Reliance on compliance – monitoring the consistency of Green Deal energy assessments in Great Britain

Dr David Jenkins
Urban Energy Research Group
Heriot-Watt University
Riccarton
EH14 4AS Edinburgh
UK
D.P.Jenkins@hw.ac.uk

Sophie Simpson
Urban Energy Research Group
Heriot-Watt University
Riccarton
EH14 4AS Edinburgh
UK
S.A.Simpson@hw.ac.uk

Dr Andrew Peacock
Heriot-Watt University
Riccarton
EH14 4AS Edinburgh
UK
A.D.Peacock@hw.ac.uk

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Abstract

The Green Deal is a British loan scheme with associated subsidies and incentives to encourage the purchase of energy efficiency measures. This paper describes the results of a recent "Mystery Shopper" study (funded by the Department of Energy and Climate Change) investigating advice being provided by different Green Deal assessors to a small sample (29) of households. Each household had four separate assessments (116 assessments in all), involving an Energy Performance Certificate, Occupancy Assessment and Green Deal Recommendation report. Each dwelling also underwent a fifth, reference assessment by assessors involved with the study. The results were compared to discern whether the Green Deal assessment process is providing consistent and coherent advice to the occupiers, for both predicted energy consumption and recommended measures. To supplement this data, a household survey was also conducted to record the experience of the occupants themselves; this included their opinion on the usefulness of each assessment, the duration of the visit and also allowed the team to compare the approaches of the four different assessors in each dwelling. The results demonstrate that, despite the use of standardised models, methodologies, and assessor training, the conclusions arrived at from the assessment process varied significantly with each assessment. Even quite basic input information (floor area, thermostat settings and dwelling orientation) was noted to vary bringing into question the quality of the advice emanating from these assessments. The results have implications for other countries following the EU Energy Performance in Buildings Directive, mandating the mass use of standardised energy assessments across a large number of homes. It is imperative that the process must undergo suitable quality control (relating to methodology, models, and those applying that methodology) if households are to have confidence in the advice from EPC-style assessments encouraging energy efficiency. More critically if, like the Green Deal, the household is being encouraged to invest large amounts of money in either upfront capital or long-term loans to fund the measures proposed by these assessments, then a lack of robust and reliable advice might have wider repercussions.

Introduction

When carrying out an assessment process across a country, that ultimately leads to both energy-saving advice and eligibility for funding, quality and consistency are key. Householders need confidence that advice is suitable for their dwelling before signing up to, potentially, large loans that require repayment over long periods of time. The Green Deal programme (DECC, 2014a), since 2012, has attempted to do this through a standardised process of energy performance assessment by qualified assessors (as discussed in the next section). This study aims to investigate whether this assessment process is indeed consistent, and whether householders are receiving suitable and useful advice for reducing their energy bills.

The small sample of households studied means that results cannot be directly extrapolated to the entire housing stock, and results will be discussed with this limitation in mind. However, if certain concerns are consistently raised across the sample then we might propose that such issues are likely to occur commonly for other homes.

This paper will discuss the results obtained when comparing these multiple assessments, looking at both the inputs used by different assessors and the results/recommendations generated. A parallel customer journey survey, administered by ICF-GHK, will also be used to provide additional contextual information such as householder-assessor interaction and assessment duration.

The paper describes the work carried out by Heriot-Watt University's Urban Energy Research Group as part of a project managed by ICF-GHK. The project was funded by the Department of Energy and Climate Change (DECC) as part of a wider study into the performance of the Green Deal.

The Green Deal

Green Deal loans are, typically, offered at 7–9 % interest to households in Britain for refurbishing homes to a lower energy standard. The loan is repaid over, up to, a 25 year period. To confirm eligibility for this finance, which may also be used in conjunction with other sources of funding (such as the Energy Company Obligation (Ofgem, 2014)), the household must be assessed by a qualified assessor. The assessment uses a version of the UK Standard Assessment Process (SAP), called Reduced-data SAP (RdSAP) (BRE, 2012), to estimate the energy consumption of the dwelling, as would be used for generation of an Energy Performance Certificate (EPC). However, this is then amended to account for specific characteristics of the dwelling as part of an Occupancy Assessment (OA), where such characteristics would be based on stock-average inputs for a normal EPC. This can include available energy bill data, as well as information on hot water usage (e.g. showers and baths per week), appliances (e.g. fridges/freezers in use) and recorded thermostat temperature. The intention of this extra stage is to produce estimated savings that are specific to that dwelling, rather than an "average" of similar dwelling types. Recommendations are then provided based on the site visit, and resulting modelling, for reducing the energy bill of that dwelling. In theory, two different assessors should recommend similar (if not identical) measures for a given household.

Assessing the assessments

Other countries (such as Germany (KFW, 2013)) have looked into the viability of loan-schemes for refurbishing homes with low-carbon measures. Specifically, the effectiveness and structure of Green Deal loans has also been much discussed ((Ingram, 2013), (Booth, 2013)). Less well studied is the assessment process that allows the Green Deal loan to be specified, and encouraged, to the householder. An independent study by consumer group Which? (Which?, 2013) highlighted issues around the quality of assessment in the early stages of the programme, with concern expressed over suitability of advice. Although this study looked at just five assessments, comparing them with what was deemed more thorough "control" assessments, it did imply that further investigation was justified. DECC have commissioned a series of studies around the Green Deal process, including the customer journey experienced by the householder.

The study described in this paper is part of this recently commissioned DECC research, with a full report available elsewhere (DECC, 2014b). With an intention of studying the consistency and quality of assessment, a number of households were recruited to arrange a series of separate Green Deal Assessments from locally registered assessors. The assessments were then collated to compare the advice given for each home, where results of Green Deal assessments have to be registered on a central database (that was accessible to the project team). The comparison was carried out across the different households but also, crucially, across the multiple assessments of the same dwelling. The original intention was to have 50 homes, each with five "Mystery Shopper" assessments (i.e. where assessors would assume they are carrying out a normal assessment). Due to householders having trouble finding 5 local assessors within the timescale available (a problem reported by another study (Which?, 2013)), the final investigation looked at four "Mystery Shopper" Green Deal assessments in 29 dwellings, with a fifth "reference" assessment carried out by assessors involved with the project (CA Design Services (CADS)). Despite constituting a small sample of dwellings, this total of 116 separate assessments, with an extra 29 assessments for reference, did highlight concerns that may have implications on the Green Deal assessment process in a wider sense.

The investigation looked at three parts of the assessment process: i) The EPC, ii) Occupancy Assessment and iii) Final recommendations.

Comparison of outputs

As mentioned, the RdSAP calculation method is used for generating results in the Green Deal assessment. By comparing the results pre- and post-OA, it was possible to indicate whether any inconsistencies were originating from this standardised calculation method, the amendment to this method provided by the OA, or a combination of the two. Due to the degree of standardisation for EPC calculations, where inputs are based on quite clear instructions to the assessor (e.g. tables of U-values for a given age of construction) it might be hypothesised that EPC results should be reasonably consistent. The results below indicate that this is not necessarily the case.

While some key input parameters were provided for investigation (from a central Energy Performance in Buildings Register (GDORB, 2014)), the full RdSAP models were not available due to the covert nature of the exercise. This partly limited the investigation into causality of inconsistencies, though several areas of input disagreement between assessors became quite clear.

When demonstrating variability, the figures will use the key in Figure 1. Maximum, Median and Minimum value are calculated from the four "Mystery Shopper" assessment values for each dwelling, whereas "Reference" value refers to the fifth assessment carried out by the retained assessor who were partners on the project. This Reference value is not necessarily the most accurate value, but it has been obtained by experienced assessors who are aware of the requirements of the study (and were also able to comment on aspects of the building that might be particularly difficult to model).

EPC RESULTS

Figure 2 demonstrates the level of variability seen across the four assessments within each dwelling. Even for this standardised energy assessment, where assessors should have been using near-identical inputs and software using the same calcu-

lation methodology, the variation is quite noticeable. Almost two-thirds of the 29 dwellings had assessments varying by at least two energy performance bands, with two dwellings having assessments spanning three bands. The average range (different between maximum and minimum) in EPC rating value across all 29 dwellings is 11.1. [NB. EPC bands are as follows: G (rating of less than 20); F (21–38); E (39–54); D (55–68); C (69–80); B (81–90); A (greater than 90).]

To investigate possible causes of this variation, Figure 3 orders the dwellings by age of construction and compares range of EPC rating returned. There is a suggestion here that the assessments of the oldest properties (pre-1900) were particularly variable. Dwellings of this age in the UK are often solid-walled, though the type of property (e.g. flat, detached, semi-detached etc) also varied within this range so other parameters must also be accounted for. The results may be indicating that some properties are more difficult to model than others or, at least, guidance is less clear for assessors such that one assessor might make a different choice to another. The degree to which this happens across the stock is not discernible from this small sample, but does reinforce concerns that SAP-based models are not always effective at modelling dwellings that differ from "average" or "typical" properties with better understood building parameters (Affinity Sutton, 2013, de Wilde, 2014, Kelly 2012).

Another key input to the EPC ratings is total floor area. Even this, relatively, simple input showed considerable variation for many dwellings, as shown in Figure 4. Across all dwellings, the average range in values was 13.7 %, though this varied considerably from dwelling to dwelling. However, there was not a strong correlation (comparing Figures 2 and 4) between floor area variation and EPC rating variation, suggesting that other parameters are also causing disagreements between assessors.

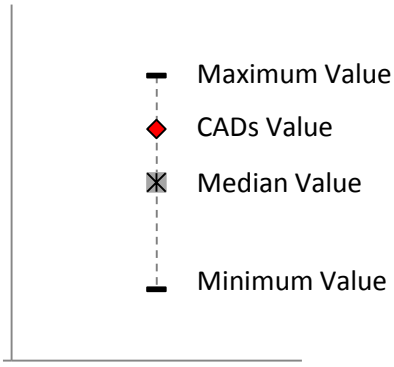


Figure 1. Key used by figures for showing variability across assessments.

The resulting space heating consumption calculated from this input is shown in Figure 5. It should be noted that these calculations are not the same as predictions emanating from the full Green Deal assessment, which uses the OA to amend the predictions. It does, however, indicate the implications of the inconsistencies in input discussed above; this is particularly true for the UK where space heating constitutes the main form of energy consumption for most homes. The mean range in space heating cost variation for all dwellings was £355 (or €454). The minimum and maximum EPC space heating costs for one dwelling (no. 19) varied by more than £1,200 (€1,534).

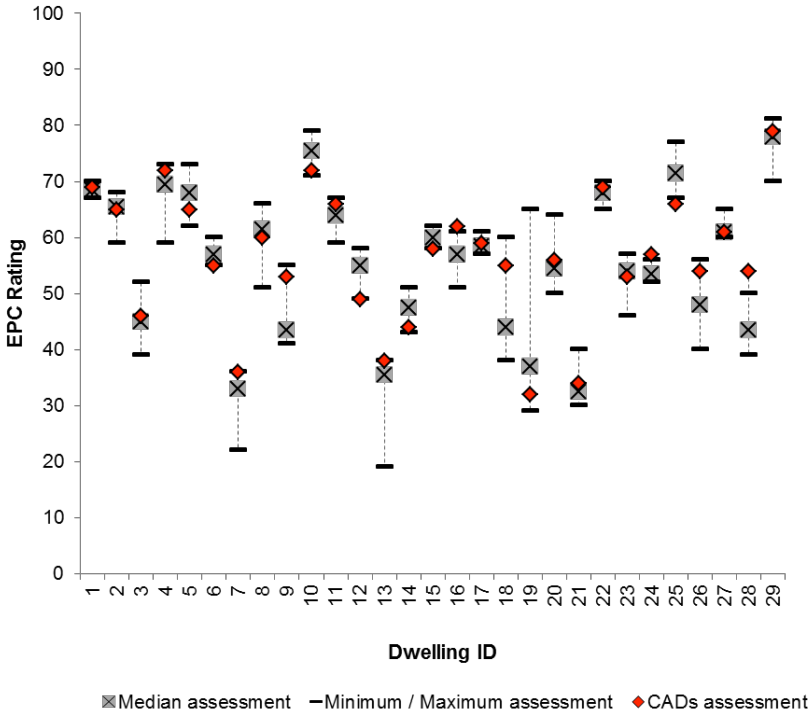


Figure 2. EPC ratings for four assessments across 29 dwellings.

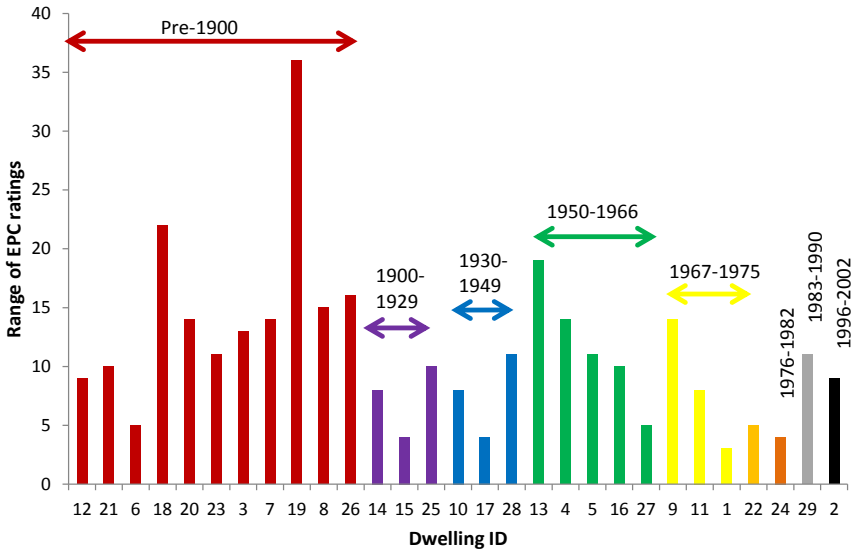


Figure 3. Range of EPC rating ordered by dwelling category.

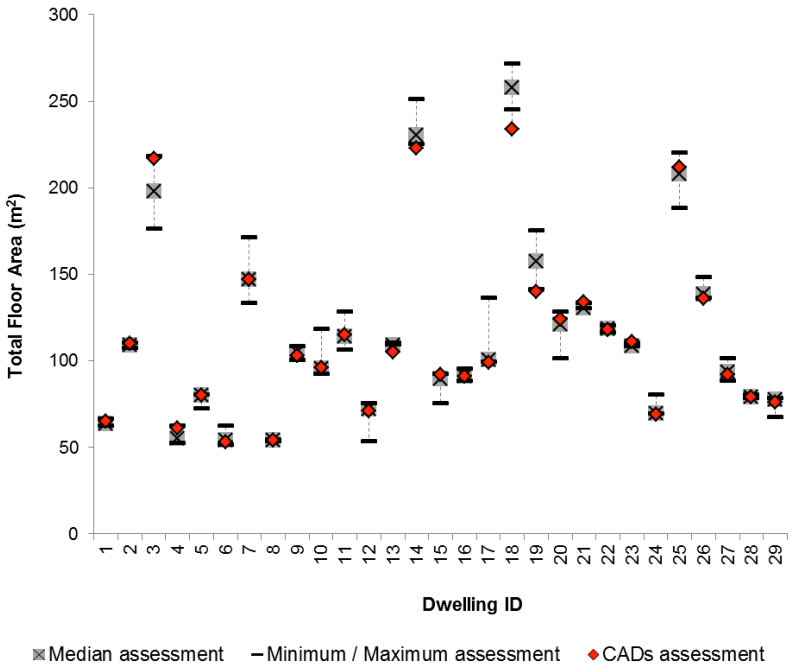


Figure 4. Inputted total floor area of four assessors per dwelling.

With these EPC results, in effect, forming a baseline calculation prior to the OA being carried out, these variations will impact the full Green Deal assessment. Additional inconsistencies emerging from the OA are discussed in the next section.

OCCUPANCY ASSESSMENTS

Within the OA there are a series of additional inputs that help tailor the assessment to a specific dwelling. One of these is the thermostat temperature, which can be altered from the default values used in the modelling if evidence is found of a different setting in use within the living area of a dwelling. Although guidance is provided to assessors for how to use this thermostat input, Figure 6 shows considerable disagreement for most dwellings.

While it is possible that, with assessors visiting homes at different times, different thermostat settings were in place across the assessments of a dwelling, 13 dwellings had a difference of 3 °C or more in the recorded heating set-point temperature. The average range across the four assessments was 2.1 °C. As this is such an important parameter in the calculation of total

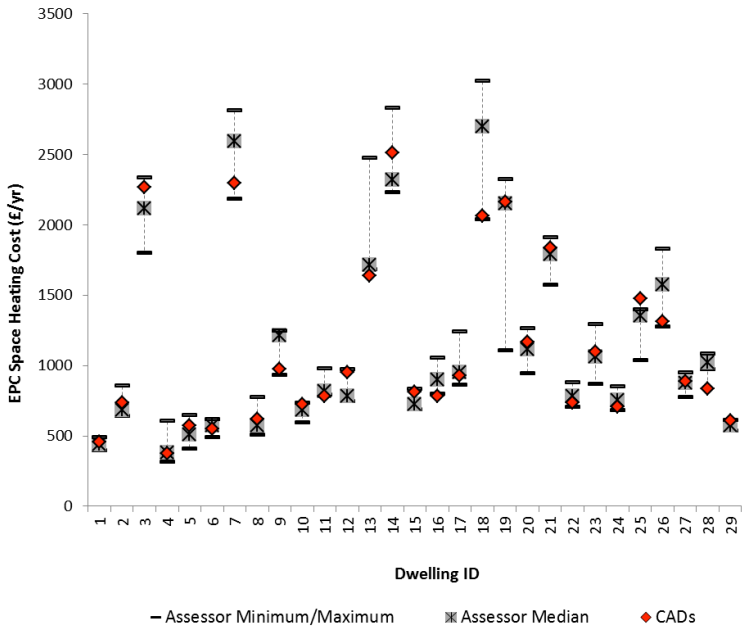


Figure 5. Space heating calculated from EPCs.

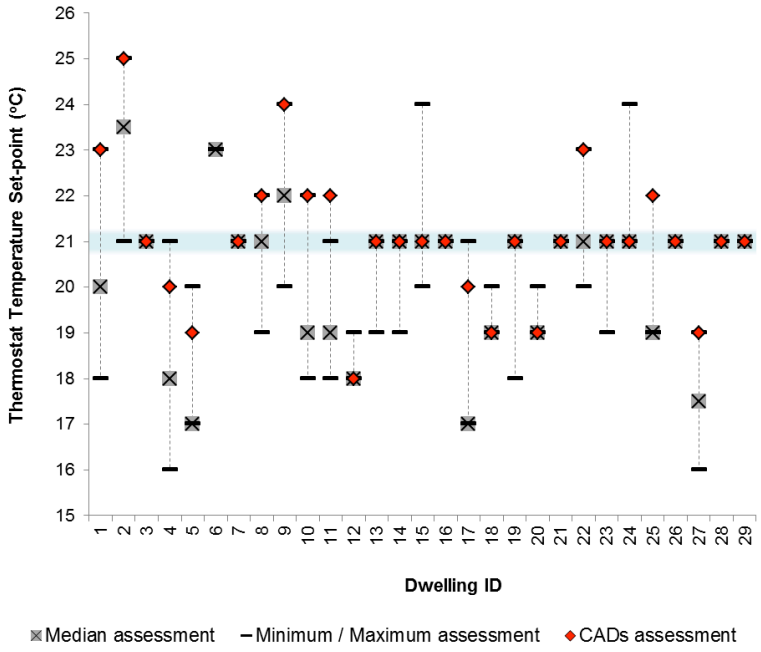


Figure 6. Thermostat temperatures recorded by assessors.

energy consumption of a dwelling, it was further explored in Figure 7. Here we see the temperature recorded by each assessor, but also the conditions reported by that assessor (where the data obtained also recorded if assessors found a thermostat or not). If assessors record that no thermostat setting was found (e.g. a thermostat does not exist), then they should use the default value of 21 °C. If the thermostat is found outside the living area, then they are advised by the methodology to add 3 °C to this recorded value and assume this is the living area temperature (which is used in the calculation). However, these basic rules were not always followed in Figure 7 (which also includes the values returned by the reference CADS assessors). Although all assessors agreed about the presence (or absence) of a thermostat in 26 of the 29 dwellings, the values returned as a result were not always the same. For example, in dwelling 8, assessors disagreed on temperature values but one assessor, having suggested no thermostat existed, then went on to use 22 °C (instead of the correct default of 21 °C). Dwellings 13, 14, 19 and 23 also had assessors stating that no thermostat existed but then, incorrectly, using non-default values for temperature set-point.

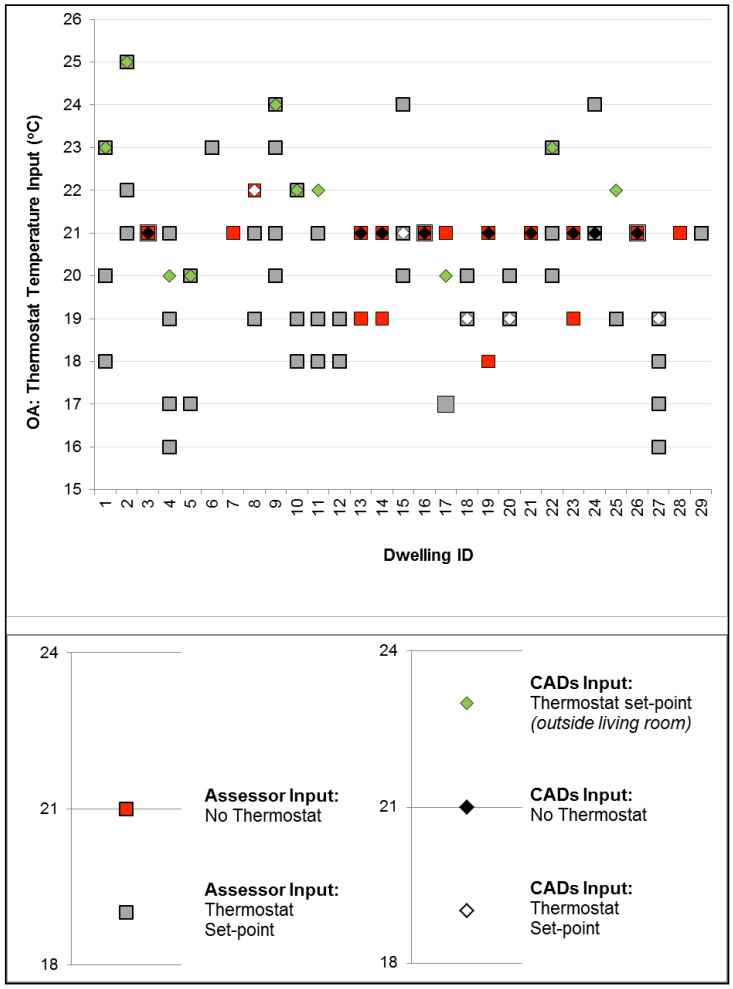


Figure 7. Approach used by assessors for specifying thermostat temperature.

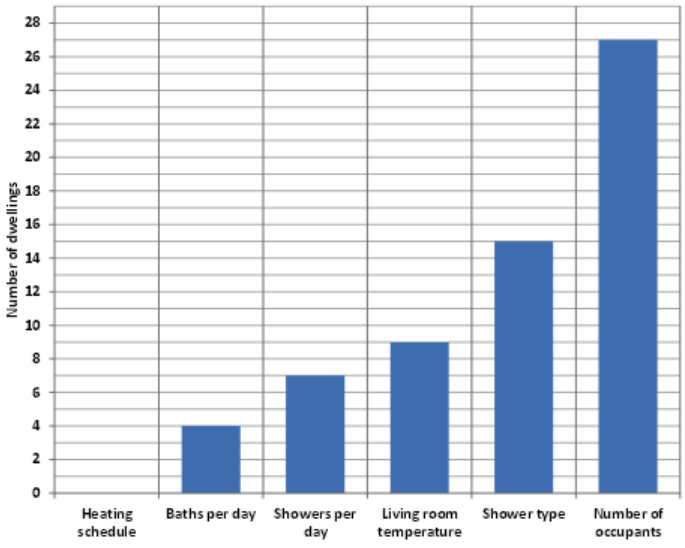


Figure 8. Level of input agreement from assessors in OA.

Part of the disagreement in set-point temperature, for homes where thermostats were detected, may stem from the definition of a "living room". Green Deal assessment guidance (BRE, 2012) states that this should be "the room used most or best heated … thus is not necessarily the room that would be designated as the living room in a normal SAP assessment". This therefore requires a degree of interpretation, and dialogue with the householder, which may be the cause of different approaches between assessors.

Other parameters in the OA also showed considerable inconsistencies amongst assessors. Figure 8 shows the number of dwelling where all four assessors agreed on particular OA input parameters. No dwelling had all four assessors agreeing on heating schedule (average number of heating hours per day) and considerable disagreement was shown across hot-water usage relating to baths and showers. Whether this was due to assessors having inconsistent methods or householders offering inconsistent information was not clear. Living room temperature, as already discussed, was only consistent in nine dwellings. The most consistent area was in number of occupants, a value that would be well understood by householders and, if the question was asked, would surely get the same response for all assessors. 27 dwellings showed all four assessors agreeing on this value.

Although not shown here, the different heating schedules reported were considerably different in some dwellings. For example, dwelling no. 23 had the four assessors using values of 6, 5, 3 and 1.5 hours per day respectively. Combined with heating set-point temperatures in particular, the Green Deal/RdSAP method will calculate substantially different space heating energy consumption from this information and, subsequently, the recommended measures are likely to be different also.

RECOMMENDED MEASURES

With recommended measures coming at the end of a Green Deal assessment, it might be imagined that the most noticeable inconsistencies would be present here, with the previously discussed disagreements being added together to produce quite different descriptions of the same dwelling. Further to that, the project also had information from a customer journey survey that documented the interaction between the householder and assessor (DECC, 2014b). It was clear that interactions could be quite different across the four assessments within the same dwelling; householders may have changed their opinion on certain measures over the course of the exercise (e.g. following feedback from previous assessors) or one assessor might ask slightly different questions to another assessor (e.g. making solar technology sound more/less profitable), which could have affected whether that initially recommended measure was included in the final report. It was also clear that, while some assessors took an approach of specifying as many measures as the methodology would allow (encouraging householders to make a decision later on), other assessors ruled out technologies that were deemed unpopular with a householder during the site visit. So for example, one householder reported that "The Assessor explained any benefits that were listed, but she said that some of them were impractical. The Assessor and I discussed the possible savings. The only one that was left was loft insulation". However, another reported that "The Advisor advised that I left any selection until after the EPC was pro-

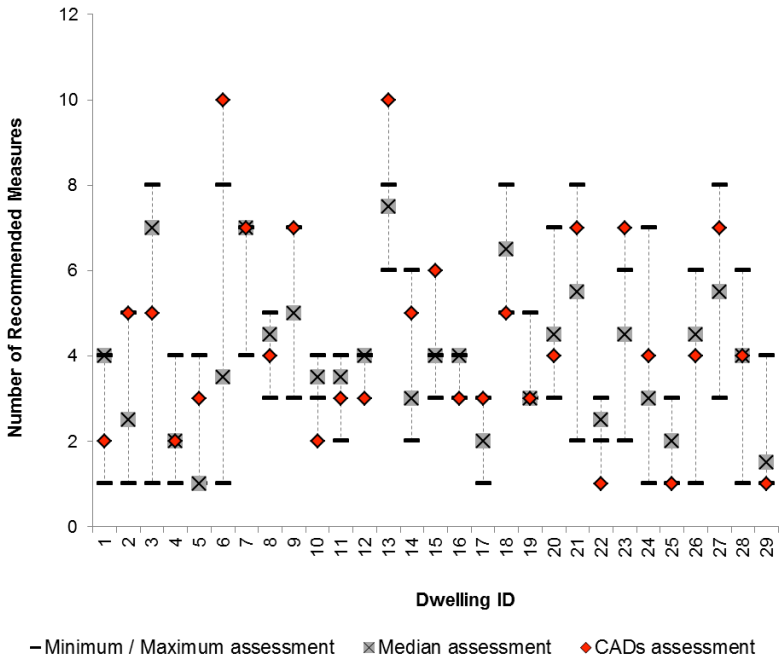


Figure 9. Number of recommendations proposed by assessors.

Table 1. Recommendations following individual assessments for dwelling no. 1.

Improvements	A1	A2	A3	A4	independent assessment
Loft insulation					
Floor insulation					
Ground source heat pump					
Solar water heating					
Hot water cylinder insulation					
Door insulation					
Solar PV					

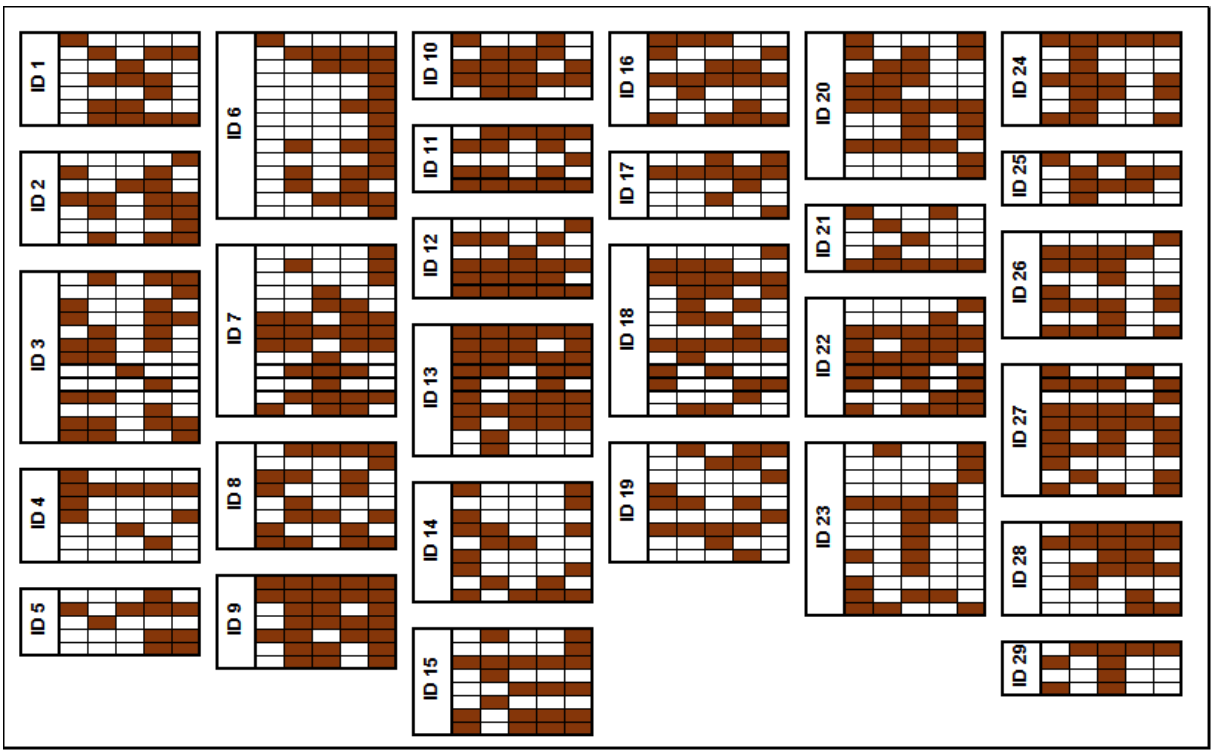
duced and then decide what I wanted to investigate". This difference in approach, as well as potentially causing confusion to the householder, will also affect the resulting savings of the measures and the effectiveness of using a Green Deal loan to pay for the capital cost; this is due to some bill savings between based on cumulative effects of multiple measures (e.g. a new boiler will save less money from a home that has also been insulated as part of the refurbishment than if the insulation measures had not been applied).

Figure 9 shows the number of measures recommended in the final Green Deal assessment reports provided to each householder. All dwellings had at least one measure recommended, with the average number recommended being four. The question of whether the observed inconsistencies stem from assessors modelling the dwelling differently (or using different inputs) or the factors mentioned above (relating to householder interaction) is quite difficult to identify. If the most inconsistent dwelling (no. 6) is investigated, one assessor recommends one measure while another recommended ten. However, if the recorded information is examined for this dwelling (e.g. floor areas in Figure 4, thermostat temperatures in Figures 6 and 7) it is noticeable that the assessors were in broad agreement across some key input parameters for this dwelling. Conversely, dwelling no. 19 had significant differences in calculated EPC space heating cost (Figure 5), yet the numbers of recommendations only varied between three and five.

Another way of displaying these inconsistencies, though perhaps not explaining their origin, is shown in Tables 1 and 2. Table 1 is a simple matrix of recommended measures for dwelling no. 1 (showing the four assessments and "CADs" independent assessment). Pictorially, the lack of similarity in each row is a sign of the inconsistency that the householder would have observed across the final reports provided to them after the assessment. It shows that three different measures were recommended just once, another measure recommended by twice, two measures recommended three times and a single measure (solar PV) recommended four times (though this technology is often included for any house with some roof space).

If this format is expanded for all 29 dwellings, where we are just interested in the number of times a measure is recommended rather than what that measure actually is, Table 2 can be produced. This demonstrates that, for this small sample, the Green Deal process is not identifying a single set of optimised

Table 2. Indication of inconsistency of recommendations across all dwellings.



recommendations for any of these dwellings. This might be thought of as contradictory to the purpose of a standardised energy assessment.

ENERGY BILLS

During the Green Deal assessment, assessors are expected to use any available energy bill data to re-calibrate their estimated savings, providing these energy bills are in an appropriate and reliable form. The RdSAP model is then used to estimate how this real energy bill will change based on modelling savings. As some homes do not have such bill information readily, or only have it available for selected months/quarters, the process for estimating savings between different properties can be markedly different. However, for several assessments of the same property, it should be expected that bills are used in the same way. Even though this study did not have detailed information concerning the use of bills, Figure 10 suggests that assessors did not approach energy bills in the same way. Only 14 of the 29 dwellings had all four assessors asking if energy bill information was present (as recorded by the householder themselves).

To investigate whether this missing step was evident in assessment duration (e.g. were assessors ignoring bills so as to reduce the time spent at the property), Figure 11 was produced comparing assessment duration with dwelling floor area but categorised into assessments where bills were asked for or not asked for. The trend across this small sample is not conclusive. There is a suggestion that in smaller properties, which might only require very short assessments, the action of asking and discussing energy bills can add a relatively significant amount of time to the assessment. This becomes less significant in larger dwellings where the assessment might already be more involved/complex due to the nature of the building. However, the spread of data (and sample size) means that such conclusions have limited statistical validity and require further investigation.

With knowledge of building modelling and SAP-based methodologies, it is possible to be more certain about whether inconsistent use of energy bills will have an impact on the figures presented to a householder. It is known that energy bills predicted by such models often have a poor correlation with real energy data (as already discussed), so altering modelled predictions to match real baseline data can dramatically change the outputs of an assessment. If some assessors recalibrate their predictions with bills while others do not, this will be an obvious source of inconsistency in Green Deal Assessment reports.

Discussion

The results of this study demonstrate some clear inconsistencies in the outputs of multiple Green Deal assessments of a small sample of dwellings. For some issues, we might suggest that it is the Green Deal methodology itself that is, at least partly, the source of these problems. For example, the Occupancy Assessment (not used prior to Green Deal Assessments in the UK) requires an assessor to apply a more nuanced understanding of energy use in the home. With individuals being able to qualify as Green Deal assessors after attending a 1-week course, but other Green Deal assessors being more experienced in the science of building assessment, it is a challenge to ensure that all households will have a consistent quality of assessment. Opening up a new market of energy assessments requires a greater number of assessors to meet that need, and this may also have an impact on quality. However, this almost implies that, prior to the Occupancy Assessment and the Green Deal itself, en-

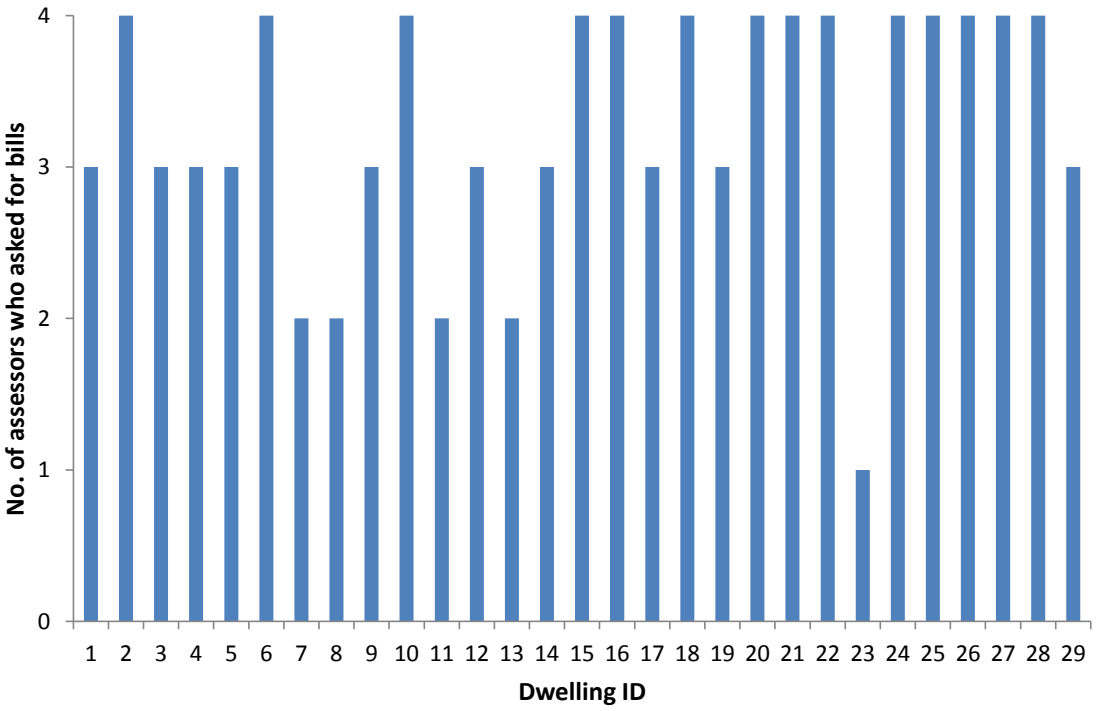


Figure 10. Number of assessors who asked for energy bills during OA.

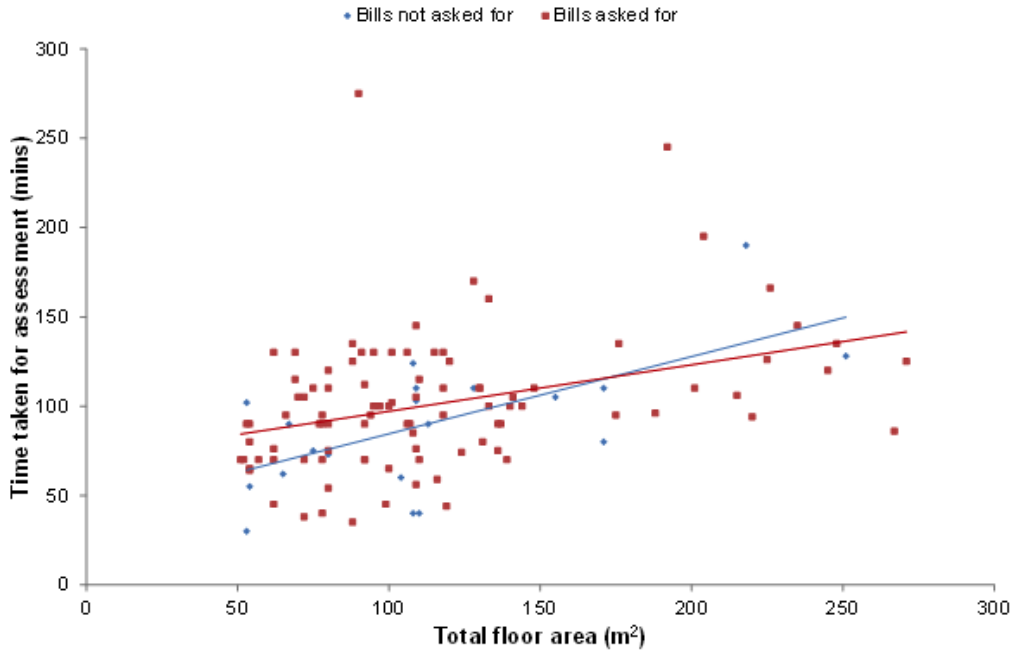


Figure 11. Duration of assessment compared to floor area and use of energy bills.

ergy assessment appeared consistent; this actually proved not to be the case for this study. Even the simpler, and more standardised, EPC assessments showed quite significant variations. Whether this stems from the assessor or assessment methodology is uncertain, though evidence has been presented (both here and the full study report (DECC, 2014b)) indicating both areas are of concern.

There is also a wider problem, not found solely from this study, which should be noted for all countries (e.g. as instructed by the Energy Performance in Buildings Directive (EPBD, 2010)) adopting steady-state model approaches for assessing the energy performance of dwellings (and, even more so, non-domestic buildings). Such models are not designed to accurately predict energy bills and it is important (though dif-

ficult) to communicate this to an end-user of a model, such as a householder. These models can, at best, broadly indicate the level of efficiency of a house that is of similar typology/construction to the one being studied. Very often, this will simply be a reflection of a few key parameters (e.g. levels of insulation, type of glazing, heating system) but, if carried out correctly, has a role in communicating to a building occupier whether action should be taken to improve the efficiency, and what that improvement might be. Perhaps the problem with Green Deal-type approaches is the fact that the outputs of the model are used to design a financial package around specific measures that could take 25 years to repay. Householders are encouraged to compare loan repayments with estimated energy bill savings, with the former designed to be less than the latter for the Green Deal. This requires a level of trust to be placed in model predictions that is arguably injudicious; the size of loan repayment is certain but the estimation of energy saving is impossible to guarantee. This is not the "fault" of the model, merely an unavoidable result of using partly or solely theoretical building models. In this case, the Green Deal is not the origin of the problem but, due to its application, magnifies an existing problem. Inaccurate, in the strictest sense of the word, performance estimations can still be useful if placed in context of the limitations of building modelling; inconsistent estimations are a more pressing problem.

Conclusions

The consistency of multiple Green Deal assessments in a small sample of dwellings was found to be quite poor when investigating EPC results, occupancy assessments and recommended measures emanating from these site visits. Some of these inconsistencies appeared to, in part, originate from disagreements in basic input information for the specification of both the dwelling and household. Other differences might be linked to interpretation of assessors when, in particular, specifying recommendations in a final assessment report. The guidance used by assessors for specifying some measures is, in some areas, unclear and may contribute to this problem. Whilst these findings cannot be extrapolated statistically to the wider stock, the fact that the noted inconsistencies are throughout the sample is a cause for concern. In that there are no known reasons why this small sample should have produced more variability than other dwellings, it is reasonable to suggest that the problems experienced in this study are unlikely to be unique to these 29 dwellings (and 116 assessments, with 29 extra independent assessments). It is suggested that the variability in energy assessments related to the Green Deal is a symptom of a wider problem of how simple energy models are used within standardised energy assessments and is, perhaps, as much a problem of communication and application as it is about building physics. The study does not look at training of assessors specifically but both the assessment results and some feedback from householders suggests that this area warrants further research; specifically, does the current energy assessment methodology and assessor training in combination ensure that households in the UK are able to access a consistent and useful service for identifying energy efficiency improvements in the home.

References

Affinity Sutton, 2013. Future Fit – Final report http://www.affinitysutton.com/media/364652/futurefit-quick-links-PDF-1.pdf.

A.T. Booth and R. Choudhary, 2013. Decision making under uncertainty in the retrofit analysis of the UK housing stock: Implications for the Green Deal, Energy and Buildings 64, 292–308.

Building Research Establishment (BRE), 2012, Appendix V: Calculation of energy use and costs using actual occupancy parameters, RdSAP 2009 version 9.91: Occupancy Assessment version, UK.

Department of Energy and Climate Change (DECC), 2014a. Green Deal: Energy saving for your home, UK https://www.gov.uk/green-deal-energy-saving-measures/overview.

Department of Energy and Climate Change (DECC), 2014b. Green Deal Assessment Mystery Shopping Research, UK https://www.gov.uk/government/publications/green-deal-assessment-mystery-shopping-research.

Energy Performance in Buildings Directive (EPBD), 2012. Directive 2010/31/EU on the energy performance of buildings (recast), EU http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF.

Green Deal Oversight and Registration Body (GDORB), 2014. Register of energy performance in buildings, UK http://gdorb.decc.gov.uk/.

V. Ingram and D.P. Jenkins, 2013. "The UK's Green Deal: a modelled case study impact review", Proceedings of European Council for an Energy Efficient Economy (eceee) 2013 Summer Study, France, 3–8 June.

S. Kelly et al, 2012. Building performance evaluation and certification in the UK: Is SAP fit for purpose?, Renewable and Sustainable Energy Reviews 16, 6861–6878.

KFW, 2013. Press Release for "KfW improves energy-efficient refurbishment scheme", Germany https://www.kfw.de/KfW-Group/Newsroom/Aktuelles/Pressemitteilungen/Pressemitteilungen-Details_10591.html.

Office of Gas and Electricity Markets (Ofgem), 2014. Energy Companies Obligation, UK https://www.ofgem.gov.uk/environmental-programmes/energy-companies-obligation-eco.

Which?, 2013. Green Deal Investigation, UK http://www.which.co.uk/energy/creating-an-energy-saving-home/guides/the-green-deal-explained/our-green-deal-investigation/.

P. de Wilde, 2014. The gap between predicted and measured energy performance of buildings: A framework for investigation, Automation in Construction 41, 40–49.

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