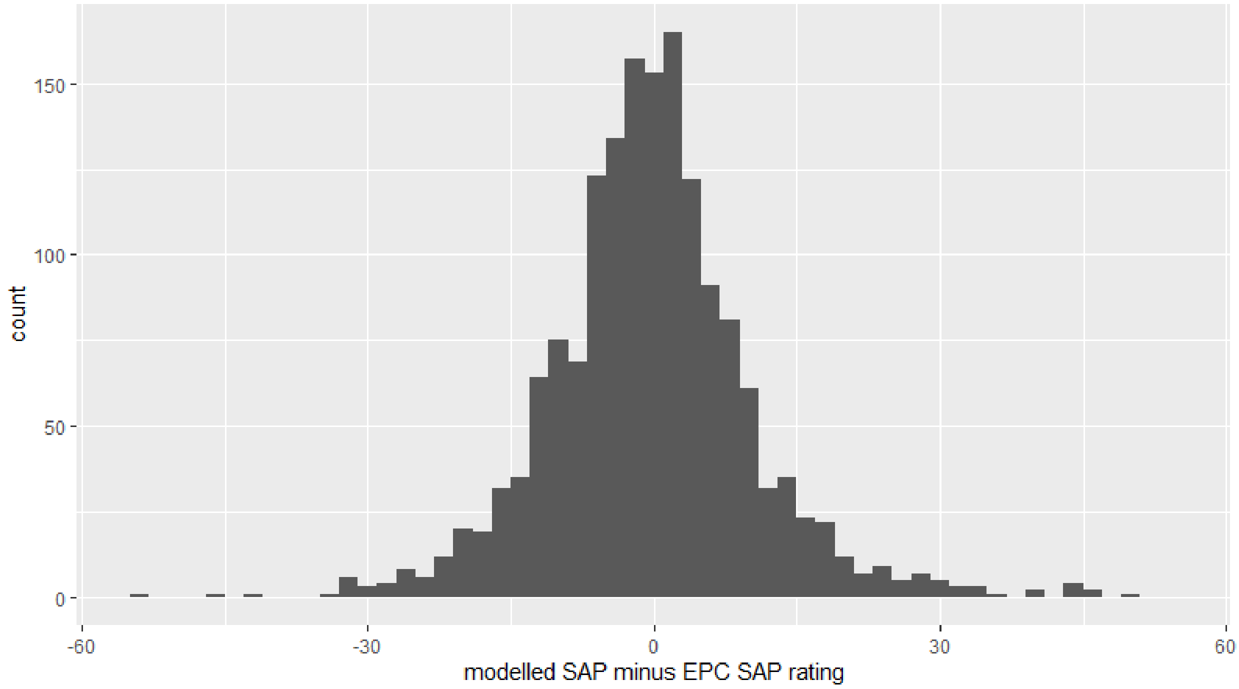
Modelled EPC vs existing EPC

An existing EPC certificate and SAP rating, from the EPC dataset, was available for 1,617 households, 65% of the sample. This enabled BRE to compare the modelled SAP rating for these dwellings with the SAP rating calculated by an EPC assessor. Figure A.5.2 shows the difference between the modelled and existing SAP rating. Overall, the modelled SAP rating was very close to the existing SAP rating, with a mean difference of 0.1 SAP points suggesting that – generally speaking – there is good agreement. However, the ratings for individual households did deviate from the existing SAP rating, and the difference had a standard deviation of 10.7 SAP points indicating that there is some spread in the results. This suggests that in some cases the quality of the input data may not be reliable.

The standard deviation value could be the result of multiple factors, including but not limited to, the reliability of the EPC assessment, the quality of the data collected from other sources (including scheme data, Trustmark data and the householders themselves), and the reliability of the models and baseline data (as described in the imputation methodology section above). In addition, changes made to the dwelling between the time of the EPC assessment and the application to the GHGV scheme could also explain the discrepancies between the existing EPC and modelled EPCs for some dwellings. For this reason, it is not possible to know whether the existing EPC (the majority of which were over 5 years old) or the modelled EPC (based on up-to-date scheme data, Trustmark data and information from the householders) are more accurate.

As 66% of the existing EPCs were over 5 years old, this analysis was repeated to only include those cases where EPC assessments were conducted within the past five years (544 households). The results were similar, the mean difference was 0.0 (1 d.p.), the standard deviation was 10.6, and there were still cases with large differences.

Figure A.5.2: Difference in modelled SAP rating and EPC SAP rating



Base: All dwellings with an EPC SAP rating (n = 1,617).
Note: the EPC assessments were not all conducted at the same time and some of the assessments may have been conducted several years ago; therefore, some of the dwellings may have had installations or changes made since their EPC assessments were conducted.

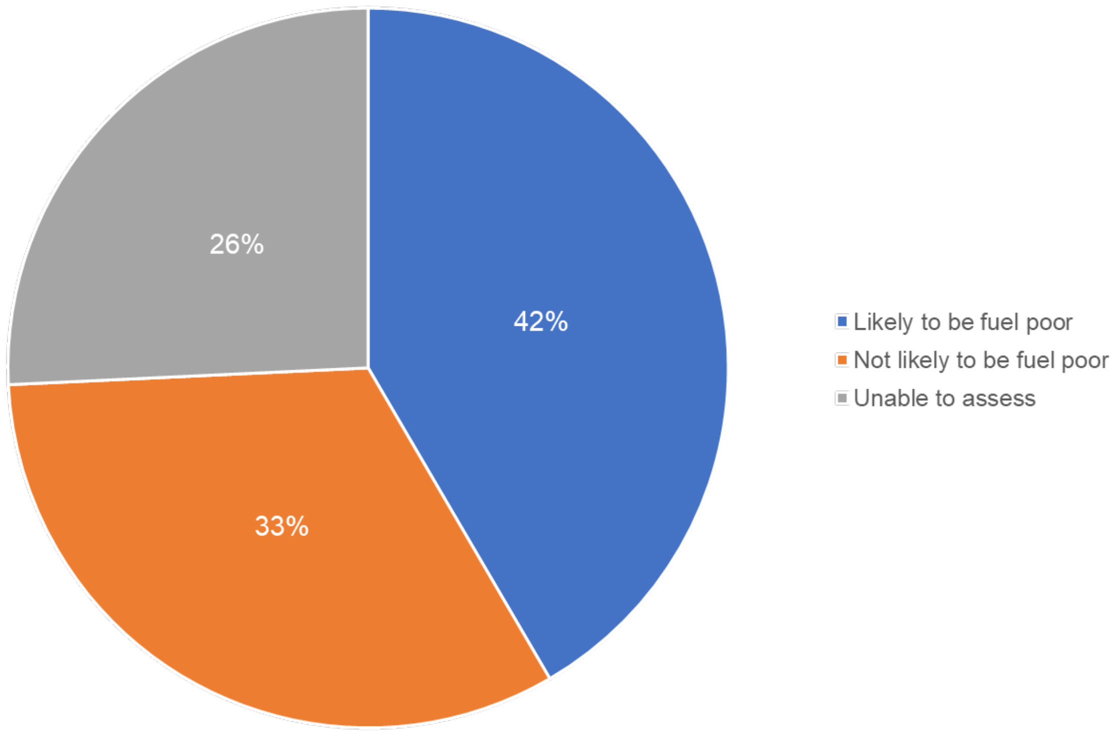
A.5.1.4 Fuel poverty status findings

Findings on fuel poverty status are presented based only on occupiers (i.e. those applying for vouchers for the property in which they live), because landlords and those applying for vouchers on behalf of others were not asked questions about AHC income.

Across all occupiers responding to the wave 1 applicant survey, 42% were assessed as likely to be in fuel poverty: a further 33% were assessed as unlikely to be in fuel poverty and an assessment could not be made for 26%[84]. The latest annual fuel poverty statistics (for 2019[85]) show that 13% of households in England are in fuel poverty, which suggests that GHGV scheme has been successful in reaching households who would be likely to be fuel poor.

[84] This comprises 23% for whom AHC income could not be assessed and 4% for whom AHC could be assessed but no EPC was available. This sums to 26% because of rounding error.
[85] Annual Fuel Poverty Statistics in England. BEIS, 2021 (2019 data).
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/966509/Annual_Fuel_Poverty_Statistics_LILEE_Report_2021__2019_data_.pdf

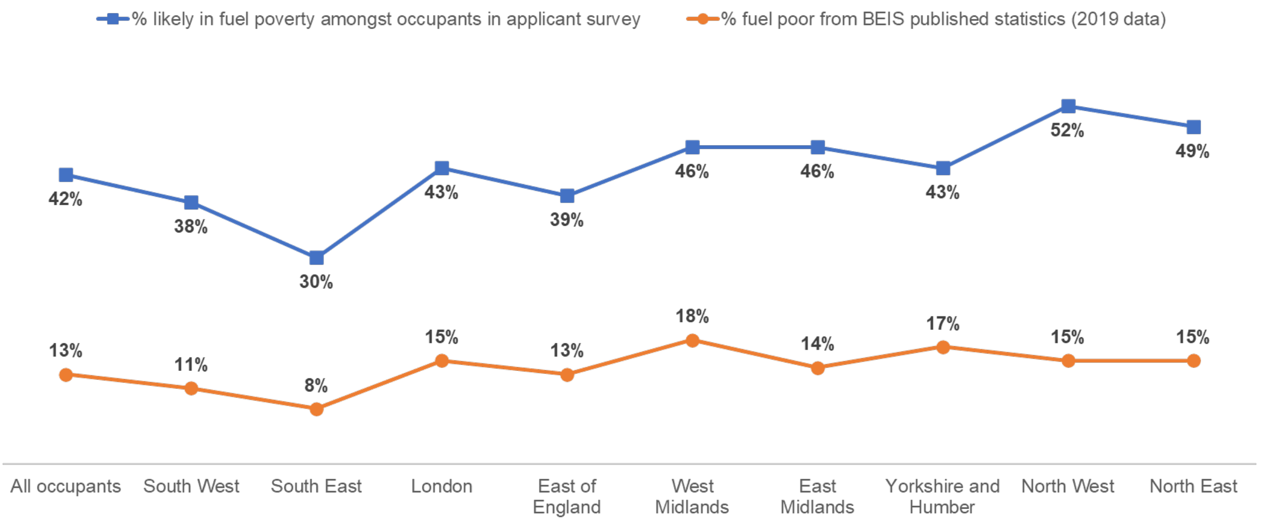
Figure A.5.3: Fuel poverty status of households



Source: Green Homes Grant Voucher Scheme Applicant Survey
Base: All occupants (applied for a voucher for the property in which they live) 3,365
Note: Does not sum to 100% because of rounding

Patterns in regional prevalence of fuel poverty amongst occupants in the wave 1 applicant survey closely mirror those from published statistics: with prevalence lower in the South West and South East of England and higher in the West and East Midlands, North West and North East England.

Figure A.5.4: Fuel poverty status of household by region



Source: Green Homes Grant Voucher Scheme Applicant Survey
Base: All occupants (applied for a voucher for the property in which they live) 3,365. Base size varies by region, none smaller than North East (159)
BEIS published statistics taken from Annual Fuel Poverty Statistics Report 2021 (2019 data) with estimates taken from 2019 English Housing Survey

Prevalence of likely fuel poverty among applicants also mirrored published statistics: a higher prevalence was recorded among those applying for measures for older properties (46% built before 1975 vs. 33% built between 1975-1995 and 21% built thereafter), houses (43%, vs. 32% for flats) and larger properties (30% amongst properties with 0-1 bedrooms, 48% amongst properties with 2-3 bedrooms and 33% with 4 or more bedrooms).

However, unlike published statistics, the wave 1 survey did not find any significant differences in fuel poverty status by heating type (gas vs. electricity).

To what extent has Green Homes Grant Voucher Scheme reached households likely to be in fuel poverty?

The higher prevalence of households likely to be fuel poor amongst occupants in the wave 1 applicant survey compared with BEIS published statistics[86] across the country on average suggests that the scheme has been successful in encouraging fuel poor households to apply. Of those households for whom a fuel poverty status could be assessed, 57% were estimated to be in fuel poverty compared with 13% national average from BEIS published statistics.

The low-income scheme in particular includes a high proportion assessed as likely to be in fuel poverty (73% vs. 34% on the main scheme), which suggests that the targeting of the scheme has been successful in encouraging fuel poor households to participate. Overall, 75% of those assessed as likely to be in fuel poverty applied for vouchers through the low-income scheme, compared with 36% who were not likely to be in fuel poverty (and 60% for whom an assessment could not be made).

However, it is notable that those likely to be in fuel poverty are significantly less likely than average to have had at least one measure installed by the time of the wave 1 survey: only 42% had completed at least one installation (v 52% not likely to be in fuel poverty and 43% for whom an assessment could not be made). This does not appear to be a function of the types of measures applied for by the different groups (see below[87]). Instead, this may indicate the presence of other barriers to completing installations which are being experienced by fuel poor households.

Measures applied for by fuel poor households

Households likely to be fuel poor were more likely to have applied for external solid wall insulation (28% vs. 13% not likely to be fuel poor), and secondary measures (27% vs. 15% not likely to be fuel poor), in particular energy efficient replacement doors (13% vs. 7%). They were also less likely to have applied for cavity wall insulation (7% vs. 14%), loft insulation (19% vs. 23%) and heat pumps (air source, ground source or hybrid: 12% vs. 18%).

Some of these findings may be explained by dwelling characteristics. For instance, uninsulated solid wall homes are more likely to be occupied by those in fuel poverty (nationally 21%) than those with uninsulated cavity walls (nationally 15%). This could be because fuel poor

[86] Fuel Poverty Statistics England, BEIS, 2021 (2019 data). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/966471/Fuel_poverty_detailed_tables_2019_data_LILEE.xlsx

[87] While those likely to be fuel poor were more likely than those not likely to be fuel poor to have applied for vouchers for insulation measures (71% vs. 66%) and less likely to have applied for low-carbon heat measures (31% vs. 36%), there were no significant differences between measure types in the proportions of survey participants who said that at least one measure had been installed (55% of those applying for insulation and the same proportion applying for low-carbon heat measures had had at least one measure installed). While households likely to be fuel poor were more likely to have applied for external solid wall insulation, which is the measure least likely to have proceeded to installation at the time of the survey, even amongst those applying for this measure fuel poor households were less likely than non-fuel poor households to have proceeded to installation at the time of the survey (31% vs. 35%) and were instead more likely to say that the installation was in progress (7% vs. 4%). Any differences in installation rates between fuel poor and non-fuel poor households therefore do not appear to be because of differences in the mix of measures applied for.

households may have already benefited from other Government schemes (e.g. CERT and ECO) to insulate cavities and lofts. This could explain why those likely to be fuel poor were less likely to have applied for loft and cavity wall insulation.

Typically, the installation of wall insulation, loft insulation and glazing have the greatest impact on a dwelling's SAP score. The fact that 71% of households likely to be in fuel poverty have applied for insulation measures, with wall (either solid or cavity) and loft insulation being the most popular measures, suggests that the measures that have the greatest impact on a dwellings SAP score are being prioritised by the fuel poor in many cases.

Table A.5.2: Households applying for each measure split by fuel poverty status.

	All occupiers (3365)	Likely to be fuel poor (1282)	Unlikely to be fuel poor (1195)	Unable to assess (888)
AT LEAST ONE INSULATION MEASURE	71%	71%	66%	75%
External solid wall insulation	23%	28%	13%	26%
Loft insulation	21%	19%	23%	22%
Cavity wall insulation	9%	7%	14%	8%
Pitched roof insulation	8%	9%	7%	8%
Under floor insulation (suspended floor)	6%	6%	8%	5%
Flat roof insulation	3%	3%	4%	3%
Internal solid wall insulation	3%	3%	2%	3%
Room in roof insulation	3%	2%	4%	3%
Under floor insulation (solid floor)	1%	1%	1%	1%
ANY LOW-CARBON HEATING	32%	31%	36%	27%
Solar thermal	18%	18%	19%	16%
Air source heat pump	12%	10%	16%	9%
Double or triple glazing	6%	8%	4%	7%
Biomass boiler	1%	1%	0%	1%
Hybrid heat pump	1%	1%	1%	1%
ANY SECONDARY MEASURE	22%	27%	15%	24%
Energy efficient replacement doors	10%	13%	7%	11%
Heating controls	9%	10%	7%	9%

	All occupiers (3365)	Likely to be fuel poor (1282)	Unlikely to be fuel poor (1195)	Unable to assess (888)
Draught proofing	1%	1%	0%	2%
Secondary glazing	1%	1%	0%	1%

Note: Only measures applied for by 1% or more of those likely to be fuel poor shown in table.
Park Home Insulation not shown because of biases in assessment because EPCs could not be calculated

It is also notable that likely fuel poor households tended to have applied for vouchers for more measures than average (1.44 measures per property, vs. 1.29 for those unlikely to be fuel poor and 1.39 for those unable to assess).

A.5.2 Phase 2 – Post-installation fuel poverty status

A.5.2.1 Methodology

The statutory fuel poverty target, set in December 2014, has a clear focus on improving energy efficiency to mitigate fuel poverty where it exists. The target is to ensure "*that as many fuel poor homes as is reasonably practicable achieve a minimum energy efficiency rating of Band C, by 2030*".[88] Improving the energy efficiency of dwellings was a key objective of GHGV scheme.

The main aim of the phase 2 analysis was to quantify the direct effects of the GHG installations on the energy efficiency of the dwellings and the fuel poverty status of households. Specifically, the analysis looked at how many households would be expected to be taken out of fuel poverty as a direct result of the energy efficiency improvement installations funded by GHGVS.

In order to isolate the effects of the GHG installation measures, other factors which influence a household's fuel poverty status such as changes in household composition, household income, fuel prices and any other changes to the dwelling were held constant for the purpose of the analysis. This approach was taken because the purpose of this analysis was to evaluate the direct influence of GHGVS on fuel poverty status. Given the significant changes to the price of energy and the impacts of the pandemic over the period of this evaluation, it was especially important to focus the analysis on the impact of the scheme itself without allowing other factors, which cannot be influenced by the scheme, to obscure the results.

The same BRESMI modelling methodology employed in phase 1 to estimate the energy efficiency of the dwelling pre-installation was used to calculate the energy efficiency of each dwelling post-installation in phase 2. The change in fuel poverty status was calculated for the same 2,477 cases that were modelled in phase 1.

As set out in the 'Derivation of Energy Efficiency Rating' section above, to perform a true RdSAP (EPC) calculation, a lot of detailed information regarding the physical characteristics of

[88] Terms of reference of the Committee on Fuel Poverty, GOV.UK, not dated. https://www.gov.uk/government/organisations/committee-on-fuel-poverty/about/terms-of-reference

the dwelling and energy efficiency measures is required. It is not feasible to acquire this level of information for dwellings being improved as part of GHGVS and BRE have therefore used their 'Simple SAP' stock model (BRESMI) to produce SAP ratings. The BRESMI model allows for an RdSAP calculation to be performed with much fewer inputs than would be normally required, by utilising in-built imputation procedures.

The SAP ratings modelled by BRESMI were used to determine, for each household, whether it was in fuel poverty before GHGVS installation and after. The analysis was based on records of the measures installed in each dwelling in the February 2022 scheme dataset provided by Ipsos. The analysis focused on the 2,477 households for which a fuel poverty status had been calculated at the pre-installation stage.

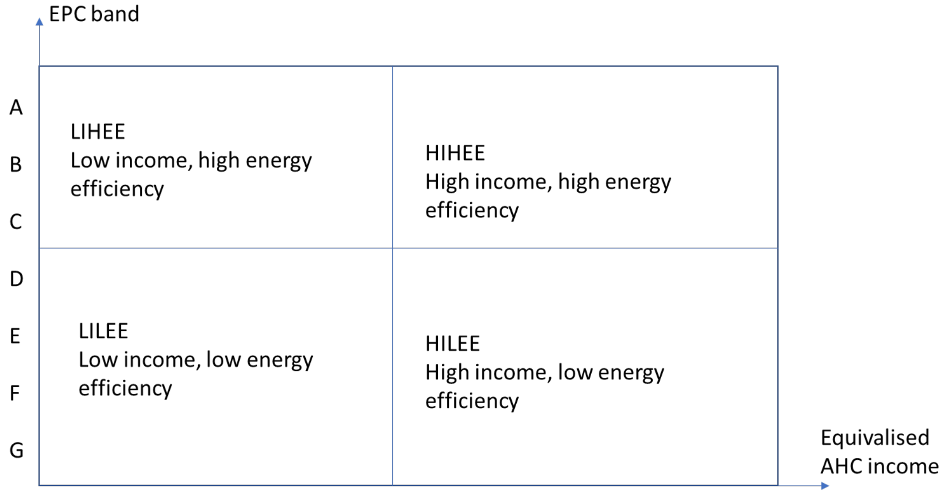
When assessing which households are in fuel poverty (using the LILEE definition), the households are divided into four quadrants, namely:

1. The LILEE quadrant - households with low income and low energy efficiency. Households where the income is below the threshold and where the Fuel Poverty Energy Efficiency (FPEER)[89] rating of their home is band D or below (these indicate households in fuel poverty).
2. The LIHEE quadrant - households with low income but living in a home with high energy efficiency. Households where the income is below the threshold but where the FPEER rating of their home is band C or above (although these households have low income, they are not deemed to be in fuel poverty by this measure because of their home's high energy efficiency).
3. The HILEE quadrant - households with higher income and living in a home with low energy efficiency. Households where the income is above the threshold but where the FPEER rating of their home is band D or below (although these homes have low energy efficiency, households are not deemed to be in fuel poverty because of their higher income).
4. The HIHEE quadrant - households with higher income and living in a home with high energy efficiency. Households where the income is above the threshold and where the FPEER rating of their home is band C or above (these households are in the most favourable category and are not considered to be in fuel poverty as their homes have high energy efficiency and they have high income).

The quadrants associated with the LILEE method are shown below, together with their associated EPC bands and equivalised AHC income levels.

[89] The fuel poverty energy efficiency rating (FPEER), is based on SAP, but accounts for the impact of policies which discount households' energy bills (e.g. the Warm Home Discount). For example, if a household has a band D EPC and they get a rebate deducted from their energy bill due to receipt of the Warm Home Discount, this could move them into an FPEER band C.

Figure A.5.5: LILEE method associated quadrants



Limitations of the BRESMI modelling method

The BRESMI model requires less detailed inputs for each dwelling characteristic than would be made using a full EPC survey. Within BRESMI there are pre-existing categories for each dwelling characteristic which necessitated us applying a 'best fit' between the available scheme data and the category assumed for BRESMI. Because of this it was not possible to model the impacts of all of the GHG installations as it was not possible to fit these installations into the BRESMI inputs. Specifically, the impacts of insulated doors, draughtproofing, underfloor insulation, heat pumps and biomass boilers on the energy efficiency of the building could not be assessed using BRESMI. However, a relatively low number of households had these types of installations, and we were able to model the impact of the installations made for the vast majority of cases. The measures which could not be assessed using BRESMI included 347 air source heat pumps, 40 biomass boilers, 168 insulated suspended floors, 29 hybrid heat pumps, 18 draught-proofing and 232 insulated replacement doors.

For a few installation measures, the BRESMI input categories did not exactly match the installations made so some had to be adapted, for example, whenever roof insulation was installed through the scheme, the final level of insulation was assumed to be the equivalent of 250 mm of mineral wool or higher, as this was the highest level of insulation that could be inputted into the BRESMI model. Secondary glazing was assumed to have the same impact as replacement double glazing. Where hot water tank insulation was installed, it was assumed to be equivalent to a hot water tank jacket. Where double or secondary glazing was installed, it was assumed to apply to every window. For this reason, i.e. because of the inexact matches between the format of the BRESMI input and the installations data, and because of some of the assumptions about the final level of insulation etc. installed, the saving reported below should be treated as estimated changes in SAP ratings. The impacts of internal solid wall insulation and external solid wall insulation were grouped together with cavity wall insulation for the purposes of reporting.

A.5.2.2 Data Sources used for model inputs

The table below shows the inputs required for the BRE SAP model to calculate an EPC rating for a particular dwelling, alongside the datasets and their priority used to inform the input values, if a dataset is not in a given row for a variable, this usually means information on that variable was missing in that dataset. For the process evaluation of GHGVS, data from the following sources were available to use as part of the modelling process:

- Data collected by GHGVS Scheme Administrator ('scheme data')
- TrustMark
- EPCs (where available)
- Applicant Surveys

Table A.5.3: EPC modelling input data sources

Model Input Variable	Primary Data Source	Secondary Data Source	Tertiary Data Source
Tenure	Applicant Survey	Scheme / TrustMark	
Dwelling Type	EPC	Applicant Surveys	
Dwelling Level	EPC		
Dwelling Age	EPC	Scheme / TrustMark	Applicant Surveys
Number of Storeys	Scheme/ TrustMark	EPC	Applicant Surveys
Number of rooms	EPC	Scheme / TrustMark	
Loft Insulation	Scheme / TrustMark	EPC	Applicant Surveys
Wall Type	EPC	Scheme / TrustMark	Applicant Surveys
Wall Insulation	Scheme / TrustMark	EPC	Applicant Surveys
Double Glazing	Scheme / TrustMark	EPC	Applicant Surveys
Main Heating System	Scheme / TrustMark	EPC	Applicant Surveys
Type of Boiler	Scheme / TrustMark	EPC	Applicant Surveys
Main Heating Fuel	Scheme / TrustMark	EPC	Applicant Surveys
Main Heating Controls	Scheme / TrustMark	EPC	Applicant Surveys
Water Heating	Scheme / TrustMark	EPC	Applicant Surveys
Hot water tank insulation	Scheme / TrustMark	EPC	Applicant Surveys
Solar hot water panels	Applicant Survey		
Photovoltaic Solar panels	Applicant Survey		
Floor area	EPC	Scheme / TrustMark	

Where there were differences in the data collected through the above sources, the data from some datasets were prioritised over others, based on perceived accuracy of the data collection method. Generally, GHGV scheme data / TrustMark data were considered the most trustworthy, followed by EPC data and finally the data collected through the applicant surveys. However, for some variables, this hierarchy changed, based on reviewing the data available from the data sources for each of the key modelling inputs. For example, for dwelling characteristics such as the dwelling age and floor area, EPC data was prioritised over scheme data, as these types of characteristics are unlikely to change over time. Loft insulation, on the other hand, can easily become outdated on an EPC, and so scheme data was often considered to be more accurate.

Where no data were available from any of the above sources, values were imputed using BRE's imputation model. This imputation process uses data from EHS to determine the likely distribution of energy efficiency measures and building features, based on key characteristics of the property (such as dwelling type and tenure) and geographical location.

A.5.2.3 Findings

Table A.5.4 shows the modelled impact of the GHGV installations on the fuel poverty status of the households.

Households with low income and living in low energy efficiency homes are classified as being fuel poor (LILEE quadrant). Table A.5.4 shows that of the 2,477 households modelled in both phase 1 and 2,180 households (14%) moved out of fuel poverty as a direct result of the GHGV installations. The table shows that the number of households in the LILEE quadrant (low income, low energy efficiency) fell by 14% because of the GHGV installations. In addition, the installations also led to 107 households (13%) moving from the HILEE quadrant (higher income, low energy efficiency) to the HIHEE quadrant (higher income, high energy efficiency).

Table A.5.4: Summary of the impact of GHGV installations on the LILEE quadrants

Quadrant	No. of households before installations	No. of households after installations	Change resulting from installations
LILEE quadrant - households with low income and low energy efficiency (SAP band D or lower)	1282	1102	-180 (14% reduction)
HILEE quadrant - households with higher income and low energy efficiency (SAP band D or lower)	834	727	-107 (13% reduction)
LIHEE quadrant - households with low income but high energy efficiency (SAP band C or higher)	210	390	+180
HIHEE quadrant - households with higher income and high energy efficiency (SAP band C or higher)	151	258	+107
Total of the four quadrants	2477	2477	-

Change in EPC rating

Table A.5.5 shows the number of dwellings below Band C before and after scheme installations. In total, 287 dwellings 14% moved from a Band D or lower to a Band C or higher because of the GHGV installations. Note, not all of the 287 households living in these dwellings were fuel poor prior to the installations as 107 were classified as high income.

Table A.5.5: Number of dwellings below Band C before and after scheme installations

	Number of dwellings before	Number of dwellings after	Change in number of dwellings resulting from the scheme installations
Number of low energy efficient dwellings (SAP Band D or lower)	2116	1829	-287 (14% reduction)
Number of high energy efficient dwellings (SAP Band C or higher)	361	648	+287

Base – all households, N=2477

Table A.5.6 shows the numbers of dwellings which moved between EPC bands as a result of the measures installed. For those dwellings which were in Band D before the measures (1,207), 280 dwellings (23%) were moved to Band C and 7 dwellings moved from Band E to Band C because of the measures installed.

Table A.5.6: Numbers of households in each EPC Band before and after measures were installed through the scheme

EPC band	B (after)	C (after)	D (after)	E (after)	F (after)	G (after)	Total
B (before)	16						16
C (before)	7	338					345
D (before)		280	927				1,207
E (before)		7	344	319			670
F (before)			11	56	115		182
G (before)				2	21	34	57
Total	23	625	1,282	377	136	34	2,477

Shaded cells show the numbers of households which underwent a change in their energy band as a result of the scheme installations.

Improvements in energy efficiency of the dwelling (change in SAP score)

The post installation energy efficiency of 2,477 dwellings were calculated using the scheme data provided by Ipsos on 7th February 2022. The impact of the installations on the dwelling energy efficiency was modelled for the following installations:

- **Roof insulation** (loft insulation, flat roof insulation, pitched roof insulation, room in roof insulation)
- **Wall insulation** (cavity wall insulation, internal solid wall insulation, external solid wall insulation, park home insulation)
- **Multiple glazing** (double glazing, triple glazing, secondary glazing)
- **Hot water tank insulation** (insulating jacket assumed)
- **Heating controls** (appliance thermostats, smart heating controls, zone controls, intelligent delayed start thermostat, thermostatic radiator valves)
- **Solar thermal** (liquid filled flat plate or evacuated tube collector)

The numbers of households receiving each of the above measures are given in the table overleaf. Once the parameters for each dwelling were amended to include the measures implemented, the dataset was fed through the BRESMI tool to generate a post-installation SAP rating for each case.

Table A.5.7 shows the modelled impact of the GHGV installations on the SAP rating of the dwellings. As a result of the scheme installations, the mean SAP rating of the dwellings increased from 56.1 to 60.6, indicating an average improvement in SAP of 4.5 points.

Table A.5.7: A summary of the installations through the scheme

	Before	After	Change resulting from the installations
Mean SAP rating calculated by BRESMI	56.1	60.6	+4.5
Standard deviation in the SAP rating	13.4	12.6	-

Figure A.5.6 and Figure A.5.7 overleaf show the distribution of SAP ratings before and after the scheme installations have been made.

Figure A.5.6: Distribution of SAP ratings before scheme installations have been made

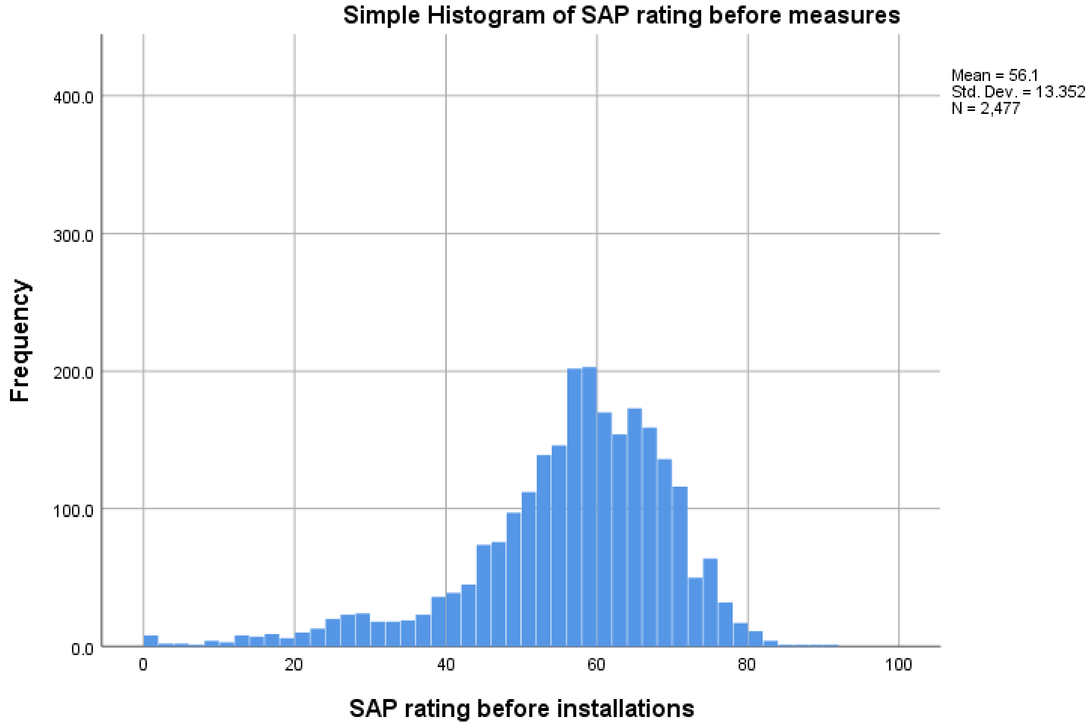


Figure A.5.7: Distribution of SAP ratings after scheme installations have been made

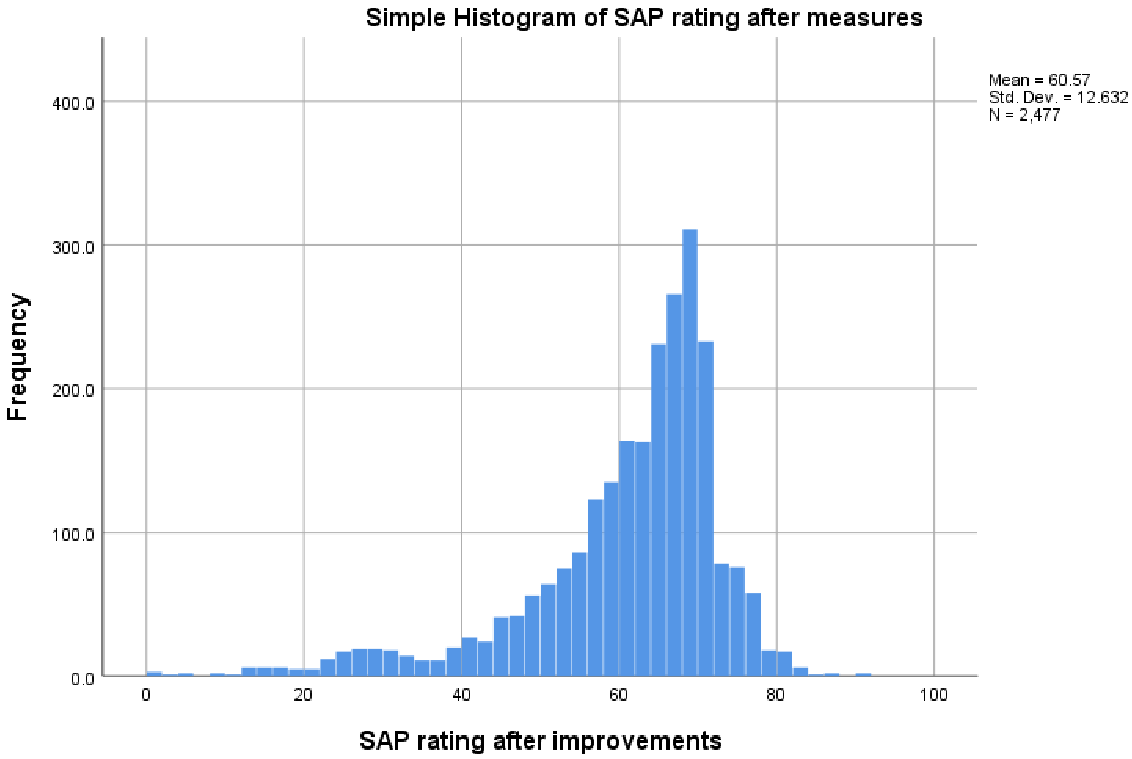


Table A.5.8 shows the average improvements to SAP resulting from each of the scheme measures. The installations that resulted in by far the largest improvement in SAP score was wall insulation (mean improvement of 9.6 SAP points). The installations that resulted in the lowest improvement in SAP score was solar hot water panels.

Table A.5.8: Average improvements to SAP resulting from scheme measures

Scheme installation measures	Mean change in SAP arising from the scheme measure	Median change in SAP arising from the scheme measure	Number of households receiving the measure	Number of households in sample
Roof insulation	4.3	2.0	844	2477
Wall insulation	9.6	10.0	857	2477
Glazing	5.4	3.0	135	2477
Heating controls	5.0	3.0	184	2477
Hot water tank insulation	4.5	4.5	4	2477
Solar hot water	2.3	2.0	380	2477

Note: as described in the 'Limitations of the BRESMI modelling method' section above, certain installation measures had to be grouped together, such as cavity and solid wall insulation, and loft and roof insulation.

Table A.5.9 shows the numbers of dwellings that had each energy measure installed before the scheme and after the scheme. It also shows the number of households receiving each measure under the scheme.

Table A.5.9: Numbers of dwellings in each category before and after the scheme measures.

	No. of dwellings in sample (a)	Number with the measure before the scheme (b)	Number with the measure after the scheme (c)	Number of dwellings that received a GHGV measure (c – b)	% Dwellings improved (c – b) / a
Fully insulated roofs	2477	496	1340	844	34%
Insulated walls	2477	938	1795	857	35%
Fully double glazed or fully secondary glazed	2477	1901	2036	135	5%
Heating controls	2477	1121	1305	184	7%
Hot water tank insulation	2477	1233	1237	4	0.2%
Solar hot water	2477	0	380	380	15%

A total of 1,537 dwellings in the sample received one measure, 361 dwellings received two measures, 43 dwellings received three measures and four dwellings received four measures, giving a total of 2,404 measures. This figure is lower than the total number of the dwellings in the sample (2,477) as some homes did not go ahead with any of the installations applied for.

Impact of single vs multiple measures on fuel poverty

As shown in Table A.5.7, the average improvement in SAP score across all dwelling was 4.5 SAP points. Table A.5.8 shows that wall insulation was the single measure that generated the largest improvement in SAP score of 9.6 points on average. For some dwellings the change in SAP score was higher or lower than this, depending on the type of wall insulation installed and wall area.

EPC band D has a range of 13 SAP points (55 – 68). Therefore, if a dwelling is at the bottom of Band D (55 SAP points) prior to the installation of improvement measures, the installation of a single improvement measure will not (on average) result in the dwelling improving to a band C, as a 14-point improvement would be required, whilst on average the most effective single improvement measure results in a 9.6-point increase in SAP score.

Of the 180 LILEE households who moved out of fuel poverty as a result of the installations of the GHGV energy measures, 175 were in an EPC band D dwelling prior to the installation and only 5 were in a Band E dwelling. In 4 out of the 5 cases where a household was lifted out of fuel poverty by raising its energy band from E to C, more than one measure was installed. In the only case where the energy band was improved from E to C using a single measure, this was due to the installation of solid wall insulation.

Taken together, these findings suggest that, for homes with the poorest energy efficiency (EPC bands E-G), multiple energy improvement measures may be required to raise the energy efficiency to an EPC band C or above, as a single measure is unlikely to be sufficient. For low-income households living in E-G dwellings, this means that multiple installation measures are likely to be required to take them out of fuel poverty (i.e. move them from LILEE to LIHEE).

Proportion of households receiving each measure type.

Table A.5.9 shows, from the sample of 2,477 cases, the proportions of households receiving the measures. This shows that the main scheme measures have largely been captured in the BRESMI analysis.

Table A.5.9: Measures implemented through the scheme

	Fraction of households receiving the measure	Modelled using BRESMI?
Loft insulation	24%	Yes
External solid wall insulation	18%	Yes
Solar thermal	15%	Yes
Air source heat pump	14%	No
Cavity wall insulation	13%	Yes
Pitched roof insulation	9%	Yes
Energy efficient replacement doors	9%	No
Heating controls	8%	Yes
Under floor insulation (Suspended floor)	7%	No
Double or triple glazing	5%	Yes
Flat roof insulation	4%	Yes
Room in roof insulation	4%	Yes
Internal solid wall insulation	2%	Yes
Biomass boiler	2%	No
Under floor insulation (Solid floor)	1%	No
Hybrid heat pump	1%	No
Draught proofing	1%	No
Secondary glazing	1%	Yes

NB: Only measures applied for by 1% or more of those likely to be fuel poor shown in table.
The figures in this table refer to the proportions of the 2,477 households for which fuel poverty could be evaluated.

Annex 6: Quality of installation and service analysis

The main data used for the quality analysis was from Trustmark audit data supplemented by information collected through the applicant survey and auditor interviews.

A.6.1 TrustMark audit data analysis methodology

TrustMark provided two types of audit data to assist with the quality analysis of installations completed for GHGVS: **audit data**, which in summary provided details on the compliance of each inspection question for every measure at all auditor visits, and **lodgement data**, which included certificate information, property details and measure type specifications. TrustMark also provided the questions that auditors use when inspecting installations. There are different sets of questions for each measure type, though they can be categorised into groups that encompass different measures such as safety issues, installed to manufacturer instructions, airtight or sealed, and paperwork and communications.

There were 1,221 distinct site visit audits recorded for GHGVS in the TrustMark Site Audit Data Report provided in January 2022. Most of these audits (approximately 1,100) took place in August and September 2021, with the remaining audits taking place in October and November 2021. A total of 21,852 questions were scored across all scheme audits. Property and measure type data corresponding to the audit data were included in the lodgement data. TrustMark also provided audit and lodgement data for Energy Company Obligation (ECO), Local Authority Delivery (LAD) and Warmer Home Discount (WHD) to facilitate scheme comparison.

The analysis of the audit and lodgement data included inputting the raw TrustMark data into three tables in Excel: audit data, lodgements, and inspection questions. An analysis of the variables in the three tables was conducted to identify quality issues for GHGVS, as well as for ECO, LAD and WHD, by region, by property type and by measure type. The non-compliance rate and a fail/pass ratio were also calculated.

A.6.2 Methodological challenges and limitations

One key limitation of the TrustMark audit dataset included missing inspection question information. The raw audit data included a column with question codes, not the questions themselves, the questions that auditors used when inspecting installations was identifiable by the corresponding question codes that were provided in an additional document. Some question codes were missing from this complementary question document, meaning that the question codes in the audit data could not be defined. Consequently, there were data that could not be analysed as they were not ascribed to specific measures, and these data have therefore not been included in the final analysis (data was not used for approximately 15% of questions). Whilst the majority of questions were included, this may have resulted in some inaccuracies when calculating non-compliance rates and fail/pass ratios for specific measures with missing question codes.

The second limitation concerned scheme comparison. The number of inspections conducted and therefore the quantity of data available for each scheme varied considerably. ECO had 3,311, the highest number of audits, while GHGVS only had just over a third as many (1,221) and LAD and Warm Homes Discount only had 94 and 6 inspections, respectively. Comparisons were therefore disproportionate and as a result were not robust. Additionally, direct scheme comparison of some variables, such as postcode and many types of property characteristics, was not possible as certain information was not collected by auditors for all schemes. Different schemes also installed different measure types. Since schemes such as WHR and LAD did not install certain measures, such as insulation installations (particularly solid floor insulation and pitched roof insulation) which are by nature more difficult to install and inspect than others, they did not have their overall non-compliance rates impacted by these issues. This is particularly evident for WHR, which had the lowest non-compliance rate of all but exclusively replaced gas boilers.

Annex 7: Jobs Impact analysis

This annex sets out an analysis of the job creation impacts of GHGVS. The analysis uses longitudinal data on the employment and turnover of firms delivering measures through GHGVS to explore how far demand stimulated by the provision of subsidies encouraged firms to create new jobs. Further analysis is completed to explore how far (a) GHGVS led to any further productivity gains by encouraging firms to redeploy furloughed workers in a productive capacity and (b) the net economic effects of GHGVS (by examining impacts on local unemployment levels).

A.7.1 Analytical Framework

This initial section sets out the overall analytical framework for assessing the employment and other economic impacts of GHGVS. It sets out the expected process by which the inputs and activities associated with GHGVS were expected to lead to their intended economic outcomes (i.e. a Theory of Change).

GHGVS was partly intended to provide a demand side stimulus to support economic recovery following the introduction of social distancing measures. The government assumed that such measures, and concern around the spread of the disease, would deter homeowners from paying for energy efficiency or other upgrades to their homes. It was anticipated that subsidies (in the form of vouchers) would help address this barrier, stimulating economic growth via the following processes:

- **Consumer spending:** GHGVS provided subsidies to consumers to fund energy efficiency installations. To the degree that consumers taking up vouchers would not have funded equivalent home improvements in the absence of GHGVS, it would be expected to have led to an increase in consumer spending on energy efficiency measures.
- **Turnover and GVA:** Increased consumer spending would be expected to translate into an increase in the turnover of installers accredited to deliver GHGVS and their overall levels of economic output (Gross Value Added) as they expand activity levels to meet the additional demand.
- **Employment impacts:** The additional demand stimulated by GHGVS may also have encouraged installers to retain workers whose jobs may have otherwise been at risk (jobs safeguarded) or (if the additional demand exceeded capacity levels) create new jobs. The strength and nature of these effects will be partly determined by:
    - How far installers were operating with excess capacity levels over the timeframe over which GHGVS was delivered. As the Coronavirus Job Retention Scheme (CJRS) allowed firms to retain workers in a non-productive capacity, some installers may have been able to meet the additional demand by redeploying those workers in a productive capacity. While this would provide an important economic benefit in the form of productivity gains (see below), in this scenario, firms may not expand their overall levels of workers employed.

  - As GHGVS was only expected to provide a short-term demand stimulus, firms reaching their limits of capacity may have sought to meet additional demand by employing workers on a temporary basis (subject to their ability to recruit appropriately skilled staff on these terms) or by seeking to seeking to outsource work to contractors or other suppliers (a supply chain multiplier effect, as described below).

- **Productivity impacts:** GHGVS also had the potential to produce productivity gains (increases in GVA per worker). This may have occurred if installers delivered installations more intensively (rather than expand their workforce). As noted above, firms taking workers out of the furlough scheme is one example of this possibility. Conversely, productivity may also have fallen if the work funded by the programme was less efficiently delivered than existing workloads.
- **Supply chain multipliers:** Installers needed to obtain appropriate materials to deliver installations under GHGVS (and some also outsourced work to contractors where they could not meet demand within their capacity or where aspects required specialist skills unavailable to the firm). Spending placed within the supply chain has the potential to lead to spin-off effects in terms of increasing the productivity or growth of suppliers.
- **Displacement:** GHGVS may have led to offsetting effects in other sectors of the economy to the degree that consumers were incentivised to divert their spending from other types of goods and services. As such, the scheme may have encouraged consumers to spend those savings when they may have otherwise left those funds in the bank. The strength of these effects may have been mitigated by the context in which GHGVS was delivered. Consumers built up ‘involuntary savings’ during the pandemic owing to a reduction in opportunities to spend. If the scheme encourage consumers encouraged to deploy savings built up during the COVID-19 pandemic, then these types of offsetting effects would be reduced (at least in the short-term).
- **Crowding out:** The additional demand stimulated by the programme also had the potential to place upward pressure on the prices of key inputs (e.g. building materials, wages, etc) or crowd out other construction activity. This would have limited the net effects of the programme as other firms would be encouraged to reduce their output and employment levels. In an economy operating at full-resource utilisation, these effects would be expected to fully offset the growth outcomes induced by GHGVS (at the national level). However, GHGVS was launched during a period in which the economy was operating below full resource utilisation and may therefore have led to a net (albeit temporary) expansion in GVA and employment. As such, the net effects of GHGVS might be better understood in terms of how far GHGVS reduced local unemployment levels.
- **Net economic benefits:** Given the potential for offsetting effects at the local and national levels, the net economic benefits of GHGVS are arguably best understood in

terms of the additional output (GVA) arising from the improved productivity of workers employed by installers.[90]

It is also feasible that parallel government schemes such as ECO, LAD and, to a lesser extent (due to different timings) SHDF(D), may have contributed to similar outcomes and that firms participating in these schemes may also experience an effect on job and business outcomes.

A.7.2 Direct effects

A.7.2.1 Data assembly

This section describes the data employed to produce the econometric analysis of direct effects on participating firms. The process of data assembly involved constructing a panel of firms that either (a) delivered measures through GHGVS or (b) did not deliver measures through GHGVS but might reasonably considered to be equivalent in other respects (a comparison group). Details of these firms were then linked to a variety of administrative datasets describing the evolution of the firms' employment and turnover levels.

Dataset of participating firms

The panel of relevant firms was identified using the following process:

- **Applications to deliver GHGVS:** BEIS supplied a dataset ('scheme data') describing details of all application to GHGVS (1887 applications in total). 477 applications were rejected due to the firms not having TrustMark accreditation and were removed from the sample. As only firms with TrustMark accreditation were permitted to deliver measures under GHGVS, this group was not considered sufficiently comparable to those delivering measures under GHGVS and these applications were removed from the sample. This gave a sample of 1,410 applications submitted by 1,109 Trustmark certified firms (noting that some firms submitted multiple applications). A total of 502 applications were not approved for other reasons, such as failing to provide the correct information or voluntary withdrawal. This gave a sample of 937 TrustMark accredited firms that were approved to deliver measures under the scheme and 172 whose applications were not approved.
- **Measures data:** This dataset was supplemented with data on 'measures' which provided an indication of the number of voucher applications from consumers associated with different suppliers, and whether these applications were approved or not approved. The dataset contained details of 169,430 applications, of which 83,154 were approved. Any applications that were not associated with a firm (e.g. due to data entry errors) were excluded from the sample. A total of 839 firms were associated with at least one application for vouchers, and a total of 777 firms were associated with at least one approved application for vouchers.
- **Lodgement data:** Data on measures highlighted which firms were associated with approved voucher applications but did not describe whether the works took place in

[90] A broader cost-benefit analysis would clearly also need to consider the environmental benefits associated with diverting consumer spending to energy efficiency measures over potential alternative uses.

practice. We therefore further enriched the dataset with information provided by TrustMark on whether the measure was 'lodged' with the TrustMark Data Warehouse, thus identifying whether the firm delivered measures under GHGVS. A total of 49,170 measures were lodged with TrustMark by 804 firms. All 777 firms associated with at least one approved voucher application were also associated with at least one lodgement. However, the data imply that 27 firms that were not associated with an approved voucher application delivered measures under the scheme. It is anticipated that this issue is caused by the absence of firm details in some records of voucher application received.

This compares to 83,154 approved voucher applications and implies that the works associated with 33,984 approved vouchers did not go forward in practice (40 percent). This approach could understate the number of firms participating in GHGVS if any measures delivered under GHGVS were not ultimately 'lodged' with TrustMark. The extent of this possible issue is unknown. Although it is possible that some work may have been undertaken and not lodged, this is unlikely as the scheme administrator performed checks against the lodgement data prior to releasing payment to the installer.

- **Companies House Reference Numbers:** As a final step, we enriched the dataset with details of the firms' Companies House Reference Number (CRN) to enable onward linking to other datasets. Where the CRN was not recorded, the missing details were retrieved from other datasets (e.g. Lodgement Data) and using the Companies House API. Using scheme data and the API we were able to match all 1,109 companies in starting sample to a corresponding CRN.

Counterfactual dataset (non-participating firms)

A credible assessment of the impacts of GHGVS requires a comparison between firms that delivered measures through GHGVS, and a group of equivalent firms that did not (to estimate what may have occurred in its absence). This is challenging in this context as those firms that delivered measures through GHGVS may differ in systematic ways to those that did not, which could bias results. For example, firms that sought to deliver measures through GHGVS may have been more willing to absorb the commercial risks associated with expanding their output or employment (and may have been more likely to grow regardless of GHGVS).

The design of GHGVS did not create substantial opportunities to address these issues robustly – it was a universal programme (no areas of England were ineligible for the programme) launched simultaneously across the country. There was no competitive process that resulted in some firms being able to deliver GHGVS, firms just had to meet the required accreditation standards (i.e. PAS 2030[91] and PAS 2035). As such, a variety of counterfactual approaches were explored as described (alongside their limitations) in Table A.7.1, alongside the resulting number of firms in the group.

The following analyses assume that the firms in the respective comparison groups did not deliver any measures. The lodgement data includes details of the primary subcontractor, and these firms are included in the treatment group. However, as monitoring data does not capture complete records of the supply chains used in the delivery of measures, it is not possible to provide complete assurance that no firms in the comparison groups did not participate in the

[91] Including both PAS 2030:2017 and 2019.

scheme. To the extent that this is a prevalent issue, the following estimates of GHGVS will be understated.

Table A.7.1: Installer level comparison group

Counterfactual group	Overview	Number of firms in group
#1: Trustmark accredited firms that **applied** to deliver measures under GHGVS that **did not deliver any measures.**	This included all firms that applied to deliver GHGVS and met its required accreditation criteria but did not deliver any measures. This removes biases driven by differences between accredited and non-accredited firms. However, comparisons could still be distorted by differences between (a) firms whose applications were approved or declined and (b) differences between approved firms that did and did not apply to deliver measures through GHGVS.	332
#2: Trustmark accredited firms **approved** to deliver measures under GHGVS **that did not deliver any measures** (subset of #1)	Limiting comparison to firms approved to deliver measures under GHGVS addresses possible biases driven by differences between firms whose application to deliver measures under GHGVS were and were not approved. However, firms that did not deliver any measures under GHGVS may differ in residual ways from those that did (e.g. they may have been less effective at marketing) that could bias comparisons.	160
#3: Trustmark accredited firms **approved** to deliver measures under GHGVS, **but were only associated with voucher applications that were not approved** (subset of #2)	This approach removes some possible differences between firms arising from their ability to engage consumers (by ensuring that comparisons are only made between firms associated with applications to deliver measures).	62
#4: Firms delivering measures at different times (Pipeline Design)	The final approach exploits temporal variation in the timing of delivery of	777

Counterfactual group	Overview	Number of firms in group
	measures by limiting comparisons to firms that delivered different volumes of measures at different times (i.e. firms delivering more activity at earlier times would be expected to see more significant employment effects in earlier periods). This approach mitigates against most possible issues caused by selection bias, although as measures were delivered over a relatively short period of time, it was only possible to take this approach with quarterly data.	

Interdepartmental Business Register (IDBR)

The firm level dataset described above was linked to the quarterly Interdepartmental Register (IDBR) to provide additional details of firm employment and turnover. Firms were linked to data on quarters ranging from January to March 2018 (Quarter 1) to April to June (Quarter 2) of 2022. This covered the period of scheme delivery between January 2021 to March 2022.

The IDBR is an administrative database that captures information on the employment and turnover of all firms registered for PAYE or VAT. Records of the relevant population of firms were linked to the IDBR by BEIS (i.e. 1,109 firms including the 777 firms delivering measures and the 332 TrustMark accredited firms that applied to deliver measures but did not do so). The nature of the data creates some challenges for an assessment of the economic impacts of GHGVS given the expectation that GHGVS would generally be expected to deliver temporary rather than on-going or permanent effects on economic activity:

- **Recording lags:** Although the IDBR is a 'live' database, information is not updated in real-time with information arriving with variable lags depending on the outcome (i.e. VAT returns arrive later than PAYE records) and the size of the firm. No records are kept in relation to the 'vintage' of the data, so information on the employment of firms in 2022 may be current or relate to prior periods, and this is not marked in the data (with recording lags being more problematic in the short-term). This means:
    - Issues of recording lags do not violate assumptions around cause and effect and will not lead to fundamentally misleading results (i.e. changes in employment driven by the scheme will only be visible in the data following the delivery of measures). The effect of the programme on employment or turnover will eventually be visible in IDBR records, though in many cases these effects will lag the delivery of installations, and this needs to be accounted for in modelling (i.e. effects will be distributed over multiple periods following the delivery of installations).

  - Owing to time constraints on the evaluation, the analysis used data available a short time following the closure of GHGVS (i.e. one quarter following the completion of the scheme). As such, it is probable that any analysis will not capture its full effects.
  - The data provides a snapshot of employment at a particular point in time. While comparisons at annual intervals can be effective in capturing impacts on on-going employment levels, it is probable that GHGVS only led to the creation of safeguarding of employment on a temporary basis. This means that it will be necessary to examine both quarterly data to fully explore the effects of GHGVS (including allowing for the possibility that the delivery of installations in a particular period leads to an effect on employment that is only visible in later quarters).
- **Sole traders:** Sole traders and unregistered businesses were not captured in the analysis as their details are not captured by the IDBR (or any other administrative datasets). This could result in an understatement of the effects of the programme to the degree that measures were delivered by these types of businesses.
- **Static observations:** To address the possibility that some firms have been sampled for the annual Business Register and Employment Survey (BRES) and (artificially) see no changes in employment or turnover,[92] some robustness checks were undertaken by excluding firms with static employment and turnover measures between 2020 and 2022 from the analysis, during this process 64 firms (6%) were removed from the sample.
- **Productivity outcomes:** The IDBR only enables the construction of a proxy measure of productivity (turnover per worker). Effects on this variable were explored. However, it should be noted that (a) turnover measures are subject to longer lags than employment measures and (b) turnover per worker only reflects changes in productivity to the degree that GHGVS does not alter the degree to which firms make use of external inputs. As GHGVS may have increased levels of outsourcing, it may have increased turnover per worker without altering underlying productivity (GVA per worker).

Business Structure Database (BSD)

The BSD is an annual snapshot of the IDBR taken in March each year. It is available through the ONS Secure Research Service (SRS) and was used to cross check results derived from the IDBR analysis. However, it is subject to the same issues as the IDBR as it based on the same underlying data.

To identify firms in the BSD we submitted our usable sample of 1,109 firms to the ONS SRS data team for matching. Our data included CRNs which were pseudonymised to create an "entref" variable, which is included in many of the business datasets held in the SRS and allows for linking GHGVS and BSD data. Using data from the BSD, we were able to match a total of 973 unique firms, an average of 81.5% for each survey year of interest. Our final

[92] If a firm is sampled for the BRES, observations of turnover and employment will be provided by their responses to the survey rather than VAT and PAYE. To minimise burdens on businesses under 'Osmotherly' rules, SMEs are invited to respond to the survey at less frequent intervals. For these businesses, information on employment and turnover are updated less frequently and may not change for several years (e.g. micro-businesses are invited to respond to the survey every five years).

sample for BSD analysis and the total number of firms matched in each year survey year is presented in Table A.7.2.

Table A.7.2: Total matched firms in the BSD by survey year

Year	No of Firms	Percent %
2020	865	77%
2021	946	85%
Total	973	100%

Annual Business survey (ABS)

The ABS is an annual census of large firms (firms with 250 employees or more) and a sample survey of SMEs. The survey is used to measure the output of the production and service sectors in the UK, and microdata (i.e. firm level observations) are available through the ONS SRS. As such we explored the potential use of ABS data given its potential to enhance the quality of the analysis as it provides:

- Average employment over the course of the year (capturing temporary effects on employment).
- GVA – providing a measure of total output (rather than turnover) and enabling the construction of more effective productivity measures (i.e. GVA per worker).
- Spending on intermediate goods and services (capturing total effects on supply chain spending – though noting that this includes spending on imports – e.g. goods and materials purchased from overseas suppliers that will produce no domestic supply chain impacts).
- Imports (which can be subtracted from spending on intermediate goods and services to provide an estimate of the increase in domestic demand associated with the scheme).

The data is also ‘time stamped’ and does not create the same issues with recording lags associated with the IDBR. The central issue with the ABS is that it only provides partial coverage of SMEs in any given year, it was therefore anticipated that constructing sufficiently large samples of firms with pre and post observations to enable statistical analysis would be challenging. To test the coverage of the sample of installers in the ABS, we matched the sample of firms constructed in section 2.1.1 with firm records in the ABS for the 2020 survey year in the SRS environment. This process resulted in a low match rate of just 22 firms, and we concluded that this coverage was no sufficient enough for further analysis. ABS data for 2021 survey year was not accessible at the time of the analysis due to poor and late data returns after lockdown.

Coronavirus job retention scheme

To enable some (partial) analysis on the effect of GHGVS in bringing workers out of furlough and to assess the impact of the CJRS, the dataset of firms was also linked to records of take-up at a firm level published by HMRC (linked via the CRN). This analysis indicated that 492 firms (44%) out of the 1,109 in the treatment and control sample under analysis had claimed CJRS at some point between December 2020 and September 2021. It was assumed that the remaining firms did not claim CJRS. While this provided longitudinal data on the share of firms claiming CJRS over the period, the following issues should be noted:

- Data is only available from January 2021, two months after GHGVS was launched. As such, baseline data on the share of firms claiming in 2020 were not available (which may have provided useful additional detail on how deeply firms were affected by the COVID-19 pandemic).
- It is only possible to derive a binary indicator of whether firms were claiming CJRS or not. This is a relatively blunt measure which does not capture varying levels of use of the CJRS programme (while information on the amounts claimed have been published, these are set out in broad categories that could not be utilised in the econometric analysis).

A.7.2.2 Methodological framework

This section sets out the approach adopted to produce estimates of the causal effects of GHGVS.

Comparability of treatment and comparison groups

Table A.7.3 shows the distribution of firms in the different groups by firm size (based on IDBR data). Firms delivering GHGVS were slightly larger than those in the comparison groups though the difference was not statistically significant.

Table A.7.3: Distribution of firms by firm size in 2020

Firm Size	Firms delivering GHGVS	Counterfactual group #1	Counterfactual group #2	Counterfactual group #3
	Firms approved to deliver measures under GHGVS, delivering measures that were lodged with TrustMark	*Firms that applied to deliver GHGVS and met its required accreditation criteria but did not deliver any measures*	*Firms approved to deliver measures under GHGVS that did not deliver any measures*	*Firms approved to deliver measures under GHGVS, but were only associated with voucher applications that were not approved*
Large (250+ employees)	2 (0%)	2 (1%)	1 (1%)	0 (0%)
Medium (50 to 249 employees)	17 (3%)	11 (4%)	9 (5%)	4 (7%)
Small (10 to 49 employees)	148 (22%)	33 (13%)	26 (15%)	10 (17%)
Micro (0 to 9 employees)	498 (75%)	215 (82%)	135 (79%)	46 (77%)

Source: IDBR (2022) Ipsos analysis of firm linked records to the IDBR

There were no significant differences in the sector profile of firms that delivered GHGVS and the three comparison groups. Around 75 percent of firms in all groups were operating in the construction sector. Firms delivering GHGVS were slightly more likely to be operating in the retail sector (which could potentially influence findings, as the retail sector was more significantly affected by COVID-19 restrictions than many others).

Table A.7.4: Distribution of firm by sector

Sector	**Firms delivering GHGVS**	**Counterfactual group #1**	**Counterfactual group #2**	**Counterfactual group #3**
	Firms approved to deliver measures under GHGVS, delivering measures that were lodged with TrustMark	*Firms that applied to deliver GHGVS and met its required accreditation criteria but did not deliver any measures*	*Firms approved to deliver measures under GHGVS that did not deliver any measures*	*Firms approved to deliver measures under GHGVS, but were only associated with voucher applications that were not approved*
Construction	505 (76%)	196 (75%)	129 (75%)	47 (78%)
Professional, scientific and technical activities	70 (11%)	24 (9%)	17 (10%)	3 (5%)
Wholesale and retail trade; repair of motor vehicles and motorcycles	28 (14%)	12 (5%)	7 (4%)	1 (2%)
Manufacturing	18 (3%)	7 (3%)	5 (3%)	3 (5%)
Electricity, gas, steam and air conditioning supply	13 (2%)	3 (1%)	2 (1%)	1 (2%)
Other	30 (5%)	19 (7%)	11 (6%)	5 (8%)

Source: IDBR (2022) Ipsos analysis of firm linked records to the IDBR

Table A.7.5 compares pre-programme turnover of firms delivering measures under GHGVS to the comparison groups. This indicates that:

- Firms delivering GHGVS tended to be smaller than firms that applied to deliver GHGVS but did not deliver any measures (driven by the presence of a small number of large firms in Group #1), but larger than Group #2 and Group #3 (firms approved to deliver GHGVS that did not deliver measures).
- However, trends in turnover growth were generally comparable across groups (with no groups seeing significant changes in their average turnover levels over the period). This analysis did not provide any prima-facie reason to reject the ‘parallel trends’ assumption underpinning the validity of difference-in-differences models.

Table A.7.5: Average (mean) turnover between 2018 and 2020

	Firms approved to deliver measures under GHGVS, delivering measures that were lodged with TrustMark	Firms that applied to deliver GHGVS and met its required accreditation criteria but did not deliver any measures	Firms approved to deliver measures under GHGVS that did not deliver any measures	Firms approved to deliver measures under GHGVS, but were only associated with voucher applications that were not approved
2018	£1,492,088	£7,950,072	£1,594,662	£1,239,787
2019	£1,443,834	£8,085,092	£1,557,316	£1,145,254
2020	£1,484,810	£7,253,875	£1,630,310	£1,507,360

Source: IDBR (2022) Ipsos analysis of firm linked records to the IDBR

Econometric model

In all cases, our analysis involved inferring the impact of GHGVS using the following econometric model:

$$lny_{it} = \alpha + \beta T_{it} + \gamma X_{it} + \delta Z_i t + \alpha^i + \alpha^t + \varepsilon$$

Our model relates the employment and turnover of firm I in period t (y_{it}) to the volume of activity or cost of measures being delivered through GHGVS in the same (T_{it}). The coefficient β captured the average effect of measures delivered through GHGVS on the outcomes of interest. This 'dose-response' relationship assumed that those firms delivering greater levels of activity via GHGVS would see more significant effects on their employment or turnover.

This specification used overall volumes of measures delivered to estimate the effects of the scheme. However, as there is variability in the level of effort associated with different types of measures, this approach could reduce the level of precision associated with the analysis. Two alternative approaches were used to explore the robustness of findings, including (a) replacing the volume-based measures with a measure of the total cost of installations and (b) an expanded specification decomposed the volume of measures delivered by measure type (allowing the effects of the scheme to vary across different types of measure). The detailed results of these supplementary analyses are provided in the Appendix, although findings were broadly consistent across approaches as described below.

Models also controlled for whether firms participated in other schemes like GHG-LAD, ECO3 and SHDF programmes[93] and the volume of measures delivered under these schemes (X_{it}) as well as differential trends across the characteristics of the firm (location, company size and age) that could possibly influence the outcomes of interest ($Z_i t$). Finally, (α^i) accounts for unobserved features of the firm that do not change over time (i.e. inherent characteristics of the business which may affect outcomes – whether it is family-run etc.), while the term (α^t) will control for time-specific shocks (e.g. macro-economic shocks such as COVID-19).

In the case of quarterly data, the model was adapted to capture possible lagged effects by including lagged measures of the treatment variable as follows (note that the conventional

[93] We did not have information on whether the companies in treatment and control groups have also participated in the RHI scheme, so we cannot account for this.

subscript t has been replaced with q in the following model to make it clear the model is using quarterly data):

$$y_{it} = \alpha + \sum_{l=0}^{3}(\beta_l T_{iq-l}) + \gamma X_{iq} + \delta Z_{iq} + \alpha^i + \alpha^t + \varepsilon$$

A.7.2.3 Results

Inter-Departmental Business Register (IDBR)

The results of the econometric analysis using IDBR data are set out in Table A.7.7. This provides findings using the regression specifications outlined in above for the four comparison groups identified in Table A.7.1. In each case, the models were estimated using Ordinary Least Squares (OLS) regression, fixed effects (controlling for time invariant but unobserved differences between firms) and two-way fixed effects (controlling for unobserved but time specific shocks affecting all firms in the sample). The findings indicate:

- **Employment**: The results consistently indicated that GHGVS had a short-term effect on employment levels. Excluding OLS findings (which are not robust to unobserved differences between firms), the results implied that the scheme led to an average on-going increase in employment of 0.03% to 0.08% (per firm, per lodgement). The evidence suggested that these effects were realised in the short-term (with no lagged effects except in two-way fixed effects models, reflected in the upper bound of the range). The lack of data post completion of the scheme makes it difficult to assess the level of persistence associated with the jobs created or safeguarded.

  Analyses based on the cost of measures delivered were similar on a qualitative basis (see Appendix for details), implying a total average effect on employment of 2.6% to 4.4% per £1m of expenditure (although the effects of the scheme tended to lag the delivery of measures in this case). Models decomposing effects by type of measure indicated that the effects of the scheme were predominantly driven by delivery of 'other heating,' 'solid wall insulation,' and 'other insulation'. Using alternative approaches did not significantly alter estimates of the total effect of the scheme as described below.

- **Turnover and turnover per worker**: There was no robust evidence that GHGVS led to an increase in turnover or turnover per worker. Modelling based on the total cost of insulation also did not indicate that the scheme led to increases in turnover (and may have reduced turnover per worker). Models decomposing effects by type of measure, however, indicated that some types of measure may have had positive effects on turnover. Overall, the evidence was less conclusive and as noted above, issues with recording lags are most acute for turnover measures and it is plausible that the absence of effects in some models arose from these types of issue.

Estimates of effects on total jobs

Table A.7.6 provides estimates of the aggregate effect of GHGVS on employment (which can be interpreted as the number of additional jobs created or safeguarded). This was estimated by applying:

- The estimated average effect on employment per lodgement (0.03% to 0.08%) over four quarters to the average number of number employees in firms delivering GHGVS measures at the baseline year of 2020 (42.1).
- This implies that the average number of jobs created or safeguarded per lodgement over the delivery of the scheme was 0.01 to 0.03 jobs[94] (i.e. 42.1 x 0.03 to 42.1 x 0.08).
- In total, the programme involved the delivery of 48,184 measures. This implies that the programme may have created or safeguarded a lower and upper bound range of 550 to 1,700 direct jobs[95] (0.01 x 48,184 to 0.03 x 48,184). Results based on alternative modelling approaches were broadly comparable (full details are provided in the Appendix), although implying a wider range of 450 to 3,850 jobs created or safeguarded.
- As noted above, these jobs were sustained over (on average) over the duration of project delivery, but the absence of post-scheme data makes it challenging to determine how far those jobs might have been sustained for a longer period.
- This implies that the direct employment impacts of GHGVS were relatively modest and that firms were largely able to accommodate additional demand within their existing capacity or reduced (or delayed) other types of work to deliver measures funded via GHGVS. Alternatively, measures delivered via GHGVS may have largely been delivered via supplier and contractors (which would not be visible in these results).

Table A.7.6: Estimated total jobs created or safeguarded

	Lower bound	**Upper bound**
Average number of employees in treated firms at baseline (period before intervention)	42.1	42.1
Total % effect over 4 periods (in period + 3 lags)	0.03%	0.08%
Average effect on number of employees per firm per measure	0.01	0.03
Number of lodgements delivered	48,184	48,184
Estimated total jobs created or safeguarded (lower bound)	544	1,696
Aggregation based on total cost of installation	455	766
Aggregation based on decomposing volumes of measures by measure type	1,652	3,864

[94] Calculated as the percentage of jobs created per lodgement as a proportion of the average number of employees per firm
[95] Calculated as the total effect over all lag periods (upper bound) or one lag period (lower bound) multiplied by the average number of firms times the number of firms delivering measures

Table A.7.7: Estimates of the impact of GHGVS on employment and turnover (effects per lodgement)[96]

Outcome / lag and Model	Comparisons with Group #1 - OLS	Comparisons with Group #1 - FE	Comparisons with Group #1 – Two-way-FE	Comparisons with Group #2 - OLS	Comparisons with Group #2 - FE	Comparisons with Group #2 – Two-way-FE	Comparisons with Group #3 - OLS	Comparisons with Group #3 - FE	Comparisons with Group #3 – Two-way-FE	Comparisons with Group #4 - OLS	Comparisons with Group #4 - FE	Comparisons with Group #4 – Two-way-FE
Employment impacts (% effect per lodgement)												
In quarter of reported lodgement	0.000640***	0.000273**	0.000294**	0.000603***	0.000268**	0.000294**	0.0151***	0.000268**	0.000323***	-	-	0.000371***
+ 1 quarter	-	-	-	-	-	-	-	-	-	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	0.000428***	-	-	0.000403***	-	-	0.000412***			0.000465***
Turnover impacts (% effect per lodgement)												
In quarter of reported lodgement	0.00121***	-	-	0.00115***	-	-	0.00115***	-	-	-	-	-
+ 1 quarter	-	-	-	-	-	-	-	-	-	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	-	-	-	-	-	-	-

[96] These models were also implemented with a sample of firms whose employment did not change at all over the period. However, this made no difference to the findings (quantitatively or qualitatively).

Outcome / lag and Model	Comparisons with Group #1 - OLS	Comparisons with Group #1 - FE	Comparisons with Group #1 – Two-way-FE	Comparisons with Group #2 - OLS	Comparisons with Group #2 - FE	Comparisons with Group #2 – Two-way-FE	Comparisons with Group #3 - OLS	Comparisons with Group #3 - FE	Comparisons with Group #3 – Two-way-FE	Comparisons with Group #4 - OLS	Comparisons with Group #4 - FE	Comparisons with Group #4 – Two-way-FE
Turnover per worker impacts (% effect per lodgement)												
In quarter of reported lodgement	0.000567*	-	-	0.000552*			0.000552*		-0.000455*	-	-	-
+ 1 quarter	-	-	-	-	-	-	-	-	-	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	-	-	-	-	-	-	-

Source: IDBR, Ipsos analysis pval in parentheses *** p<0.01, ** p<0.05, * p<0.1. Outcome variables in natural logarithms and estimated effects can be interpreted as the % effect per lodgement. Only statistically significant findings have been reported.

Business Structure Database and Annual Business Survey

We repeated our analysis of the IDBR to validate our results using annual BSD data. The results are set out in Table A.7.8. Results show that models applied to the BSD data produced a similar pattern of results. with significant positive effects found across all comparison groups for employment, turnover and turnover per worker using OLS. However, results produced using more robust fixed effects were not statistically significant, suggesting that there was no robust evidence that GHGV led to an increase in employment, turnover, or turnover per worker. This could suggest that any employment effect was largely temporary, which would not be unexpected given the nature of the scheme.

Table A.7.8: Estimates of the impact of GHGVS on employment and turnover (effects per lodgement)

Outcome / leg and Model used	Comparisons with Group #1 - OLS	Comparisons with Group #1 - Two-way FE	Comparisons with Group #2 - OLS	Comparisons with Group #2 - Two-way FE	Comparisons with Group #3 - OLS	Comparisons with Group #3 - Two-way FE	Comparisons with Group #4 (pipeline design) - OLS	Comparisons with Group #4 (pipeline design) - Two-way FE
Employment impacts (% effect per lodgement) - In year of reported lodgement	0.00196**	0.0012	0.00195**	0.0012	0.00200**	0.0012	-	0.00131
Turnover impacts (% effect per lodgement) - In year of reported lodgement	0.00880***	0.0028	0.00887***	0.0027	0.00858***	0.0026	-	0.00249-
Turnover per worker impacts (% effect per lodgement) - In year of reported lodgement	0.00684***	0.0016	0.00692***	0.0015	0.00659***	0.0014	-	0.00119

Source: BSD, Ipsos analysis pval in parentheses *** p<0.01, ** p<0.05, * p<0.1. Outcome variables in natural logarithms and estimated effects can be interpreted as the % effect per lodgement.

Annual Business Survey

We explored the potential use of ABS data for the 2020 survey year with the aim of further verifying our findings from the IDBR and BSD. Due to low matching rates and sample sizes, we were unable to identify sufficient firms to produce useful results.

Coronavirus Job Retention Scheme

The econometric model outlined above was adapted to explore the effects of CJRS (using a logistic regression model in place of OLS). These models used monthly data and made allowances for the possibility that (a) the impact of measures lodged under the scheme may be visible in months before the measure was lodged (i.e. if lodgements lagged delivery) and (b) how far any effect on the likelihood that the firm makes use of CJRS is sustained after the measure was lodged).

The results are set out in Table A.7.9 and indicate that GHGVS had no effect on the likelihood that firms made use of the CJRS programme. As noted above, this will not capture any effects where the scheme encouraged firms to reduce (rather than end) its use of CJRS.

Table A.7.9: Estimates of the effects of GHGVS on the likelihood firms were claiming CJRS

Control for other schemes (LAD, SHDF, ECO3)	No	No	No	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Control group	Comparisons with Group #1	Comparisons with Group #2	Comparisons with Group #3	Comparisons with Group #1	Comparisons with Group #2	Comparisons with Group #3
Month before lodgement	-0.0045 (0.730)	-0.0042 (0.746)	-0.0037 (0.780)	0.0008 (-0.959)	0.0019 (-0.908)	0.0025 (-0.878)
Month of lodgement	0.0189 (0.287)	0.0188 (0.288)	0.0182 (0.308)	-0.0337 (0.127)	-0.0341 (0.124)	-0.0342 (0.126)
Month after lodgement	-0.0186 (0.287)	-0.0179 (0.304)	-0.0177 (0.314)	0.0159 (0.429)	0.0142 (0.480)	0.0138 (0.497)
Two months after lodgement	-0.0136 (0.463)	-0.0132 (0.475)	-0.0129 (0.491)	-0.0020 (0.920)	-0.0023 (0.911)	-0.0021 (0.916)
Three months after lodgement	-0.0007 (0.965)	0.0003 (0.986)	0.0017 (0.917)	0.0085 (0.669)	0.0111 (0.585)	0.0127 (0.539)
Observations	3,816	3,537	3,024	3,816	3,537	3,024

P-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

A.7.3 Unemployment impacts

A.7.3.1 Econometric model

A spatial analysis model was adopted to examine the effects of GHGVS on unemployment using monthly data on claimant numbers at the Middle Layer Super Output Area (MSOA) and Local Authority District level. MSOAs are small areas used for the purposes of reporting Census statistics and contain an average of approximately 8,000 households.

There are some uncertainties regarding where impacts on unemployment are most likely to be felt. If installers largely serve local demand (or use locally based labour), then any effects might be expected to be visible in the areas benefitting from installations. However, if installers travelled large distances, then reductions in unemployment are likely to be visible in the locations in which installers were based. Analysis of the straight-line distance between installers and installations (based on their postcodes) indicated that the suppliers travelled an average distance of 64km to the installation. The median distance travelled was 32km. This implies that in many cases, the supplier will have had to travel beyond the boundary of its LA[97] to deliver the measures. Qualitative research with suppliers of heat pumps suggests this was the case (with these firms covering a larger distance across the country than most insulation providers). If the supplier tended to use workers residing close to its HQ locations, then findings oriented on the postcode of the measure could produce misleading results.

As such, the approach adopted explored the effect of the scheme on unemployment by comparing MSOAs in which installers were located to areas that did not contain installers that delivered measures. Areas that did not benefit may differ in systematic ways to those that did, which could distort comparisons. For example, if installers were predominantly located in urban areas that faced more significant shocks from the COVID-19 pandemic (and larger reductions in unemployment once restrictions were eased), this could overstate the impacts of GHGVS (most measures were delivered during this period of recovery).

As with analysis at the firm level, there were no eligibility or other criterion that could be exploited to address these issues. As such, a two-stage approach was adopted:

- **Matching:** A statistical matching approach was adopted to ensure that the areas in which GHGVS installers were located were only compared to other areas sharing similar characteristics prior to the launch of the scheme. This included information on industry structure, unemployment levels prior to launch of the scheme (to control for differences between the exposure of areas to the COVID-19 pandemic), and annual incomes (as a proxy for local productivity). Demand side characteristics were not included in the model as the focus is on the location of the supplier rather than the location of installations.
- **Fixed effects model:** The effects of GHGVS were estimated using the matched sample, using the following econometric model:

$$y_{jq} = \alpha + \beta T_{jq} + \alpha^{i} + \alpha^{t} + \varepsilon$$

[97] On the basis of an average area of 368 square kilometres, the average radius of one LA would be almost 11km (assuming of course, its shape can be roughly represented as a circle).

This model explains claimant numbers (y) in area j and quarter q, as a function of the volume of completed installations delivered by an installer in the area (T_{jm})[98]. The coefficient β captures the average reduction in (quarterly) unemployment associated with each completed installation (which can be aggregated across the total number of installations to provide an estimate of the total reduction in unemployment associated with the scheme). The model controls for unobserved features of areas that do not change over time (α^i), and unobserved time specific shocks (α^t) that could influence unemployment levels (e.g. reintroduction of social distancing restrictions in January 2021).

The focus of the analysis was also broadened from the MSOA to the Local Authority level. The purpose of this analysis was to (a) establish how far the effects of the scheme on unemployment spilled over into areas outside of the MSOA in which installers were located, and (b) to examine possible ‘crowding out’ effects where the expansion of installers led to adverse effects on other employers locally (e.g. by increasing upward pressure on wages).

Differences between areas that did and did not receive measures delivered through GHGVS

The analysis focus on the postcode of the installer or sub-installer. A postcode was available for 700 of 804 suppliers (87%) in the dataset accounting for the delivery of 49,186 of 57,339 measures (86%). Each firm was associated with a single postcode (presumed to be the HQ site), and it was unknown how far firms operated from multiple plants (which could lead to noise in the data, and potentially biased findings if those firms delivering larger volumes were more likely to operate from multiple locations).

There are 6,791 MSOAs in England. Installers were based in 605 MSOAs, giving a pool of 6,186 MSOAs without installers that delivered the scheme. A comparison between these two groups of areas indicated that:

- The two groups of areas shared very similar numbers of unemployed claimants prior to the launch of the scheme in November 2020 (328 claimants on average).
- Areas in which installers were located were characterised by higher employment shares for the construction industry (11.0% vs 7.3%) and lower employment shares for the retail (9.6% vs 10.1%) and the food and accommodation sectors (7.5% vs 8.1%). This would suggest that areas without installers were potentially more exposed to the ongoing issues caused by the COVID-19 pandemic.
- Job density (number of jobs per hectare) was higher in areas in which installers were located (indicating they were clustered in more urban areas).
- Net annual incomes were higher in areas with no installers (£34,900 vs £38,800 on average).

These differences may introduce bias into the assessment of impact where these factors are indirectly linked to the outcome; for example areas with a larger share of the workforce in the retail and hospitality sectors were more at risk throughout the pandemic period and may see unemployment rise and fall more rapidly. Similarly more economically dense areas may have suffered more from reduced footfall throughout the pandemic and may also have unemployment rise and fall more rapidly as they recovered.

[98] Note that there are similar issues of defining the quantum of ‘dose’ as for the modelling at firm level.

Sample sizes were more constrained when aggregated to Local Authority District level. Installers were present in 257 of 309 local authority districts, giving a potential comparison sample of 52 local authority districts. Differences between local authority districts were also more pronounced. Job density was substantially higher in areas without installers (57 vs 8 jobs per hectare) implying that comparison areas were highly concentrated in inner city locations (13 of the 57 comparison areas were in London, including most inner London boroughs). Net annual incomes were also higher in areas without installers (£38,000 vs £34,500).

Propensity score matching (PSM)

A first step to mitigate the issues of bias involved the application of Propensity Score Matching to ensure that the two regions (i.e. those containing installers that did and did not deliver lodgements) shared similar characteristics at the point prior to the lodgements being delivered. The purpose of this step was to remove any observable differences between the two groups, to raise confidence that any differences in their characteristics could be reasonably attributed to GHGVS (rather than differences in their regional make up, for example). This procedure is commonly associated with evaluation designs reaching Level 3 on the Maryland Scale.

To improve the comparability of the two groups, a PSM approach was implemented. This involved a first-stage regression to estimate the probability that each area of the treatment and comparison groups would receive a lodgement, based on the observed baseline characteristics and geographic composition variables. The following variables were included:

- Numbers of unemployed claimants in November 2020 (to control for baseline exposure to the economic shocks associated with the COVID-19 pandemic)
- Employment shares for the construction, retail, and food and accommodation industries (in September 2020).
- Job density (jobs per hectare) to control for differences in levels of urban development which were in turn correlated with the depth of the economic shock associated with the pandemic.
- Net annual incomes (to control for differences in productivity across areas).

This data was then included in the regression models used for propensity score matching. The regressions were used to generate a ‘propensity score’ for each member of the treatment and comparison areas (the probability of treatment assignment conditional on observed baseline characteristics). The propensity score was then used to match areas in the sample that received lodgements under GHGVS and those that did not receive any, where they shared similar probabilities of receiving lodgements based on their pre-GHGVS characteristics. The matching was undertaken on a ‘nearest neighbour’ basis – i.e. each area was matched to the area it shared most in common with. A requirement for ‘common support’ was imposed (any areas with installers that did not share features in common with the comparison group were excluded from the analysis).

This approach was effective in balancing the MSOA samples. The overall mean percentage bias[99] in the two groups reduced from 13.2% to 3.4% for the MSOA model and there were no

[99] The standardised percentage bias is the percentage differences in the averages for the treated and comparison groups, as a percentage of the square root of the average of the sample variances for the treated and comparison groups.

statistically significant differences between groups in terms of any of the characteristics described above.

Matching at the Local Authority District level was less effective - a straightforward nearest neighbour approach reduced the mean level of bias from 28.6% to 18.9% and significant differences between local authority districts remained in the matched sample. A kernel matching approach (in which areas with installers were permitted to match with multiple comparison areas based on their levels of similarity) proved moderately more effective, reducing the mean level of bias to 6.0 percent (as presented below). However, it is likely that the small number of comparison local authority districts weakened the effectiveness of the matching approach at this level.

Table A.7.10: Post matching comparison of characteristics postcode of installer – MSOA

Variable	Samples	Treated	Control	%bias	% reduction bias	t	p>t
Number of claimants - Nov 2020	Unmatched	328.04	327.69	0.2		0.04	0.969
	Matched	328.04	326.16	0.9	-440	0.15	0.88
% of employment in construction – Sep 2020	Unmatched	0.10996	0.07304	36.2		8.77	0
	Matched	0.10996	0.10882	1.1	96.9	0.18	0.856
% of employment in retail and hospitality – Sep 2020	Unmatched	0.09553	0.10128	-7.8		-1.73	0.084
	Matched	0.09553	0.09431	1.6	78.8	0.3	0.761
% of employment in accommodation & food services – Sep 2020	Unmatched	0.07515	0.08128	-9.7		-2.25	0.025
	Matched	0.07515	0.07501	0.2	97.8	0.04	0.968
Job density	Unmatched	22.069	15.825	9.3		2.67	0.008
	Matched	22.069	17.674	6.5	29.6	1.08	0.282
Net Annual Income	Unmatched	33,838	34,892	-15.8		-3.55	0
	Matched	33,838	33,167	10.1	36.3	1.91	0.057

Table A.7.11: Post-matching comparison of characteristics postcode of installer – LA

Variable	Samples	Treated	Control	%bias	% reduction bias	t	p>t
Number of claimants - Nov 2020	Unmatched	7324.5	6425.2	13.3		0.8	0.424
	Matched	5892.8	5707.8	2.7	79.4	0.41	0.683
% of employment in construction – Sep 2020	Unmatched	0.09566	0.07848	27		2	0.047
	Matched	0.09498	0.0989	-6.2	77.2	-0.61	0.543
% of employment in retail and hospitality – Sep 2020	Unmatched	0.10162	0.09343	33.1		2.37	0.018
	Matched	0.1007	0.09795	11.1	66.4	1.31	0.19
% of employment in accommodation & food services – Sep 2020	Unmatched	0.07631	0.07823	-4.6		-0.38	0.704
	Matched	0.0774	0.07238	12.1	-161.5	1.44	0.151
Job density	Unmatched	7.9782	57.066	-26.1		-2.95	0.003
	Matched	6.3251	7.2816	-0.5	98.1	-1.01	0.313
Net Annual Income	Unmatched	34,502	38,007	-67.3		-4.53	0
	Matched	35,178	35,368	-3.6	94.6	-0.41	0.681

A.7.3.2 Results

Table A.7.12 outlines the estimated impacts of GHGVS on the claimant count for MSOAs and LAs. Model 1 includes only area level fixed effects with this model then augmented to include time fixed effects in Model 2. The results showed:

- **Temporary reductions in unemployment**: The analysis identified:
  - **MSOA:** At the MSOA level, each measure delivered led to a reduction in unemployment of 0.018 claimants (based on results controlling for time specific shocks which capture the effect of easements in lockdown restrictions and associated economic recovery). In other words, for every 1,000 measures installed, this would equate to 18 fewer Universal Credit claimants. This effect was temporary - with each measure leading to a corresponding increase in the number of claimants of 0.014 claimants in the quarter following the delivery of the measure.
  - The aggregate reduction in employment was estimated at 910 claimants at the MSOA level (48,184 measures multiplied by 0.018 claimants) for a period of one quarter. This is broadly in line with the estimated direct effect on installers (indicating that any crowding out of other economic activity was limited at the local level).
  - **LA**: Findings at the Local Authority District level did show significant effects, though at an implausibly high magnitude (some 35 times larger than at the MSOA level) and with unexpected temporal patterns (i.e. the findings imply that the scheme caused increases in unemployment before subsequent reductions). As noted above, statistical matching at this level was substantially more challenging owing to the very small number of (and relatively unique) local authority districts without installers. As such, it is considered likely that the estimates are likely biased by simultaneity problems (i.e. the delivery of the scheme coincided with the easement of social distancing restrictions, and models are likely misattributing broader reductions in unemployment to the installation of measures).

The findings would also carry the implication that there were high levels of deadweight and/or crowding associated with the scheme. The additional GVA associated with the scheme can be approximated based on the average quarterly wage[100] for the construction sector in November 2020 (£8,944)[101] to the reduction in the number of unemployed claimants. This would give an indicative estimate of the additional output associated with scheme of £8.1m. This only represents a small share of total spending on the scheme. This would raise questions around VfM in terms of the effect of the scheme purely as a stimulus measure (although clearly if it diverts spending to energy efficiency measures from other things, then this is an important aspect of effectiveness).

However, it is also important to note that owing to the variety of lags associated with measures of employment at the firm level, the apparent difference between the scale of effects at the firm

[100] On the basis that GVA is approximately equal to the sum of wages and profits.
[101] Annual Survey of Hours and Earnings, ONS

and the area level may potentially be a result of an understatement of the firm level impacts of the scheme.

A.7.4 Limitations

As highlighted above, there are several limitations associated with the analysis which need to be borne in mind:

- **Strength of evaluation design:** The design of the scheme was not conducive for the construction of comparison groups (i.e. its universality and the absence of eligibility criteria that could be exploited). As such, it has been necessary to draw comparison groups from the general population of TrustMark accredited firms or areas that did not benefit from the scheme. There may be unobservable differences between firms and/or areas that could bias results (in an unknown direction).
- **Data lags:** The scheme was designed to provide a temporary (rather than an on-going) stimulus to employment and economic activity. This is problematic in the context of the administrative data available on the employment and turnover of firms – which arrives with variable lags making it challenging to isolate short term changes in firm performance. It is likely that this feature of the data has introduced challenges in estimating the direct impacts of the scheme (and in particular, the estimated effects of the scheme are likely to be understated).
- **National impacts:** Finally, the interpretation of the estimated results as impacts at the national level results rests on an assumption of no offsetting displacement or crowding out effects at this spatial scale (or positive spillovers via multiplier effects). This assumption cannot be tested. It should also be noted that there may have been some displacement of activity from the comparison group (which could lead to an overstatement of the impact of the scheme).

Table A.7.12: Estimated effect of GHGVS installations on unemployment – MSOA level results

	Model 1	**Model 2**	**Model 3**
Fixed effects	Yes	Yes	Yes
Time fixed effects	No	Yes	Yes
Controls for delivery of LAD scheme	No	No	Yes
Controls for unobserved trends (LA model only)	No	No	Yes
MSOA			
T	-0.07195***	-0.01854**	-0.01886**
T+1	-0.05029***	-0.01488**	0.01343*
T+2	-0.46878***	-0.07837	-0.07887
Observations	9,288	9,288	9,288

	Model 1	Model 2	Model 3
R-squared	0.031	0.761	0.761
LAD			
T	-0.626	-0.497	0.639**
T+1	0.455	0.096	-0.794***
T+2	-13.198***	-4.622***	-0.647**
Observations	2,044	2,044	2,044
R-squared	0.006	0.006	0.57

Table A.7.13: Comparison of effect of GHGVS on unemployment – MSOA postcode of lodgement vs postcode of installer

	MSOA (delivery postcode)	MSOA (supplier postcode)
Fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
Controls for non-construction employment	Yes	Yes
Controls for other schemes	No	No
T-1	0.155	0.0136
T	-0.445***	-0.0156*
T+1	-0.886***	-0.0638*
T+2	-0.792***	0.00819
T+3	-0.043	-0.0480*
Observations	40,224	6,966
R-squared	0.752	0.751

Table A.7.14: Aggregation of unemployment impacts and indicative value – MSOA and LA level impact postcode of installer

	Estimated effect per measure	Number of measures installed	Estimated impact on number of claimants	Average wage (quarterly)	Estimated gain in £(m)
MSOA:					
In period measures are installed	-0.016	48,184	-752	8,944	£6.7
One period after measures are installed	-0.064	48,184	-3,074	8,944	£27.5
Two periods after measures are installed	-	48,184	-	8,944	-
Three periods after measures are installed	-0.480	48,184	-2,313	8,944	£20.6
LA:					
In period measures are installed	-	48,184	-	8,944	-
One period after measures are installed	-2.07	48,184	-99,645	8,944	£891.2
Two periods after measures are installed	-1.68	48,184	-80,708	8,944	£721.9
Three periods after measures are installed	-2.81	48,184	-135,349	8,944	£1,210
Average/total over 12 months	-	-	-105,234	8,944	£941.2

A.7.5: Appendix

Table A.7.16 reproduces the firm level regression models described above, replacing the volume-based treatment measures with a cost-based measure (using the total cost of installation recording in programme monitoring information). These analyses were implemented to explore the sensitivity of estimates to variation in the volume of work associated with the installation of different types of measure. These models found an effect on employment of 2.57%[102] to 4.38%[103] per £1m of installation cost.

Table A.7.15 shows cost estimates of the aggregated effect of GHGVS on employment (which can be interpreted as the number of additional jobs created or safeguarded per £1,000,000 spent). Cost estimates are based on the total cost of the installation including both the voucher and consumer contribution. This was estimated by applying:

- The estimated average effect on employment per £1,000,000 spent (2.57% to 4.38%) over four quarters to the average number of employees in firms delivering GHGVS measures at the baseline year for 2020 (42.1)
- This implies that the average number of jobs created or safeguarded per £1,000,000 spent over the delivery of the scheme was 1.08 to 1.84 jobs (i.e. 42.1 x 0.0257 to 42.1 x 0.0438).
- The total cost of all measures was £421,106,842. This suggests that the programme may have created or safeguarded a lower and upper bound range of 455 to 776 direct jobs.[104]

Table A.7.15: Estimated total jobs created or safeguarded (effects per cost of measure installation)

	Lower Bound	**Upper Bound**
Average number of employees in treated firms at baseline (period before intervention)	42.1	42.1
Total % effect over 4 periods per £1,000,000 (in period + 3 lags)	2.57%	4.38%
Average effect on number of employees per firm per £1,000,000	1.08	1.84
Total cost of measures delivered	**£421,106,842**	**£421,106,842**
Estimated total jobs created or safeguarded over in period and lags	**455**	**776**

[102] Two-way fixed effects model with comparison group 2 (with significant effects three quarters post installation)
[103] Two-way fixed effects with comparison group 4 (with significant effects one and three quarters post installation)
[104] Calculated as the total effect over all lag periods (upper bound) or one lag period (lower bound) multiplied by the average number of firms times the number of firms delivering measures

Table A.7.16: Estimates of the impact of GHGVS on employment and turnover (effects per cost of measure installation)

Outcome / lag and Model	Comparisons with Group #1 - OLS	Comparisons with Group #1 - FE	Comparisons with Group #1 – Two-way-FE	Comparisons with Group #2 - OLS	Comparisons with Group #2 - FE	Comparisons with Group #2 – Two-way-FE	Comparisons with Group #3 - OLS	Comparisons with Group #3 - FE	Comparisons with Group #3 – Two-way-FE	Comparisons with Group #4 - OLS	Comparisons with Group #4 - FE	Comparisons with Group #4 – Two-way-FE
Employment impacts (% effect per lodgement)												
In quarter of reported lodgement	-	-	-	-	-	-	-	-	-	-	-	-
+ 1 quarter	-	-	-	-	-	-	-	-	-	-	-	0.0136*
+ 2 quarters	-	-	-	-	-	-	-	-	-	-	-	-
+ 3 quarters	-		0.027***	-	-	0.0257**	-	-	0.0257**	-	-	0.0302***
Turnover impacts (% effect per lodgement)												
In quarter of reported	0.0614**	-	-	0.0559**	-	-0.0388*	0.0559**	-	-0.0434*	-	-	-

Outcome / lag and Model	Comparisons with Group #1 - OLS	Comparisons with Group #1 - FE	Comparisons with Group #1 – Two-way-FE	Comparisons with Group #2 - OLS	Comparisons with Group #2 - FE	Comparisons with Group #2 – Two-way-FE	Comparisons with Group #3 - OLS	Comparisons with Group #3 - FE	Comparisons with Group #3 – Two-way-FE	Comparisons with Group #4 - OLS	Comparisons with Group #4 - FE	Comparisons with Group #4 – Two-way-FE
lodgement												
+ 1 quarter	-	-	-	-	-	-	-	-	-	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	-	-	-	-	-	-	-
Turnover per worker impacts (% effect per lodgement)												
In quarter of reported lodgement	0.042*	-	-0.0431*	0.0398*	-	-0.0442**	0.0398*	-	-0.0502**	-	-	-0.0391*
+ 1 quarter	-	-	-	-	-	-	-	-	-	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	-	-	-	-	-	-	-

Source: IDBR, Ipsos analysis pval in parentheses *** p<0.01, ** p<0.05, * p<0.1. Outcome variables in natural logarithms and estimated effects can be interpreted as the % effect per lodgement. Only statistically significant findings have been reported.

A.7.5.1: Modelling by decomposing volumes of measures delivered by type

Table A.7.17 provides an extension of the measure volume analysis and includes results based on a breakdown of measure volumes by type and producing estimates of the aggregate effect of GHGVS on employment by lodgement type (which can be interpreted as the number of additional jobs created or safeguarded per lodgement type). This was estimated by applying:

- Estimated effect on employment per lodgement type including other heating (0.26% lower and 0.33% upper), other insulation (0.22% lower and 0.68% upper) and solid wall insulation (0.14% lower and 0.20 upper) to the average number of number employees in firms delivering GHGVS measures at the baseline year of 2020 (42.1). This implies that the average number of jobs created or safeguarded per lodgement over 4 periods, including the in period and 3 lags, was around 0.1 jobs per firm across all measures[105].
- In total, the programme involved the delivery of 48,184 measures of which 1,124 were other heating, 9,876 other insulation and 10,514 solid wall insulation. Using these lodgement types implies that other heating (152), other insulation (922) and solid wall insulation (628) collectively have created or safeguarded a lower bound estimate of 1,652 and an upper bound of 3,864 direct jobs in total.

Table A.7.17: Estimated total jobs created or safeguarded by lodgement type

	Other Heating – Lower Bound	Other Heating – Upper Bound	Other Insulation – Lower Bound	Other Insulation – Upper Bound	Solid Wall Insulation – Lower Bound	Other Wall Insulation– Upper Bound
Average number of employees in treated firms at baseline (period before intervention)	42.1	42.1	42.1	42.1	42.1	42.1
Total % effect over 4 periods (in period + 3 lags)	0.26%	0.33%	0.22%	0.68%	0.14%	0.20%
Average effect on number of employees per firm per measure	0.10	0.13	0.09	0.28	0.05	0.08
Total number of measures delivered	48,184	48,184	48,184	48,184	48,184	48,184
Number of measures delivered by measure type	**1,124**	**1,124**	**9,876**	**9,876**	**10,514**	**10,514**
Estimated total jobs created or safeguarded over in period and lags (by measure type)	**122**	**155**	**911**	**2,825**	**619**	**884**

[105] 0.01 jobs per firm is calculated by taking 0.03% of 42.1 or the average number of employees in the treated group of firm pre intervention

Table A.7.18: Estimates of the impact of GHGVS on employment and turnover (effects per lodgement by type): Employment impacts (% effect per lodgement)

Measure Type	Cavity Wall	Doors and Windows	Loft Insulation	Micro Generation	Other Heating	Other Insulation	Park Home Insulation	Solid Wall Insulation
Comparisons with Group #1								
In quarter	-	-	-		0.0032**	0.0007*	-	-
+ 1 quarter	-	-	-	-	-	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	0.0014*
+ 3 quarters	-	-	-	-	-	0.0014***	-	-
Comparisons with Group #2								
In quarter	-	-	-	-	0.0032**	0.0007**	-	-
+ 1 quarter								
+ 2 quarters	-	-	-	-	-	-	-	0.0014*
+ 3 quarters	-	-	-	-	-	0.0014***	-	-
Comparisons with Group #3								
In quarter	-	-	-	-	0.0031**	0.0007**	-	-
+ 1 quarter	-	-	-	-	-	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	0.0014*
+ 3 quarters	-	-	-	-	-	0.0014***	-	-
Comparisons with Group #4								
In quarter	-	-	-	-	0.0026*	-		0.0006*
+ 1 quarter	-	-	-	-	-	0.0008**	-	-
+ 2 quarters	-	-	-	-	-	-	-	0.0014**
+ 3 quarters	-	-	-	-	-	0.0006*	-	-

Source: IDBR, Ipsos analysis pval in parentheses *** p<0.01, ** p<0.05, * p<0.1. Outcome variables in natural logarithms and estimated effects can be interpreted as the % effect per lodgement. Only statistically significant findings have been reported

Table A.7.19: Estimates of the impact of GHGVS on employment and turnover (effects per lodgement by type): Turnover impacts (% effect per lodgement)

Measure Type	Cavity Wall	Doors and Windows	Loft Insulation	Micro Generation	Other Heating	Other Insulation	Park Home Insulation	Solid Wall Insulation
Comparisons with Group #1								
In quarter	-	-	-	-	-	-	-	-
+ 1 quarter	-	-	-	-	0.0094*	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	0.0026***	-	-
Comparisons with Group #2								
In quarter	-	-	-	-	-	-	-	-
+ 1 quarter		-0.00376*	-	-	0.0086*	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	0.0028***	-	-
Comparisons with Group #3								
In quarter	-	-	-	-	-	-	-	-
+ 1 quarter	-	-0.0037*	-	-	0.0087*	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	0.0028***	-	-
Comparisons with Group #4								
In quarter	-	-	-	-	-0.0060**	-	-	-
+ 1 quarter	-	-0.0039*	-	-	0.0099**	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	0.0031***	-	-

Source: IDBR, Ipsos analysis pval in parentheses *** p<0.01, ** p<0.05, * p<0.1. Outcome variables in natural logarithms and estimated effects can be interpreted as the % effect per lodgement. Only statistically significant findings have been reported

Table A.7.20: Estimates of the impact of GHGVS on employment and turnover (effects per lodgement by type): Turnover per worker impacts (% effect per lodgement)

Measure Type	Cavity Wall	Doors and Windows	Loft Insulation	Micro Generation	Other Heating	Other Insulation	Park Home Insulation	Solid Wall Insulation
Comparisons with Group #1								
In quarter	-	-	-	-	-0.0076**	-	-	-
+ 1 quarter	-	-	-	-	0.0080*	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	-	-	-
Comparisons with Group #2								
In quarter	-	-	-	-	-0.0067**	-	-	-
+ 1 quarter	-	-	-	-	0.0087*	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	0.0013*	-	-
Comparisons with Group #3								
In quarter	-	-	-	-	-0.0067**	-	-	-
+ 1 quarter	-	-	-	-	0.0079*	-	-	-
+ 2 quarters	-	-	-	-	-	-	-	-
+ 3 quarters	-	-	-	-	-	0.0014*	-	-0.0013*
Comparisons with Group #4								
In quarter	-	-	-	-	-0.0087***	-	-	-
+ 1 quarter	-	-	-	-	0.0089**	-	-	-
+ 2 quarters	-	-	-	-	-0.0110**	-	-	-
+ 3 quarters	-	-	-	-	-	0.0016**	-	-

Source: IDBR, Ipsos analysis pval in parentheses *** p<0.01, ** p<0.05, * p<0.1. Outcome variables in natural logarithms and estimated effects can be interpreted as the % effect per lodgement. Only statistically significant findings have been reported

Annex 8: Applicant survey questionnaire

GREEN HOMES GRANT VOUCHER SCHEME
APPLICANT SURVEY WAVE 2
Version 2
5th March 2022

INTRODUCTION AND CHECK DETAILS

Thank you for taking the time to answer these questions. You originally took part in a survey in July 2021 about your experiences of applying to the Green Homes Grant Voucher Scheme. At that time you said you were happy for us to contact you again. We are interested in finding out a little more about your experiences since then.

If someone else in your household completed the survey last time, please pass the survey invitation onto them so they can complete the survey, as it is important that it is completed by the same person.

This questionnaire should take no longer than 20 minutes to complete. If you cannot complete the survey in one session and would like to stop and return later, just close the window and your responses will be saved. When you are ready, simply log in again using the same password to return to the same point in the survey. Taking part in this survey is voluntary and answers will be kept completely confidential.

This questionnaire relates to an application for the Green Homes Grant Voucher Scheme for [SHOW TEXT FROM 'ADD1', 'ADD2' & 'POSTCODE' IN SAMPLE FILE]

A privacy notice explaining how your data is processed, how long it will be held, and what your rights are, is available at: **www.ghgsurvey.org/privacy**

If you agree to take part in the survey, please click on the 'Next' button to begin.

ASK OCCUPIERS, LANDLORDS, AND THOSE WHO OWN A PROPERTY LIVED IN BY SOMEONE ELSE

(Single Code)

[IF OCCUPIER – CODE 1 AT BASELINE A2] Are you still living at the property listed below?
[IF LANDLORD OR OWNS PROPERTY LIVED IN BY SOMEONE ELSE – CODE 2-3 AT BASELINE A2] Do you still own the property listed below?
[SHOW ADDRESS]

-

1. Yes
2. No
3. Don't know
4. Prefer not to say

- SKIP TO F7 IF CODE 3,4

ASK ALL

(Grid, Single Code)

- USE SCHEME DATA

- According to our records, you applied for the following energy efficient or heating improvement(s) under the Green Homes Grant Voucher Scheme for [IF CODE 1 AT BASELINE A2: this property IF CODE 2-4 AT BASELINE A2: the property at the address listed below]. The table below shows the improvements applied for and the status of the application. For each one, please can you say whether this is correct.
- IF CODE 4 AT BASELINE A2: SHOW ADDRESS

5.

- SHOW MEASURES APPLIED FOR FROM SCHEME DATA AS ROWS IN GRID, WITH YES/NO/DON'T KNOW AS COLUMNS, FOR EXAMPLE:

Q.1 Improvement	Q.2 Status	Q.3 Yes, correct	Q.4 No, not correct	Q.5 Don't know
Q.6 Cavity wall insulation	Q.7 Installation complete and voucher redeemed.	Q.8	Q.9	Q.10
Q.11 Loft insulation	Q.12 Installation complete but voucher not redeemed.	Q.13	Q.14	Q.15
Q.16 Double/triple glazing	Q.17 Voucher issued but installation not complete through the Green Homes Grant Voucher Scheme. Q.18 Q.19 You may have had the installation completed outside the scheme, or not had the installation at all. Q.20	Q.21	Q.22	Q.23
Q.24 Heating controls	Q.25 Applied for voucher but voucher not issued. Your application may have been rejected / you may have withdrawn your application. Q.26	Q.27	Q.28	Q.29

[IF SHOWING A COMPLETED INSTALLATION ABOVE: If any measures have been substantially installed but you are still waiting for the installer to finish small elements of the work (e.g. cosmetic work) or make small repairs, please select 'Yes' for that improvement. Please only select 'No' if the work has not been started or is not substantially complete.

ASK ALL WHO HAVE HAD INSTALLATION COMPLETED [FROM SAMPLE, AND AS CHECKED AT A 2]

(Grid, Single Code)

Our records show the that the energy efficient or heating improvement(s) was installed in the month shown below. Is this correct?

- SHOW ALL MEASURES NOTED AS HAVING BEEN COMPLETED IN THE SAMPLE AND THEN CHECKED AT A 2. SHOW MEASURES AND INSTALLATION MONTH AND YEAR AS ROWS IN GRID. SHOW YES/NO/DON'T KNOW AS COLUMNS

1. Yes
2. No
3. Don't know

ASK IF CODED NO (CODE 2) AT A 3

(Grid, Numeric box)

When was [MEASURE] installed?
Please enter month and year in the boxes below

- SHOW AS GRID WITH MEASURES AS ROWS. PROVIDE NUMERIC BOX FOR MONTH AND YEAR FOR EACH MEASURE.
- SHOW DON'T KNOW

ASK ALL WHO HAVE CHANGED PROPERTY – CODE 2 AT A 1 AND HAVE COMPLETED AN INSTALLATION AT A 2

(Grid, Single Code)

[IF OCCUPIER- CODE 1 AT BASELINE A2] You said that you are no longer living in the property shown below. Did you live in the property at the time [IF ONE MEASURE: the installation was completed? / IF TWO OR MORE MEASURES: the installations were completed?]
[[IF LANDLORD OR OWNS PROPERTY LIVED IN BY SOMEONE ELSE – CODE 2-3 AT BASELINE A2] You said that you no longer own the property shown below. Did you own the property at the time the installation was completed?

-
- [SHOW ADDRESS FROM SAMPLE FILE] [ASK FOR EACH MEASURE]

1. Yes
2. No
3. Don't know

SKIP TO F7 IF CODE 2 OR 3

Reasons applications did not proceed

ASK FOR ALL MEASURES APPLIED FOR BUT WHERE INSTALLATION WAS NOT COMPLETED [FROM SCHEME DATA / AS CHECKED AT A 2A 2]

(Grid, Single Code)

Are [OCCUPIER/you / ELSE / you or the people who live at the property] still planning to proceed with the installation of [MEASURES] in the property? This may include funding the work outside of the Green Homes Grant Voucher Scheme.
Please select one answer only [IF MORE THAN ONE MEASURE: for each improvement]

-
- SHOW ALL MEASURES CODED 'YES, CORRECT' FOR 'INSTALLATION NOT COMPLETED' OR 'APPLIED FOR VOUCHER BUT VOUCHER NOT ISSUED' FOR ANY MEASURE AT A2. SHOW AS GRID. SHOW MEASURES AS COLUMNS AND RESPONSES AS ROWS.
-

1. Have already completed the installation outside of the Green Homes Grant Voucher Scheme
2. Planning to proceed with the installation
3. Currently considering whether or not to proceed with the installation
4. Decided not to proceed with the installation
5. Don't know [EXCLUSIVE PER COLUMN]

ASK ALL PLANNING TO PROCEED WITH INSTALLATION (CODE 2 AT B 1)

(Grid, Numeric box)

When do you think [measure] will be installed? If you're not sure, please give your best estimate.

- SHOW AS GRID WITH MEASURES CODED 2 AT B 1 AS ROWS. PROVIDE NUMERIC BOX FOR MONTH AND YEAR FOR EACH MEASURE.
- SHOW DON'T KNOW

ASK ALL WHO HAD INSTALLATION COMPLETED WITHOUT GHGVS (CODE 1 AT B 1) OR WILL PROCEED WITH INSTALLATION OR ARE CONSIDERING (CODES 2 OR 3 AT B 1)
IF PARTICIPANT SATISFIES BOTH CONDITIONS (E.G. HAS ALREADY INSTALLED OUTSIDE OF GHGVS AND IS ALSO CONSIDERING FURTHER INSTALLATIONS) ASK QUESTION TWICE

(Grid, Multi Code)
[IF CODED 1 AT B 1] Why did [IF CODED 3 OR 4 AT BASELINE A2 you or the people who live at the property IF CODED 1 OR 2 AT BASELINE A2 you] decide to have [MEASURES] installed without a Green Homes Grant Voucher ?

Please select all that apply [IF MORE THAN ONE MEASURE: for each improvement]

[IF CODED 2 OR 3 AT B 1] Why are [IF CODED 3 OR 4 AT BASELINE A2 you or the people who live at the property/ IF CODED 1 OR 2 AT BASELINE A2 you] having [MEASURES] installed (or considering having them installed) outside of the Green Homes Grant Voucher Scheme?
Please select all that apply [IF MORE THAN ONE MEASURE: for each improvement]

COLUMNS

- SHOW MEASURES CODED AS 1-3 AT B 1 AS RELEVANT

ROWS

1. Able to get the improvements installed through another scheme
2. The process of applying / getting the voucher took too long
3. Installer was not able to schedule the installation within a reasonable/convenient timeframe
4. Installer was unable to complete the installation before the Green Homes Grant Voucher expired
5. The installation could not be completed through the Green Homes Grant Voucher Scheme (e.g. wanted a particular type of installation that was not covered by the scheme)
6. Installer was unwilling to complete the work through the Green Homes Grant Voucher Scheme / installer withdrew from the scheme
7. The installer was unable / unwilling to complete the work for another reason
8. Cheaper to get installed outside of the scheme
9. We/friends/family members are installing/have installed the improvements
10. Difficulties finding an installer
11. Other (please specify)
12. Don't know [EXCLUSIVE PER COLUMN]

ASK ALL GETTING INSTALLATIONS THROUGH OTHER SCHEMES (CODE 1 AT B 3)

(Multi Code)
Through which other scheme(s) are/were [IF CODED 3 OR 4 AT BASELINE A2 you or the people who live at the property/ IF CODED 1 OR 2 AT BASELINE A2 you] able to get the energy efficient or heating improvements installed or support for the costs?
Please select all that apply

-

1. Energy Company Obligation (ECO) scheme
2. Domestic Renewable Heat Incentive (RHI)
3. A 'Green' home mortgage from a bank or building society
4. Home Upgrade Grant (HUG) or Green Homes Grant Local Authority Delivery (LAD) scheme
5. / Another scheme (please write details in the box provided) [SPECIFY BOX]
6. None of these EXCLUSIVE
7. Don't know EXCLUSIVE

ASK ALL WHO HAVE COMPLETED INSTALLATION WITHOUT GHG OR PLANNING TO PROCEED OR STILL CONSIDERING (CODES 1, 2 OR 3 AT B 1)

(Grid, Multi Code)

Do any of the reasons below describe why the installation of [INSERT MEASURE] could not be completed through the Green Homes Grant Voucher Scheme?

Please select all that apply [IF MORE THAN ONE MEASURE: for each improvement]

COLUMNS

- SHOW MEASURES CODED AS COMPLETED WITHOUT GHGV OR PLANNING TO PROCEED/STILL CONSIDERING AT B1

ROWS

1. Delays because installer/staff was **fully booked**/did not have staff to complete the installation
2. Delays because of **lack of stock/materials**
3. Delays because of **time of year/weather**
4. Delays because of **social distancing/COVID-19 pandemic**
5. Unable to complete installation before **Green Homes Grant Voucher expired**
6. Chose to delay the installation for other reasons (e.g. finances, changes in household, illness, new baby)
7. Difficulties finding an installer
8. Delayed for another reason (please specify)
9. None of these [EXCLUSIVE PER COLUMN]
10. Don't know [EXCLUSIVE PER COLUMN]

ASK ALL WHO DECIDED NOT TO PROCEED WITH APPLICATION (CODE 4 AT B 1)

(Grid, Multi Code)

[IF CODED 4 AT B 1] Why did [IF CODED 3 OR 4 AT BASELINE A2 you or the people who live at the property/ IF CODED 1 OR 2 AT BASELINE A2 you] decide not to proceed with the installation of [INSERT OPTION CODED 4 AT B 1]?

Please select all that apply [IF MORE THAN ONE MEASURE: for each improvement]

COLUMNS

- SHOW MEASURES CODED DECIDED NOT TO PROCEED (CODE 4 AT B 1)

ROWS

1. There was a change in financial circumstances/unable to afford installation
2. The price increased since the original quote
3. The financial saving from the installation would not be as high as hoped
4. Disruption associated with the installation
5. Negative stories about the energy efficient or heating improvement/installation
6. Lack of time/other priorities
7. Difficulties associated with social distancing/COVID-19 pandemic
8. Process of arranging installation too difficult
9. Unable to arrange installation before the Green Homes Grant Voucher expired
10. Chosen installer was unable to complete the installation at all
11. Installation could not go ahead for other reasons (e.g. structure of property, issues with lease)
12. Difficulties finding a suitable installer
13. Other (please specify)
14. Don't know [EXCLUSIVE PER COLUMN]

ASK ALL WHO SAID THE CHOSEN INSTALLER WAS UNABLE TO COMPLETE INSTALLATION (CODE 10 AT B 6)

(Grid, multi code)

You said that the installation of the energy efficient or heating improvements listed below did not go ahead because the chosen installer was unable to complete the installation. Please select which, if any, of the reasons below the installer gave for not completing the installation.
Please select all that apply

- SHOW MEASURES FOR WHICH CHOSEN INSTALLER UNAVAILABLE (CODE 10 AT B 6)

1. Lack of staff / too busy with other work
2. Did not have the materials required for the installation
3. Unable to do it within a reasonable time
4. Cost provided was too high
5. Installation was considered not to be suitable for the property after the installer had reviewed it / conducted a survey
6. Issues with the GHG Vouchers scheme meant the installer did not want to proceed
7. Another reason (please specify)
8. Did not give a reason [EXCLUSIVE PER COLUMN]
9. Don't know [EXCLUSIVE PER COLUMN]

VIEWS OF THE INSTALLATION PROCESS

ALL WHO HAVE HAD AT LEAST ONE INSTALLATION COMPLETED THROUGH THE SCHEME [FROM SCHEME DATA AND CHECKED AT A 2]

The next few questions are about the process of installing the energy efficient or heating improvements. As a reminder, the improvements that have been installed are [SHOW ALL MEASURES CODED 1 'YES CORRECT' FOR 'COMPLETED INSTALLATION THROUGH GHGV' AT A 2].

ALL WHO HAVE HAD AT LEAST ONE INSTALLATION COMPLETED THROUGH THE SCHEME [FROM SCHEME DATA AND CHECKED AT A 2]

(Grid, Single Code)

Thinking about having [MEASURE] installed, how satisfied were you with the following?

- REVERSE SCALE

ADAPTED FROM ECO QUESTIONNAIRE

- SHOW MEASURES THAT HAVE BEEN INSTALLED [FROM SCHEME DATA AND CHECKED AT A 2]

ASK FOR MAXIMUM 2 MEASURES. IF MORE THAN 2 MEASURES APPLY, SELECT 2 AT RANDOM, WITH PRIORITY FOR HEAT PUMPS, SOLAR

- ROWS

A. How long you had to wait for the installation to be scheduled
B. The amount of information you were given on what the installation process would involve
C. Whether the installer took your views on how the installation should be completed into account
D. Whether the installer completed the work on the date agreed
E. The amount of time it took the installer to complete the work
F. The amount of disruption the installation caused (e.g. noise, mess)
G. How well informed you were kept through the installation process
H. The amount of information you were given on the measure (e.g. shown how it works, operating manuals, guarantees)
I. How clean and tidy the property was left after the installation was complete
J. The quality of the improvement installed (e.g. whether the installation was free of defects or health and safety issues)
K. The effectiveness of the improvement (e.g. whether it works as expected)
L. The suitability of the installation (e.g. whether it is fit for purpose)
M. The after-installation service provided
N. The aesthetics of the installation (e.g. whether the installation is visually appealing)

- COLUMNS

1. Very satisfied
2. Fairly satisfied
3. Neither satisfied nor dissatisfied
4. Fairly dissatisfied
5. Very dissatisfied
6. Don’t know

ALL WHO HAVE HAD AT LEAST ONE INSTALLATION COMPLETED THROUGH THE SCHEME [FROM SCHEME DATA AND CHECKED AT A 2]

(Grid, Single Code)
Since the installation of [INSERT MEASURES INSTALLED], have you experienced any difficulties or faults, or had reason to complain?

- SHOW MEASURES INSTALLED [FROM SCHEME DATA AND CHECKED AT A 2]

1. Yes
2. No
3. Don't know
4. Prefer not to say

ALL WHO HAVE EXPERIENCED DIFFICULTIES SINCE INSTALLATION (CODE 1 FOR ANY MEASURES AT C 2)

(Open text)
Please could you describe the difficulties or faults that you have had with the energy efficient or heating home improvement(s)?

- SHOW OPEN TEXT BOX FOR EACH MEASURE CODED YES AT C 2

98. Don't know
99. Prefer not to say

ALL WHO HAVE EXPERIENCED DIFFICULTIES SINCE INSTALLATION (CODE 1 FOR ANY AT C 2)

(Grid, Single Code)
Have these issues been resolved?

- SHOW MEASURES CODED YES AT C 2

1. Yes
2. No
3. Don't know
4. Prefer not to say

ALL WHO HAVE EXPERIENCED DIFFICULTIES SINCE INSTALLATION (CODE 1 FOR ANY AT C 4

(Grid, Single Code)
Thinking about the issues that you experienced, how satisfied or dissatisfied were you with the following?

- FOR EACH MEASURE CODED YES AT C 2

A. The length of time taken to resolve the difficulty/fault/complaint
B. The overall service provided by the installer to resolve the difficulty/fault/complaint

- COLUMNS

5. Very satisfied
6. Fairly satisfied
7. Neither satisfied nor dissatisfied
8. Fairly dissatisfied
9. Very dissatisfied
10. Don't know

ALL WHO HAVE REDEEMED THE GHG VOUCHER [FROM A 2]

(Multiple Code)

Our records show that you redeemed a Green Homes Grant Voucher(s) after an installation was completed. Which, if any, of the difficulties shown below did you experience in redeeming the voucher(s)?

- ROTATE CODES 1-6 BUT KEEP CODES 7-9 FIXED
-

1. Difficulties getting documents from the installer to enable me to redeem the voucher
2. Difficulties accessing or using the Green Homes Grant Voucher website (e.g. accessing my account, uploading the required information)
3. Queries from the scheme administrator about the installation/further information was required
4. The voucher redemption was initially declined
5. Needed to chase Green Homes Grant Scheme administrator to get payment
6. The voucher redemption has been completely declined/cannot get payment
7. Any other difficulties (specify)
8. Did not experience any difficulties
9. Don't know

ALL WHO PAID TOWARDS THE COST OF IMPROVEMENTS [FROM SCHEME DATA]

(Grid, Multiple Code)

How was your / your household's contribution towards the cost of the improvements financed?

-
- SHOW ALL COMPLETED MEASURES [FROM SCHEME DATA AND AS CHECKED AT A2] FOR WHICH THE SCHEME DATA INDICATES THE CONSUMER MADE A FINANCIAL CONTRIBUTION
-
-

1. Savings or regular income from current account
2. Loan from bank or building society
3. Mortgage extension
4. Gift/loan from friends or family
5. Loan/finance scheme through installer or provider
6. Other finance (e.g. credit card, high street loan)
7. Paid for in some other way (specify)
8. Don't know
9. Prefer not to say

PROPERTY CHANGES SINCE INSTALLATION

[ASk all who have had installation completed through GHGVS [scheme data and checked at A 2] AND are occupiers [code 1 at baseline a2]]

The next few questions are about the property since [SHOW MEASURES INSTALLED THROUGH GHGVS] [IF ONE MEASURE: was / IF TWO OR MORE MEASURES: were] installed through the Green Homes Grant Voucher Scheme. Other changes or improvements may have been made to the property, but please don't include these in your answers.

We would like you to think back to winter 2021 and compare how things may have changed for your household since [IF ONE MEASURE: this improvement was / IF TWO OR MORE MEASURES: these improvements were] installed.

ASk all who have had installation completed through GHGVS [scheme data and checked at A 2] AND are occupiers [CODE 1 at baseline a2]

(Single Code)

Compared with the same time last year, since [MEASURES] [IF ONE MEASURE: was / IF TWO OR MORE MEASURES: were] installed, how much easier or more difficult is it to heat the property to a comfortable temperature?
Please select one answer only

- REVERSE SCALE

1. A lot easier
1. A little easier
2. No difference
3. A little more difficult
4. A lot more difficult
5. Don't know

ASk all who have had installation completed through GHGVS [scheme data and checked at A 2] AND are occupiers [CODE 1 at baseline a2]

(Single Code)

And still comparing back to the same time last year, since [MEASURES] [IF ONE MEASURE: was / IF TWO OR MORE MEASURES: were] installed, how much warmer or colder has the property generally been?
Please select one answer only

- REVERSE SCALE
-
-

1. Much colder nowadays compared with before
2. A bit colder
3. About the same
4. A bit warmer
5. A lot warmer nowadays compared with before
6. Don't know

ASk all who have had installation completed through GHGVS [scheme data and checked at A 2] AND are occupiers [CODE 1 at baseline a2]

(Single Code)

And still compared with the same time last year, since [MEASURES] [IF ONE MEASURE: was / IF TWO OR MORE MEASURES: were] installed, which of these best describes how the temperature drops when the heating is switched off? Please choose one answer only.

1. It drops a lot more quickly nowadays compared with before
2. It drops a little more quickly
3. It drops at about the same speed
4. It drops a little more slowly
5. It drops a lot more slowly nowadays compared with before
6. Don't know

ASk all who have had installation completed through GHGVS [scheme data and checked at A 2] AND are occupiers [CODE 1 at baseline a2]

(Single Code)
And still compared with the same time last year, since [MEASURES] [IF ONE MEASURE: was / IF TWO OR MORE MEASURES: were] installed, how comfortable has the property generally been? Please choose one answer only

1. A lot more comfortable nowadays compared with before
2. A little more comfortable
3. No difference
4. A little less comfortable
5. A lot less comfortable nowadays compared with before
6. Don't know

ASk all who have had installation completed through GHGVS [scheme data and checked at A 2] AND are occupiers [CODE 1 at baseline a2]

(Grid, Single Code)
Compared with the same time last year, since [MEASURES] [IF ONE MEASURE: was / IF TWO OR MORE MEASURES: were] installed, how, if at all, have the following problems changed in the property? For each, please say if they have got better, got worse, or there has been no change.

A. Difficulty heating property to a comfortable temperature, even with the heating on
B. Property being too warm/difficult to cool
C. Too expensive to heat property to a comfortable temperature
D. Damp walls, floors, foundations, etc.
E. Rot in windows, frames or floors
F. Mould/mildew
G. Condensation/steamed up windows
H. Draughts

1. GOT A LOT WORSE
2. GOT A LITTLE WORSE
3. NO CHANGE
4. GOT A LITTLE BETTER
5. GOT A LOT BETTER
6. WAS NOT A PROBLEM BEFORE IMPROVEMENTS WERE INSTALLED
7. DON'T KNOW

ASk all who have had installation completed through GHGVS [scheme data and checked at A 2] AND are occupiers [code 1 at baseline a2]

(Single Code)
And still compared with the same time last year, since [MEASURES] [IF ONE MEASURE: was / IF TWO OR MORE MEASURES: were] installed, have there been any changes in these things in your household ?

A. The amount your household spends on energy bills
B. How long your heating is switched on for
C. How much your household uses electric room heaters or other additional sources of heating

1. A LOT MORE THAN BEFORE IMPROVEMENTS WERE INSTALLED
2. A LITTLE MORE
3. NO CHANGE
4. A LITTLE LESS
5. A LOT LESS THAN BEFORE IMPROVEMENTS WERE INSTALLED
6. NOT APPLICABLE [ONLY SHOW FOR ROW C]
7. DON'T KNOW

ASk all who have had installation completed through GHGVS [scheme data and checked at A 2] AND are occupiers [code 1 at baseline a2]

(Multi Code)

Would you say the installation of [INSERT MEASURES INSTALLED] has had an impact on your health or the health of other people in your household?

Please choose one answer only

ECO QUESTIONNAIRE

1. Yes – impact on physical health
2. Yes – impact on mental health
3. Yes – impact on both physical and mental health
4. No - it has made no difference
5. Don't know
6. Prefer not to say

ASK ALL WHO SAY THERE HAS BEEN AN IMPACT ON HEALTH [CODES 1-3 AT D 7]

(Single Code)

What type of impact has it had on the health of you and/or other people in your household?

Please choose one answer only

ECO QUESTIONNAIRE

1. A strong positive impact
2. Some positive impact
3. Some negative impact
4. A strong negative impact
5. Prefer not to say
6. Don't know

ASK ALL WHO HAVE HAD AN INSTALLATION COMPLETED [FROM SAMPLE AND AS CHECKED AT A 2]

Single Code

Aside from the improvements we've been talking about which are listed below, have any other energy efficient or heating improvement(s) been installed to this property since you first applied for a Green Homes Grant Voucher?

- SHOW ALL MEASURES INSTALLED [FROM SAMPLE AND CHECKED AT A 2]

Please select all that have been installed from the list below.

- EXCLUDE MEASURES ALREADY INSTALLED [FROM SAMPLE FILE AND CHECKED AT A 2]

1. Double/triple glazing
2. Energy efficient doors
3. Loft insulation
4. Cavity wall insulation
5. Solid wall insulation
6. Draught proofing
7. Solar panels - for generating electricity or hot water
8. Efficient electric heating
9. Heat pump - uses electricity to draw heat from the ground, water or air to heat your home
10. Heating controls - including thermostats, timer clocks, smart heating controls
11. Smart meter – a smart meter sends your energy supplier meter readings automatically. They usually come with a home energy monitor that provides information about energy use
12. None of these
13. Don't know

IF ANY 1-11 CODED AT D 9

(Grid, Multiple Code)
How were these other improvements paid for?
Please select one answer only [IF MORE THAN ONE MEASURE: for each improvement]

- SHOW MEASURES FROM D 9
-

1. Paid for entirely by me / my household
2. Paid for partly by my household, and partly funded under a government, local authority or council scheme
3. Entirely funded under a government, local authority or council scheme
4. Paid for partly / entirely by someone else, but not part of a government, local authority or council scheme
5. Paid for in some other way (please write in box)
6. Don't know

IF ANY NON-GHGV INSTALLATIONS FUNDED BY OTHER SCHEME (CODES 2-3 AT D 10)

(Grid, Multiple Code)
Which government scheme(s) were the energy efficient or heating improvement(s) funded by?
SHOW MEASURES CODED 2-4 IN PREVIOUS QUESTION

-

1. Energy Company Obligation (ECO) scheme, CERT, CESP, EEC
2. Domestic Renewable Heat Incentive (RHI)
3. Green Homes Grant Local Authority Delivery Scheme
4.)
5. Another scheme (please write in box)
6. None of these [EXCLUSIVE]
7. Don't know [EXCLUSIVE]

OVERALL IMPRESSIONS

The next few questions are about your views of the Green Homes Grant Voucher Scheme overall.

ASK ALL

(Single Code)
Taking all your experiences into account, overall, how satisfied or dissatisfied are you with the Green Homes Grant Voucher Scheme?
PLEASE SELECT ONE ANSWER ONLY

- REVERSE SCALE

1. Very satisfied
2. Fairly satisfied
3. Neither satisfied nor dissatisfied
4. Fairly dissatisfied
5. Very dissatisfied
6. Don't know

ASK ALL WHO HAVE HAD INSTALLATION COMPLETED THROUGH GHGVS [SCHEME DATA AND CHECKED AT A 2]

(Grid, Single Code)

Taking everything into account, overall, how satisfied or dissatisfied are you with the energy efficient or heating improvement(s) listed below?

PLEASE SELECT ONE ANSWER ONLY [IF MORE THAN ONE MEASURE: for each improvement]

SHOW ALL MEASURES INSTALLED

1. Very satisfied
2. Fairly satisfied
3. Neither satisfied nor dissatisfied
4. Fairly dissatisfied
5. Very dissatisfied
6. Don't know

ASK ALL WHO HAVE HAD HEAT PUMPS (ANY TYPE) INSTALLED [SCHEME DATA AND CHECKED AT A 2]

(Grid, Single Code)

How satisfied or dissatisfied are you with the following aspects of your heat pump?

A. The amount of noise it generates when running
B. How effectively it heats the property to the desired temperature

1. Very satisfied
2. Fairly satisfied
3. Neither satisfied nor dissatisfied
4. Fairly dissatisfied
5. Very dissatisfied
6. Don't know

ASK ALL WHO HAVE HAD AT LEAST 1 MEASURE INSTALLED UNDER VOUCHERS [SCHEME DATA CHECKED AT A 2]

(Grid, Single Code)

If the Green Homes Grant Voucher scheme had not been available, how likely would [IF APPLIED ON BEHALF OF OTHERS, CODE 3 OR 4 AT BASELINE A2 you or the people who live at the property/ IF APPLIED AS HOMEOWNER OR LANDLORD, CODE 1 OR 2 AT BASELINE A2 you] have been to have had the following improvements installed to this property anyway?

- REVERSE SCALE

SHOW ALL MEASURES INSTALLED

COLUMNS

1. Very likely
2. Fairly likely
3. Neither likely nor unlikely
4. Fairly unlikely
5. Very unlikely
6. Don't know

ASK ALL WHO HAVE HAD INSTALLATION COMPLETED THROUGH GHGVS [SCHEME DATA AND CHECKED AT A 2]

(Single code)

As a result of having energy efficient or heating improvements installed, would you say you are more or less likely to consider other energy efficient or heating improvements in the future?

REVERSE SCALE

ECO QUESTIONNAIRE

1. A lot more likely
2. A little more likely
3. No difference
4. A little less likely
5. A lot less likely
6. Don't know

ASK OCCUPIERS [CODE 1 AT BASELINE A2]

(Grid, Single Code)

Which, if any, of the following energy efficiency improvements would you consider making to the property in the future? This could mean upgrading things you already have in the property, or installing something new.

- D 9

COLUMNS

A. Would consider this
B. Would not consider this
C. Already have this
D. Not applicable / not relevant for my property
E. Don't know

1. Double/triple glazing
2. Energy efficient doors
3. Loft insulation
4. Cavity wall insulation
5. Solid wall insulation
6. Draught proofing
7. Solar panels - for generating electricity or hot water
8. Efficient electric heating
9. Heat pump - uses electricity to draw heat from the ground, water or air to heat your home
10. Heating controls - including thermostats, timer clocks, smart heating controls
11. Smart meter – a smart meter sends your energy supplier meter readings automatically. They usually come with a home energy monitor that provides information about energy use

ASK LANDLORDS [CODE 2 AT BASELINE A2]

(Multiple Code)

Which, if any, of the following energy efficiency improvements would you consider making in any properties you rent out to tenants in the future?

1. Double/triple glazing
2. Energy efficient doors
3. Loft insulation
4. Cavity wall insulation
5. Solid wall insulation
6. Draught proofing
7. Solar panels - for generating electricity or hot water
8. Efficient electric heating
9. Heat pump - uses electricity to draw heat from the ground, water or air to heat your home
10. Heating controls - including thermostats, timer clocks, smart heating controls
11. None of these [EXCLUSIVE]
12. Don't know

ASK ALL WHO HAVE HAD AT LEAST 1 MEASURE INSTALLED [SCHEME DATA CHECKED AT A 2 OR INSTALLED OUTSIDE OF SCHEME AT B 1]

(Grid, Single Code)
How likely would you be to recommend the improvement(s) listed below to people you know?
Please choose one answer only

SHOW MEASURES INSTALLED [FROM SCHEME DATA AND AS CHECKED AT A2 OR B1]

1. I have already recommended it to someone
2. Very likely
3. Quite likely
4. Neither likely nor unlikely
5. Quite unlikely
6. Very unlikely
7. Don't know

HOUSEHOLD STRUCTURE & DEMOGRAPHICS

ASK OCCUPIERS

And now some questions about you and your household. We appreciate that these questions were answered when you completed the first survey last year, but we are asking again so we can understand how things have changed.

•

ASK OCCUPIERS

(Multi Code)

Including you, how many people are there in each of the following age groups currently living in your household?

• RANGE 0-20 PER AGE CATEGORY

C-19 HOUSEHOLD SURVEY

•

Enter the numbers below for each (if there is nobody in your household in an age category please enter 0)

1. Under 5
2. 5-13
3. 14-24
4. 25-44
5. 45-64
6. 65-74
7. 75-84
8. 85+

ASK OCCUPIERS

(Single Code)

Does anyone in your household have any long-standing illness, disability or infirmity that limits their normal day to day activities?

ECO QUESTIONNAIRE

By ‘long-standing’ we mean anything that has troubled you/them over a period of time or that is likely to affect you/them over a period of time.

Normal day to day activities include everyday things like eating, washing, walking and going shopping. Please choose one answer only.

1. Yes
2. No
3. Don't know
4. Prefer not to say

ASK OCCUPIERS

(Single Code)

Which of these options best describes the working status of the chief income earner in your household? The Chief Income Earner is the person in your household with the largest income, whether from employment, pensions, state benefits, investments or any other source. If two or more people in the household have the same income, please answer about the person who is the oldest.

If the Chief Income Earner is TEMPORARILY off work for some reason (e.g. temporarily laid off, furloughed, off work because self-isolating) please answer about their working status before they were temporarily off work.

ECO QUESTIONNAIRE

Please choose one answer only

1. Full-time paid work (30+ hours per week)
2. Part-time paid work (8 – 29 hours per week)
3. Part-time paid work (Under 8 hours per week)
4. Retired
5. Still at school
6. In full time higher education
7. Unemployed (seeking work)
8. Not in paid employment (not seeking work)
9. Don't know
10. Prefer not to say

ASK OCCUPIERS

(Single Code)

Which of these options best describes your household's total income, before taxes and any other deductions?

ECO QUESTIONNAIRE

This includes the combined earnings of the household from employment or self-employment, income from benefits and pensions, and income from other sources such as interest from savings.

Please choose the row which most closely applies. Please choose one answer only.

PER ANNUM	**PER MONTH**	**PER WEEK**
Under £5,000	Under £400	Under £100
£5,000 - £9,999	£400 - £829	£100 - £199
£10,000 - £15,999	£830 - £1,329	£200 - £309
£16,000 - £19,999	£1,330 - £1,649	£310 - £389
£20,000 - £24,999	£1,650 - £2,099	£390 - £489
£25,000 - £29,999	£2,100 - £2,499	£490 - £579
£30,000 - £34,999	£2,500 – £2,899	£580 - £679
£35,000 - £39,999	£2,900 - £3,349	£680 - £769
£40,000 - £44,999	£3,350 - £3,749	£770 - £869
£45,000 - £49,999	£3,750 - £4,149	£870 - £969
£50,000 - £74,999	£4,150 - £6,249	£970 - £1,449
£75,000 or more	£6,250 or more	£1,450 or more

1. Don't know
2. Prefer not to say

•

(Single Code)
Is your household's total income, before taxes and any other deductions, £16,000 or more a year?
ECO QUESTIONNAIRE

1. Yes - £16,000 or more per year
2. No - less than £16,000 a year
98. Don't know
99. Prefer not to say

ASK OCCUPIERS

(Single Code)
[IF CODED 2 AT B1 AT WAVE 1] Once your household has paid your mortgage/[IF CODED 3 AT B1 AT WAVE 1] Once your household has paid your mortgage and the rental on your property/ [IF CODED 4,5,6 AT B1 AT WAVE 1] Once your household has paid your rent/[CODED 1,7,8, 11 AT B1 AT WAVE 1]Once your household has paid any housing costs], would you say the money you have left each month is more than <enter number>, or less than this?
C-19 HOUSEHOLD SURVEY
<number to be entered according to no of adults (14+) / children (0-13) coded at J1 and reference excel sheet>

1. We have more than <enter number> left each month after we have paid our [IF CODED 2 AT B1 AT WAVE 1] mortgage/[IF CODED 3 AT B1] mortgage and rental on the property/ [IF CODED 4,5,6 AT B1 AT WAVE 1] rent/[CODED 1,7,8, 11 AT B1 AT WAVE 1] housing costs]
2. We have less than <enter number> left each month after we have paid our [IF CODED 2 AT B1 AT WAVE 1] mortgage/[IF CODED 3 AT B1 AT WAVE 1] mortgage and rental on the property/ [IF CODED 4,5,6 AT B1] rent/[CODED 1,7,8, 11 AT B1 AT WAVE 1] housing costs]
3. Don't know
4. Prefer not to say

ASK ALL

Thank you for answering our questions so far. We very much appreciate your time. To remind you, this survey is being conducted by Ipsos on behalf of the Department for Business, Energy and Industrial Strategy (BEIS) .

ASK ALL

(Multi Code)
BEIS or other researchers working on their behalf may wish to carry out further research amongst people who have applied for Green Homes Grant Vouchers as part of this study.

Would you be willing for BEIS or other researchers working on their behalf to contact you to invite you to take part in further research on this topic in the next 12 months?
You do not have to say now whether you would actually take part in the research, just whether you would be happy to be contacted about it.

1. Yes - happy for BEIS to contact me
2. Yes - happy for other researchers working on their behalf to contact me
3. No [EXCLUSIVE]
98. Don't know [EXCLUSIVE]
99. Prefer not to say [EXCLUSIVE]

ALL GIVING PERMISSION FOR RECONTACT

(Open)
To enable us to contact you, please write your details in the boxes below
Please collect name of person completing survey, email address, telephone number Please add options as relevant
Open box for name

Check appropriate format for email address or tick box Prefer not to provide email address
Check appropriate format for telephone number or tick box Prefer not to provide telephone number

If participant doesn't provide name and one of email address or telephone number, please bring up text box saying 'So that we can contact you, we need to know your name and either your email address or telephone number'.

ASK ALL

(Open)
To enable us to send you the £10 electronic voucher to thank you for taking part in this survey, please enter your email address below.

OPEN
Check email address using standard process

Please also show option: Prefer not to provide email address – I understand Ipsos MORI will not be able to give me the £10 voucher

ASK ALL

Your answers have now been submitted.

Thank you very much for taking part in this important study about the Green Homes Grant Voucher Scheme.

This publication is available from: www.gov.uk/government/publications/green-homes-grant-voucher-scheme-evaluation