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Evaluation of the Domestic Private Rented Sector Minimum Energy Efficiency Standard Regulations

2020 Interim Process and Impact Evaluation: Technical Annex

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Executive summary

The Energy Efficiency (Private Rented Property) (England and Wales) (Amendment) Regulations 2016 establish a minimum level of energy efficiency for privately rented property in England and Wales. The regulations for the domestic properties, which are the focus of this report, was passed by the Parliament in March 2015 and came into force for new and renewed tenancies in April 2018, and for all tenancies in April 2020. The regulations target the most inefficient properties, namely those with an Energy Performance Certificate (EPC) rate of F or G. The EPCs are certificates indicating the energy efficiency of domestic and non-domestic properties through a standard A-G labelling system with A being the most efficient properties and G the least efficient ones. The regulations require landlords of domestic properties that have an EPC rate of F or G to improve them to a minimum of E or register for an exemption, if entitled to do so. Non-compliance can result in a fine of up to £5,000 for the landlord. Local authorities in England and Wales are responsible for enforcing compliance with the regulations.

Aims of the analysis

The impact assessment described in this report focuses on the analysis of the compliance with the regulations and their impact on the energy efficiency and energy costs of the affected properties, as measured by the 'Standard Assessment Procedure' (SAP) rate[1] included in the EPCs, and CO2 emissions as measured by the 'Environmental Impact' (EI) rate. The analysis of compliance assesses the overall compliance with the regulations and the extent to which compliance rates differ across residential units with different characteristics, including energy efficiency changes. With regard to the impact of the regulations on energy efficiency, analysis discussed in this report allows an estimate of whether the introduction of the regulations has had an impact of the likelihood of a residential unit attaining the minimum EPC rate, as compared to a control group. In the case of energy efficiency and CO2 emissions, one can also to assess the average increase in the SAP and EI score which can be attributed to the regulations and then resulting reduction in annual energy costs and CO2 emissions. These results are then scaled up to the whole PRS market based on the sample used in the QEA analysis and a scaling variable.

Data sources used in the evaluation

Both the analysis of compliance and the assessment of the impact of regulations on energy efficiency heavily rely on the national EPC dataset as the main data source. EPCs have been mandated for rental properties since 1st of October 2008, with each certificate valid up to 10 years.

For the compliance analysis, all EPCs since the mandated year are used for the purpose of identifying both the most recent and previous EPC (where available). For the impact on energy performance only EPCs issued after 01/01/2014 have been used in the analysis reported here.

[1] The SAP is the only official, government approved system for assessing the energy rate for a home. Being an index between 1 and 100, the SAP allows the comparison of energy performance of different homes. The higher the SAP rate, the higher the energy efficiency of a home. The EPC labels are created based on the underling SAP rate.

The list of exempted properties is also used in the study, e.g. to discard these properties from the treated group when assessing the impact of the regulations on energy efficiency. In order to assess the change in the level of efficiency of residential units across time, only units with at least two EPC were used. Assessment of the policy is complicated by the fact that a new algorithm was introduced in April 2018 that generated increased SAP and EI rates for the properties being assessed. This impact manifests itself in both the properties affected by the regulations and those not being affected so that the impact cancels out when one looks at the impact of the regulations in the properties being affected compared to those not being affected.

Methodology for assessing the compliance to the regulation

A cut-off date of 1 April 2020 was set from which to calculate all identified PRS dwellings EPC levels as being in level E and above. Any properties identified as a PRS property and having EPC level F or G in its most recently lodged EPC, and not being on the exemption list, were identified as being evidenced as non-compliant. A number of exemptions were not matched to the PRS dataset for reasons of missing PRS EPCs or unidentified addresses.

Analysis of the change in EPC level and value was performed for all PRS dwellings where a previous EPC existed, this created a reduced dataset from the full PRS stock above. When evaluating the change in EPC level and value, only dwellings with a current and previous EPC and a positive increase shown between the two EPCs were used to identify the type of refurbishment changes that were made. This means that dwellings with an EPC feature change that resulted in a downgrade in their EPC are not included in the retrofit analysis.

Analysis of non-compliant properties (i.e. in F&G and no exemption) by dwelling characteristics was performed to show difference in features of non-compliant properties among the stock.

Methodology for assessing the impact of the regulations on energy efficiency

Three treated groups were used to assess the impact of the regulations on energy efficiency. The first one, named ‘Established Private Rental Properties’, comprises residential units with an EPC rate of F or G prior to the regulations, that are classified as privately rented both before and after the introduction of the regulations. The second one, named ‘Recent Private Rental Properties’, comprises residential units with an EPC rate of F or G prior to the regulations, that are classified as privately rented after the introduction of the regulations but were likely to have different tenure use before the regulations were introduced. The third treated group, ‘Private Rental Properties’ is simply the sum of the other two groups. Scottish properties with a F or G rated EPC issued before the introduction of the regulations in England and Wales were used as control group.

The impact of the regulations on energy efficiency has been assessed by adopting two methodologies, Difference-in-Differences (DiD) and Change-in-Changes (CiC), two different variables of interest and conducting robustness analysis in the form of a modified version of DiD and the implementation of DiD in subsamples of the treated and control groups. This extensive body of evidence is the most important strength of the current approach, and the fact that it overall agrees with regard to the impact of the policy is of considerable value to policy-makers.

The DiD was used in relation to the 'SAP' and EI scores and a binary variable. This was defined as 'property improved to minimum standard of EPC band E' (value equal to 1) vs 'property not improved' (value equal to 0). The value of the outcome variable for a residential unit included in the treated or control group was determined by the last EPC among those issued before the introduction of the policy (set to 01/04/2018) and the last EPC in the dataset. Two models were estimated, one including only fixed and time effects, the other incorporate total floor area and main fuel as covariates. A much wider set of variables was used to create subsamples of the treated and control groups to implement DiD for those properties only having given characteristics with regard to this set of variables, which included: 1) Property Type: houses versus flats; 2) access to the gas grid: on grid versus off grid; 3) main fuel: electricity versus gas; 4) size of the property: small, medium or big, each including one third of the sample; 5) walls type: cavity versus solid walls, and 6) method of construction: traditional vs. non-traditional.

Results from assessing compliance to the regulation

The analysis shows that as of 1 April 2020 there were 2,973,310 properties with EPCs marked as private rental and 129,557 were in level F&G without an exemption, or 4.4% of all registered PRS dwellings. There were 7,855 properties with exemptions and 3,284 were in F & G levels. To determine the effect of the regulations on changing EPC levels, a sample of 569,278 properties drawn from the EPC register that includes only those properties with at least one EPC before October 2017 and 1 EPC after April 2018, we conclude that only 14% of the PRS properties that were F or G prior to the regulations coming into force can be classified as non-compliant.

Overall, EPCs among the PRS tended not to be updated before their mandated period, with the mean time between the current and previous EPC being 10 year. However, for PRS dwellings with EPC's E and below tended to replace their EPCs after 5 years. Also, the distribution of the EPC level among property and dwelling type showed that terraced houses tended to have worse performance levels. The most common technical changes among PRS dwellings that hade an increase in their EPC rating included low energy lighting, floor, roof and wall insulation.

Estimates of the impact of the regulations on energy efficiency

This interim analysis found that the regulations have already had a statistically significant impact on the energy efficiency of private rental sector properties. This has been observed both in terms of the odds of achieving an EPC rated E or above, and in terms of the increase in the SAP rate. Properties affected by the regulation in the EPC dataset used in this study were found to display an increase of about 5 SAP points in their SAP rate compared to properties not affected by the regulations.

Analysis discussed in this report clearly points at the regulations affecting the energy efficiency of the properties covered by them. As a consequence of the introduction of the regulations, the most inefficient properties in the privately rental market contained in the EPC dataset used in this study, namely those with an Energy Performance Certificate (EPC) rate of F or G, have been much more likely to increase their level of energy efficiency to a minimum of an E-rated EPC. Result from this study, robust across estimated models and treated groups, indicates that the odds of achieving an EPC rated E or above in the properties affected by the regulations is at least 8 times the level observed in the control group.

The impact of the regulations on energy efficiency was also assessed on the SAP and EI rates. The SAP is the only official, government approved system for assessing the energy rate for a home. Being indexed between 1 and 100, the SAP allows the comparison of energy performance of different homes. The higher the SAP rate, the higher the energy efficiency of a home. The EPC labels are created based on the underling SAP rate. The EI rate follow a similar logic and also ranges between 1 and 100, with higher rates implying lower CO2 emissions. The impact of the regulations on the energy efficiency of private rental properties has been estimated to be about 5 SAP points, while the impact on the EI rate has been estimated to be about 3 points.

In the case of the EPC dataset used in this study, it was also found that the impact of the regulations is higher in those PRS properties with a lower SAP rates before the introduction of the regulations. As additional evidence toward ascertaining the impact of the regulation, control and treated groups presented strong similarities before the introduction of the regulations, but radically differed after the regulations took effect. The distribution of properties affected by the regulations shows a kink near a SAP rate equal to 39. This is exactly the value separating EPC band F from band E, showing the extent to which properties have increased their SAP rate to comply with the regulations. As an example, after the introduction of the regulations about 2% of the affected properties have a SAP rate between 29 and 38 while a minimum of about 37% have a rate between 39 and 48. These percentages for the control group are 17% and 21% respectively.

Assessment of the impact of the regulations for subsamples of the treated and control groups used in this study provided further evidence on the robustness of the results and clarified the factors influencing the increase in the SAP and EI rates brought about by the adoption of a new algorithm in April 2018. Subsamples were generated based on the following variables: property type, access to the gas grid, main fuel used for heating, property size, walls type and method of construction. By looking at the impact of the regulations across properties with different characteristics one can ascertain whether the impact of the regulations differ depending on house characteristics but also which characteristic influence the change in the SAP and EI scores introduced by the new algorithm. In fact, for those characteristics influencing the increase in the SAP, one would expect to see a similar impact of the regulations in the properties with those characteristics and the properties without them. Walls type and method of construction are likely to influence the increase in the SAP rate obtained from the new algorithm. On the other hand, none of the variables considered was found to play a considerable role in explaining the different impact of the regulation in recent and established private rental properties.

This interim analysis has shown that in the case of the EPC dataset used in this study, the regulations have already had a statistically significant impact on the energy efficiency of private rental sector properties, leading to an average increase of about 5 SAP and about 3 EI points in the SAP and the EI rate of properties covered by the regulations compared to properties not affected by them.

The impact of the regulations on energy costs implies an average reduction of about £120 in annual energy costs, in the case of the properties contained in then EPC dataset used in this study, although savings are higher in those units with the lowest SAP ratings before the introduction of the regulations, reflecting findings for the SAP rate described above. In terms of CO2 emissions, the regulations delivered average annual savings up to 500 kgCO2 per year in the properties comprised in the QEA sample. Market wide impacts of the regulations implied a reduction up to £50 million in annual costs and 144 kilotons in CO2 emissions.

Contents

1 Introduction

1.1 The regulations

This report describes the result from the Quasi-Experimental Analysis (QEA) part of the evaluation of the domestic private rented sector (PRS) minimum energy efficiency standard (MEES) regulations. It reports results related to the impact of the regulations on energy efficiency and levels of compliance with the regulations.

The Energy Efficiency (Private Rented Property) (England and Wales) (Amendment) Regulations 2016 establish a minimum level of energy efficiency for privately rented property in England and Wales . These regulations cover both domestic and non-domestic properties. The focus of this report is on domestic properties.

The domestic PRS MEES regulations affect properties rented on a specific set of tenancies (i.e. assured tenancies, regulated tenancies and domestic agricultural tenancies) and mandated to have an Energy Performance Certificate (EPC). The regulations target the most inefficient properties, namely those with an Energy Performance Certificate (EPC) rating of F or G. It requires landlords of domestic properties that have an EPC rating of F or G to improve them to a minimum of E or register for an exemption, if entitled to do so.

The regulations were first discussed via a consultation in 2014-2015, leading to the regulations passed by the Parliament in March 2015. However, they only came into force for new and renewed tenancies from April 2018, and for all tenancies from April 2020.

Compliance with the regulations occurs over a period of time, concluded at the end of March 2020. In addition, landlords renting properties rated of F or G can apply for an exemption from the regulations, on specific grounds, namely “High cost”, “All improvements made”, “Wall insulation”, “Consent”, “Devaluation” and “New landlord”. The regulations only apply to let properties, so if a landlord takes no action but leaves their property unlet or decide to sell it, they are compliant with the regulation. Non-compliance can result in a fine of up to £5,000 for the landlord. Local authorities in England and Wales are responsible for enforcing compliance with the regulations. More information on the regulations can be found online . More information on the impact of the regulations can be found in the main synthesis report of this evaluation.

1.2 The aims of the impact assessment

The impact assessment described in this report focuses on the analysis of the compliance with the regulations and their impact on the energy efficiency of the affected properties, as measured by the SAP rate included in the EPCs attached to the properties.

The analysis of compliance aims at assessing the overall compliance with the regulations therefore addressing the following evaluation question:

- 1a) What proportion of landlords/properties have complied with the regulations?

This can be addressed in relation to the proportion of properties as the ownership of residential units is unknown so that at least in the impact assessment component of the evaluation, one

cannot draw any judgement on the behaviour of different landlords. On the positive side, however, one can assess the extent to which compliance rates different across residential units with different characteristics so that one can address the following evaluations question:

- 1b) In what circumstances is compliance not taking place?

With regard to the impact of the regulations on energy efficiency, analysis discussed in this report allow to estimate whether the introduction of the regulations has had an impact of the likelihood of a residential unit attaining the minimum EPC rate, as compared to a control group. One can also to assess the average SAP increase (expressed in terms of the SAP rate) which can be imputed to the regulations. These findings contribute to address the following evaluation questions after incorporate additional analysis is implemented on the results reported here, as discussed in the main synthesis report of this evaluation:

- 2a) How many energy efficiency installations were installed in PRS properties?
- 2b) How many of these installations can be attributed to the PRS regulations?
- 2c) What are the carbon, energy and cost level impacts of these installations?

2 Impact assessment methodology

Feasibility of the dates and the methodological approaches used in this report was explored in the scoping analysis for both the analysis of compliance and the assessment of the impact of regulations on energy efficiency. In particular, the scoping analysis explored the feasibility of using the EPC datasets as sampling frame for both the treated and control group, the implementation of address matching to the list of properties being exempted and the ability of identifying privately rented properties from the information contained in the EPC dataset. Scoping analysis also allowed narrowing the set of methodological approaches used in the estimation of the impact of the regulations on energy efficiency. The scoping analysis increased the confidence in the feasibility of this study both in terms of data availability and methodological approaches. This has allowed quick implementation of the analyses documented here, after major data hurdles and methodological debate, had been settled by the scoping analysis.

2.1 Data sources used in the evaluation

Two main data sources have been used in the evaluation, one related to Energy Performance Certificates in England and Wales (https://www.epcregister.com) and in Scotland (https://www.scottishepcregister.org.uk), the other listing the rental properties obtaining an exemption from the regulations.

Energy Performance Certificate data

The scoping research assessed the use of the domestic section of the public England and Wales EPC dataset (https://www.epcregister.com) as a sampling frame for both the treated and some of the control groups which could be used in the analysis. The use of the Scotland EPC dataset was not assessed in the scoping research as a potential sampling frame for control groups, due to delays in accessing the data. It was however acknowledged that the Scottish properties, which are not affected by the PRS MEES, would be the best source for control groups. Both datasets contain EPCs from their introduction in 2008 to the end of March 2020, although at the moment of the scoping report only data up to December 2019 were available (see section 2.3.1 for further discussion of control group selection). The EPC datasets include all certificates, regardless of the reason for which they are issued, i.e. private rentals, social rentals, sales, new dwellings and a range of other options. The field ‘transaction type’ was used to select the properties used as treated and control group, as discussed below.

EPCs have been mandated for rental properties since 1st of October 2008, with each certificate valid up to 10 years but only EPCs issued after 01/01/2014 have been used in the analysis reported here. In addition, in order to assess the change in the level of efficiency of residential units across time, only units with at least two EPC were used for this study. In some cases, an implausibly high number of EPCs was issued for the same residential unit and sometimes several EPCs were issued for the same unit in the same inspection date. For this reason, units with either an implausible number of EPCs[2] or two or more EPCs issued in the same ‘inspection date’ were dropped.

[2] Properties with more than seven EPCs issued between 2008 and 2020 were dropped from the sample as the number of EPC was judged implausibly high. This implies dropping about 1,000 properties out of about 1.7 million.

Exemptions Register data

Exemptions registered in the PRS Exemptions Register were used to identify the properties that, had it not been for the exemption scheme, would have been compelled to raise the rate of their EPC to the minimum standard of E. Exemptions are however time limited, and for this reason, exempted properties within bands F or G were removed from the treatment group only if they had a valid exemption and no EPC rate E or above.

2.2 Assessing compliance with the regulations

The evaluation of the compliance with the regulations aimed to assess the extent to which the landlords of residential units which are subject to the regulations have complied, at an overall aggregate level. This included addressing following evaluation questions:

- 1a) What proportion of landlords/properties have complied with the regulations?
- 1b) In what circumstances is compliance not taking place?

The first question pertains to the need to understand the overall level of compliance, accounting for those properties that have sought and secured an exemption to the regulations. The compliant dwellings would achieve the regulation of an EPC E on or before the required date of 1 April 2020.

The second question focuses on better understanding the circumstances, i.e. building types, performance levels and other attributes of the dwellings where landlords have not been shown to comply with the regulation.

Data sources and methodological approach

The scoping report considered two sources of data to undertake the evaluation of compliance: the EPC dataset, described above, and the English Housing Survey (EHS). The approach to estimating the overall compliance level was to calculate the total number of dwellings with EPC lodgements for privately rented transactions that were compliant with the regulation as of the 1 April 2020. Further analysis would be undertaken using the more detailed dwelling attributes drawn from the EPC dataset.

The methods used in evaluating the compliance included using the EPC dataset extract that covered all property lodgements as of the 1 April 2020 and determining the overall compliance level along with calculating the number of properties that were not compliant and their attributes.

Further, additional analysis was carried out using the English Housing Survey (EHS) in order to determine what the rate of refurbishment and type of performance changes have been taking place within the PRS leading up to the introduction of the regulations. In subsequent analysis, it will be possible to use the EHS to identify overall compliance using high-quality assessor data.

Strengths and weakness of the current approach

The analysis approach used in the compliance evaluation is a straightforward calculation of properties within the EPC dataset (required for all privately rented dwellings) that are not

compliant with the regulation on the date required, and which do not have an approved exemption.

Whilst this is a straightforward concept, determining the actual compliance level is more challenging due to the limitations of the data sources.

The EPC dataset is known to be of varying quality[3] that makes evaluating the actual compliance level using the lodged data quite challenging. The data extract downloaded all the most recent EPCs for dwellings with a private rental transaction, along with the previous EPC where available. In some cases, for dwellings with two EPCs there were 'downgrades' noted, along with other erroneous conditions, such as dwellings with completely different walls types between the years. The implication for any analysis is that by using the EPC dataset one must include a margin of error related to the quality of the dataset. Despite these limitations using the EPC dataset for analysis of compliance and the impact of the regulations on energy efficiency was considered as the best approach available to the team.

The EHS, whilst being a high-quality survey of dwellings and their energy performance features, is limited in terms of its overall sample size and its current coverage that does not extend past the regulation compliance date. The latest available data for the EHS is 2017/18.

Plans for future phases of the evaluation

The approach to evaluating compliance going forward will make use of both the EPC dataset and the EHS survey using similar methods as described above. Despite the limitations with both datasets, they remain the only available sources of information that could be used to determine the overall compliance levels of the PRS stock.

2.3 Assessing the impacts of the regulations on energy efficiency, energy cost and CO2 emissions

The evaluation of the impact of the regulations on energy efficiency, energy costs and CO2 emissions has been implemented by evaluating the change in the EPC in a counterfactual setting where the change in a group affected by the regulation is compared to the change in a group not affected by them (control group). Two methodological approaches' have been used to look at slightly different angles of the impact of the regulations on energy efficiency, Difference-in-Differences and Change-in-Changes, as detailed below. Results discussed in this report will contribute to answering the following evaluation questions, after additional analysis is implemented on the results reported here, as discussed in the main synthesis report of this evaluation:

- 2a) How many energy efficiency installations were installed in PRS properties?
- 2b) How many of these installations can be attributed to the PRS regulations?
- 2c) What are the carbon, energy and cost level impacts of these installations?

[3] Hardy & Glew, 2020. An analysis of errors in the Energy Performance certificate database. Energy Policy. Vol 129. https://doi.org/10.1016/j.enpol.2019.03.022

This section describes the strategy followed in the formation of treated and control groups and in the estimation of the impact of the regulations.

2.1.1 Formation of treated and control groups

A scoping study for the evaluation concluded that the most appropriate control group to use in this impact assessment was properties from Scotland. Other control groups considered were owner occupied properties in England and Wales and social rented properties in England and Wales. The main reasons why Scotland was favoured are listed below:

- Control groups comprising English and Welsh F or G rated owner-occupied properties and English and Welsh F or G rated social rentals properties were explored but were discarded as they did not meet the parallel trend assumption (see section 2.3.2) or comprised a very small number of properties, respectively.
- The Scottish housing stock is broadly similar to the English and Welsh housing stock, with PRS being the least efficient tenure in each country. In 2018, 10%[4] of the Scottish PRS stock was band F or G, while in England 5.4%[5] of PRS were F and G, and in Wales 7.4%[6] of PRS were F and G.
- The tenure of specific properties is known to change over time as properties are sold and purchased. It is also the case that one of the potential impacts of the PRS regulations is that F and G rental properties are sold into another tenure as landlords are unwilling to upgrade them. These issues could result in contamination of the control group.

It should, however, be noted that there are some caveats when using Scottish properties as a control group. The primary concerns are:

- The energy efficiency policy environment is Scotland is different to England and Wales. While the lack of a minimum energy performance standard is the difference which allows Scotland to act as a control group, a minimum standard is being introduced in 2020. It is possible that awareness of the standard being introduced has influenced behaviours. If that was the case, the impact attributed to the regulations in the report would be a conservative estimate of the actual impact. It is also the case that the Scottish Home Energy Efficiency Programme providing additional funding to landlords that is not available in England and Wales.
- The sample sizes available in Scotland require that the control group comprise both private rental and owner occupied properties, limiting the direct comparability.

As a first step in forming treated and control groups, information in the PRS Exemptions Register was address matched to the whole EPC database in order to remove exempted properties from the analysis[7]. Potential matches between the addresses in the EPC and those

[4] Scottish House Condition Survey https://www.gov.scot/publications/scottish-house-condition-survey-2018-key-findings/pages/5/#Section3.3
[5] English Housing Survey 2018/19 https://www.gov.uk/government/statistics/english-housing-survey-2018-to-2019-headline-report
[6] Welsh Housing Conditions Survey 2017/18 https://gov.wales/welsh-housing-conditions-survey-energy-efficiency-dwellings-april-2017-march-2018
[7] Address matching was implemented as the UPRN key (contained in the PRS Exemptions Register) is not available in the public version of the EPC data.

in the exemption dataset have been assessed according to the Levenshtein ratio[8]. Based on past experience, a Levenshtein ratio of over 80% used to register a positive match is an adequate compromise between the opposite risks of accepting erroneous matches and discarding correct ones. The address matching process include two stages.[9] If no match in the first stage met the 80% threshold, the second stage was implemented. If the threshold was not met at the second stage, a no match was registered or theta specific exemption.

The second step in the formation of the treated groups requires to identify the actual economic use of residential units based on pre- and post-regulation EPCs. This was based on the information recorded in the 'transaction type' field of the EPCs. One complication is that the property use of residential units registered by the EPC can be different from the actual use of the properties.[10] A set of rules was trialled in the scoping report to investigate the feasibility of their implementation. Based on the final set of rules, described in Annex 1, three treated groups were formed. The first one, named 'Established Private Rental Properties', comprises residential units with an EPC rate of F or G prior to the regulations, that are classified as privately rented both before and after the introduction of the regulations. The second one, named 'Recent Private Rental Properties', comprises residential units with an EPC rate of F or G prior to the regulations, that are classified as privately rented after the introduction of the regulations but had different economic use before the regulations were introduced. The third treated group, 'Private Rental Properties' is simply the sum of the other two groups.

Table 2.1: Identification of treated groups

Group type	Pre-regulation property use	Post-regulation property use
Private Rental Properties	F or G rated properties with any transaction type	properties with 'Private Rentals' transaction type
Established Private Rental Properties	F or G rated properties with 'Private Rentals' transaction type	properties with 'Private Rentals' transaction type
Recent Private Rental Properties	F or G rated properties with any transaction type but 'Private Rentals'	properties with 'Private Rentals' transaction type

In a similar fashion, control groups were formed based on the property use and EPC rates of residential units prior to the regulations. Possible control groups are summarised in Table 2.2.

Table 2.2: Identification of control groups

[8] The Levenshtein distance is a string metric measuring the difference between two strings. This is the minimum number of single-character edits, including insertions, deletions or substitutions, which are required to change one word into the other. The Levenshtein ratio is imply the Levenshtein distance divided by the length of the initial word to be matched.

[9] In the first stage of the matching, the potential matches to a specific exemption are the properties in the EPC dataset with the same postcode and house number of the exemption to match. For example, if the exemption address is "4 Smith Rd, London, WC2A 0PP", the algorithm will search for any EPC within the postcode 'WC2A 0PP' that also contains a '4' in its address. In the second stage, the matching is repeated after adopting a less stringent data filtering condition, so that the potential matches to a specific exemption would include all the properties in the EPC dataset with the house number of the exemption to match in the same postcode after dropping the last digit of the postcode. If the exemption address is "4 Smith Rd, London, WC2A 0PP", the algorithm will search for any EPC within the postcode 'WC2A 0P' that also contains a '4' in its address.

[10] As an example a property could be sold and then rented out by using the EPC generated during the sale. It is also the case that some of the transaction types in the EPC database are not very indicative of the property use.

Group type	Pre-regulation property use
control group 1	Scottish F or G rated private rental properties
control group 2	Scottish F or G rated properties
control group 3	Scottish F or G rated owner-occupied properties

Control groups comprising Scottish properties were thought to be generally preferable to control groups comprising English properties. In particular, control group 1 is likely to comprise units which are most similar to those in the treated groups, as they share the same tenure type. Control group 3 on the other hand comprises residential units occupied by the owner and for this reason they might differ systematically from the treated group which include only privately rented properties. Control group 2 comprises the properties in both control group 1 and 3 and as a consequence it lies in between these two control groups in terms of the preference order of the control groups. Results are reported only for control group 2 as the number of properties included in control group 1 was considered too small.

2.1.2 Use of the EPC dataset

As the aim of this work is to analyse compliance with the regulations and their impact on the energy efficiency and energy costs of the affected building stock. In the long term, the evaluation will make use of the English Housing Survey data, which is recognised as the authoritative stock profile data. However, for this interim impact evaluation, the EPC register is the only robust and available data source. Given the EPC does not comprehensively include all properties in England and Wales, it is necessary to consider the appropriateness of the EPC register as the primary data source.

Section 3.3 provides an overall comparison of the energy efficiency profiles of the EPC register and the EHS data. As one can conclude based on the comparison in 3.3, the two datasets are fairly similar, although there are slightly more EPC band E dwellings in the EPC, slightly less D and a higher proportion of A or B properties.

When looking at the profile of F and G properties within each data source, overall there is a strong match between the data sources. In relation to the compliance assessment, which uses the entire EPC database, the EPC database does under-represent some dwelling types, most notably smaller properties and semi-detached properties (see section 3.3 for more detail). In relation to the sub-sample selected for use in the difference in difference analysis flats are over-represented in both the English and Welsh treated groups and the Scottish control group (see section 4.2 for more detail).

Extrapolation of the impact assessed in the EPC sample to the whole building stock (as described in section 4.4) is implemented through computing the impact for non-traditionally built homes and traditionally built home separately in the EPC dataset and then obtaining the market wide estimates by weighting these two impacts by the relative share of the two home types above. The selection of the non-traditionally built and traditionally built homes to compute the market wide impact was due to the fact that this characteristic was found to be influential in determining the impact of the change in the EPC algorithm which occurred in April 2018 so that by analysing these two groups separately the impact of the algorithm change in the houses covered by their regulations should be relatively similar to those not affected by the policy change. The market wide extrapolation would therefore be unreliable only if non-traditionally

built homes in the EPC are systematically different from those in the EHS, and the same applies for the traditionally built homes. No immediate reasons supporting these systematic differences were encountered in the analysis.

2.1.3 Analytical approaches to estimation

Baseline approach: panel DiD

Difference-in-Differences (DiD) is a technique often used to estimate the effect of a policy on a so-called treated group, in comparison to a control group, in quasi-experimental studies, where units are not assigned randomly to the treatment and the control groups. DiD is based on the comparison of difference in outcomes, first across time for the treatment and the control group, and then across groups.

When dealing with multiple time periods and covariates, the generalized DiD approach takes the form of a regression model with time and group fixed effects. Specifically, the analytical framework of DiD relies on the following regression where the impact of a policy on a variable of interest y_{it} (the outcome variable) is expressed by the coefficient δ:

$$y_{it} = \delta T_{it} + x'_{it}\beta + \xi_t + \alpha_i + \varepsilon_{it} \qquad (1)$$

where y_{it} is an outcome variable, T_{it} 'SAP' scoreis a vector of strictly exogenous control variables (including a constant), ξ_t and α_i are time and unit effects, and ε_{it} a disturbance term.

This approach has been implemented for three variables: the 'SAP' score, a binary variable representing 'property improved to minimum standard of EPC band E' (value equal to 1) vs 'property not improved' (value equal to 0), and finally the Environmental Impact ('EI') score. From the results for the SAP score one can obtain the impact of the regulations on energy costs. Similarly, from the results for the EI score, one can obtain the impact on CO2 emissions. Both formulas can be found in BRE (2014)[11].

The value of the outcome variable for a residential unit included in the treated or control group was determined by the last EPC among those issued before the introduction of the policy (set to 01.04.2018) and the last EPC after the introduction of the policy.[12]. In terms of control variables, the following controls were considered: 1) total floor area, and 2) main fuel were considered. Limited control variables can be included in the DiD approach as control variables need to take values varying across time, as otherwise one would not be able to distinguish them from the included individual fixed effect, while being exogenous so that their value is not influenced by the possibility of the treatment. A much wider set of variables is used to create subsamples of the treated and control groups to implement DiD for those properties only having given characteristics with regard to specific variables, as described below.

The impact of the regulations on energy costs and CO2 emissions was computed based on the impact on the SAP and EI score. There is a direct relationship between SAP score and energy costs, and between the EI score and CO2 emissions. The relationship between energy cost and the SAP score produced by BRE is as follows:

[11] BRE (2019) SAP 2014 SAP 2012The Government's Standard Assessment Procedure for Energy Rating of Dwellings, www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf
www.bregroup.com/wp-content/uploads/2019/10/SAP-10.1-01-10-2019.pdf

[12] The property use of a specific residential unit, however, is determined by a more complex decision rule which is described in Annex 1.

$$energy\ cost\ = \begin{cases} 10^{(117-SAP)/121} & if \quad SAP < 51.2 \\ (100 - SAP)/13.95 & if \quad SAP \geq 51.2 \end{cases},$$

while the relationship between CO2 emissions and the EI score, also produced by BRE is:

$$CO_2\ emissions\ = \begin{cases} 10^{(EI-200)/-95} & if \quad EI < 62.1 \\ (EI - 100)/-1.34 & if \quad EI \geq 62.1 \end{cases}$$

In the case of the DiD results, the impact of the regulations on the SAP and EI rate is added to the average EI and SAP rate observed in the control group after the introduction of the regulations so that one can compute their impact on energy costs and CO2 emissions by converting this computed value and the value observed in the control group and taking the difference between them. In the case of the CiC, implemented for the SAP rate only, the impact on the SAP rate is added to each percentile of interest for the distribution of the counterfactual rather than summing it to the control group.[13]

Parallel Trends Assumptions

DiD allows for the comparison of a treated and a control group if the outcome variable displays similar trends in the absence of treatment. The parallel trends assumption, is a key assumption required by the DID, implying that in the absence of the policy being assessed, the variable of interest in the treated and control group would have continued to move together. In practice, verification of this assumption can be implemented either graphically or through regression-based tests, with the purpose of estimating the significance of the difference in the trend before the policy as introduced, i.e. pre-treatment period. These tests can be implemented by assessing whether the time effect in each year in pre-treatment is significantly different in the treated and the control group or by whether the linear time trend is significantly different in the treated and the control group.

Robustness Approaches

Robustness of the results obtained from the DiD described above is assessed in three different ways:

- Implementing a modified version of DiD, discussed in Bertrand et al (2004), based on implementing a DiD on two observations, one obtained from averaging all observations in the pre-treatment period, and the other from averaging the value of the observations occurring after the regulations were introduced.
- Implementing the changes-in-changes, CiC introduced by Athey and Imbens (2006). This is a generalization of DiD which does not rely on any functional form assumption and the assumption of parallel trend. It allows for heterogeneity in the impact of the treatment by estimating the effect for each unit in the treated group rather than the average effect for the whole sample like the DiD. In the case of the PRS MEES regulations, it is reasonable to assume that their impact depends on the starting level of the SAP rate so that the highest impact manifest itself in those properties with the lowest SAP rate before the regulations were introduced. More details can be found in Annex 3.

[13] This is because a counterfactual distribution is computed as part of the implementation of the methodology.

- Implementing DiD in subsamples of the treated and control groups. These subsamples were created based on the type of the property (generate a subsample including houses and the other including flats), whether a property had access to the gas grid (generate a subsample including unit with no access, and another sample including those units on the grid), and depending the main fuel used for heating (generate a subsample including the units using electricity as main fuel and the another using gas. In the case of the size of the property, residential units were divided into three subsamples of same size, one including the smallest units, another the largest ones and a third including the remaining units. The remaining last four subsamples were created based on the type of walls, generate a subsample including units with cavity walls and another with solid walls[14], and based on the method of construction, generate a subsample including non-traditional houses[15] and the other traditional houses.

The use of a placebo test as robustness strategy was also considered in the scoping but was not implemented in the analysis leading to the final report due to the limited number of options available to carry the tests both in terms of placebo (pretend) treated group and or treatment period.[16]

Another approach that can be employed to test the robustness of the analysis is the use of placebo tests. Multiple types of placebo tests can be carried out, depending on the information available and on the data structure.

2.1.4 Scaling up methodology

The results from the QEA can also be used to compute the impact on the regulations on the whole private rental sector rather than in the sample used in this study. In the simplest way this could be achieved by multiplying the results obtained for the average property in the EPC sample by the number of properties in the private rental sector which were classified as F or G in terms of the energy efficiency rating. To make the scaling process more representative and take into account possible impact of the change in the EPC algorithm in April 2018, one can use the results of the DiD across subsamples of the treated and control groups to identify the variable which most influence the impact of the change in the EPC algorithm on EPC score. One can use the results for the subgroups determined by the variable above ('scaling variable') to scale up results from the DiD based on the share of the categories related to the scaling variable, e.g. house and flats, in the overall stock of rental properties which were rated F and G in the EHS. Assuming that there are only two categories (A and B) determined by the scaling variable, the scaling up methodology implies carrying out the computation below

$$y_{MARKET} = rental\ properties_{FG}(y_A s_A + y_B s_B) \qquad (2)$$

where y_A and y_B are the results for the variable of interest obtained by the DiD when using only properties from category A and B, respectively, s_A and s_B are the share of rental

[14] This includes houses with walls made of stone (either granite/whinstone or sandstone), solid bricks or cob, as well as system build houses

[15] This includes timber framed houses and so-called system build houses

[16] This implies selecting a group not affected by the policy and treat it a pretend treatment group compared to a control group so that estimated effect of the regulations should be zero. Another possibility is to choose a pretend treatment date and assess whether a significant effect of the policy could be estimated at that date. In either case, significant effects of the policy intervention found in the placebo group or at the place treatment date cast doubts on any significant impact estimated when comparing the real treated group to a control group.

properties rated F and G from category A and B so that $s_A + s_B = 1$ and $rental\ properties_{FG}$ are the overall number of rental properties which were rated F and G in the EHS.

2.1.5 Strengths and weakness of the current approach

The analysis approach used in relation to the estimation of the impact on energy efficiency, energy costs and CO2 emissions is an exhaustive procedure, building evidence from the use of two methodologies (Difference-in-Differences and Change-in-Changes), three different variables of interest and integrate robustness analysis in the form of a modified version of DiD and the implementation of DiD in subsamples of the treated and control groups. This extensive body evidence is the most important strength of the current approach, and the fact that it overall agrees with regard to the impact of the policy is of considerable value to policy-makers. The conversion of the SAP and the EI rate on energy costs and CO2 emissions build on established practice developed by the BRE, accepted and understood in the industry and governmental departments.

As discussed in the section related to compliance, the EPC dataset presents some limitation which might have prevented conclusive findings in relation to the impact of the regulations on energy efficiency, energy cost and CO2 emissions. A change in the algorithm also introduced in April 2018 is particularly influential as it implies a marked increase in the SAP and EI rates of several residential units, both in the treated and control group, as it is evident in Figure 4.1 for the SAP rate. Another limitation in the study is the lack of uncertainty in relation to the use of residential units as EPC not necessarily reflect the economic use of the property. It is also possible that some of the improvement in the SAP and EI rates observed in the control group after the introduction of the regulations is due to the Scottish landlords increasing energy efficiency in anticipation of a similar set of regulations in Scotland in April 2020 for renewed tenancies and from March 2022 for all tenancies, although it was delayed to October 2020 because of COVID-19.If this was the case, the estimates discussed here can be considered a conservative estimate of the impact of the regulations. The methodology used to compute the impact of the regulation on the whole stock assumes that the properties in the EPC dataset are representative of the properties in the stock for the subgroups created based on the characteristics used to do the scaling.[17] This is an assumption one is not able to verify but on the other hand there no specific reasons for assuming that this should not be the case.

2.1.6 Plans for future phases of the evaluation

The approach to evaluating the impact on energy efficiency going forward will not be able to use Scottish properties as they become affected by similar regulations. As a consequence, one will have to rely on a comparison with owner-occupied properties in England and Wales rated F or G prior to the regulations or private rentals rated E or above prior to the regulations. Either choice is problematic for the DiD approach as, at least in the sample available for this study, the assumption of parallel trends does not hold. There are also concerns in relation to the fact that impact of the changes in the algorithm mentioned above vary depending in the average SAP rate of a property. This implies that the use of properties rated E or above prior to the regulations would have a further complication, additional to the fact that the set improvements in property rated E is completely different to the set of improvement available in properties rated F or G. Further discussion with BRE might clarify the reasons for the jump in SAP rate observed when the algorithm was revised. Without further clarity on the topic, a data driven

[17] As an example if one used property type as scaling variable with all the existing types grouped into two categories, flat and house, the scaling up methodology implies that the houses and the flats which are comprised in the QEA sample are representative of the houses and the flats in the F and G rated private rental market.

adjustment to address the jump in SAP rate while the lack of meeting the parallel trend assumption could be tackled through the Synthetic Control Method[18] or the Synthetic Difference-in-Differences estimator[19]. These two estimators don't assume the existence of a adequate control group to meet specific assumptions, like in the case of the DiD, but re-weight potential control units so that a control group match pre-exposure trends in the treated group can be produced. Another option would be to explore the implementation of only the CiC approach which has been very insightful in this report.

Feasibility of the dates and the methodological approaches used in this report was explored in the scoping analysis for both the analysis of compliance and the assessment of the impact of regulations on energy efficiency. In particular, the scoping analysis explored the feasibility of using the EPC datasets as sampling frame for both the treated and control group, the implementation of address matching to the list of properties being exempted and the ability of identifying privately rented properties from the information contained in the EPC dataset. Scoping analysis also allowed narrowing the set of methodological approaches used in the estimation of the impact of the regulations on energy efficiency. The scoping analysis increased the confidence in the feasibility of this study both in terms of data availability and methodological approaches. This has allowed quick implementation of the analyses documented here, after major data hurdles and methodological debate, had been settled by the scoping analysis.

[18] Abadie A., Diamond A. and J. Hainmueller (2010). Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program, Journal of the American Statistical Association, 105(490):493–505, 2010

[19] Arkhangelsky D., Athey S., Hirshberg D. A., Imbens G. W. and S. Wager (2020) Synthetic Difference in Differences, https://arxiv.org/abs/1812.09970

3 Compliance with the regulations

Key points:

- Compliance levels among the PRS to the regulations are approximately 96%, with approximately 129,557 PRS dwellings having non-compliant EPCs.
- PRS landlords with a previous EPC have generally sought to comply with the regulation showing a considerable drop in non-compliant properties preceded the compliance cut-off date.
- The majority of dwellings that had previously been in EPC level F&G, and who experienced an increase in their EPC level, had installed a form of insulation, either roof, wall or floor and their combination.

3.1 Introduction

Compliance with the MEES regulation requires that all privately rented sector dwellings are at least EPC level E on or before 1 April 2020, unless an exemption has been granted. The purpose of this analysis is to determine the level of compliance among the PRS in terms of their meeting the minimum efficiency standard. In its most simplistic form, the analysis aims to identify all compliant and stated non-compliant properties, along with any features that might help to explain their non-compliance.

The EPC database provides what should be a comprehensive source of information on which to identify compliant and non-compliant properties. However, there are a number of known issues and limiting factors that act to challenge this analysis of compliance.

The main challenges of using the EPC data are quality, coverage and continuity, including:

- The EPC's are known to be of varying quality[20] and this leads to uncertainty in both input data describing the performance features and also the EPC levels themselves. Known problems include unexpected changes in dwellings characteristics (i.e. floor area or type), 'downgrades' to stated performance features, and resulting downgrades to EPC values. This variation is commonly assigned to assessor interpretation bias and only sometimes a true change in state (e.g. an addition).
- Lack of detail on PRS and EPC data, including: whether an EPC issued for private rental is still a privately rented dwelling or whether it has become subsequently owner occupied or sold; lack of a centralized and updated PRS register from which to otherwise identify properties; delays or timeliness of reporting of data.
- Lack of overall PRS data, including local authorities' PRS licensing and reporting processes; enforce and enforcement procedures

[20] Hardy & Glew, 2020. An analysis of errors in the Energy Performance certificate database. Energy Policy. Vol 129. https://doi.org/10.1016/j.enpol.2019.03.022

- 'Dark' or unlicensed private rentals, or lack of EPCs when one is otherwise required, along with bad actors within the private rental market
- The period that an EPC lasts being 10 years with no requirement for landlords to update the EPC with upgrades.
- In addition, as part of the compliance analysis, there was also consideration for the broader PRS dynamics that could influence the obligation and the potential for additionality among the stock. This includes:
- Understanding the 'churn' of the PRS, i.e. the number and type of properties entering and leaving the market.
- Establishing the 'natural' rate of change in the EPC levels among PRS stock over time before, during and following the implementation of the regulations.
- Assessing the gaps in compliance reporting among PRS properties during the periods and their interaction with other energy performance requirements, i.e. the 10 year renewal of the EPC.

3.2 Findings on overall levels of compliance to date

The number of PRS dwellings with a current lodgement in the EPC dataset as of the bulk download date of 20 August 2020 were 2,973,610 properties with EPCs that were linked to the exemptions database. From these, a small number of records were removed due to their having transaction dates prior to 2007 and EPC levels of 'I' or EPC values of greater than 120. This left a dataset used in the compliance analysis dataset of 2,973,310 records. The exemption database contained 7,855 properties for which only 3,702 were matched to the compliance analysis dataset.

Table 3.1 shows that as of 1 April 2020 there were 132,841 PRS dwellings with their most recent EPC marked as private rental in EPC level F and G. Of these, 129,577 are marked with no exemption, or 4.4% of the total PRS stock and 3,702 properties were matched to the exemption list. However, not all exemptions were matched to the EPC database with the maximum exemption numbers would total only 7,855 properties, or 6% of all F&G properties.

Table 3.1: EPC Compliance level for dwellings with current EPC as of 1 April 2020

	PRS Dwellings	
	Exemption group	
	Not exempt	Exempt
EPC Level	N	N
A	632	.
B	119,667	1
C	886,111	17
D	1,265,199	117
E	564,289	284
F	97,674	2,193

	PRS Dwellings	
	Exemption group	
	Not exempt	Exempt
EPC Level	N	N
G	31,883	1,091
Unmatched		4,152
All	2,965,455	7,855

Using the unmatched exemption dataset, the most frequent stated reason for an exemption were all eligible improvements were made, lack of funding, or consent for action was denied.

Table 3.2: Reasons for exemption as of 1 April 2020

	PRS Dwellings
Exemption description	N
All relevant improvements have been made	2,226
Consent denied or subject to unreasonable conditions	1,263
Cost to landlord exceeds cap	940
Devaluation of more than 5%	23
New landlord under qualifying circumstances	62
No suitable funding	2,732
Wall insulation would have a negative impact	609
All	7,855

There were 569,278 PRS dwellings with a current and previous EPC. Of those dwellings, the stock that was in EPC level F and G was 85,346, or 14.8% of the PRS stock with two EPCs in those bands. The analysis shows that between the current and previous EPC that more than 64,826 PRS dwellings moved from EPC F and G to E and above, or a 77% reduction.

Table 3.3: EPC Compliance level for dwellings with a previous EPC as of 1 April 2020

	Current EPC			Previous EPC		
	All	Not exempt	Exempt	All	Not exempt	Exempt
EPC Level	N	N	N	N	N	N
A	102 (<1%)	102	.	60 (<1%)	60	.
B	15,847 (3%)	15,847	.	30,099 (5%)	30,099	.
C	164,721 (29%)	164,713	8	129,743 (23%0	129,743	.
D	248,005 (44%)	247,929	76	201,535 (35%)	201,528	7

	Current EPC			Previous EPC		
	All	Not exempt	Exempt	All	Not exempt	Exempt
EPC Level	**N**	**N**	**N**	**N**	**N**	**N**
E	120,386 (21%)	120,124	262	122,490 (22%)	122,454	36
F	15,499 (3%)	14,735	764	66,503 (12%)	65,599	904
G	4,718 (1%)	4,436	282	18,843 (3%)	18,398	445
All	569,278 (100%)	567,886	1,392	569,273 (100%)	567,881	1,392

To determine the rate of compliance following the announcement of the regulation, a sample of 74,278 properties drawn from the EPC register that includes only those properties with at least one EPC before October 2017 and 1 EPC after April 2018, we conclude that only 14% of the PRS properties that were F or G prior to the regulations coming into force can be classified as non-compliant, or 86% became compliant. For those properties that had their previous EPC on or after 1 October 2017 the compliance level is 94%.

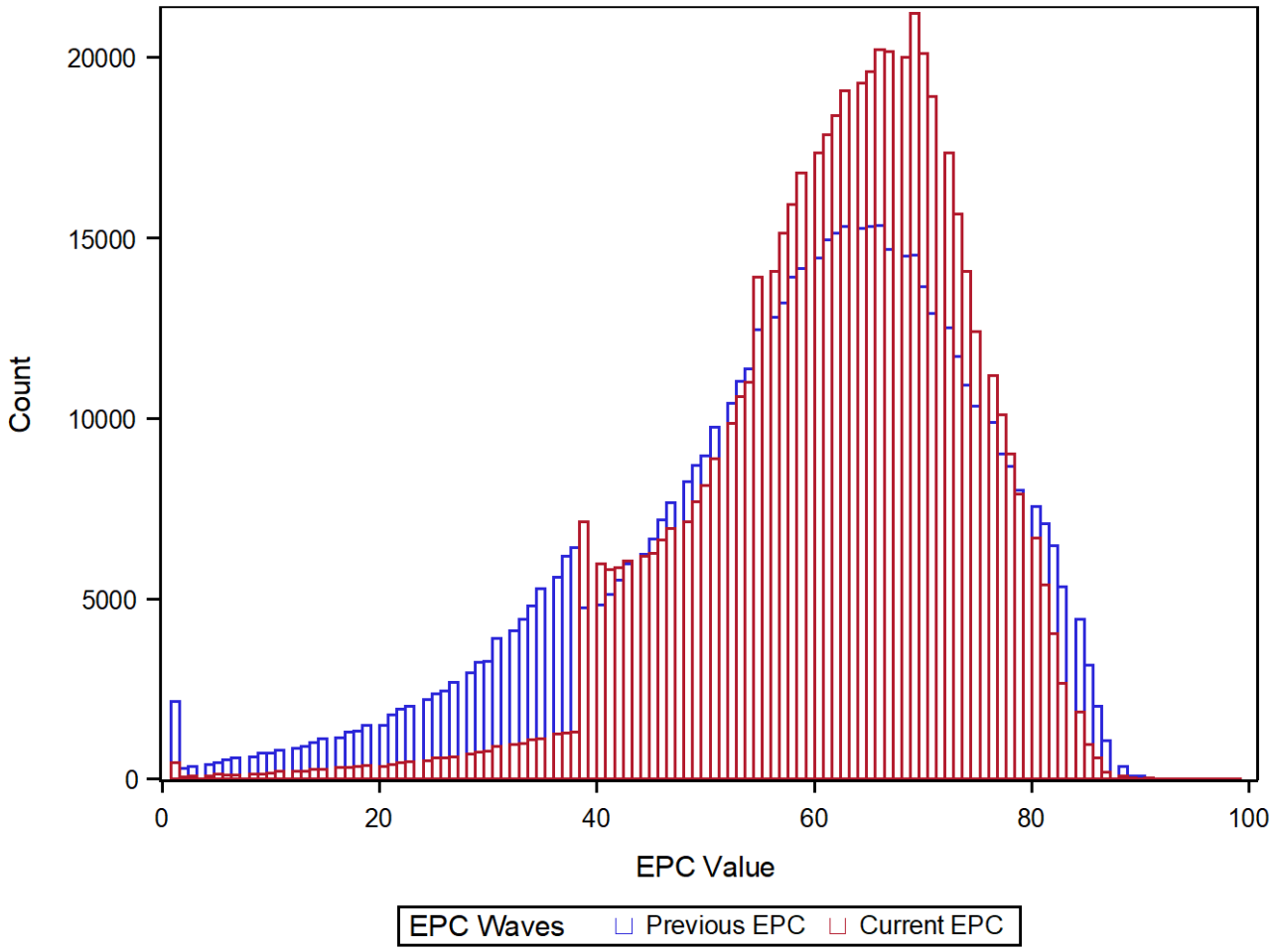
Table 3.4: EPC Compliance level for dwellings with a previous EPC before 17 October 2017

			Current EPC					All	
Policy announcement	**Exemption group**	**Previous EPC**	**A/B**	**C**	**D**	**E**	**F&G**	**N**	**%**
Post-policy	Not exempt	F&G	5	286	1,650	4,633	406	6,980	6 %
	Exempt	F&G	.	5	45	173	269	492	55 %
Pre-policy	Not exempt	F&G	99	5,204	22,558	35,202	10,421	73,484	14 %
	Exempt	F&G	.	.	16	64	714	794	90 %

Figure 3.1 below shows that the regulation is noticeably impacting on the PRS stock in terms of their EPC values, with a discontinuity in the distribution of PRS stock between the current EPC and the previous value. There is some uncertainty to this shift due to a change in the SAP method that took place in 2018 that adjusted wall U-values for both solid and cavity wall properties, but it is expected these effects would occur both across the whole distribution of PRS properties and not only those in F&G.

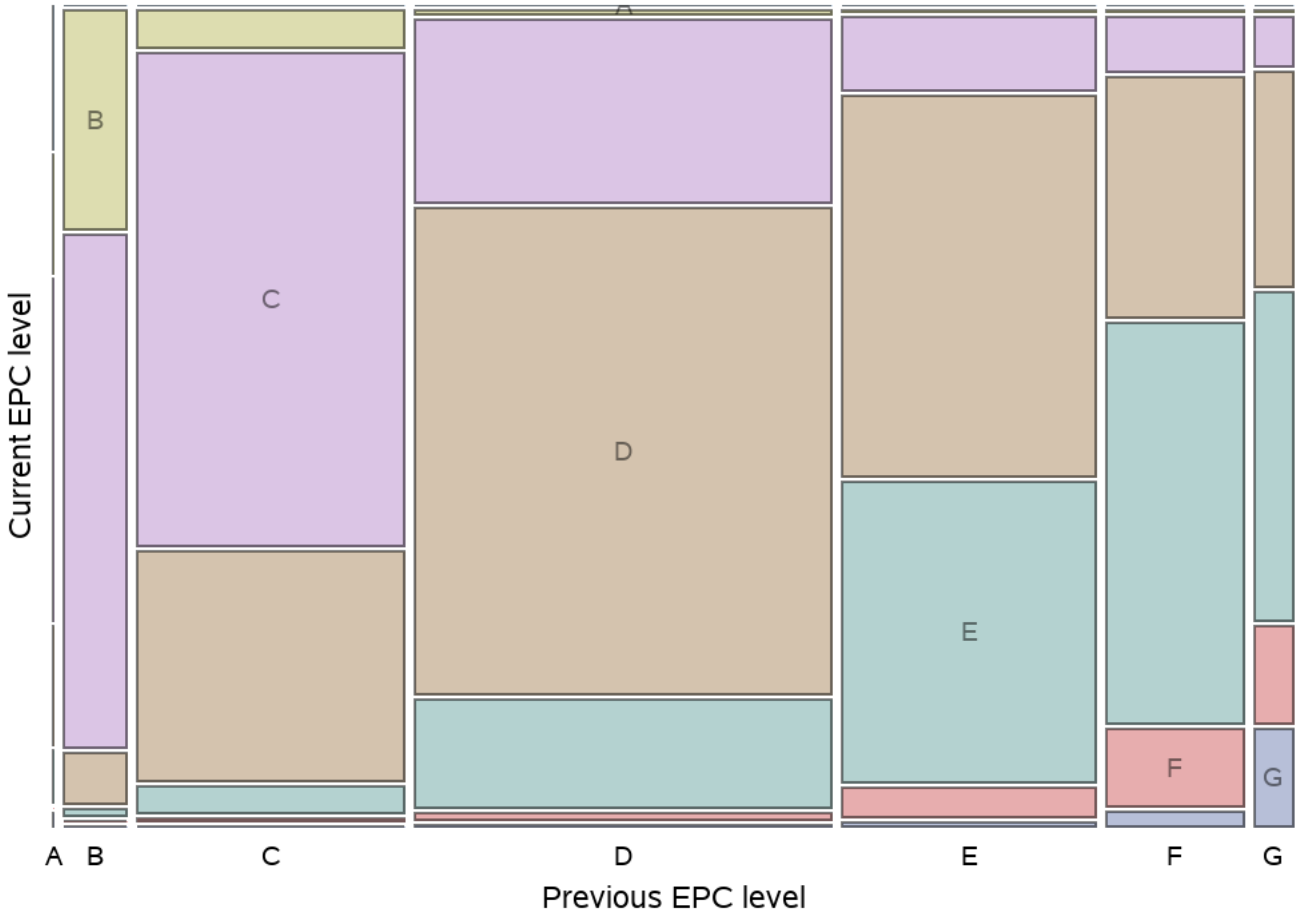
What is clear from the figure below is that there has been a shift in the levels achieved that have gone beyond EPC level E (i.e. 39-54), with the bulk of the shift occurring within the EPC level D (i.e. 55-68) and C (i.e. 69-80). This suggests that landlords are going beyond simply meeting the minimum standard of points (i.e. 39), though there is a slight increase at that value threshold.

Figure 3.1: EPC values for current and previous EPC for non-exempt PRS properties



This trend in the change between the previous and the most current EPC for dwellings in bands E, F and G are towards achieving (for the most part) at least level E and many have sought level D. Overall, however, there is an upward trend in the EPC levels being achieved between the two certificates.

Figure 3.2: Change between previous and current EPC for non-exempt PRS dwellings



What is clear, however, is that PRS landlords are not necessarily proactively seeking new EPCs whether or not their property has been refurbished and their performance improved. Figure 3.3 below shows that the majority of certifications were issued around the 10-year mark, as required by statute, though a sizable number have seemingly renewed their EPC within 2.5 years of their first being issued.

Figure 3.3: Years between previous and current EPC for all PRS dwellings

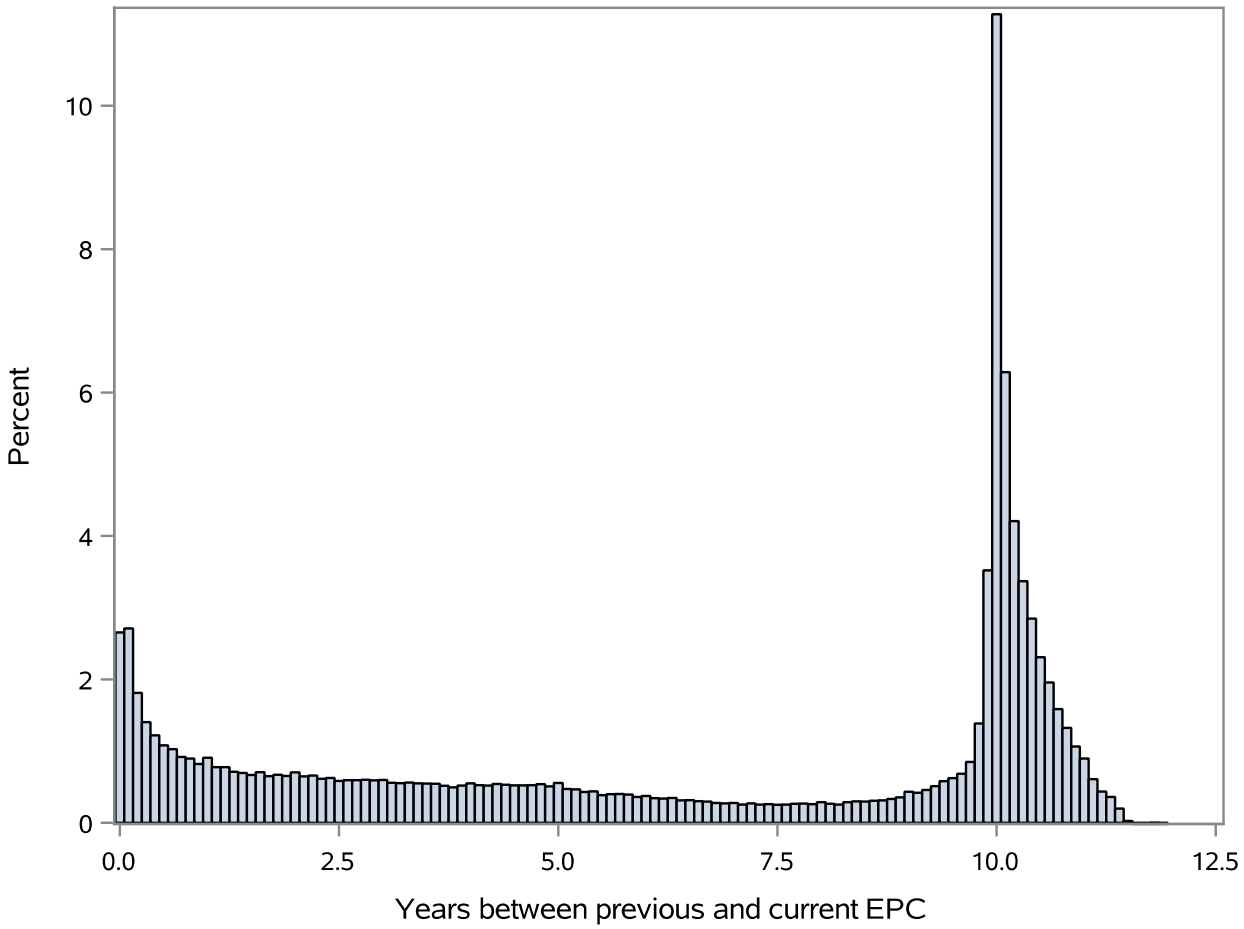


Table 3.5 below shows that dwellings with higher EPC levels (C and above) tended towards longer average time between issuing of EPC, i.e. 8-10 years, while less efficient properties tended to have their EPC issued after around 5 years. The implication being that PRS landlords of worse efficiency dwellings have been making some efforts to showcase improvements.

Table 3.5: Years between previous and current EPC by EPC level for all PRS dwellings

	Years between previous and current EPC	
Previous EPC level	**Mean**	**Median**
A/B	8.72	10.03
C	7.77	9.98
D	6.31	7.58
E	5.88	5.85
F	5.25	5.02
G	5	4.48
All	6.52	8.39

3.3 Comparison between EPC database and the English Housing Survey

The above analysis shows that as of 1 April 2020 there were 2,969,157 properties with EPCs marked as private rental. Of those, 2,965,455 were without an exemption and 129,557 of these were in level F&G, or 4.4% of all listed PRS dwellings are shown to be 'stated non-compliant', i.e. have their most recent EPC as being in band F or G and not being on the exemption list.

According to the English Housing Survey (EHS) 2018-19, there are 4,804,782 PRS properties, of which 255,747 properties (5.3%) are estimated to be in EPC band F&G. This implies that according to the database, the estimated number of PRS without an EPC marked as 'rental (private)' within the EPC 2020 is somewhere in the range of 1,800,000 properties.

The EHS is considered the definitive standard, outside the Valuation Office Agency, for describing the English dwelling stock. Comparing the EPC database to the EHS on available collected variables shows that the EHS PRS stock and the EPC PRS database have some strong points of comparison. There are slightly more EPC band E dwellings in the EPC database, slightly more small (<50m2) dwellings and a higher proportion of EPC A or B properties.

Although comprehensive comparison is not possible due to the limited number of EPC variables, the EPC database does have broadly comparable characteristics in terms of their EPC bands, floor area bands and dwelling types (see Table 3.6). Further, although sizable, the 1.8M missing EPCs might be missing at random and would allow for a comparable scaling to the whole stock to be performed.

Table 3.6: PRS EHS 2018/19 comparison to EPC database 2020 level by EPC dwelling type, floor area and dwelling type

	PRS - private rental sector	
	EHS 2018	**EPC 2020**
	Percent	**Percent**
EPC Bands		
A/B	1	4
C	31	30
D	48	43
E	14	19
F	4	3
G	1	1
All	100	100
Total Floor Area		
<50m2	17	22
50-69m2	33	30
70-89m2	29	25
90-109m2	12	12
>110m2	10	11
All	100	100
Dwelling Type		

	PRS - private rental sector	
	EHS 2018	EPC 2020
	Percent	Percent
EPC Bands		
Bungalow	5	4
Detached house	7	6
Flat	39	44
Semi-detached house	16	14
Terraced house	33	31
All	100	100

When looking at only those properties in EPC bands F & G, the proportion of the PRS lodged in the EPC Database do show differences to the EHS F & G stock (see Table 3.7) below. There are fewer 50-69m2 properties in the EPC register and more >110m2. While for property type, there are similar levels of bungalows detached dwellings and flats, though half as many semi-detached dwellings.

The impact of the under-representation of specific property types can be considered by assessing how common these properties are within the PRS housing stock. Semi-detached dwellings make up a quarter of the PRS F and G stock, so the under-representation here cannot be dismissed. It is for this reason, as well as the uncertainty around the properties that are missing from the EPC database, that caution should be taken when using the EPC register to assess compliance. The EPC data provides a useful insight, but should not be taken as conclusive evidence of the level of non-compliance.

Table 3.7: PRS EHS 2018/19 comparison to EPC database 2020 level by for EPC F & G dwellings by floor area and dwelling type

	PRS - private rental sector F&G Properties only	
	EHS 2018	EPC
Total Floor Area	**Percent**	**Percent**
<50m2	21%	22%
50-69m2	30%	22%
70-89m2	21%	22%
90-109m2	12%	13%
>110m2	16%	21%
Dwelling Type		
Bungalow	11%	8%
Detached house	14%	16%
Flat	31%	35%
Semi-detached house	26%	17%
Terraced house	19%	24%
All	100%	100%

3.4 Findings on levels of compliance across different landlord/property types

The EPC dataset provides a limited set of attributes pertaining to the dwelling characteristics, including the dwelling type, size, along with energy performance features of the dwelling, including roofs, walls, windows and main heating systems.

Table 3.8 below shows the current EPCs for non-exempt PRS dwellings. A high proportion of flats and houses have non-compliant EPCs. Flats in particular pose a problem for landlords as they may be unable to achieve a higher rated EPC without substantial costs or are restricted due to ownership or leasehold limitations. In these cases, however, it would have been expected that an exemption would be sought.

Table 3.8: Current EPC level by dwelling type

		Current EPC level						
		Not exempt						All
Property type	Built form	A/B	C	D	E	F	G	N
Bungalow	Detached	40	643	3,371	3,317	646	229	8,324
	Enclosed End-Terrace	.	19	33	30	2	1	85
	Enclosed Mid-Terrace	.	15	15	9	2	.	41
	End-Terrace	4	156	367	356	44	16	948
	Mid-Terrace	8	192	553	431	61	15	1,262
	Semi-Detached	24	710	2,508	1,618	235	124	5,238
Flat	Detached	734	6,502	6,929	3,738	551	230	18,729
	Enclosed End-Terrace	1,106	6,368	4,591	2,108	279	77	14,547
	Enclosed Mid-Terrace	2,126	5,893	2,613	999	148	51	11,841
	End-Terrace	1,559	18,124	18,954	9,096	1,098	397	49,314
	Mid-Terrace	7,051	44,421	34,955	13,782	1,550	522	102,393
	Semi-Detached	2,024	23,301	25,261	11,389	1,369	423	63,880
House	Detached	137	3,753	9,239	8,645	1,872	676	24,686
	Enclosed End-Terrace	7	979	2,105	1,434	119	21	4,670
	Enclosed Mid-Terrace	12	395	2,219	1,514	84	56	4,283
	End-Terrace	99	7,578	20,476	12,934	1,451	297	42,928
	Mid-Terrace	309	26,557	69,138	25,011	2,180	496	123,790
	Semi-Detached	169	11,228	33,301	18,317	2,389	551	66,238
Maisonette	Detached	19	290	451	313	47	10	1,136
	Enclosed End-Terrace	2	185	218	128	17	7	557
	Enclosed Mid-Terrace	16	174	136	76	5	5	412

Property type	Built form	Current EPC level						
		Not exempt						All
		A/B	C	D	E	F	G	N
	End-Terrace	16	1,124	2,207	1,197	146	60	4,760
	Mid-Terrace	103	3,420	4,765	2,053	224	101	10,697
	Semi-Detached	17	1,332	2,326	1,133	124	31	4,972
Park home	Detached	.	.	2	8	7	5	22
All		15,582	163,359	246,733	119,636	14,650	4,401	565,753

Table 3.9 shows the top elements that have changed between the previous and current EPC for all dwellings that showed an increase in the EPC level. The analysis shows that changes were concentrated in roof insulation, floor insulation, floor and roof, wall and roof insulation, and wall insulation. The implication is that insulation seems to be the primary means of achieving the improvement in EPC value, as compared to improvements in heating systems or windows.

Table 3.9: Change in energy performance elements between previous and current EPC for non-exempt PRS dwellings that experienced an increase in EPC value

Change in performance feature	All PRS dwellings		Previous F&G PRS dwellings	
	Frequency	Percent	Frequency	Percent
fabric insulation & low-E lighting	188578	64.52	36960	50.05
fabric insulation	38392	13.14	8123	11
fabric insulation, main heating upgrade & low-E lighting	29770	10.19	17803	24.11
low-E lighting	23604	8.08	3929	5.32
fabric insulation & main heating upgrade	5486	1.88	3222	4.36
heating upgrade & low-E lighting	3727	1.28	2221	3.01
main heating upgrade	2728	0.93	1587	2.15
Frequency missing	13195		2318	

Notes: fabric insulation includes: loft insulation, wall insulation, floor insulation and window upgrades; heat upgrades include: new condensing boilers (standard and combi).

3.5 Findings on changes in performance of the PRS stock

According to the English Housing Survey, energy efficiency level has experienced an increasing trend in the private rented sector. Figure 3.4 illustrates the energy efficiency rate pattern in the private rented sector from the year 2010 to the year 2018. As the figure shown, the energy efficiency band A/B remains constant while either the C rate or D rate has increased around 10% between 2010 and 2018. In contrast, the lowest rates (F/G rates) has decreased significantly during this period, which declined from 17% to 5%. The figure shows that the overall energy efficiency rate band has improved in the UK's private rented sector after the year 2010.

Figure 3.4: Energy performance levels of PRS 2010 to 2018

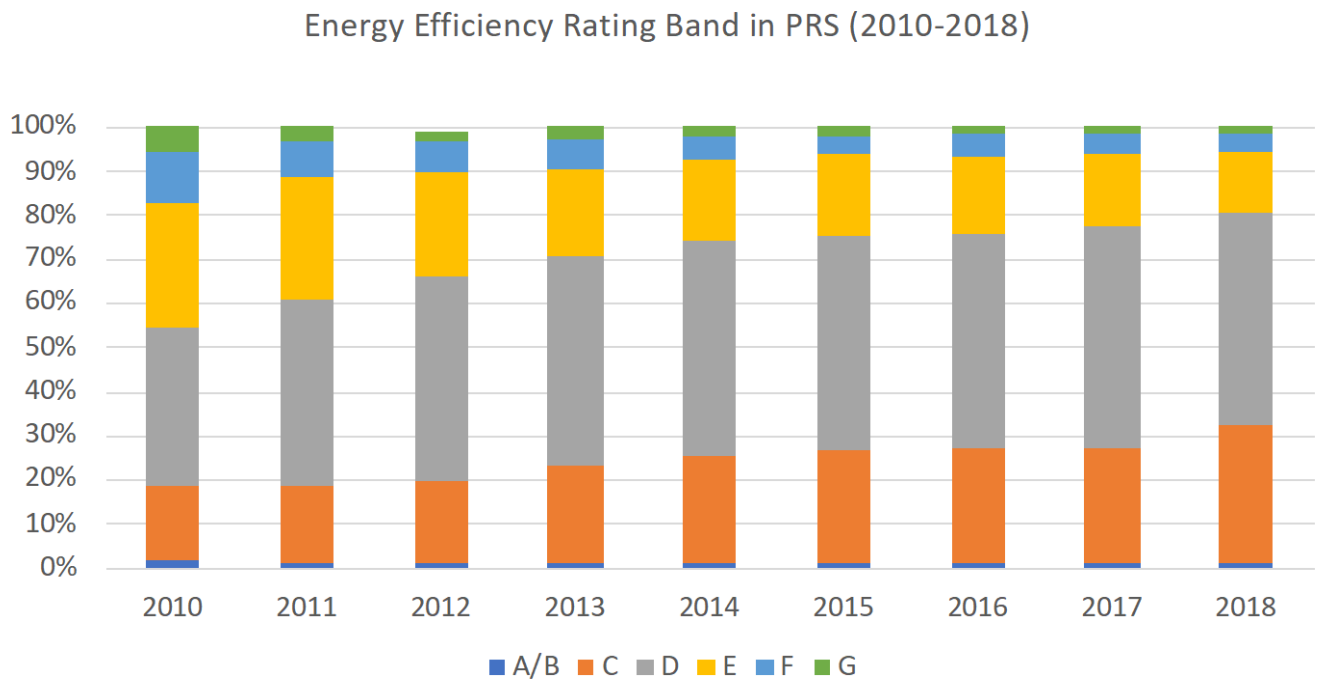


Table 3.10 shows there has been a gradual rise in the investment of energy efficient technologies in the private rented sector from 2010 to 2018. The analysis shows that up to 2018 there has been an increase in the level and rate of growth in central heating, condensing boilers and cavity insulation within the PRS.

Table 3.10: Number of PRS dwelling by key technology and rate of change

							thousands of dwellings			Rate of change 2016 to 2018
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
central heating	2,983	3,265	3,335	3,708	3,875	3,965	4,066	4,060	4,070	0.06
condensing-combination boiler	913	1,126	1,301	1,643	1,879	2,161	2,309	2,371	2,537	4.82
cavity with insulation	719	829	927	1,075	1,422	1,366	1,420	1,419	1,479	2.07

4 Impacts on energy efficiency, energy cost and CO2 emissions

Key points:

- The impact of the regulations was measured by assessing impact on three treated groups (private rental properties, further split into established and recent private rental properties)
- This interim analysis found that the regulations have already had a statistically significant impact on the energy efficiency and environmental impact of private rental sector properties.
- This has been observed both in terms of the odds of achieving an EPC rated E or above, and in terms of the increase in the SAP and EI rate.
- Properties covered by the regulations are much more likely to meet the required level of energy efficiency, with the odds of achieving an EPC rated E or above in the properties affected by the regulations being at least 8 times the level observed in the control group.
- Properties affected by the regulation were found to display an increase of about 5 SAP points in their SAP rate compared to properties not affected by the regulations, and of about 3 EI points in the EI rate.
- The impact of the regulations was found to be higher in those units with the lowest SAP ratings before the introduction of the regulations. Energy efficiency characteristics of the treated groups radically differ from the control group after the introduction of the regulations.
- Results on the impact of the regulations are robust to subsampling the treated and control groups based on the characteristics of the properties. The increase in the SAP and EI rate brought about by the new algorithm introduced in April 2018 appears to be related to walls type and method of construction.
- None of the property characteristics used in this study was found to play a considerable role in explaining the different impact of the regulations on recent and established rental properties.
- The impact of the regulations on energy costs implies an average reduction of about £120 in annual energy costs, although savings are higher in those units with the lowest SAP ratings before the introduction of the regulations.
- The impact of the regulations on CO2 emissions implies average annual savings up to 500 kgCO2 per year.
- Market wide impacts of the regulations implied reduction up to £50 million in annual costs and 144 kilotons in CO2 emissions.

4.1 Introduction

The impact of the regulations on energy efficiency has been assessed by adopting two methodologies, Difference-in-Differences (DiD) and Change-in-Changes (CiC), three different variables of interest and conducting robustness analysis in the form of a modified version of DiD and the implementation of DiD in subsamples of the treated and control groups. The fact that the results contained in this extensive body of evidence overwhelmingly unanimously point at the regulation affecting the energy efficiency of the properties being affected is a significant result of considerable value to policy-makers.

4.2 Samples used in the analysis

The sample used in the DiD and CiC differ from the wider EPC dataset as only properties with the following characteristics can be can be used in the analysis:

- Properties have at least two EPC issued within specific within specific timespans, namely one before the introduction of the regulations, one after;
- EPC issued before the introduction of the regulations is either F or G rated.

When looking only at these properties, the proportion of the PRS lodged in the EPC Database do show differences to the EHS F & G stock (see Table 4.1). Difference can also be seen between the F & G properties in the EPC Database and those in the EHS F & G stock (see Table 3.4) above. There are fewer smaller properties in the Scottish properties in the EPC (which is used as control group) compared to the EHS while the opposite it is true in the case of the English and Welsh properties. There are some differences also in relation to the shares of property types. In particular, bungalows seem to be much more common in the Scottish EPC dataset used in the analysis compared to the English and Welsh counterpart, with the share in the EHS falling in between the two EPC datasets. Houses tend to under-represented in the EPC datasets compared to the EHS while flats are over-represented in the case the English and Welsh EPC dataset.

On one hand this implies that the estimates of the impact of the regulations for the treated groups used in this report – see section 4.3 and 4.4 - are likely be conservative, due to the lower impact estimated for flats, see Table 4.6, which are overrepresented in the used sample. On the other hand, as the estimates presented in this report do not take into account any ‘in-use factors’, for example any comfort taking or degradation of the technology over its lifetime, they are therefore likely to over-estimate the impact of the regulations. It is therefore helpful that these two sets of factors affect the estimates presented in this report in opposite direction, so that to an extent they offset each other. It is worth mentioning that results in section 4.5 are less likely to be affected by the over-representation of flats in the treated groups, as they are obtained based on ‘method of construction’.

Table 4.1: PRS EHS 2018/19 comparison to EPC databases for EPC F & G dwellings by floor area and dwelling type

	PRS - private rental sector properties only		All properties
	EHS 2018	EPC (England and Wales)	EPC (Scotland)
Total Floor Area			
< 50m2	21%	34%	14%
50-69m2	30%	22%	19%
70-89m2	21%	21%	28%
90-109m2	12%	11%	18%
> 110m2	16%	12%	22%
Dwelling Type			
Bungalow	11%	6%	26%
Flat	31%	54%	32%
House	59%	40%	42%

4.3 Findings on overall impacts on energy efficiency to date

Impacts of the regulation on the likelihood of achieving EPC band E or above

A quantitative estimate of the impact of the regulations on the likelihood of the properties covered by the regulations meeting the required level of energy efficiency can be obtained by running a DID in a specification with logistic functional form allowing for the binary nature of the dependent variable.[21] Results from this specification strongly point at the regulations increasing the likelihood of properties meeting the required level of energy efficiency. As one can see in Table 4.1, the estimated coefficients are very similar across treated groups (private rental, recent private rental and established private rental properties) and estimated models (the model with fixed and time effects, here named 'baseline model', and the model incorporates time-varying control variables, here named 'model with control variables'). The value of the coefficient is slightly higher for recent private rental properties than established private rental properties with the consequence that the coefficient for the treated group including both type of properties (private rental properties) falls somewhere in between. From the coefficients one can then determine the odds ratio, a key concept in logistic models. The odds are determined from probabilities and range between 0 and infinity. They are defined as the ratio of the probability of success and the probability of failure. In the case of this analysis, the odds are equal to the probability of reaching EPC band E divided by the probability of failing to do so. The odds ratio in Table 4.2 is the ratio between the odds of achieving EPC band E for the treated properties divided by the odds of achieving the same EPC band in the control group. It appears that the regulations have a very strong impact on the likelihood of

[21] This would correspond to (1) with the binary variable discussed in 2.3 as the dependent variable and logistic functional form rather than linear. The binary variable is defined as 'property improved to minimum standard of EPC band E'. In other words, if the property has been improved to meet an EPC rated E or above, the value of this variable is 1 while the value is 0 if the EPC band E has not been reached.

meeting this threshold, with odds in the treated group being between 9 and 14 times (depending on the sub-groups) the odds for the control properties.

Table 4.2: Results from binary models for the treated groups assessed in this study[22]

	Baseline model	**Model with control variables**
Private Rental Properties		
coefficients	2.48**	2.37**
odds ratio	11.99	10.73
Recent Private Rental Properties		
coefficients	2.62**	2.59**
odds ratio	13.78	13.34
Established Private Rental Properties		
coefficients	2.34**	2.24**
odds ratio	10.33	9.42

Impacts of the regulations on the SAP rate

A quantitative estimate of the impact of the regulations on the SAP rate can be obtained by running a DID in a linear model.[23] In this case interpretation of the results is slightly simpler as the estimate of the coefficient δ in (1) conveys the additional SAP rate which can be imputed to the regulations. This estimates takes into account the change in SAP points observed in the control group which is not affected by the policy. Table 4.3 presents two models, one with fixed and time effects, here named 'baseline model', and the other incorporate time-varying control variables, here named 'model with control variables'. One can see the impact is stronger in the recent private rental properties for which the effect of the regulation is estimated to be an increase in energy efficiency between 8.0 and 10.0 SAP points, depending on the estimated model. in the case of established private rental properties, the impact falls to a range between 1.3 and 3.0 SAP rates.

Again, the group including both property types falls somewhere in between with a range between 5.1 and 5.2 SAP points. All estimated coefficients are statistically significant at the 99% confidence level. in case of the private rental properties, one is able to run model incorporate properties with the pre-regulations EPC being issued between April 2015 and March 2018[24], therefore strengthening confidence on the results from this treated group. In the case of the other two treated groups in Table 4.3, only properties with the first EPC between April 2016 and March 2018 could be incorporated in the sample. In the case of established private rental properties however, only the test of parallel linear trends is non-statistically

[22] ** indicates result s significant at the 99% confidence level.
[23] This corresponds to (1) with the SAP rate as the dependent variable.
[24] Years in the table are defined according to the fiscal year so the first month of the year is April of the previous calendar year and the final month is March of the current year. As an example 2018 starts in April 2017 and ends in Mach 2018. This has been defined so as to reflect the fact that the policy is introduced in April 2018 and build year dummy variables indicating time periods only before or after the introduction of the policy.

significant while the test based on time effects is significant but only at the 10% significance level.

Table 4.3: Estimated impact of the regulations on SAP rate from the baseline DiD approach for the treated groups assessed in this study[25]

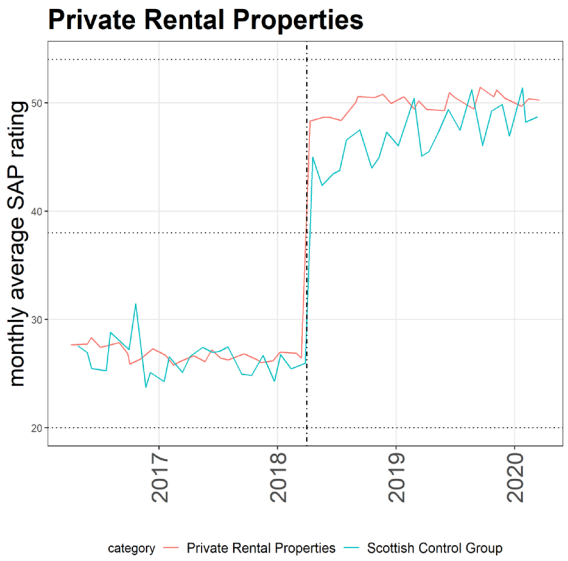
Treated	Baseline model	Model with control variables
Private Rental Properties	5.1**	5.2**
Recent Private Rental Properties	10.0**	8.0**
Established Private Rental Properties	1.3**	3.0**

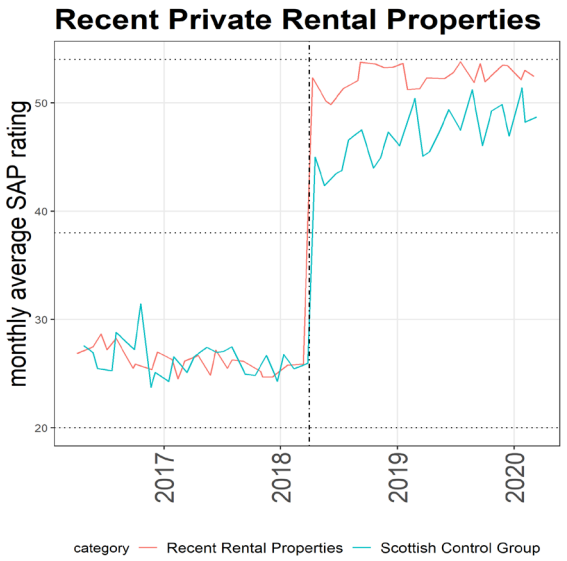
Figure 4.1 shows the monthly average SAP rates for the properties comprised in the treated (private rental, recent private rental and established private rental properties) and control groups (Scottish F or G rated properties). Only the properties with at least one EPC after the introduction of the policy and one prior to it are kept in the sample. Figure 4.1 presents graphical evidence that the assumption of parallel trend is satisfied in the period prior to the announcement of the regulations for the treated groups used in this study. This result which is confirmed by regression-based tests discussed in section 2.3.

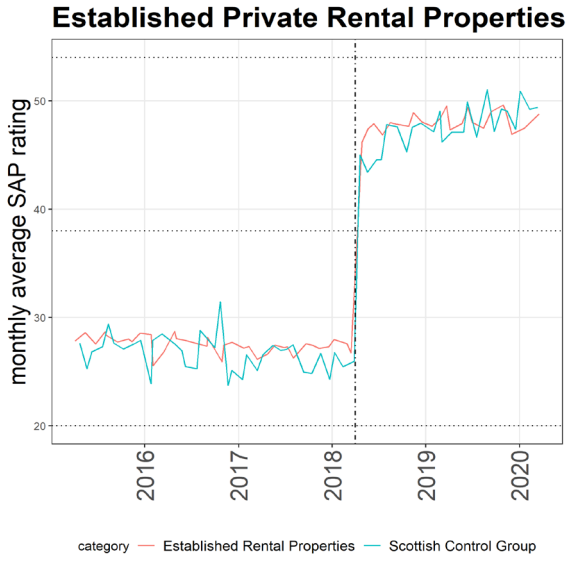
The main feature emerging from the figure is the sudden change in the average value of the EPC issues after March 2018 which can be observed both in the treated and control groups. In the case of the control group this is entirely due to a change in the algorithm used to compute the SAP rate in the EPC. This is thought to be mainly related to a change in the u-values that are assigned to solid wall properties.[26] Based on the new algorithm solid wall properties (both of traditional and non-traditional built) are more efficient than previously thought. Further investigation of the change in the algorithm is being undertaken with BRE.

[25] ** indicates results significant at the 99% confidence level.
[26] Entwistle T. 2018. New algorithms to calculate EPC ratings, https://www.landlordzone.co.uk/news/new-algorithms-calculate-epc-ratings/

Figure 4.1: Monthly average SAP rate for the properties in the treated and control groups used in this study







Robustness Approaches

Results on the impact of the regulations on the SAP rate are confirmed through the robustness approaches discussed in section 2.3. The impact of the regulations on the SAP rate estimated based on the approach in Bertrand et al (2004) addressing concerns related to possible serial correlation in the variable of interest is presented in Table 4.4. The sample for this model is obtained by incorporate all EPC issued between 2016 and 2020 for the residential properties used in this study so that an average of the EPCs before and after the introduction of the regulations could be computed and a linear model such as (1) is estimated for these two observations. In Table 4.4, one can see the impact is very similar to the impact reported in Table 4.3.

Table 4.4: Estimated impact of the regulations on SAP rate from the DiD approach allowing for potential serial correlation in the variables for the treated groups assessed in this study[27]

Treated	Baseline model	Model with control variables
Private Rental Properties	6.0**	6.2**
Recent Private Rental Properties	9.2**	8.2**
Established Private Rental Properties	2.4**	4.1**

Results on the impact of the regulations on the SAP rate are also confirmed by the application of the Change-in-Changes (CiC) method of Athey and Imbens (2006). In the case of the CiC, one can estimate the impact of the regulations for each percentile of the distribution of units in the treated group rather than estimating an average treatment effect for the whole group like in the case of the DiD. Once again, one can see the smaller impact of the regulations on the established private rental properties, by comparing the estimated impact of the policy at the 10th, 20th, 30th 40th, 60th and 80th percentile across the three treated groups presented in Table 4.5. It also becomes evident that the impact of the regulations is higher in those units with the lowest SAP rates before the introduction of the regulations. This is shown in Table 4.5, where the estimated impact decreases from the lowest to the highest percentiles, with the lowest percentile comprising the residential units with the lowest SAP rate.

Table 4.5: Results from the CiC models for the treated groups assessed in this study.

	Estimated impact	Confidence interval	Statistically significant at 95%
Private Rental Properties			
10th percentile	13.7	(11.9 - 15.4)	True
20th percentile	8.9	(7.1 - 10.7)	True
30th percentile	6.3	(5.1 - 7.5)	True
40th percentile	4.8	(3.4 - 6.3)	True
60th percentile	2.0	(0.3 - 3.6)	True
80th percentile	0.0	(-1.2 - 1.2)	False
Recent Private Rental Properties			

[27] ** indicates results significant at the 99% confidence level.

	Estimated impact	Confidence interval	Statistically significant at 95%
10th percentile	16.1	(14.6 - 17.7)	True
20th percentile	12.2	(10.7 - 13.8)	True
30th percentile	11.1	(9.6 - 12.6)	True
40th percentile	10.4	(9 - 11.8)	True
60th percentile	5.9	(4.2 - 7.7)	True
80th percentile	1.9	(0.7 - 3.2)	True
Established Private Rental Properties			
10th percentile	11.1	(9.47 - 12.64)	True
20th percentile	6.1	(4.59 - 7.59)	True
30th percentile	3.4	(2.12 - 4.7)	True
40th percentile	0.8	(-0.88 - 2.48)	False
60th percentile	-3.7	(-5.4 - -1.94)	True
80th percentile	-4.7	(-6.03 - -3.38)	True

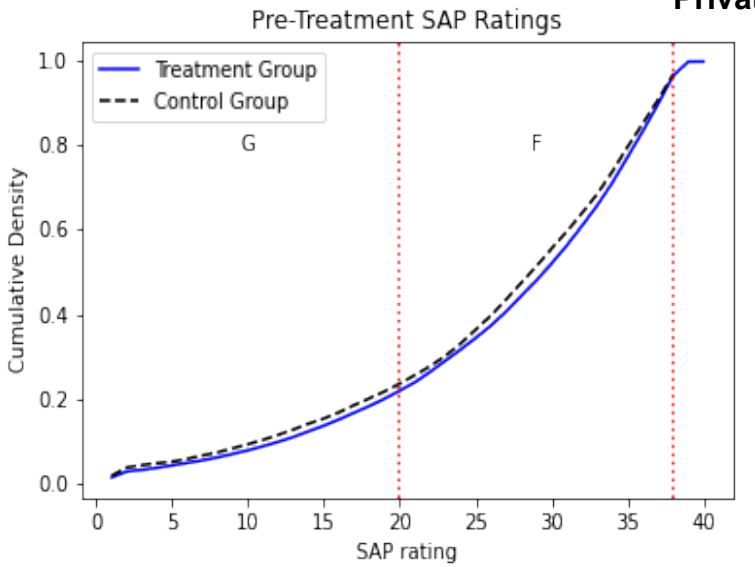
The graphs of the cumulative density function before and after the introduction of the regulations validates the use of the control group and the conclusions on the impact of the regulations on energy efficiency discussed above. The empirical cumulative density function is obtained by ordering the residential units based on the value of the SAP rate in their EPC.[28] One can notice in the graphs in the left column of Figure 4.2 that the cumulative function is very similar in the control and treated group, therefore validating the choice of the control group. Perhaps more importantly, one can see that the distribution of both groups shifts after the introduction of the regulations. The curve related to the control group shifts to the right because of the increase in the SAP rate brought about by the change in the algorithm discussed above. In the case of the treated group, the shift of the curve to the right is much stronger and, in addition, a kink at the 39 SAP rate, the threshold mandated by the regulations, take shape.[29] To the left of the threshold, representing the units not complying with the regulations, the function increases very slowly while to the right of 39 threshold the curve becomes much steeper and like in the case of the control group more or less linear.

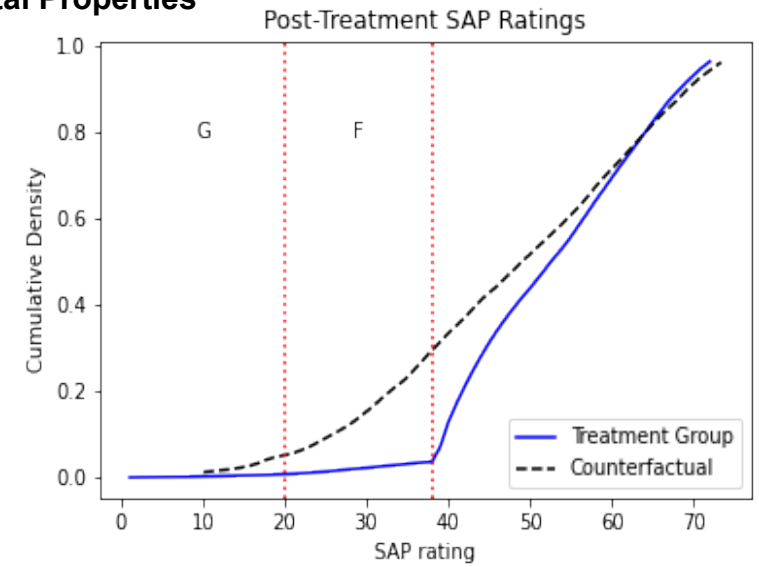
[28] This implies that each residential unit can be placed in a Cartesian coordinate system where x-axis indicates the value of the SAP rate of a specific unit and the y-axis indicates the proportion of the units which have a lower SAP rate.

[29] A SAP rate of 39 is the minimum rate required to comply with the regulations as this value implies an EPC band E. The EPC bands are as follows: EPC band A = 92-100 SAP points; EPC band B = 81-91 SAP points; EPC band C = 69-80 SAP points; EPC band D = 55-68 SAP points; EPC band E = 39-54 SAP points; EPC band F = 21-38 SAP points; EPC band G = 1-20 SAP points.

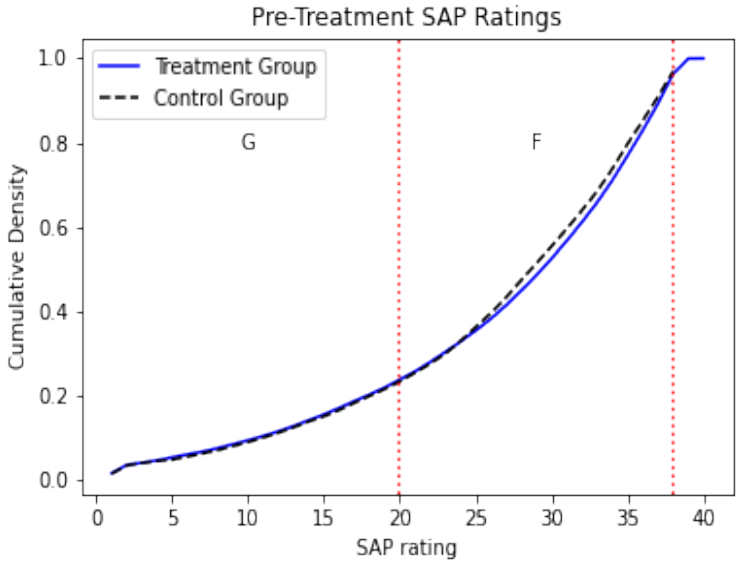
Figure 4.2a: Cumulative density function in pre-treatment and post-treatment periods for treated groups assessed in this study

Private Rental Properties





Recent Private Rental Properties



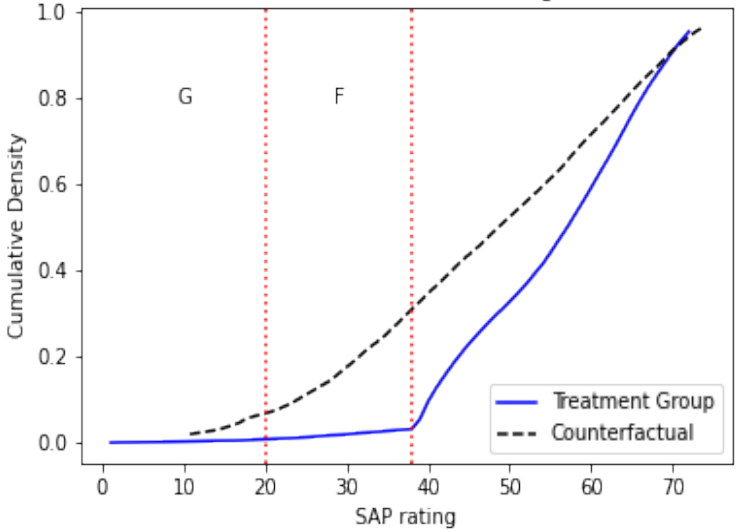
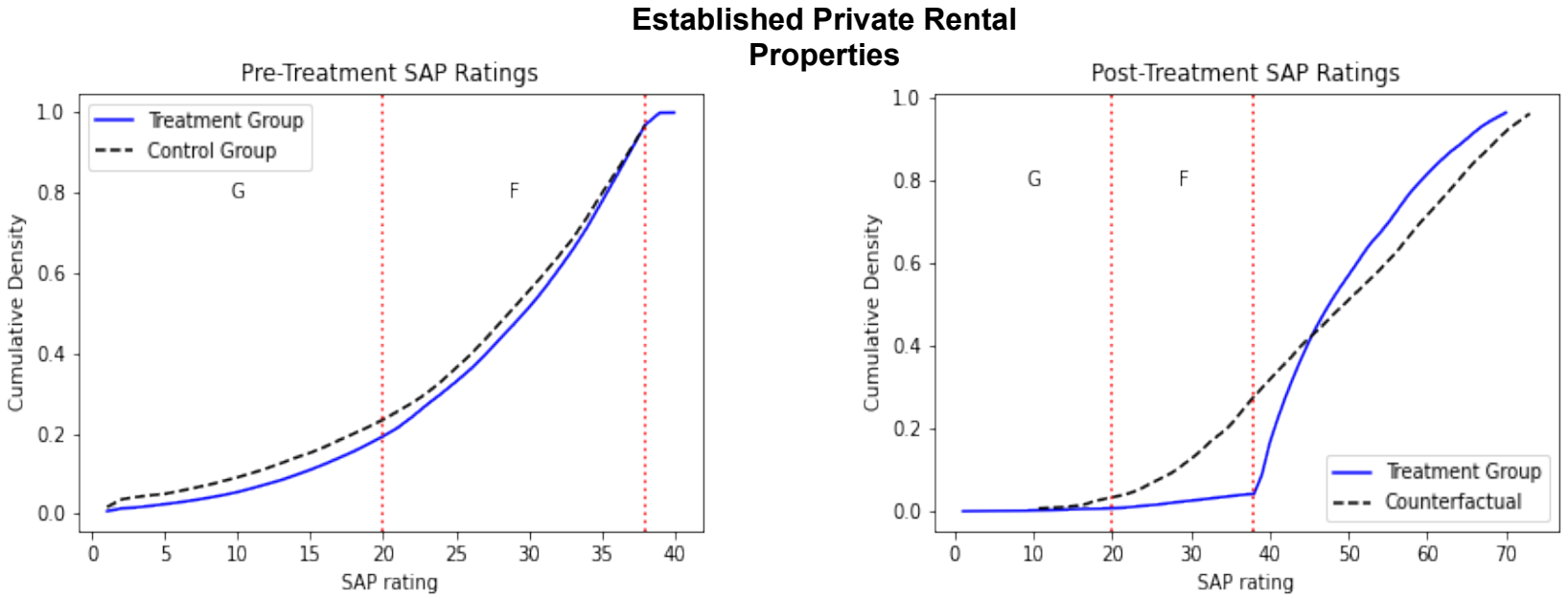


Figure 4.2b. Cumulative density function in pre-treatment and post-treatment periods for treated groups assessed in this study



An indicator of the extent to which the regulations have driven the increase in the SAP rate observed in the treated group can be built by computing the percentage of properties in the treated and control groups that after the regulations have a SAP rate between 29 and 38 and between 39 and 48, i.e. 10 points to the left and to the right of the minimum required to obtain an EPC with band E mandated by the regulations. As one can see in Table 4.6, at most only 2% of the properties have an EPC with SAP rate between 29 and 38 in any of the three treated groups. A minimum of about 25% of the properties in the three treated groups however have an EPC with SAP rate between 39 and 48. The corresponding percentages in the control group are 17% and 21%, reflecting the fact that the shape of the distribution to the right of the 39 SAP rate threshold is not significantly different from the shape to its left in the case of the properties not affected by the regulations (i.e. the control group). This can also be seen in Figures 4.2a and 4.2b.

Table 4.6: Percentages of units with SAP rate between 29 and 38 and between 39 and 48 in the treated and control groups assessed in this study.

	Percentage of properties with SAP rate between 29 and 38	**Percentage of properties with SAP rate between 39 and 48**
Private Rental Properties	2%	37%
Recent Private Rental Properties	1%	26%
Established Private Rental Properties	2%	49%
Control group	17%	21%

Results on the impact of the regulations on energy efficiency are also confirmed by running the same models across subsamples of the treated and control groups used in the study. This analysis is interesting to explore 1) the factors which are related to the change in the EPC values taking place after the introduction of the new algorithm and 2) those which might explain the systematic difference in the impact of the policy in recent and established private rental properties. One would expect the impact of the regulations to be fairly similar in the subsamples generated according to the factors influencing the change in SAP rate when the new algorithm was introduced. Similarly, estimated differences with regard to the impact of the regulations in established and recent rental properties should decrease in the subsamples generated by the factors influencing the different impact in the two treated groups.

In the case of property type, Table 4.7 shows that regulations always a have a smaller impact in flats rather than houses but the impact is considerably different across treated groups. As an example the impact in houses which are established rental properties is about 3 SAP points, while it is well above 10 in houses part of recent properties rental properties. As a consequence, property type is not likely to be an explanatory factor for the sudden change in the SAP rate brought about by the new algorithm, and the differential impact of the regulations across treated groups. The same can be concluded for access to the gas grid. In fact, higher impact of the regulations is observed once (in the case of recent private rental properties) among the properties on the grid and once (in the case of established private rental properties) among those without access to it. The same conclusion can be drawn for the main fuel used for heating - higher impact of the regulations is observed once among units using gas and once among those using electricity. The impact of the size of the properties is promising in the case of established private rental properties (where the impact of the regulations is about 2-3 SAP points across the three categories of size. It is less so in the case of recent private rental properties where the impact in small properties is about half the size in the other two categories. Also walls type and method of construction seem to play a role in the change in the

EPC values taking place after the introduction of the new algorithm, as the estimated impact of the regulations is generally quite similar. On the other hand, the difference between rent and established rental properties persists.

Table 4.7: Estimated impact of the regulations on SAP rate from the baseline DiD approach across subsamples of treated and control groups assessed in this study[30]

	assumptions met?	Baseline model	Control factors
Private Rental Properties		5.1**	5.2**
flat	yes	0.3	2.2**
house	yes	11.5**	7.8**
on gas grid	yes	8.3**	7. 5**
off gas grid	yes	4.9**	4.3**
main fuel: electricity	yes	4.2**	4.0**
main fuel: gas	yes	6.6**	7.2**
size: small	yes	1.2	3.0**
size: medium	yes	8.2**	6.9**
size: large	yes	9.2**	6.0**
walls type: cavity	yes	5.6**	4.9**
walls type: solid	yes	7.9**	5.6**
method of construction: traditional	yes	7.1**	6.1**
method of construction: non-traditional	yes	6.1**	5.5**
Recent Private Rental Properties		10.0**	8.0**
flat	yes	2.0*	3.0**
house	no – 95%	15.1**	11.4**
on gas grid	yes	10.8**	10.5**
off gas grid	yes	7.3**	5**
main fuel: electricity	yes	4.5**	4.2**
main fuel: gas	yes	9.0**	10.4**
size: small	yes	5.4**	4.6**
size: medium	yes	13.3**	10.3**
size: large	yes	12.5**	9.0**
walls type: cavity	yes	9.4**	7.6**
walls type: solid	yes	11.3**	8.4**
method of construction: traditional	yes	10.7**	8.9**
method of construction: non-traditional	yes	9.0**	6.0**
Established Private Rental Properties		1.3 **	3.0**
flat	yes	-1.4+	1.8*
house	yes	2.6**	3**
on gas grid	yes	2.9**	1.6

[30] ** indicates results significant at the 99% confidence level, * at the 95% confidence level and + at the 90% level.

	assumptions met?	Baseline model	Control factors
off gas grid	yes	2.1**	3.8**
main fuel: electricity	yes	4.2**	3.9**
main fuel: gas	yes	0.2	-1.0
size: small	yes	-0.9	2.1*
size: medium	no – 90%	2. 9**	2.8**
size: large	yes	2.6**	2.4**
walls type: cavity	yes	1.3+	2.3**
walls type: solid	yes	2.7**	3.3**
method of construction: traditional	yes	2.0**	3.6**
method of construction: non-traditional	yes	4.4**	5.3**

Impacts of the regulations on energy cost

Impact of the regulations on energy costs has been computed based on the relationship between the SAP rate and expected cost of energy consumed within the home described in 2.3. Based on the BRE formula, the regulations delivered annual savings equal to about £120 per year. Savings are higher in the case of recent rental properties (£195 when using the baseline models with time and fixed effects only and £243 when using the model incorporating additional control variables) compared to established private rental properties for which costs savings are estimated to be £33 or £72, depending on the model being used.

It should be noted that the calculation of costs from SAP rating has two implications for interpretation of findings:

- The findings presented here do not account for 'in-use factors', for example any comfort taking or degradation of the technology over its lifetime. They are therefore likely to over-estimate the impact of the regulations if compared to the policy impact assessments.
- The findings presented here are presented in 2012 energy prices. Caution should be taken when comparing to the impact assessments for the regulations which use 2013 prices.

Table 4.8: Computed reduction in annual energy cost imputed to the regulations based on the results presented in Table 4.3

Treated	Baseline model	Model with control variables
Private Rental Properties	£122	£124
Recent Private Rental Properties	£195	£243
Established Private Rental Properties	£33	£72

Impact of the regulations on energy costs has also been easily computed based on the results obtained from the CiC estimator in Table 4.4. The results in Table 4.9 show the extent of the variation in the savings delivered by the regulations. As one would expect these are particularly

high for the properties in the percentiles of the distribution, i.e. with a very low SAP rates. Annual savings above £500 can be attribute to the regulations.

Table 4.9: Computed reduction in annual energy cost imputed to the regulations based on the results presented in Table 4.4

	Private Rental Properties	Recent Private Rental Properties	Established Private Rental Properties
10th percentile	449	535	356
20th percentile	267	364	182
30th percentile	174	299	96
40th percentile	122	258	21
60th percentile	49	146	-91
80th percentile	0	47	-117

A quantitative estimate of the impact of the regulations on the SAP rate can be obtained by running a DID in a linear model.[31] In this case interpretation of the results is slightly simpler as the estimate of the coefficient δ in (1) conveys the additional SAP rate which can be imputed to the regulations. This estimates takes into account the change in SAP points observed in the control group which is not affected by the policy. Table 4.3 presents two models, one with fixed and time effects, here named 'baseline model', and the other incorporate time-varying control variables, here named 'model with control variables'. One can see the impact is stronger in the recent private rental properties for which the effect of the regulation is estimated to be an increase in energy efficiency between 8.0 and 10.0 SAP points, depending on the estimated model. in the case of established private rental properties, the impact falls to a range between 1.3 and 3.0 SAP rates. Again, the group including both property types falls somewhere in between with a range between 5.1 and 5.2 SAP points. All estimated coefficients are statistically significant at the 99% confidence level. in case of the private rental properties, one is able to run model incorporate properties with the pre-regulations EPC being issued between April 2015 and March 2018[32], therefore strengthening confidence on the results from this treated group. In the case of the other two treated groups in Table 4.3, only properties with the first EPC between April 2016 and March 2018 could be incorporated in the sample. In the case of established private rental properties however, only the test of parallel linear trends is non-statistically significant while the test based on time effects is significant but only at the 10% significance level.

4.4 Findings on overall impacts on CO2 emissions

Computation of the impact of the regulations on CO2 emissions requires the estimation of the impact of the EI rate and then the conversion into CO2 emissions by using the BRE formula described in Section 2.3. Reflecting the results presented for the SAP rate, the impact is stronger in the recent private rental properties for which the effect of the regulation is estimated to be an increase in EI rate between 6.7 and 8.0 EI points, depending on the estimated model.

[31] This corresponds to (1) with the SAP rate as the dependent variable.

[32] Years in the table are defined according to the fiscal year so the first month of the year is April of the previous calendar year and the final month is March of the current year. As an example 2018 starts in April 2017 and ends in Mach 2018. This has been defined so as to reflect the fact that the policy is introduced in April 2018 and build year dummy variables indicating time periods only before or after the introduction of the policy.

In the case of the sample including both property types the impact of the regulations is estimated to be an increase between 3.0 and 3.4 EI points. In the case of established private rental properties, all models violate the parallel trend assumptions at the 5% significance level. Table 4.10 reports the model incorporating properties with the pre-regulation EPC being issued between April 2016 and March 2018, for the sake of completeness, although these results are not considered reliable. The same time span is used in the estimation of the impact of the regulations on recent private rental properties, while in the case of the sample comprising both types of properties, those with the first EPC dating back to April 2015 could be incorporated in the sample.

It should be noted that the calculation of carbon savings from SAP ratings has two implications for interpretation of findings:

- The findings presented here do not account for 'in-use factors', for example any comfort taking or degradation of the technology over its lifetime. They are therefore likely to over-estimate the impact of the regulations if compared to the policy impact assessments.
- The findings presented here are presented in 2012 carbon values. Caution should be taken when comparing to the impact assessments for the regulations which use 2013 prices.

Table 4.10: Estimated impact of the regulations on Environmental Impact rate from the baseline DiD approach for the treated groups assessed in this study[33]

Treated	Baseline model	Model with control variables
Private Rental Properties	3.0**	3.4**
Recent Private Rental Properties	8.0**	6.7**
Established Private Rental Properties[34]	-1.4*	-0.4

Results on the impact of the regulations on the EI rate are confirmed by running the same models across subsamples of the treated and control groups used in the study, an approach described in Section 4.2 for the SAP rate. As discussed above subgroup analysis is interesting to explore 1) the factors which are related to the change in the EPC (and EI) values taking place after the introduction of the new algorithm and 2) the factors which might explain the systematic difference in the impact of the regulations in recent and established private rental properties. The results in Table 4.11, confirm the result shown in Table 4.7 for energy efficiency.

Regulations have had a smaller impact in flats rather than houses with the impact being very different across treated groups like in the case of the SAP rate. In the case of access to the gas grid, the properties on the grid tend to be more positively affected by the regulations, confirming results for the SAP rate. The same conclusion can be drawn for the main fuel used for heating, with use of gas as heating in fuel in rental properties tending to be associated with higher impact of the regulations. In the case of the size of the properties, the impact of the regulations is highest in medium-sized properties, followed by large properties and small

[33] ** indicates results significant at the 99% confidence level.
[34] As parallel the trend assumption is violated in the case of established Private Rental Properties, these results are not reliable.

properties, with the size of the impact however differing across treated groups. Both walls type and method of construction seem to play a role in the change in the EI values taking place after the introduction of the new algorithm, as the estimated impact of the regulations is generally quite similar, with the exception of the established private rental properties where results tend not to be statistically significant and not to meet the assumption of parallel trend. Like in the case of EPC rate, however, the difference in the impact of the regulations across treated groups persists.

Table 4.11: Estimated impact of the regulations on EI rate from the baseline DiD approach across subsamples of treated and control groups assessed in this study[35]

	Assumptions met?	Baseline model	Control factors
Private Rental Properties		3.0**	3.4**
flat	yes	-2.3**	-0.3
house	yes	8.1**	6.2**
on gas grid	yes	5.3**	4.6**
off gas grid	no – 5%	1.2*	1.6**
main fuel: electricity	yes	1.4*	1.4*
main fuel: gas	yes	5.4**	4.3**
size: small	yes	-1.1	0.7
size: medium	yes	6.8**	5.9**
size: large	yes	4.6**	3.4**
walls type: cavity	no – 5%	2.8**	2.4**
walls type: solid	yes	3.4**	3.5**
method of construction: traditional	yes	3.2**	3.2**
method of construction: non-traditional	yes	3.8**	3.8**
Recent Private Rental Properties		8.0**	6.7**
flat	yes	0.9	2.0**
house	yes	11.6**	9.8**
on gas grid	yes	7.9**	7.0**
off gas grid	yes	5.8**	4.0**
main fuel: electricity	yes	3.2**	3.0**
main fuel: gas	yes	6.5**	6.5**
size: small	yes	3.1**	3.4**
size: medium	yes	11.4**	10.1**
size: large	yes	8.6**	6.6**
walls type: cavity	yes	7.5**	5.9**
walls type: solid	yes	8.3**	7.2**
method of construction: traditional	yes	7.9**	6.8**
method of construction: non-traditional	yes	7.2**	7.0**

[35] ** indicates results significant at the 99% confidence level, * at the 95% confidence level and + at the 90% level.

	Assumptions met?	Baseline model	Control factors
Established Private Rental Properties		-1.44**	-0.38
flat	yes	-4.0**	-1.6*
house	yes	-0.6	0.4
on gas grid	yes	0.2	-1.1
off gas grid	no – 1%	-1.9**	-0.2
main fuel: electricity	yes	0.6	0.6
main fuel: gas	yes	-0.3	-2.
size: small	yes	-3.8**	-1.1
size: medium	no – 5%	0.3	0.3
size: large	yes	-1.2	-1
walls type: cavity	no – 1%	-3.3**	-1.8*
walls type: solid	yes	-1.2.	0
method of construction: traditional	no – 5%	-1.8**	-0.5
method of construction: non-traditional	yes	0.9	1.6

Finally, in terms of the impact on CO2 emissions, computed based on the relationship between the EI rate and expected emissions in 2.3, the regulations delivered annual savings of up to 500 kgCO2 per year. In the case of recent private rental properties, savings were at least double, namely 1,150 or 1,000 kg CO2 per year in the baseline model and the model incorporating additional control variables, respectively. The impact of the regulations in the case of established properties is reported for completeness in Table 4.12, although those results are not reliable due to the assumptions of parallel trends.

Table 4.12: Computed reduction in annual CO2 emissions, measured in kgCO2 per year, based on the results presented in Table 4.10

Treated	Baseline model	Model with control variables
Private Rental Properties	445	501
Recent Private Rental Properties	1,156	987
Established Private Rental Properties[36]	-233	-6

4.5 Market wide impacts

Market wide impacts for energy costs and CO2 emissions can be computed by scaling up the average impact on single homes through the methodology discussed in Section 2.3.3. Based on information from the EHS[37], 303,000 properties were estimated to be EPC-rated F and G in

[36] As parallel the trend assumption is violated in the case of established Private Rental Properties, these results are not reliable.
[37] This is taken from Annex Table 2.7: Energy efficiency rating bands, by tenure, 2007 and 2017.

2017. The robustness analysis in 4.2 and 4.3 revealed that walls type and method of construction are the variables which most influence the change in the SAP and EI score introduced by the change in the algorithm in April 2018. Considering that results in the case of walls type are not reliable when implanting DiD for the EI score across subgroups created by this variable, as evidenced by the rejection of the parallel trend assumption in Table 4.10 for Private Rental Properties with cavity wall, method of construction is used as scaling up variable. From the analysis of the EHS dataset one can find that 93% of the PRS properties rated F and G in 2017 were built based on a traditional method of construction and 7% with a non- traditional method.

The first step consists in converting the impact of the regulations on the average PRS property built with a traditional and a non-traditional method of construction (shown in Table 4.7 and Table 4.11) into annual energy cost and CO2 savings by using the formula in BRE (2014)[38]. The results are shown in Table 4.13. Bearing in mind a compliance rate of 96% and the number of properties estimated to be EPC-rated F and G in the EHS, one can conclude that the regulations have delivered up to 50 million pounds cost savings (50 million pounds when using the baseline model and 43 million when using the model with additional variables) and 144 kiloton CO2 savings.

Table 4.13: Computed average reduction in annual energy cost and CO2 emissions of the regulations based on the results presented in Table 4.6 and Table 4.10.

	Baseline model	**Model with control variables**
Annual energy cost savings (£)		
Traditional	173	148
Non-traditional	148	133
Annual CO2 savings (kgCO2)		
Traditional	489	489
Non-traditional	581	581

[38] BRE (2019) SAP 2014 SAP 2012The Government's Standard Assessment Procedure for Energy Rating of Dwellings, www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf
www.bregroup.com/wp-content/uploads/2019/10/SAP-10.1-01-10-2019.pdf

5 Conclusions

Key points:

- This interim analysis found that the regulations have already had a clear and statistically significant impact on the level of compliance and the level of energy efficiency of private rental sector properties.
- Compliance level among the PRS stock was 96% as of 1 April 2020
- PRS landlords have generally sought to comply with the regulation showing a considerable drop in non-compliant properties preceded the compliance cut-off date
- The majority of dwellings that had previously been in EPC level F&G, and who experienced an increase in their EPC level, had installed a form of insulation, either roof, wall or floor and their combination
- Properties covered by the regulations are much more likely to meet the required level of energy efficiency, with the odds of achieving an EPC rated E or above in the properties affected by the regulations being at least 12 times the level observed in the control group.
- Properties affected by the regulation were found to display an increase of about 5 SAP points in their SAP rate compared to properties not affected by the regulations, with the impact varying between about 2 SAP points in established private rental properties and up to 9 SAP points in recent private rental properties.
- Results on the impact of the regulations are robust to subsampling the treated and control groups based on the characteristics of the properties.
- The increase in the SAP rating brought about by the new algorithm introduced in April 2018 appears to be related to property size, walls type and method of construction
- The impact of the regulations on energy costs implies an average reduction of about £120 in annual energy costs, although savings are higher in those units with the lowest SAP ratings before the introduction of the regulations.
- The impact of the regulations on CO2 emissions implies average annual savings up to 500 kgCO2 per year.

5.1 Introduction

The Energy Efficiency (Private Rented Property) (England and Wales) (Amendment) Regulations 2016 has mandated a minimum level of energy efficiency for privately rented property in England and Wales. These properties were required to achieve an Energy Performance Certificate (EPC) with a minimum of band E. The EPCs are certificates indicating the energy efficiency of domestic and non-domestic properties through an A-G labelling system with A being the most efficient properties and G the least efficient ones. The regulations essentially outlawed privately rented properties with an EPC band equal to F or G, unless they

obtained an exemption granted on the basis of a limited set of specific circumstances. Non-compliance with the regulations result in a fine of up to £5,000 for the landlord. Local authorities in England and Wales are responsible for enforcing compliance with the regulations.

This impact assessment focused on the analysis of the compliance with the regulations and their impact on the energy efficiency of the affected properties, as measured by the 'Standard Assessment Procedure' (SAP) rate included in the EPCs.[39] The SAP score underlines the EPC bands and in particular one needs a minimum SAP rate of 39 to achieve the EPC band E mandated by the regulations. The analysis of compliance assessed the overall compliance with the regulations and the extent to which compliance rates differed across residential units with different characteristics. The analysis of the impact of the regulations on energy efficiency estimated the impact of the regulations on likelihood of a residential unit attaining the minimum EPC band and their impact on the SAP score.

The impact assessment was complicated by the fact that a new algorithm was introduced in April 2018 that generated increased SAP rates for the properties being assessed. This impact manifest itself in both the properties affected by the regulations and those not being affected so that it cancelled out when estimating the impact of the regulations in the affected properties compared to those not being affected. Despite this hurdle, it was concluded that the introduction of the regulations had a very clear and statistically significant impact on both the compliance and the level of energy efficiency.

5.2 Conclusions on the overall impacts of the regulations to date

Compliance with the regulations

Compliance levels among the PRS to the regulations are approximately 96%, with approximately 129,557 properties remaining in F&G by 1 April 2020. The distribution analysis shows that a considerable drop in non-compliant properties preceded the compliance cut-off date, meaning that PRS landlords have generally sought to comply with the regulation. Many of the worst performing homes (i.e. EPC lower than E) had EPC transaction dates of around 5 years, compared to those in EPC C and above whose replacement span was around the required 10 years.

Of those dwellings that had previously been in EPC level F or G, and which experienced an increase in their EPC rate, the majority had installed a form of insulation, either roof, wall or floor and their combination. The focus on insulation, as compared to heating system improvements, means that actions outside of other regulations (i.e. gas safety checks) are driving performance improvements.

For the remaining non-exempt dwellings, there is no currently discernible pattern between their being stated non-compliant. It is unclear if these dwellings are simply not taking action or whether unknown characteristics are acting as limiting factors, such as landlord circumstances, lack of tenancy.

[39] The SAP score is an index between 1 and 100 allowing the comparison of energy efficiency across different properties. The higher the SAP rate, the higher the energy efficiency of a home.

Overall, the regulations have been effective at shifting the majority of the PRS stock to achieve the desired EPC level E.

Conclusions on the impact of the regulations on energy efficiency

This interim analysis found that the regulations have already had a clear and statistically significant impact on the energy efficiency of private rental sector properties, as measured by the likelihood of **achieving** the required EPC band E and the underlying SAP rate. This occurred in all the three threated groups used in the analysis, namely:

- 'Established Private Rental Properties' (units with an F or G EPC band prior to the regulations which were classified as privately rented both before and after the regulations),
- 'Recent Private Rental Properties' (units with an F or G EPC band prior to the regulations which are classified as privately rented only after the introduction of the regulations) and
- 'Private Rental Properties' (simply the sum of the other two groups).

Scottish properties with a F or G rated EPC issued before the introduction of the regulations in England and Wales were used as control group.

As a consequence of the introduction of the regulations, the most inefficient properties in the privately rental market, namely those with an F or G Energy Performance Certificate (EPC) band have been much more likely to increase their level of energy efficiency to a minimum of an E-rated EPC. This result, which is robust across treated groups, indicates that the odds of achieving an EPC band E or above in the properties affected by the regulations is at least 8 times the level observed in the control group.

The positive impact of the regulations on energy efficiency was confirmed by analysis the increase in the SAP rate. The impact of the regulations on the energy efficiency of private rental properties has been estimated to be about 5 SAP points. Estimated impact, however, varies between about 1 SAP points in established private rental properties and up to 10 SAP points in recent private rental properties. It was also found that the impact of the regulations is higher in those properties with a lower SAP rates before the introduction of the regulations. As additional evidence supporting the impact of the regulations, control and treated groups presented strong similarities before the introduction of the regulations, but radically differed after the regulations took effect. As an example, after the introduction of the regulations about 2% of the affected properties have an SAP rate between 29 and 38 while a minimum of about 37% have a rate between 39 and 48. These percentages for the control group are 17% and 21% respectively.

The impact of the regulations was also estimated based on the characteristics of the properties affected by the regulations. This also enabled the analysis of the characteristics likely to influence the change in the SAP score introduced by the new algorithm mentioned above. Property size, walls type and method of construction are likely to influence the increase in the SAP rate obtained from the new algorithm. On the other hand, none of the variables considered was found to play a considerable role in explaining the different impact of the regulation in recent and established private rental properties.

The impact of the regulations on energy costs implies an average reduction of about £120 in annual energy costs, although savings are higher in those units with the lowest SAP ratings

before the introduction of the regulations, reflecting findings for the SAP rate described above. In terms of CO2 emissions, the regulations delivered average annual savings up to 500 kgCO2 per year in the properties comprised in the QEA sample. Market wide impacts of the regulations implied a reduction up to £50 million in annual costs and 144 kilotons in CO2 emissions.

5.3 Future analysis of the impacts of the regulations

This interim analysis has shown that the regulations have already had a statistically significant impact on the energy efficiency of private rental sector properties, leading to an average increase of 5 SAP points in the SAP rate of properties covered by the regulations compared to properties not affected by them. Based on the relationship between SAP rate and other variable such as energy consumption, CO2 emissions and energy costs one can then assess the impact of the regulations of the variables. In the next step of the evaluation, liaison with Building Research Establishment (BRE) will clarify the relationship of the variables above to the SAP rate so that the findings of this report in terms of SAP rate can be translated in terms of energy consumption, CO2 emissions and energy costs.

The evaluation of the impact on energy efficiency of the regulations going forward cannot rely on the use Scottish properties as control group due to the fact that they become affected by similar regulations in October 2020. As a consequence, one will have to rely on a comparison with owner-occupied properties in England and Wales rated F or G prior to the regulations or private rentals rated E or above prior to the regulations. Either choice implies addressing the likely difference in the trends in energy efficiency between these control groups and the properties affected by the regulations, and requires a better understanding of the factors influencing the change in the SAP score produced by the new algorithm. Further discussion with BRE might clarify the reasons for the change in the SAP score observed when the algorithm was revised. Without further clarity on these reasons, a data driven adjustment could however be employed to address the sudden change in the SAP score. Another option would be to implement methodologies not requiring similarity across time between the treated and the control groups.

Annex 1: Procedure to identify property use pre- and post-regulations

The aim of this process is to accurately identify the long-term use of each residential unit with an EPC.

The baseline case to choose EPCs for each residential unit is to select 1) the most recent EPC issued before the introduction of the regulations; and 2) the latest EPC issued after the introduction of the regulations. These are names baselined EPCs in the remainder of this section.

EPCs are issued for the following 'transaction types': 1) new buildings; 2) social rentals; 3) private rentals; 4) sales; 5) stock conditions surveys (periodical surveys, carried out mainly for social housing); and 6) a number of policy-related entries[40], such application for RHI and Feed-In Tariffs (FiT). As some of these transaction types are not indicative of long-term use of the residential units, e.g. 1), 5) and 6), it becomes sensible to utilise the information on energy efficiency rate and structure of a residential unit from those indicated above in the baseline case, while obtaining information on the long-term use of the unit from the field transaction type of a different EPC.

As more than one observation may be available before and after the regulations, Figure A. 1 summarises the rules which have been developed to better characterise the long-term use of the residential unit which might not be related to the transaction type rin the two baseline EPCs. The rules are applied sequentially, as graphically represented in Figure A. 1.

First of all, the different types of 'transaction types' reported in the EPC are grouped into 4 cases: new buildings; 2) social or private rentals; 3) sales; 4) residual cases such as stock conditions surveys and policy-related entries. After this grouping, the following steps are implemented:

- As a first screening, if either the pre- or post-regulation EPC indicates the construction of a new dwelling, all the EPCs preceding the EPC with 'new dwelling' transaction type are dropped.
- Information from pre- or post-regulation EPCs indicating private and social rentals (case 1 in Figure A. 1) is not questioned.
- If the pre-regulation EPC indicates a sale, case 2 in Figure A. 1, the previous EPCs is inspected to ensure that the transaction does not indicate changing ownerships between two landlords. A similar process occurs for the post-regulation EPC with the only difference that following, rather than previous, EPC is inspected. Due to the possibility of obtaining misleading classification as a result of this process, only the two previous EPCs issued within 5 years from the baseline EPC are inspected.
- If the pre- or post-regulation EPC indicates a 'transaction type' part of the residual category, case 3 in , with an exception, not depicted in for the sake of clarity. This exception covers the instance of a unit whose pre-regulation EPC defines as being privately or socially rented, while displaying a transaction type part of the 'residual'

[40] The complete list of values for policy-related EPCs is: "assessment for green deal", "ECO assessment", "FiT application", "following green deal", "RHI application".

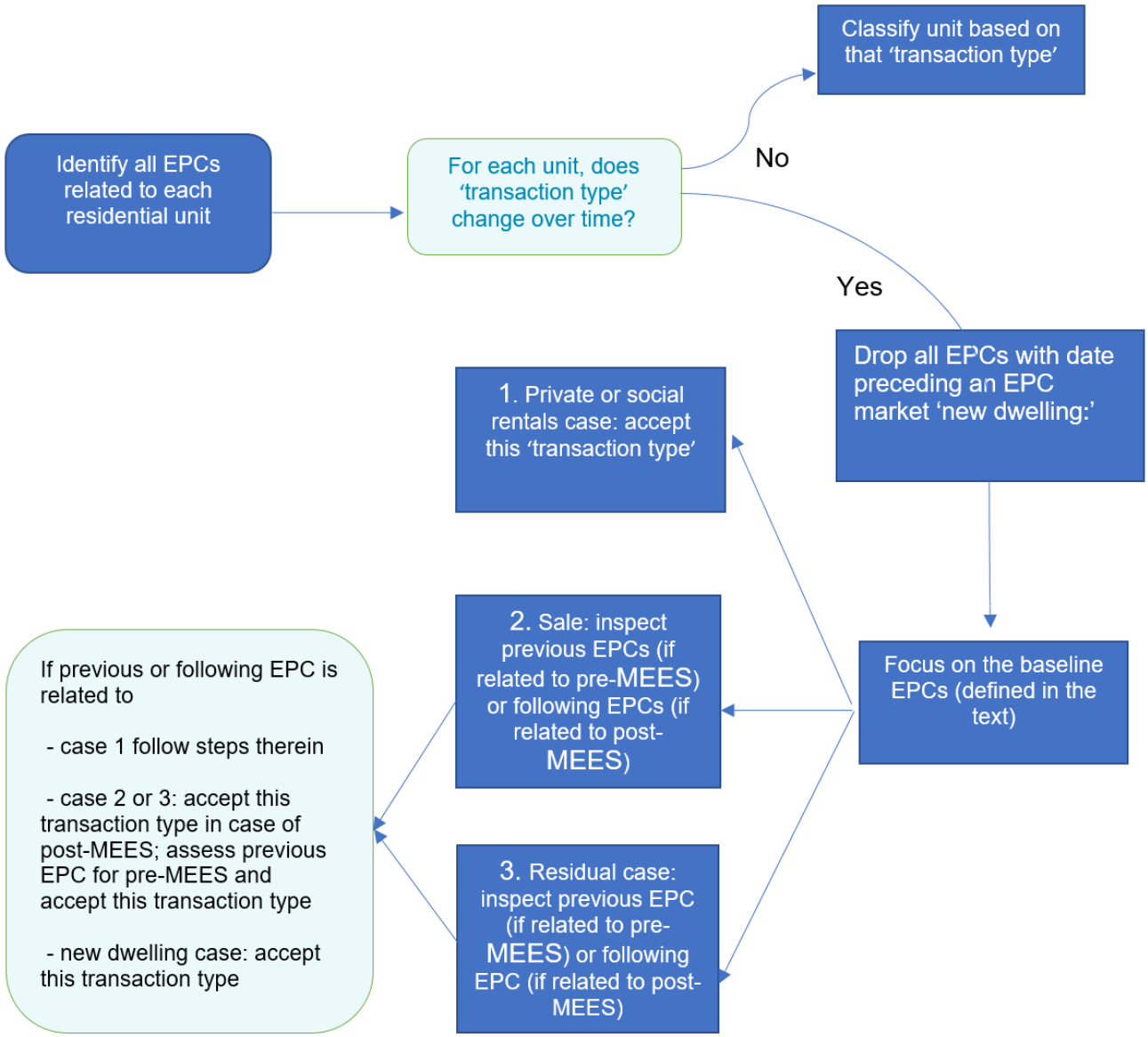
category in the post-regulation EPC. In this case, it is assumed that the pre-regulation use of the property has not changed after the MEES. For example, a property, privately rented prior to the intervention, which displays a post-regulation EPC of the type ‘ECO assessment’ is assumed to have remained in the private rental market at the time of the post-regulation observation.

As an example, consider a pre-regulation EPC reporting "RHI application". As part of the managed exceptions, the residential unit would be associated to the ‘transaction type’ reported in the EPC preceding the pre-regulation certificate – case 3 in Figure A. 1, but all the other characteristics would be sourced from the pre-regulation EPC. In addition, the managed exceptions take into account the fact that a sale transaction may be the pathway to enter or exit the rental market. As an example, consider a post-regulation EPC reporting "sale ". If there is evidence, within a reasonable range of time, that the same unit is privately rented after the sale, case 2 in Figure A. 1, it is sensible to file that residential unit as a private rent while reporting all the other characteristics from the post-regulation EPC[41].

At this point, one can form treated and control groups described in in Section 2.3 of the report based on the EPC rate band and ‘transaction type’ on the EPC selected based on the process above.

[41] This case might not be very common bearing in mind that the implementation of the regulations occurs over a period of time up to April 2020 and that EPCs up to September 2019 are contained pin the dataset used in this study. On the other hand, adding EPCs up to March 2020 or drawing forth the introduction of the regulations – for example due to announcement effect – might make this case much more common in the dataset.

Figure A.1: Classifying property use



Annex 2: Changes-in-Changes

Known as changes-in-changes, CiC is a generalization of the standard DiD introduced by Athey and Imbens (2006) which does not rely on any functional form assumptions such the linear function implied by DiD in (1). Changes-in-changes has been utilized both as a primary methodological technique as well as in robustness checks for the results from a linear model[42]. It allows for variation of treatment and time effects across individuals. It estimates the treatment effect for each section of the distribution of individuals rather than estimating an average treatment effect for the whole sample, like in the case of the DiD. In our setting, it is reasonable to assume that the impact of the regulations may depend on the starting level of the SAP rate. In other words, the lower the SAP rate before the regulations were introduced, the higher the expected impact. As an example, the impact of the regulations is likely to be higher in properties which had an EPC rate of G before the regulations were introduced rather than in those which were F-rated, if both sets of properties aim to achieve a rate of E after the introduction of the regulations.

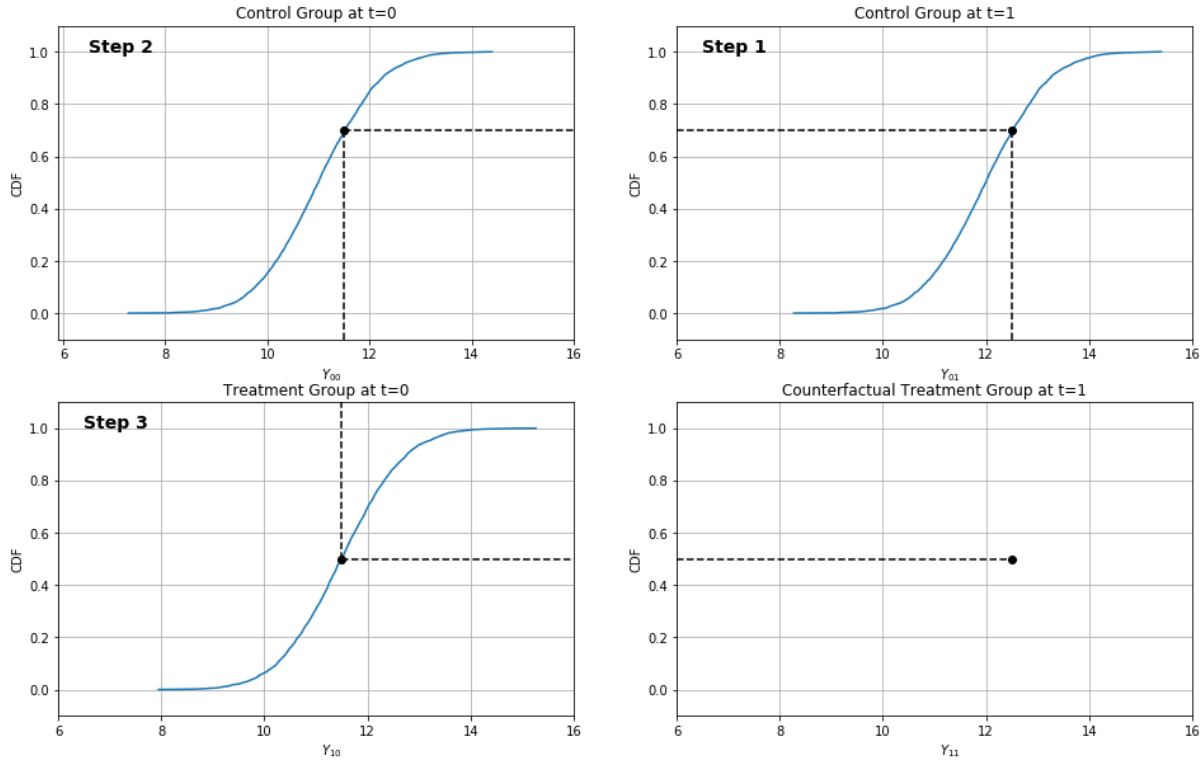
Formally, the model is defined so that treated outcomes satisfy $Y_i^I = h^I(U_i, T_i)$ and non-treated outcomes satisfy $Y_i^N = h^N(U_i, T_i)$, where U_i are the unobservable characteristics of unit i and h^I and h^N which affect the variable of interest Y_i non- negatively across all values taken by U_i . Furthermore, the distribution of U is allowed to vary between the treatment and control group, but not over time within each group. Under these conditions, the computation of the treatment effect becomes straightforward as one only needs to compare the realised and counterfactual outcomes for a realisation of U = u:

$$\delta(\mathrm{u}) = h^I(\mathrm{u}, 1) - h^N(\mathrm{u}, 1)$$

The starting point for the estimation of the treatment effect is therefore finding similar values of u in the treatment and control group. The monotonicity assumption of the outcome functions guarantees that a ranking (quantiles) of the dependent variable is implicitly a ranking of the unobservables, u. Therefore, by fixing a quantile and thus a value of the outcome variable Y, one is fixing the level of unobservables. The operation $F_{Y,01}(y)$ translates a value of Y into its respective quantile of the distribution. The second operation $F_{Y,00}^{-1}\left(F_{Y,01}(y)\right)$ transforms the quantile from the first operation into the corresponding outcome Y in the control group before treatment. In essence, this estimates the time effect applied to the level of y in the control group. The outermost step $F_{Y,10}(F_{Y,00}^{-1}\left(F_{Y,01}(y)\right))$ then applies the time effect to the appropriate level of Y in the treatment group pre-treatment. As all three distributions stem from the same equation $h^N(U_i, T_i)$, the procedure traced a fixed level of U through the different distributions. Figure 2.1 illustrates the equation step-by-step.

[42] Athey and Imbens 2017, The state of applied econometrics

Figure 2.1: Visual representation of CIC methodology



Based on the distribution of the counterfactual, the average treatment effect can be estimated by computing:

$$\delta^{CiC} = E[Y_{11}^{I}] - E\left[F_{Y,01}^{-1}(F_{Y,00}(Y_{10}))\right]$$

A relevant assumption for this model is time invariance between groups: the distribution of unobservable characteristics within groups is constant across time. Without this assumption, it is not possible to separate between time and treatment effect. One caveat of the CiC is the requirement of overlapping distributions in the outcome variable, as the impact of a policy can be estimated only for the range in the outcome variable observed in the control and the treatment group. In the PRS MEES context, this rules out use of control group 3 and 4, as the overlap of the pre-treatment distribution rate is clearly nil.

Annex 3: EPC/SAP Sensitivities

The change in EPC level is the outcome of changes in the input values for the EPC calculation, which is known to be sensitive to several of important factors that can result in larger or smaller changes in EPC level depending on what is changed.

Stone et al (2014)[43] undertook a study to evaluate the different inputs to SAP that accounted for the most variance in the energy rating for housing in England. Their results of a variance-based global sensitivity analysis showed that heating system efficiency, external wall U-value and dwelling geometry account for 75% of the variance of the energy rating of gas central heated houses in England. They determined that improvements to heating system efficiencies and wall U-values among the worst performing housing (i.e. EPC F and G) will have a significant impact on their calculated performance level. However, they also identified that 'constant' factors such as building geometry have a significant impact on CO2 emission calculation. Additionally, they determined that energy carriers (i.e. electricity vs gas) also have significant influence on EPC. They show that low energy lighting has a significant impact on the SAP rating due to the higher cost factor for electricity, while switching to gas heating will also result in SAP improvements.

A study by Hughes et al (2013)[44] showed very similar results, finding that internal demand temperature is by far the most significant parameter, followed by main heating system efficiency, external temperature, floor area, storey height and heating regimes.

Also, a study by Crawley et al (2019)[45] evaluated the 'model error' (i.e. difference in input variables between two EPCs for the same property). Their study found that the process of creating an EPC introduces measurement error such that repeat assessments of the same property give different ratings, compromising their reliability. Their study used EPC data from 1.6 million dwellings with two EPCs and evaluated the input data for each EPC and the change level. The findings showed that "the predicted error (one standard deviation) was found to generally decrease with EPC rating, from 8 EPC points at the upper end of the F band to 2.4 in the B band. This error leads to a significant probability of mis-classification of dwelling band and its associated policy consequences, for example, a 13% probability of an E dwelling being rated as F or lower, and therefore, being unable to be rented out."

These studies imply that differences in 'fixed' building features, such as inconsistent floor areas between EPCs, may have unanticipated changes in EPC levels. While fuel switching and changes to heating systems will also have considerable effect on EPC levels.

The implications for this study are that it is expected that a certain amount of error on input data is likely to have an impact on the EPC level changes, and that this change will be sensitive to the type of error or difference in inputs, in particular factors that affect dwelling size and energy carrier (i.e. electricity).

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[43] Andrew Stone, David Shipworth, Phill Biddulph & Tadj Oreszczyn (2014) Key factors determining the energy rating of existing English houses, Building Research & Information, 42:6, 725-738, DOI: 10.1080/09613218.2014.905383

[44] Martin Hughes, Jason Palmer, Vicky Cheng & David Shipworth (2013) Sensitivity and uncertainty analysis of England's housing energy model, Building Research & Information,41:2, 156-167, DOI: 10.1080/09613218.2013.769146

[45] Crawley, J.; Biddulph, P.; Northrop, P.J.; Wingfield, J.; Oreszczyn, T.; Elwell, C. Quantifying the Measurement Error on England and Wales EPC Ratings. Energies 2019, 12, 3523. https://doi.org/10.3390/en12183523

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