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Evaluating the evaluations: Evidence from energy efficiency programmes in Germany and the UK

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ABSTRACT

To make robust judgments of an energy efficiency programme's economic effectiveness, we need to know how much energy and CO_2 is actually being saved through the financial support it provides. But most evaluations of home retrofit energy efficiency programmes depend on calculated, rather than measured, levels of energy consumption. This fails to take into account the discrepancies that have been observed in practice, between calculated and actual energy consumption both before and after refurbishment. Evaluations of energy efficiency programmes ideally need to consider rebound effects, free rider effects, reduced savings due to insufficient technical quality, and discrepancies between actual and calculated pre-refurbishment energy consumption. This paper investigates and compares evaluations of two prominent energy efficiency programmes in the Germany and UK–the CO_2-Building Rehabilitation Programme and the Supplier Obligation. We show that evaluations of the Supplier Obligation explicitly address most of the reduction effects whereas this is not the case for the CO_2-Building Rehabilitation Programme.

1. Introduction

Households produce some 25% of the European Union's (EU's) CO_2 emissions [1] and could offer 27% of the EU's energy savings potential in the years to 2020 [2], over half of which could potentially be achieved through reduction in heating energy consumption [3]. A portion of such savings would come from replacement of old buildings with new, energy-efficient designs, but since most buildings standing today will still be in use in 2020 and beyond, most European countries have policies and programmes to support and accelerate the thermal refurbishment of their existing residential building stock [4].

A prominent policy instrument for supporting thermal refurbishment of dwellings is subsidies provided or mandated by central government, usually offered as grants or subsidised loans for approved projects [1,3]. The public has an interest in assessing how effectively this money is being spent. Further, since resources have to be allocated among competing projects in energy efficiency and CO_2 reduction, there is a need to quantify these subsidies' effectiveness in metrics, such as kWh saved or tonne of CO_2 reduced, per Euro spent [5], so that robust comparisons can be made with economic efficiencies of energy savings in other sectors.

The American Council for an Energy Efficient Economy [6] recently ranked the UK and Germany first and second among the world's 12 largest economies for their energy efficiency activities. These two countries are often named as positive examples of innovative energy efficiency policy, and their home energy efficiency programmes are often applauded for their success.

Germany's CO_2 Building Rehabilitation Programme (CBRP–called the *CO_2-Gebäudesanierungsprogramm*) receives much attention internationally and Germany is often labelled a 'front runner' [7] in energy efficient building refurbishment. Lowe [8] highlights that Germany is one of the few countries in the world that has a large-scale funding programme for energy efficient refurbishment, and Boonekamp and Eichhammer [9, p. 273] call the CBRP a successful example of 'long term financial efforts' with 'considerable impacts in terms of energy savings and CO_2 emissions reductions'.

Similarly, the UK's Supplier Obligation (SO) is frequently hailed as a successful policy instrument. The International Energy Agency (IEA) has 'strongly commend[ed] the UK government for the creative approach to energy efficiency taken with the [SO 2002–2008] Commitment' [10] and considers the 'Energy Efficiency Commitment an impressive success' [11]. Similar praise can be found elsewhere [12,13].

These commendations are largely based on evaluations carried out for the government responsible for the funding and regulatory framework. However, a substantial body of literature covering several decades of energy research suggests estimated savings in evaluations are often higher than actual, measured savings [14–26].

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To make robust judgments of an energy saving programme's economic effectiveness, we need to know how much energy and CO_2 is actually being saved through the financial support they provide. But most evaluations of home energy efficiency programmes depend on calculated, rather than measured, levels of energy consumption. This fails to take into account the discrepancies that have been observed in practice, between calculated and actual energy consumption both before and after refurbishment [27]. These discrepancies are often framed in terms of the 'rebound effect' [28] or 'comfort-taking', where consumers increase the level of energy services after refurbishment. Hence the savings are not as high as those calculated. This is taken into account in the UK evaluations, but not in those in Germany.

A further source of discrepancy has recently been explored by Sunikka-Blank and Galvin [29] and labelled 'the prebound effect'. This refers to the situation where energy consumption *prior* to refurbishment is lower than the calculated value. Estimates of energy saved through refurbishment almost invariably use a calculated figure for pre-refurbishment consumption, based on the building's physical characteristics. But in a review of data sources of actual, measured consumption in German homes, Sunikka-Blank and Galvin [29] found actual consumption to be, on average, 30% below the calculated levels recorded in dwellings' energy certificates. They identified a similar phenomenon in Dutch, French, Belgian and UK homes. This again can lead to overestimates of the amount of energy saved through refurbishment, as householders cannot save energy that was not already being consumed.

A third source of discrepancy is believed to come from the technical quality of the refurbishments. This is difficult to identify precisely, because over-consumption after refurbishment could be caused by the rebound effect. However, in a study comparing the calculated and measured heating energy consumption of 100,000 dwellings, Greller et al. [30] suggested that part of the discrepancy between calculated and actual consumption might be explained by technical faults in the exacting processes of applying insulation materials. Further, in interviews with leading practitioners and building physicists throughout Germany, Galvin [31] found there is widespread belief among these professionals that the skills and processes of applying insulation in advanced, low-energy refurbishments are very often not sufficient to achieve the standards aimed for.

A problem of a quite different kind, in estimating the quantity of energy saved through a government funding programme, is the so-called 'free-rider effect' [21,32–35]. 'Free riders' may be defined as homeowners who would have refurbished anyway, whether or not subsides were on offer. Therefore, it is argued, even if we accurately estimate the total amount of energy saved through refurbishments in which subsidies have a role, this will not tell us how much energy the subsidies saved, as a good portion of it would have been saved anyway.

While evaluations of the UK SO do take free rider effects into account, German evaluations of the CBRP do not.

This paper investigates and compares the UK and German subsidy programmes by exploring: (a) the total quantity of energy and CO_2 that appears to have been saved through the subsidies; (b) the economic efficiency of energy saved through the subsidies, in Euros per kilowatt-hour (€/kWh); and (c) the economic efficiency of CO_2 saved, in Euros per tonne (€/t).

The remainder of this paper proceeds as follows: Section 2 provides essential background information on the two policy instruments and compares the official results. Section 3 introduces and offers estimates of the rebound and prebound effects in energy-efficiency refurbishment in Germany and the UK, it also discusses free rider effects and their potential impact. Sections 4 and 5 review existing evaluations of Germany's CBRP and the UK's SO programmes respectively, offering a critical analysis. Section 6 concludes.

2. Background

2.1. Supplier Obligation (SO)

The basic concept of the SO is that the government imposes an energy savings target on large energy suppliers (gas and electricity) that has to be achieved at the customer end, which may relate to energy consumption or carbon emissions [36]. Businesses and industrial end-users are not covered by the scheme. The target is set by the Department of Energy and Climate Change (DECC) for a defined period of time using a bottom-up approach assuming an illustrative mix of various energy saving measures that is likely to be used in order to deliver the obligation. It is defined in terms of expected savings over the technical lifetime of the measures promoted via the obligation.

The energy regulator, the Office of Gas and Electricity Markets (OFGEM), administers and enforces the SO. Energy suppliers may engage directly with customers or promote measures via third parties including local authorities, delivery agents, and installers [36].

The SO began in 1994 as the Energy Efficiency Standards of Performance (EESoP). It became the Efficiency Commitment (EEC1) in 2002; the EEC2 in 2005; and the Carbon Emissions Reduction Target (CERT) in 2008. For the post-CERT period a new scheme, called Energy Company Obligation (ECO), is planned [37]. For a detailed analysis of the development of the SO see Rosenow [36].

2.2. CO_2-Building Rehabilitation Programme (CBRP)

The CBRP has developed through a number of phases since its inception in 2001 [38–40]. Federal subsidies are channelled to home refurbishment and new build projects via the German Development Bank (KfW - *Kreditanstalt für Wiederaufbau)* as interest rate reductions and in some years also as grants. To qualify for a loan, a refurbishment must be designed to consume no more than 115% of the *new build* legal maximum primary energy demand for space and water heating, as prescribed in the thermal building regulations (*Energieeinsparverordnung*–EnEV) [41]. As the legal new build standard is 40% more stringent than the refurbishment standard, the trigger level for subsidies is about 30% more stringent than the legal refurbishment standard. Generally, the greater this improvement beyond the legal standard, the greater the subsidy.

The rationale for this approach is that the standards demanded in the EnEV have been set at such levels as to fit neatly with current costs of thermal refurbishment. Hence, policymakers argue, it does not actually cost a homeowner anything to refurbish to EnEV standard, as the thermal improvement will pay for itself, whereas it does cost to go beyond this standard, because at these levels of thermal refurbishment the costs escalate and the return per € diminishes considerably [5,31].

This would seem to imply that CBRP subsidies are only financing the most economically-inefficient extremes of thermal refurbishment. Federal policymakers argue, however, that the offer of CBRP subsidies induces homeowners to refurbishment by offering them something for nothing [31]. Hence, they argue, the few billion Euros in the CBRP annual budget 'trigger' *(auslösen)* the spending of tens of billions of private capital on thermal refurbishments.

This point is basic to how evaluations of the economic effects of the CBRP are performed. The federal subsidies are the only money

Table 1
Total expenditure, carbon and energy savings 2001–2007.

	Carbon emissions saved in million t CO_2 (lifetime)	Energy saved in TWh (lifetime)	Subsidies in billion €	Subsidies in € per t CO_2	Subsidies in € cent per kWh
SO	79	235	1.7	21	0.7
CBRP	74	173	4	48	2.0

Source: Own calculations based on various sources [40,44–61,66–69].

counted in the equations, while all the fuel and CO_2 savings are counted.

2.3. Comparison of official results

The accounting methodology for energy and carbon savings differs in the UK and Germany, hence the following comparison carries inherent limitations.

The German evaluations performed for the CBRP calculate annual reduction of carbon emissions rather than the induced lifetime CO_2 emissions reductions. However, the annual reductions can be converted into lifetime emissions saved by assuming an average lifetime of measures of 30 years, as shown by an additional analysis complementing the evaluation of Clausnitzer et al. [42] by Gabriel and Balmert [43].

The figures used in the UK for the SO (EEC 2 and CERT) do not include the energy and carbon savings carried over from previous obligation periods; only those savings actually achieved under the respective scheme are considered. Savings under EEC 2 are only reported in TWh, and conversion factors from the Department for Environment, Food and Rural Affairs (DEFRA) have been used to convert energy savings into carbon savings taking into account the proportion of different fuels saved as reported by OFGEM. In order to get annual figures for saved carbon emissions the total carbon savings of EEC 2 were prorated according to annual energy savings. For CERT saved carbon emissions have been reported on an annual basis by OFGEM but no figures for energy savings are available. Using the same energy/carbon ratio as EEC 2, annual energy savings were calculated for CERT.

The figures are not readily comparable for several reasons: First, the evaluation methodology applied changed over time (for example, energy savings were discounted under early versions of the SO, but this is not any longer done). Second, the figures calculated for this paper are based on the assumptions outlined above and need to be revised for a like-for-like comparison.

This paper's detailed comparison of savings and expenditure covers the period 2002–2007 only, as the CBRP started in 2001, detailed evaluations of the SO began in 2002, and the last evaluation of the SO was published in 2008. SO figures refer to financial years whereas the CBRP data is based on calendar years.

2.4. Carbon and energy savings

From 2002 to 2007 the CBRP generated savings of about 74 Mt CO_2 (lifetime) compared to savings by the SO of 79 Mt CO_2 (lifetime). In more recent years, the SO delivered higher savings than the CBRP. Fig. 1 displays these savings over time.

Concerning energy savings, the picture looks slightly different: The CBRP saved about 173TWh (lifetime) whereas the SO resulted in 235 TWh (lifetime), i.e. 35% more than the CBRP. The difference is most likely due to the fact that households in the UK use a higher proportion of gas for heating [44] which has a lower carbon factor than heating oils that are used in Germany [45]. Also the carbon factor for electricity is higher in Germany than in the UK [46,47]. These circumstances are likely to result in higher energy savings per unit of carbon saved for the SO.

2.5. Financial resources spent

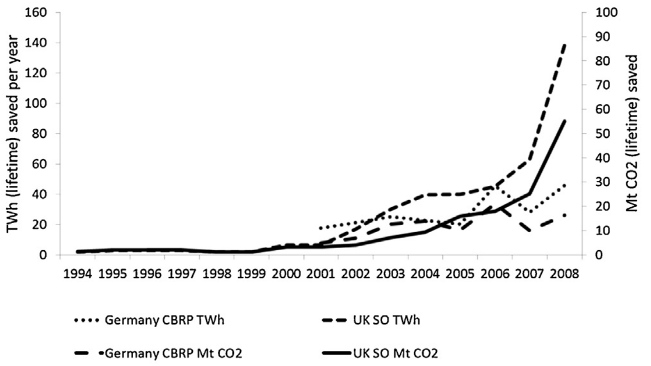
The financial resources for the two instruments are provided via two very different routes: In case of the SO the energy customers paid for the scheme with their bills, while the CBRP funding was based on taxpayers' money. In both cases households receiving financial resources for energy efficiency measures make an additional contribution to the overall cost. In some cases third parties such as social housing providers and local authorities may also add funding. However, in order to be able to compare the two instruments it is reasonable to exclude these contributions and compare only the cost that the public bears either through tax or a premium on the energy bill.

From 2002 to 2007 about €1.7 billion were spent by energy suppliers to comply with the SO [48,49]. In the same period federal funding for the CBRP amounted to as much as €4 billion [40]. Table 1 relates the cost figures to the energy and carbon savings. It should be noted that these costs include subsidies only, not the portion of refurbishment costs paid by the homeowners.

The table shows that, based on the official results, the CBRP requires 2–3 times the financial resources per t CO_2 (lifetime) or TWh (lifetime) as the SO. One reason could be that German dwellings are more energy efficient than the UK's [50], which can therefore benefit proportionately more from cheaper upgrade measures at lower levels. Further, CBRP subsidies are only given for top-end retrofits, where the marginal return per euro invested is low [5]. Note that the cost figures do not include the benefits in terms of saved energy costs. For a comparison to other carbon reduction programmes those would need to be included.

3. Evaluating energy efficiency programmes

The figures presented above rely on the evaluations commissioned by the respective governments and agencies. We now discuss which factors should be taken into account in evaluations of energy efficiency programmes followed by a critical analysis of the methodologies used in the evaluations of the CBRP and the SO.



Source: [39]

Fig. 1. CO_2-emissions in Mt (lifetime) and TWh (lifetime) saved per year (SO data is for financial years whereas CBRP data is for calendar years).
Source: [39].

3.1. Rebound effects

The rebound effect, or Khazzoom-Brookes Postulate [51], is grounded in Jevons' [52] insight that 'it is a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth.' It is argued that increasing energy efficiency makes it cheaper to produce goods and services, leading to greater wealth, which drives energy consumption higher than before the efficiency improvements. This occurs on the micro level, both directly and indirectly [53,54], and also on the economy-wide, macro level [54]. The present study is concerned only with direct micro rebound effects, namely the percentage of the energy saved through refurbishment that is taken back, to provide increased thermal comfort or convenience after refurbishing.[1]

There are various assessments of the magnitude of the rebound effect for domestic heating. Greening et al. [53] reviewed 75 studies and found rebound effects of 10–30% for space heating. A review of over 500 studies for the UK Energy Research Centre found rebound effects for home heating averaging less than 30% [54]. Haas and Biermayr [55] estimate a figure of 30% for home heating in Austria, a country with similar climate, building standards and indoor culture to those of Germany.

Localised studies in Germany show similar trends. Erhon [56] found actual consumption increasing steadily above calculated values as thermal standards became higher, i.e. as calculated consumption, given here in kilowatt hours per square metre of floor area per year (kWh/m^{2}a), became lower. This started at 0% for detached houses of 150kWh/m^{2}a, and multi-dwelling buildings of 100kWh/m^2, and reached 50% for the most energy-efficient dwellings of both types. Loga et al. [57] found similar effects in homes with calculated consumption ratings lower than 50kWh/m^{2}a, while Kaßner et al. [58] found actual consumption of 65% above calculated for dwellings with calculated ratings of 75kWh/m^{2}a. Thomsen et al. [59] reported 100% over-consumption in a study of 'advanced solar low-energy buildings'. A recent study suggests that the rebound for space heating ranges between 12% for owners to 49% for low-income tenants [60]. Greller et al.'s [30] study of 100,000 dwellings, referred to above, revealed progressive magnitudes of over-consumption increases in parallel with progressing tightening of legal standards over the past decade. These figures are not strictly the 'rebound effect' because their baseline is current calculated consumption, rather than calculated savings in consumption. But they are useful measures as they show the same phenomenon: over-consumption compared to the calculated rating, in low-energy dwellings.

The picture in the UK is similar. A study by Milne and Boardman [61] suggested that rebound effects for insulation measures are likely to be around 30% in the UK. For electrically heated dwellings Henderson et al. [62] reported rebound effects of 18%. Without quantifying the contribution of the rebound effect, the total measured shortfall from expected savings in gas heated homes is 55% [63]. This figure includes technical shortcomings and other reduction effects which are not rebound effects. The rebound effects for fuel poor households in the UK may be as high as 65–100% [64]. However, Martin and Watson [65] showed that although low income customers displayed slightly higher rebound effects, there was little difference in rebound effects between average and low income customers. More recent analysis of seven popular energy efficiency measures arrived at much lower figures of 5–15% for direct and indirect rebound effects [66].

3.2. Prebound effects

Sunikka-Blank and Galvin [29] reviewed eight studies which analysed measured and calculated consumption figures for a total of 3400 German dwellings, plus measured ratings only for an additional 1 million. They found a clear trend was evident in the studies: on average, the higher the calculated energy rating (i.e. the less energy-efficient the building), the larger the percentage difference between measured and calculated consumption. The authors labelled this the 'prebound effect', as it is the opposite of the rebound effect. It refers to the percentage by which the measured consumption of a dwelling is *lower* than the calculated consumption. For example, a dwelling with a calculated rating of 200 kWh/m^{2}a that is consuming 160 kWh/m^{2}a is showing a prebound effect of 20%. Though there were slight differences in the results of the studies reviewed, generally the prebound effect was, on average, 0% for dwellings of calculated rating 100 kWh/m^{2}a, rising through 30% for ratings of 220 kWh/m^{2}a, up to 55% for ratings of 500 kWh/m^{2}a. While these were average values, the measured consumption of individual dwellings varied widely (see Greller et al. [30], Bild 1, for a graphical representation of the range of differences). However, average figures are useful for the present study, because, in the absence of evidence to the contrary, we may presume that the discrepancies between calculated and measured energy consumption in buildings that are about to be refurbished belong to the same statistical distribution as those in the total residential building stock.

A further finding was that, on average, for buildings of calculated consumption below 100 kWh/m^{2}a, the prebound effect became negative, i.e. the rebound effect came into effect.

Sunikka-Blank and Galvin [29] compared these findings to those of comparable studies in France [67], the Netherlands [68], Belgium [28] and the UK [69] and found similar trends.

3.3. Free rider effects

A point of controversy in the energy efficiency literature has been the issue of free riders and their impact on the effectiveness of programmes [16,17,20,21,32–35,70–73]. Free riders 'are programme participants who would have purchased and installed an energy efficiency measure even in the absence of the programme' [74, p. 18]. This phenomenon is also referred to as 'deadweight' [75].

Kreitler [32] estimates that free rider effects can reduce estimated savings by up to 80%, and Loughran and Kulick [76] estimate this at 50–90%. Malm [33] estimates free rider effects on high efficiency heating system purchases at almost 90%. A cross-evaluation survey on US demand side management programmes resulted in estimates of 0–50% with an average of 12.2% [73].

A recent study in Germany [77] calculates that up to 50% of estimated savings may be lost due to free riders. The impact of free riders depends very much on the type of measure and the specific context in which the measure is provided.

Responding to the critics, some stress that while free rider effects exist, they are offset by so-called 'free driver' or spillover effects, which result from measures being installed as a result of but not through the programme. This is the case when people install additional measures over and above the programme's incentives or if non-participants take up measures as a result of the programme [73]. Recent evaluations of energy efficiency programmes show that spillover effects can be substantial and counterbalance a significant proportion of the free rider effects [78].

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[1] Short of a detailed thermodynamic examination of the building envelope and heating system it is impossible to know what portion of this difference is genuine 'take-back' and what is due to technical shortcomings in the refurbishments.

4. Evaluations of the Supplier Obligation

4.1. Existing evaluations

DECC commissioned independent evaluations of EEC 1 and EEC 2 conducted by Eoin Lees Energy [48,49]. In addition, OFGEM provided annual reports on the results of the SO since 2002 and, with support of the Energy Saving Trust, a summary review of EESoP 1–3 covering 1994–2002 [79]. Those reports result from the Regulator's duty to report to the Secretary of State on the Programme. Until the end of EEC 2, OFGEM reported the accounted lifetime savings in terms of TWh broken down by energy supplier and measure. Since 2008 the target metric changed to t CO_2 (lifetime) and energy savings are no longer reported.

This paper focuses on the independent evaluations carried out by Lees [48,49] because the OFGEM reports are more an accounting procedure based on an ex-ante agreed scoring system rather than a comprehensive evaluation. Lees critically discusses assumptions made in the accounting process and contrasts those with 'real' data. The evaluations include detailed estimates for energy savings broken down by measure and the cost of the SO to energy suppliers, receiving households, and others.

4.2. In-depth appraisal of the evaluation

The evaluations carried out by Lees [48,49] essentially correct the energy saving scores used by OFGEM to account for the savings achieved by the obligated parties.

Because the SO always focused on small energy users–first households and small businesses and then just households–the approach taken by the Regulator to verify the savings was based on deemed savings rather than measured savings. The values for those deemed savings were generated by using models such as the BRE Domestic Energy Model (BREDEM). Measures for which reliable engineering estimates of energy savings existed were given a specific energy savings score (later carbon emissions savings).

According to Lees [49], the following steps were carried out to correct the energy savings reported by OFGEM in the evaluations:

- remove any uplift factors from the energy saving values: Some measures (called innovative action) received higher energy saving scores in order to incentivise additional technologies with a lower cost effectiveness. These uplifts are subtracted in the evaluations.
- correct for the heat replacement effect for lighting and appliances which results in increased fossil fuel usage: More efficient forms of lighting and appliances result in less waste heat which is subsequently compensated by increased space heating.
- remove the fraction of energy savings taken in the form of increased comfort: See section 4.3 on rebound effects.
- update the energy saving values for insulation measures and the lifetimes for heating measures to be consistent with those used in most recent obligation period: This is based on the assumption that most recent scores have been revised based on new evidence.
- convert from fuel standardised units to the actual units of the fuel: EEC 1 and EEC 2 used a fuel-weighted accounting system depending on the carbon content of the fuel saved.

The SO evaluations also account for free rider effects (section 4.4). Prebound effects are addressed by adjusting the modelled savings based on measured savings across a sample of households (see Section 4.3)

4.3. Prebound and rebound effects

Rebound effects are partially taken into account in evaluations of the SO. However, this is related to space heating and insulation only. The EEC 1 evaluation used a 30% rebound factor for the calculation of savings from insulation [48], the same factor was used when setting the energy savings score for the different measures for EEC 2. However, the comfort factor was reduced to 15% during CERT [49] as a result of research commissioned by DECC on discrepancies between actual and estimated savings [80]. DECC states that analysis allows for a comfort factor of 40% for insulation measures in the super priority group, a group of customers thought to be most vulnerable (15% in priority group, a group of those over 70 and on certain benefits) and 25% for heating measures in the super priority group (0% in the priority group) [81]. It is likely that similar figures will be used in the CERT evaluation.

Similarly to Germany, the modelled energy consumption pre-refurbishment is higher than actual consumption. However, the main difference to the evaluations of the CBRP is that since the beginning of the SO those effects have effectively been cancelled out already at policy design stage by frequent revisions of the energy savings scores used in the target setting and accounting process that follows. The revisions are based on observed savings within a sample of recipients of measures rather than modelled hypothetical savings. Research by the Building Research Establishment (BRE) in the 1980 showed the gap between the two and suggested an overall 'reduction factor' of 30% [62], and there is evidence that it still exists [82]. This reduction factor includes rebound effects, prebound effects, and technological shortcomings of measures. Although the prebound effect is not explicitly quantified for every measure, it is included in the part of the reduction factor applied to energy savings classified as 'other'.

Further verification was undertaken by assessing the validity of the energy savings scores used for attributing savings to the various measures. A range of studies was commissioned by government and stakeholders [62–65,80,83–86]. The latest research on energy savings is currently conducted as part of the National Energy Efficiency Data framework [87]. The results of the above studies were used to optimise the deemed savings scores for future obligations.

It is beyond the scope of this paper to validate the reduction factors applied for the various measures, but in theory, this process accounts for both rebound and prebound effects at the policy design and evaluation stage.

4.4. Free rider effects

In the UK, free rider effects are explicitly considered in the design of the SO when the savings scores are defined for different types of measures [48,49]. During EEC 1, free rider effects have been estimated to be less than 30% for all measures other than DIY loft insulation. The underlying methodology is to compare past uptake rates with those in the obligation period and derive the percentage of activity that is additional to business as usual. However, the author of the evaluation admits that the figures derived include 'guesstimates' [49, p. 32] and could be improved. The evaluation suggests further analysis to validate the estimates and the relationship between the market penetration of a product and the associated free rider effects.

The initial factors used for free rider effects were higher than calculated by the evaluation and total free rider effects were estimated to be 20.7% compared to the initial assumption of 27.6%. These estimates were taken into account in subsequent policy design and the correction factors for free rider effects were amended. The EEC 2 evaluation stresses that free rider effects are below 20% for most of the important measures (in terms of their contribution to the overall target) except for DIY loft insulation. Overall, 14% of the savings were attributed to free riders. However, given the higher free rider effects factors for wet and cold appliances, the overall losses due to free riders accounted for about 20% [49]. When the SO was extended in April 2011, DECC decided that for the remainder of the obligation period there would be negligible free rider effects being subsidised by the programme. This is due to the high number of filled cavity walls and insulated lofts [88]. However, a detailed analysis is missing. Previous evaluations systematically assessed free rider effects and it is likely that the post-CERT evaluation will provide more clarity.

5. Evaluations of the CO_2 Building Rehabilitation Programme

5.1. Existing evaluations of the CBRP

The first detailed evaluation of the CBRP, Kleemann et al. [89], analysed its 2001 effects using the IKARUS space heating model. This gives energy and carbon savings based on calculated building performance. The figures from the sample were extrapolated to all the buildings that received KfW funding. No detailed evaluation exists for 2002–2004, but Doll et al. [90] provide estimates for the carbon savings achieved in these years, quoting an unpublished presentation of the Federal Ministry of Transport, Building and Urban Development (BMVBS–*Bundesministerium für Verkehr, Bau und Stadtentwicklung*) from 2006. IER and PROGNOS [91] also offer figures for energy savings achieved in 2002 and 2003. In reports prepared for the KfW for 2005–2010, Clausnitzer et al. [42,92,93] and [94] offered detailed evaluations of the programme, including energy and carbon emissions saved. Diefenbach et al. [95] use a similar method in their evaluations for 2005–2010, also prepared for the KfW.

5.2. In-depth appraisal of the evaluations

Clausnitzer et al. [92] follow the same methodology and format as the bulk of the post-2005 evaluations, and may be used as an example. It estimates CO_2 and energy savings achieved through the support of CBRP subsidies given in 2007. The owners of 1022 properties that had received CBRP support were surveyed and 658 responded. Respondents gave details on the type, location and orientation of the building, plus its thermal features (insulation, windows, heating system, etc.) before and after refurbishment, and the energy source used for heating. Using these parameters the authors employed a simplified method, developed by Loga et al. [96], to calculate heating energy consumption, in line with energy ratings given in German energy performance certificates. This gives theoretical results based on the presumed technical quality of the building, and does not take rebound and prebound effects into account. The authors modified this according to a building typology classification method (apparently produced by the Institut Wohnen und Umwelt, but mis-referenced in Clausnitzer and colleagues' studies) and the likely effects of each building's geographical location and orientation to the sun. A software tool was then used to give the expected energy and CO_2 emission savings per year from this data.

Further consideration was given to the likely technical lifetime of the thermal refurbishment measures (e.g. 40 years for roof insulation; 20 for boilers–[92, p. 54]). From these figures the annual energy and CO_2 emission savings, produced as a result of the refurbishments, were calculated. As a cross-check on survey data a 'sub-sample' (number and selection method not given) of properties were visited. The results were then extrapolated to all domestic properties that received CBRP funding, to produce national totals. The study concludes that CBRP funding of €0.9 billion for 2007 supported the saving of 330,000 t of CO_2 per year and 0.94 TWh of energy per year. Assuming a 30-year average for the technical lifetime of the refurbishments [92, p. 68], this equates to total savings of 9.9 million t of CO_2 and 28.2 TWh. For the €0.9 billion given by the CBRP in 2007 this equates to a cost of €85 of federal subsidy per t of CO_2 saved, and €0.03 per kWh saved.

From these results we can calculate what this implies for the average dwelling. According to the study, the subsidies enabled 88,590 dwellings, of total floor area 7.75 million m^2, to save a total of 940 GWh of heating energy per year. This equates to a saving of 121 kWh/m^2a, or 54% of an average pre-refurbishment consumption of 226 kWh/m^2a (see below).

The results of Clausnitzer et al. [42,92–94], supported by Diefenbach et al. [95] show a sharp fall in the savings per m^2 of floor area as from 2008: energy savings rose steadily, from 110 kWh/m^2a in 2005 to 131 kWh/m^2a in 2008, then fell to 84 kWh/m^2a and 82 kWh/m^2a in 2009 and 2010 respectively. This is most likely because prior to April 2009 only whole-house refurbishments were eligible for subsidies, but from April 2009 single refurbishment measures–such as replacing a window or insulating a roof–became eligible. However, in 2010 cost came down by almost 40% per unit of energy and CO_2 saved, probably a result of including single measures.

5.3. Prebound and rebound effects

The prebound effect depends, as noted in Section 2, on the (calculated) pre-refurbishment energy consumption. The studies evaluating the CBRP do not give this value, but only the calculated savings. The pre-refurbishment figure can be estimated as follows.

In 2007 the legal maximum (calculated) consumption for whole-house refurbishments was 150 kWh/m^2a. To qualify for CBRP funding a refurbishment design had to under-reach this by 30%, i.e. it must reach 105 kWh/m^2a. Clausnitzer et al.'s [92] survey revealed an average (calculated) saving in that year of 121 kWh/m^2a, hence the pre-refurbishment calculated rating would have been 226 kWh/m^2a. This is close to Germany's average (calculated) consumption of 225 kWh/m^2a. The national average prebound effect associated with this value is approximately 30% [29]. Hence we may assume an average actual pre-refurbishment standard of 158 kWh/m^2a.

The rebound effect, as noted above, tends to occur for multi-dwelling buildings rated below (better than) 100 kWh/m^2a and detached homes below 150 kWh/m^2a. So for a cohort averaging 105 kWh/m^2a we might expect a fairly small average rebound or 'over-consumption' effect. Based on the findings of Sunikka-Blank and Galvin [29] we cautiously estimate this to be around 10%, bringing the actual final consumption to 115 kWh/m^2a.

If these values are applied to 2007 refurbishments, the average energy saved falls from 121 kWh/m^2a to 43 kWh/m^2a, or from 54% (of calculated pre-refurbishment consumption) to 27% (of actual pre-refurbishment consumption). The cost of energy saved rises from €0.03/kWh to €0.087/kWh, and of CO_2 saved rises from €85/t CO_2 to €234/t CO_2. For the 2007 cohort, total energy and CO_2 saved over the refurbishments' 30-year technical lifetime fall from 28.2 to 12.2 TWh and 9.9 to 4.3 million t respectively.

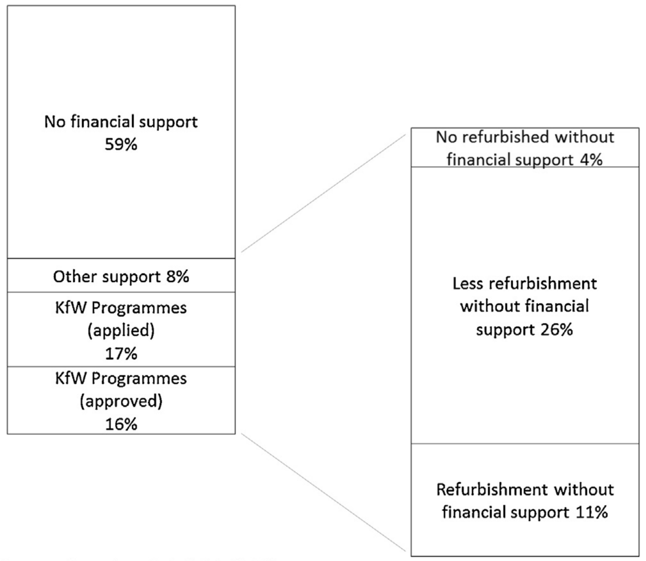
Despite the length of the evaluations (over 250 pages), they give only minimal information on methodology. While their authors must have estimated the (calculated) pre- and post-refurbishment energy consumption, they give only the difference between these two. Further, their questionnaire asked only about building characteristics, not about energy bills, so an opportunity to explore the validity of their calculated data was missed. In the absence of further information, and in line with the growing evidence of prebound and rebound effects, we estimate the actual savings to be those given above, for prebound and ‘rebound’ (i.e. overconsumption) effects of 30% and 10% respectively.

5.4. Free rider effects

None of the evaluations studies carried out for KfW [42,89,92–94] mention free rider effects. An evaluation of the CBRP and other policies focusing on home energy efficiency carried out for the Federal Office for Building and Regional Planning (BBR) stresses that there is no reliable data for free rider effects and models the implications of 0–30% free rider effects [97]. Only one evaluation study of carbon reduction policies carried out for the Federal Ministry for Economy and Labour explicitly discusses free rider effects with regard to the CBRP [91]. Without quantifying the effect, the authors of the study provide qualitative estimates for various policy instruments. For the CBRP they estimate that free rider effects are high. The study highlights that no reliable data exists and that future research needs to address this gap.

Since the IER study no reliable estimates have been made available [98–100]. There is, however, some evidence that indicates free rider effects. A survey covering 244 households that received energy efficiency advice shows that 59% of those who invested in energy efficiency measures did not apply for financial support such as the CBRP [101]. Of the 41% who applied for financial support for the investment in energy efficiency measures 81% submitted applications to KfW programmes, most probably to the CBRP. Only 9% of the 41% who did apply for financial support would not have undertaken the investment i.e. just 4% of all households that did invest in energy efficiency improvements would not have refurbished their homes without the financial support offered by programmes such as the CBRP. Of those who applied for financial support 64% stated that they would have done less energy efficiency improvement without any support. More importantly, 11% of those who received or applied for financial support stated that they would have refurbished their homes to the same standard in absence of any support (Fig. 2). This suggests free rider effects of at least 11% plus an unknown percentage included in the 64% of households who would have undertaken some but not all of the investment without financial support.

The figures suggest that some of the energy efficiency refurbishments that are supported by the CBRP would have happened anyway. Given that the study was based on a small number of households one needs to be cautious when interpreting the results, even though the overall validity of the study design was critically peer-reviewed and generally approved by the Wuppertal Institute [102]. In addition to the small sample size, the study is also more than 6 years old and the CBRP’s requirements did change over the years. Also, the method used suffers from two problems: a) it may provide unreliable estimates when the wording of the questionnaire is inappropriate and b) it does not allow for an estimate of the level of inaccuracy [16]. Others question the validity of such methods because intentions are not very good predictors of actual behaviour. Asking people about their decision and whether they would have done it without financial support does not produce reliable estimates of free riders [103].



Source: based on Friedrich [101]

Fig. 2. Financial support for refurbishment and impact on decisions of households. Source: based on Friedrich [101].

Still, the evidence illustrates that there is a real need for more research in Germany making use of a much bigger sample size and generating more reliable data. So far free rider effects have been either ignored or downplayed in the evaluations of the CBRP. An evaluation study on the economic effects of the CBRP funded by the KfW argued that an assessment of whether investments in energy efficiency improvements would have been undertaken regardless of the financial support provided by the CBRP was outsight of the analysis. The CBRP would raise awareness in the first place and therefore trigger investments in energy efficiency improvements (free drivers, see section 3.3), mainly through giving advice to households [104]. However, research on German energy advice programmes also indicates significant free rider effects of 66–89% depending on the type of energy efficiency measure [99].

6. Conclusions

The literature on the evaluation of energy efficiency programmes is heavily dominated by US scholars, while contributions from German and British scholars are rare. As a result of critical research, evaluations of energy efficiency programmes in the US became much more sophisticated over time [17]. Similar attempts could help improve the validity of the evaluations in Germany and the UK. This paper is a first step by critically evaluating the evaluations of two prominent energy efficiency policies in Germany and the UK.

The UK evaluations account for all three of the savings reduction effects. Rebound effects are explicitly subtracted from calculated savings for some measures both in the evaluations and at policy design stage. Prebound effects are addressed by using adjusted savings scores based on observed rather than modelled savings (although their contribution to the total reduction factor applied is unknown). Free rider effects are explicitly considered in savings estimated from various energy efficiency measures. Nevertheless, it is beyond the scope of this paper to assess the accuracy of the estimates of these three factors in the UK.

In contrast, evaluations of the German CBRP do not account for any of these reduction effects. Our critical review of the evaluation for 2007 Clausnitzer et al. [92] suggest that, when rebound and prebound effects are taken into account, actual savings may be only half as great as the evaluation estimates, quite apart from any possible free-rider effects.

There are increasing calls for actual, rather than estimated, savings to be used in assessments of energy saved through refurbishments [e.g. 27,30].

Despite repeated demands for doing so, in Germany free rider effects are not included in any of the evaluations of the CBRP. There is insufficient data on free rider effects in Germany but the evidence that exists suggests that those effects may be significant. A thorough assessment of potential free rider effects and their systematic considerations in the evaluations would improve the reliability of the results.

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