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Fuel poverty, affordability, and energy justice in England: Policy insights from the Warm Front Program

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ABSTRACT

Millions of homes around the world suffer from "fuel poverty," commonly defined as the necessity to spend more than 10 percent of their income paying energy bills. This article first discusses how home energy efficiency schemes, such as those that pay to weatherize doors and windows, install insulation, and give free energy audits, can significantly reduce the prevalence of fuel poverty. It then examines the "Warm Front" program in England, which over the course of 2000–2013 saw 2.3 million "fuel poor" British homes receive energy efficiency upgrades to save them money and improve their overall health. Warm Front not only lessened the prevalence of fuel poverty; it cut greenhouse gas emissions, produced an average extra annual income of £1894.79 per participating household, and reported exceptional customer satisfaction with more than 90 percent of its customers praising the scheme. This study details the history, benefits, and challenges of the program, and it teases out six noteworthy lessons for energy analysts, planners, and policymakers.

1. Introduction

This study examines the second largest national program ever conceived and implemented to address fuel poverty: England's Warm Front Home Energy Efficiency Scheme. From 2000 to 2013, Warm Front removed about 2.36 million English households from fuel poverty. Warm Front interventions have been credited with reducing carbon dioxide emissions per home by 1.5 tons per year, displacing £610.56 in modeled, potential annual energy costs and generating an average annual increase in income per customer of £1894.79. Notable achievements include more than one million homes refitted with draught proofing and cavity wall insulation, 722,300 lofts insulated, the replacement of 479,000 boilers, and 75,000 new electric central heating systems installed, among others. Moreover, the Warm Front scheme accomplished these tasks with an extremely high satisfaction rate, with an average annual customer satisfaction score of 92.3 percent for its most recent year [1]. But how did it accomplish these feats? What challenges did it have to overcome, and which remain, now that the program is over? What is the likely future of fuel poverty in England?

To provide insight into these questions, this article proceeds as follows. After introducing the issue of affordability and fuel poverty as a major energy policy and justice concern, the article articulates the connections between thermal comfort, mental health, and physical health. It then details the frequently inequitable nature of household energy consumption, with poorer households paying a greater share of their income on energy services than wealthier and middle class households. It then describes the history of the Warm Front Program before assessing its benefits, identifying its challenges, and presenting six lessons and insights for energy analysts and planners.

In embarking on this path, the study makes at least three contributions. First, it makes visible and humanizes the topic of fuel poverty and vulnerability, one that is all too often ignored in contemporary energy policy discussions [2,3]. Though many may take it for granted, having a warm, comfortable, well-lit home is an instrumental part of modern, industrialized life. Without sufficient warmth or electricity, modern families must suffer the harsh climates of winter without heat, leading to hundreds of thousands of excess winter deaths every year, or rely on "coping" strategies such as cutting down on expenses related to food or medical care to pay their energy bills. Second, rather than focus on national or geopolitical energy security concerns, it centers on the household dimensions of energy security, a scale under-examined in

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contemporary energy research [4,5]. Third, it centers the discussion of fuel poverty not only on traditional notions of affordability or household energy poverty, but also on novel notions of energy justice, ethics, and recognition [6–8].

2. Background: affordability, fuel poverty, and energy justice

Affordability matters from an energy policy perspective—when energy prices rise and households cannot afford heat or electricity, it is functionally the same as if they lack access to reliable energy services altogether. In addition, less affluent families spend a larger proportion of their income on energy services, hindering the accumulation of wealth needed to make investments to escape their poverty. One study looking at the effects of increases in energy prices in four developing Asian economies from 2002 to 2005 found that poorer households paid 171% more of their income for cooking fuels and 120% more for transportation, 67% more for electricity, and 33% more for fertilizers when compared to the expenditures on energy from middle- and upper-class households [9].

The concept of "fuel poverty" is one useful way of framing the issue of affordability. Initially defined as "households with high fuel expenditure as those spending more than twice the median on fuel, light and power," it is now commonly associated with households that must spend greater than 10 or 15 percent of their monthly income on energy services [10–12]. The European Union states that it is "persons, families and groups of persons whose resources (material, cultural and social) are so limited as to exclude them from the minimum acceptable way of life in the Member State to which they belong [13]."

To be clear, poverty, influenced deeply by income, is not identical with fuel poverty, conditioned by household income as well as fuel prices and the energy efficiency of residential building stock [14]. As one study put it bluntly, "raising incomes can lift a household out of poverty, but rarely out of fuel poverty [15]." As another team of researchers have noted:

> *Fuel poverty is a difficult concept. It is not the same as poverty. Some people are poor but can afford adequate warmth. Others with incomes above the accepted poverty line nevertheless cannot afford to be warm - because their home is difficult or expensive to heat. There are also people who purchase warmth only at the expense of adequate diets or going short in other ways. There are also those who live on in cold conditions despite having incomes which are sufficient to purchase adequate warmth - because of helplessness or fear of fuel bills [16].*

Thus, low-income households with sound investments in energy efficiency may not be in fuel poverty, whereas households with larger incomes in less efficient homes may be in fuel poverty [17]. Though the classic definition of fuel poverty is the "10 percent of household income" metric, another way of measuring it is those households that actually spend more on energy than on food [18]. Still others rely on the term "severe fuel poverty" to indicate needing to spend 15–20 percent of household incomes on energy, i.e. between three- and four-times the median for a given year, and "extreme fuel poverty," those needing above 20 percent or greater than four times the median for a given year [10].

Conceptions of fuel poverty have been heavily influenced by Boardman [19,20], who initially argued that "fuel poverty occurs when a family is unable to afford adequate warmth because they live in an energy-inefficient home [21]," that fuel poverty "occurs when a household is unable to afford adequate energy services in their home on their present income," and that it "relates to consistent, defined standards of energy services, not just actual expenditure [17]." Her work has been primarily concerned with fuel poverty in the United Kingdom, where she calculated that the poorest 30 percent of households spend less money per person on fuel than the other 70 percent of households, but pay twice as much as a proportion of their monthly budget. She calculated that an astounding 68 percent of homes with incomes in the lowest decile in the United Kingdom were in fuel poverty in 2006.

The problem is most certainly not limited to the United Kingdom. In New Zealand, about one-quarter of homes suffer from fuel poverty due to a generally poor quality of housing in terms of thermal efficiency, comparatively high levels of income inequality, and rapid increases in the real price of residential electricity [15]. In Austria, a "large number of households live in deprived conditions, carrying multiple burdens (lack of financial resources, energy-inefficient dwellings, old devices, energy costs or long-term illnesses) [22]." In Hungary, the problem of fuel poverty can be too *much* heat that cannot be controlled rather than too little. There, the fall of the Soviet Union "progressively brought energy prices to full-cost recovery levels, reduced household incomes and left a legacy of inefficient and deteriorating residential buildings lacking basic energy efficiency requirements [18]." When Hungarians cannot pay their heating bills, in serious cases they can lose their home as accumulated housing and utility bills force families to move to less valuable properties as a way to repay their energy debts [18].

The impacts of fuel poverty extend well beyond defaulting on energy bills, and can threaten personal wellbeing and modern notions of equity, justice, and fairness. O'Brien found that fuel poverty results in "inadequately heated housing" and, as a result, higher rates of mortality among the elderly, a greater prevalence of circulatory and respiratory diseases in adults, reduced physical and emotional well-being, and an increased risk of falls, mental health illness, social isolation, and hospital admissions [14]. More severely, fuel poverty quite literally kills people who go without essential heat and then suffer "excess winter mortalities." One epidemiological study looked at 11 industrialized countries in both the Northern and Southern Hemispheres and found a clear correlation between the winter months and unusually high rates of mortality [23]. Average excess winter deaths—defined as the extra deaths in the four winter months in comparison with the previous and succeeding four months—across a dozen countries amounted to 278,409 in 2008, exceeding the global number of deaths (about 166,000) attributed by the WHO (World Health Organization) to climate change. This makes fuel poverty as urgent a health issue as climate change, given that a 2006 WHO review of 10 countries projected that the attributable fraction of excess winter deaths due to housing conditions was 40 percent [15].

Such findings have been confirmed by scores of independent assessments [24–26]. To cite a few prominent examples, Liddell has found that cold-related deaths from fuel poverty can occur through "changes in blood pressure and blood chemistry during cold weather, which in turn increase the risk of catastrophic cardio- or cerebro-vascular events such as strokes, myocardial infarctions or pulmonary embolisms" as well as the suppression of immune systems [27]. The Marmot Review Team demonstrated that countries with more energy-efficient housing had lower excess winter deaths, that children living in cold homes are more than twice as likely to suffer from a variety of respiratory problems than children living in warm homes, and that cold housing increases the level of minor illnesses such as colds and flu and exacerbates existing conditions such as arthritis and rheumatism. It also noted that cold housing negatively affects dexterity and can heighten the risk of accidents and injuries in the home [28]. A team of researchers led by the WHO's Collaborating Center for Housing Standards and Health documented that "an inadequate supply of energy may also mean an inadequate supply for other basic domestic needs such as for food storage and cooking, maintenance of personal and

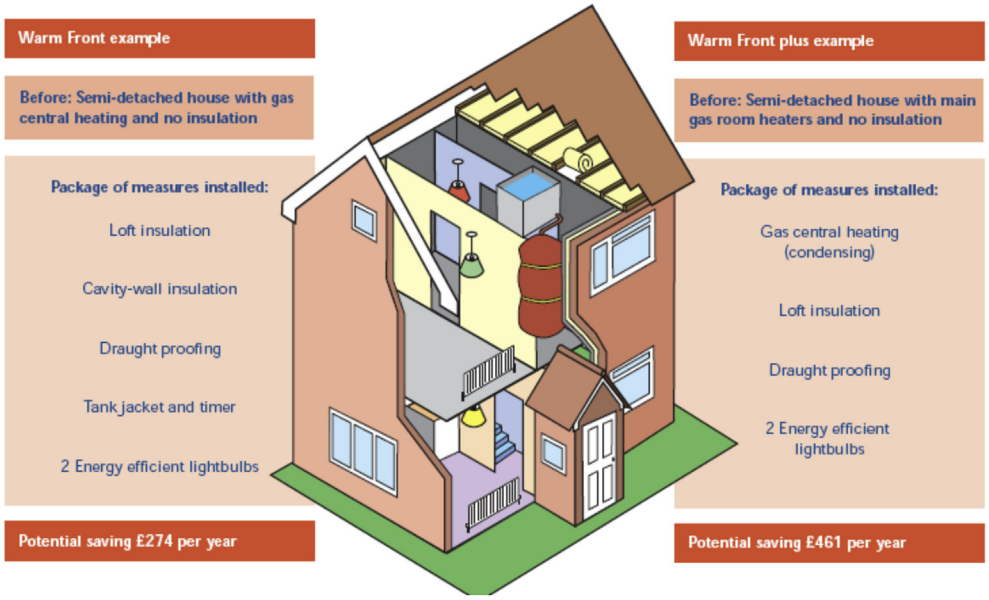


Fig. 1. Common household energy efficiency upgrades sponsored under England's warm front scheme, 2004.

domestic hygiene, and artificial lighting. Each of these could result in threats to health such as food poisoning, spread of infections, slips and fall injuries, fire injuries (from candles or oil lamps) and carbon monoxide poisoning (from inappropriate unflued heat sources) [29]." When it doesn't kill and sicken people directly, fuel poverty forces households to "cope" with inadequate energy services in a variety of ways. Surveys of the fuel poor have found that they will resort to wearing coats and outdoor clothing indoors, sleeping together with pets or in one room to keep warm, having hot drinks, or even staying with relatives—actions that can all negatively impact mental health [30].

Walker and Day have compellingly argued that fuel poverty cuts across issues of ethics and justice as well [31]. Fuel poverty intersects with procedural justice because fuel poor households have little time to participate in energy policymaking decisions or to learn about energy efficiency, and it intersects with justice as recognition because being fuel poor "can be read as a lack of recognition of the needs of certain groups, and, more fundamentally, as a lack of equal respect accorded to their wellbeing. This is particularly significant given that fuel poverty does not have equal consequences across different social and demographic groups [31]."

3. The history of the Warm Front Program in England

England's Warm Front Home Energy Efficiency Scheme, hereafter referred to as WF (Warm Front), successfully reduced the extent of fuel poverty among 2.36 million English homes from 2000 to 2013. WF was "a major component of government strategy to eliminate fuel poverty in England and enable even the poorest households to maintain healthy indoor temperatures [32]." Managed initially by the Department for Environment, Food, and Rural Affairs, it provided grant funded packages of insulation and heating improvements to eligible households. The scheme has lowered greenhouse gas emissions affiliated with low-income households, increased incomes and accrued billions of pounds of energy savings, and achieved these feats with strong approval ratings from its customers.[1]

[1] These claims do depend on the self-reported data and projections from WF reports and documents being accurate.

WF began in June 2000 after a 1999 Inter-Ministerial Group on Fuel Poverty was instructed to develop a formal Fuel Poverty Strategy intended to identify and then address the causes of fuel poverty throughout all of the United Kingdom [33]. Based upon their input, the Warm Homes and Energy Conservation Act was passed in November of 2000, culminating in the creation of the UK's 2001 Fuel Poverty Strategy to assist the fuel poor primarily through WF in England and through other similar schemes in the devolved administrations of Scotland, Wales and Northern Ireland [34]. The 2001 Fuel Poverty Strategy officially noted that "a fuel poor household is one that cannot afford to keep adequately warm at reasonable cost. The most widely accepted definition of a fuel poor household is one which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth. This is generally defined as 21 °C in the living room and 18 °C in the other occupied rooms [10]."

More specifically, WF provided packages of "insulation and heating measures depending upon the needs of the householder and the construction of the property." In 2001, it offered grants of up to £1500 to those wishing to install loft and/or cavity wall insulation, draught proofing, gas wall heaters, dual element foam insulated immersion tanks, and heating repairs and replacements. This first grant was available to households with children or pregnant women on certain qualifying income related benefits, as well as those in receipt of disability benefits. Under a "WF Plus" component, it offered grants of up to £2500 to households claiming qualifying income related benefits and occupied by those over the age of 60 for insulation measures and heating system upgrades including new central heating systems [35]. The WF scheme was altered after a Government Spending Review in 2010. This resulted in a substantial reduction of the WF budget and a change in the eligibility criteria of the scheme, ostensibly to better target vulnerable households living in energy inefficient homes. From 2011 to 2012 households had to be in receipt of income related benefits *and* be living in a thermally inefficient home *and/or* not have a working central heating system. In its revised state, qualifying WF households received up to £3500 in grants or £6000 where oil central heating and other alternative technologies were recommended, until the scheme stopped accepting applications in January, 2013. Fig. 1 shows the types of upgrades made under both the WF and WF Plus schemes using data from the National Audit Office.

The WF scheme worked either by having homeowners and tenants self-apply online, over the phone, and through the mail, or by referrals from previous customers. If an application met WF's eligibility criteria, a WF surveyor visited the home to conduct a residential energy audit. During this audit, the surveyor corrected simple problems that required less than 3 h of time, in other cases surveyors ruled out homes that were already energy-efficient. If homes passed inspection, they were allocated an installer who would suggest energy efficiency measures, prices, and an installation date. The final phase involved the actual installation of retrofits and equipment, with work completed for insulation within three months and within five months for heating systems. After installation, the WF team inspected a random sample of 5 percent of homes with new heating systems and 10 percent of those with insulation.

WF was strategically designed to be different than earlier home efficiency efforts. It originally had two scheme managers, Eaga Partnership (later named Carillion Energy Services) and TXU Powergen, instead of relying on a single actor or a government agency [36]. Actual installations of energy efficiency equipment were allocated to installers through competitive bids done electronically via email. The scheme provided training and "aftercare service visits" at least once a year so that customers received free service to "prolong the life of their systems [1]." Older schemes targeted almost exclusively those in public housing and offered a grant maximum of only £315, whereas WF applied both to private rented and owner occupied housing and increased the minimum grant amount by almost five times. Older schemes permitted only insulation, whereas WF expanded eligible technologies to include insulation measures as well as heating systems, boiler replacements, energy audits, energy efficient light bulbs, timer controls for space and water heating, and hot water thermal jackets. WF also relied on a "fuel poverty indicator" to predict the extent of fuel poverty in different household types, comprised by a national English House Condition Survey and Census data [29]. WF, lastly, was given more explicit and "reasonably practicable" targets to be accomplished. It was required to (a) help 800,000 homes experiencing fuel poverty by 2004, (b) reduce household fuel use by 60 percent in participating homes, and (c) reduce cold-related deaths and related diseases by 2010.

In an attempt to reach those goals, the Warm Homes and Energy Conservation Act, operating in tandem with Warm Front, (a) set up a framework for completely eradicating fuel poverty country-wide in all vulnerable households (occupied by the disabled or long-term sick, elderly, or children) by 2010, and (b) set the target of eliminating fuel poverty in all households by 2016 [34,37]. Table 1 shows how WF started with an annual budget of roughly £93 million per year but expanded to a peak of £420 million in 2008–2009 [36,38]. The sheer financial scale of the program—£3.2 billion expended, 2.36 million homes receiving assistance, 2.85 million measures installed—makes it the second largest fuel poverty effort ever implemented, behind the Weatherization Assistance Program in the United States, which has assisted 6.2 million families [39].

Table 1
Annual budget expenditures for England's Warm Front scheme, 2000 to 2013.

Fiscal year	Households receiving assistance	Expenditure (2012£ million)
2000/01	97,600	93
2001/02	307,700	250
2002/03	219,300	202
2003/04	189,000	184
2004/05	208,100	194
2005/06	173,200	219
2006/07	253,100	353
2007/08	268,900	383
2008/09	233,600	420
2009/10	213,000	387
2010/11	127,900	374
2011/12	33,100	109
2012/13	35,000	69
Total	**2,359,500**	**3237**

4. The benefits of the Warm Front Program

WF did not accomplish all of its targets or those enshrined in the Warm Homes and Energy Conservation Act, but it did result in a multitude of benefits related to (1) successful investments in household energy efficiency, (2) thermal comfort and customer satisfaction, (3) improved health, and (4) a net positive cost curve (meaning it saved more than it cost). This section of the paper discusses each in turn.

4.1. Rapid investments in household energy efficiency

The most obvious benefit was investments in household energy efficiency measures that otherwise wouldn't have happened given the low-incomes of the fuel poor in England. In 2002, after its first year of operation, WF assisted 303,000 households who received an average of £445 worth of energy efficiency improvements that reduced annual fuel bills by £150 per year [35]. By 2004, it reached more than 700,000 households, though the average household received only 1.1 energy efficiency measure [40]. By the time it ended in early 2013, more than 2.3 million households had received assistance through 2.8 million separate measures installed, or 11 percent of all homes nationwide, with the most common types of assistance shown in Table 2: loft insulation (0.7 million), draft proofing (0.6 million), cavity wall insulations (0.5 million), and replacement boilers (0.5 million) [38].

Nonetheless, WF implemented these investments quickly and more cheaply than other private sector actors could have. An independent review from the National Audit Office estimated that it took an average of 64 working days to have a heating system installed and only 27 working days to have a property insulated—meaning that even major upgrades to homes were done in a matter of weeks rather than months [36]. Furthermore, it was able to do so at lower prices than private installers, figures reflected in Table 3, and at costs cheaper than other sources of electricity [36]. Prices dropped even further in 2010 when Warm Front introduced an electronic bidding system where installers were able to see available jobs on an open portal and bid for work they wished to complete; contracts were then awarded to the least cost bidder, the result being that prices fell 30 to 60% further for most products [41].

Due in part to the WF scheme and in part to falling energy prices, fuel poverty dropped drastically throughout the UK from 5.1 million homes in 1996 to 1.2 million homes in 2003 during the first few years of the program. When it ended in January 2013, WF had reached 2.3 million homes (with 130,000 households receiving assistance that winter). Presuming that each household saves about 11.2 GJ per year for the next 20 years, the amount modeled and

Table 2
Types of measures installed under the Warm Front Program, 2000–2013.

Loft insulation	722,295
Draught proofing	577,913
Cavity wall insulation	491,242
Hot water tank jackets	157,957
Boiler replacements	479,234
New gas central heating	190,694
Heating repairs	121,476
Electric central heating	75,586
Gas wall heaters	24,752
Factory insulated dual immersion hot water tank	8767
Oil central heating	4383
Total	2,854,299

Table 3
Private installer prices compared to England's Warm Front scheme prices.

Technology	Average price based on private installers (£)	Average price for Warm Front scheme participants (£)	Price savings (£)	Price savings (%)
New natural gas fired central heating with five radiators	3463	2325	1138	33
New natural gas fired central heating with six radiators	4790	3951	839	18
Like-for-like gas fired boiler replacement	1661	1491	170	10
Like-for-like oil fired boiler replacement	2455	2196	259	11

reported by the government, then the WF saves energy at a price of about 2.4 p/kWh, equivalent to 3.85 cents/kWh.[2]

4.2. Thermal comfort and customer satisfaction

Evaluations have revealed that the WF scheme improved indoor living temperatures and received high rates of customer satisfaction. A major national health impact assessment of WF undertaken by the WF Study Group[3] revealed that "the scheme has significantly raised average indoor temperatures [32]." A series of household surveys, physical monitoring, and energy audits with thousands of homes confirmed significant increases in indoor temperature among participants. Moreover, the study found that WF increased daytime living room temperatures by an average of 0.58–2.83 °C, that it reduced the amount of energy needed to maintain warmth by 5–10 percent, and that it improved air quality in the home with less detectable dust and mold [42]. WF also increased the proportion of households reporting being "thermally comfortable" from 36.4 percent to 78.7 percent [43]. This large national assessment concluded that "WF energy efficiency improvements lead to substantial improvements of both living room and bedroom temperatures which are likely to have benefits in terms of thermal comfort and wellbeing [44]."

Also noteworthy is the high levels of self-reported satisfaction with the WF scheme. A second independent evaluation from the National Audit Office in 2009 found that 86 percent of households assisted by the Scheme were "satisfied with the quality of work done," and only 5 percent were "dissatisfied." Moreover, the most common complaint among this 5 percent related to delays, implying that the problem was not with energy efficiency equipment per se but with not receiving it quickly enough [36]. A third evaluation from the DECC in 2014 found that fewer than 5 percent of complaints made through the previous decade of the program were upheld, with precise numbers available in Fig. 2 [41].

4.3. Improved public health

The WF scheme improved the physical and mental health of England's fuel poor. The fuel poor there, firstly, are more prone to excess winter deaths caused by exposure to cold and the incidence of circulatory and respiratory disease, found to be three times higher in the coldest quarter of housing stock compared to the warmest 25 percent [30]. Fuel poverty in the UK has been correlated with higher rates of hospital admission, as well as reductions in the budgets for food and other basic commodities, leading to "a

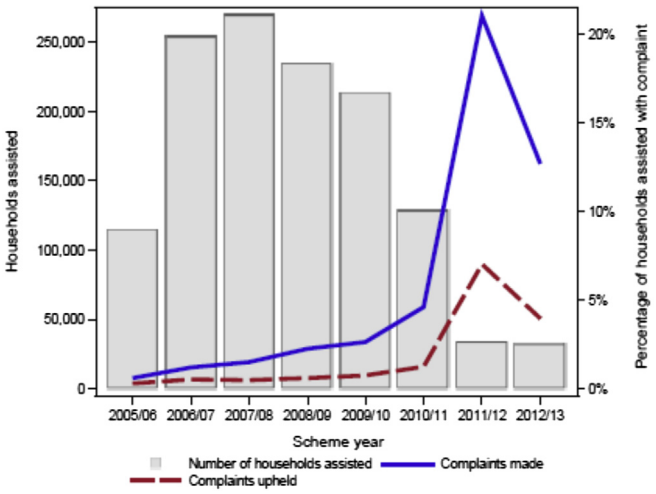


Fig. 2. Warm front complaints as a proportion of households assisted.

Table 4
Coping strategies undertaken by fuel poor households in the United Kingdom.

	% households surveyed
Turned heating off, even though would have preferred to have it on	35%
Turned the heating down, even though would have preferred it to be warmer	33%
Turned out lights in my home, even though would have preferred to have them on	22%
Turned the heating down or off in some rooms but not others, even though would have preferred not to	20%
Only heated and used one room in the house for periods of the day	14%
Used less hot water than would have preferred	15%
Had fewer hot meals or hot drinks that would have liked	4%
None	37%

Table 5
Cost and years of life saved under England's Warm Front scheme.

Intervention	Cost (£)	Months of life saved	Average cost per life year saved (£) over 10 years
Insulation	280	0.26	12,905
Heating	1130	0.51	26,629
Insulation and heating	1410	0.56	30,449

[2] Presuming that 127,930 households received assistance in calendar year 2011, and that each household saves 11.2 Giga Joules per year for the next 20 years, WF will save roughly 28,656,320 GJ or 7,960,088,890 kWh. With total costs of £195,000,000 for that calendar year, this amounts to undiscounted savings of about 2.4 pence per kWh, or 3.85 U.S. cents per kWh. This estimate is done independently and using different data (and methodology) than the one below estimating abatement costs of carbon.

[3] The national health impact evaluation of Warm Front was carried out by The Centre for Regional Economic and Social Research at Sheffield Hallam University in partnership with London School of Hygiene and Tropical Medicine and University College London. It is sometimes collectively referred to as the Warm Front Study Group.

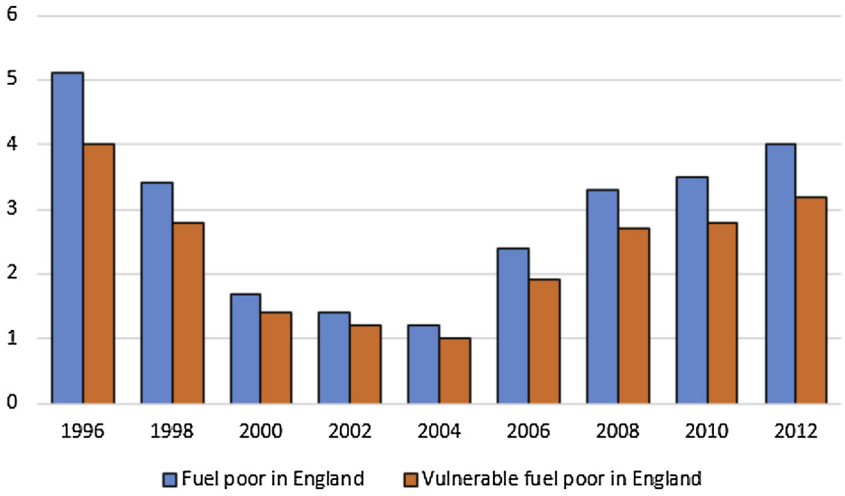


Fig. 3. Fuel poverty in England, 1996 to 2012 (millions of households).

fall in calorie intake for adults and children at a time of increased need for nutritional energy" as households "cope" by cutting back on essentials to pay their fuel bills [30]. For example, the household survey depicted in Table 4 shows that almost two-thirds of fuel poor homes either "turn off their heat" or "turn it down" to save money [30].

The WF Scheme, in response, reduced morbidity and mortality associated with fuel poverty and has also lessened the risk of chronic medical conditions such as cardiovascular and cerebrovascular diseases, diabetes, respiratory and renal diseases, Parkinson's disease, Alzheimer's disease, and epilepsy [29]. The Warm Front Study Group found "significant health benefits" not previously estimated, advantages including higher temperatures, satisfaction with their heating system, greater thermal comfort, and less stress. They concluded that WF resulted in the "alleviation of fuel poverty and the reduction of stress associated with greater financial security" and that it was "more successful than implied [45]." Many households also reported "perceptions of improved physical health and comfort, especially of mental health and emotional wellbeing and, in several cases, the easing of symptoms of chronic illness [33]."

4.4. Benefits that surpass costs

Lastly, and perhaps most germane, WF had a positive cost curve, producing benefits that far exceeded expenses. The simplest calculation concerns direct benefits from improved efficiency. Presuming the government's numbers can be trusted, and that all households shown by a benefit entitlement check to be eligible for additional benefits capitalized on them, from 2001 to 2011 the WF Scheme cost roughly £2.4 billion, but with an average annual increase in benefits per household of £1894.79, it generated £87.2 billion in undiscounted savings for fuel-poor English homes over a 20 year period.[4]

However, even this calculation conservatively estimates the true benefits from WF. As part of the national health impact evaluation, the Warm Front Study Group looked at the costs of the program and the average cost per life year saved. Table 5 shows that the combined cost of insulation and upgrading the heating system averaged £1410 [46]. This resulted in an increase in temperature from investments in insulation and heating which added an extra 0.56 months to the lives of a 65 year old couple living together (0.33 months for the man and 0.22 for the woman). Over ten years the average undiscounted cost of extending a recipient's life by one year would be £30,449 if heating and insulation is installed. If only insulation is installed the resulting temperature rise adds an extra 0.26 months to the lives of the couple but the average cost of extending a recipient's life by one year is much less at £12,905 [46].

The lesson is that the WF scheme extends lives relatively cost effectively, a conclusion also confirmed by studies outside of England. One survey of energy efficiency measures implemented in Northern Ireland found that investments in reducing fuel poverty had a positive cost curve when one accounted for reduced health care expenditures in houses that had an intervention compared to those that did not [47]. Similarly, a study in New Zealand estimated the value of the health, energy and environmental benefits of retrofitting insulation into 1350 low-income buildings and found that total benefits in present value terms were 1.5–2 times the cost of fitting the insulation [29].

5. Challenges facing the Warm Front Program

Despite these benefits, the WF scheme confronted serious challenges. These fall into the categories of (1) rising levels of fuel poverty throughout the country, (2) cost effectiveness, (3) targeting, and (4) fuel consumption, which this section of the paper details in turn.

5.1. Rising levels of fuel poverty

The most apparent challenge is that the WF scheme did not meet the Warm Homes and Energy Conservation Act target of ensuring that by 2010 (and later, 2016) no vulnerable households would remain in fuel poverty. Instead, national rates of fuel poverty have been increasing, rising from about 1.1 million homes in England in 2004 to 3.3 million in 2008 and 4.0 million in 2012, when 18 percent of all households in the UK were defined as fuel poor, as Fig. 3 illustrates [48]. As one study from

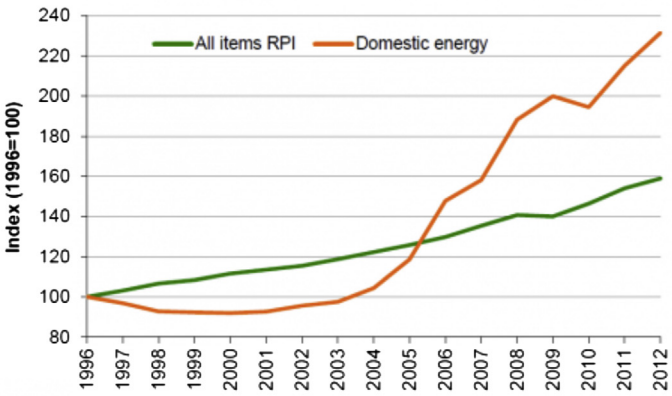
[4] According to data available in the WF's Annual Report, 2.3 million households received assistance from WF over the course of 2001–2011. According to them "the average annual increase per customer identified" under a benefit entitlement check amounted to £1894.79 individually or £4,358,017,000 as a whole (if one multiplies that amount for all 2.3 million households), rising to £87,160,340,000 when multiplied over the duration of 20 years. It must be noted, however, that this calculation is simplistic. Benefits reported in the Annual Report are entirely theoretical and computed using a method called the Standard Assessment Protocol. Actual savings will vary by household, and would not take into consideration the rebound effect discussed in the Challenges section.

the Association for the Conservation of Energy warned, "given the increases in the number of fuel poor households over recent years, the 2010 target has not been met and the 2016 target is in serious jeopardy [37]." Even worse, vulnerable households are still the "hardest hit" by fuel poverty, accounting for 80 percent of fuel poor households in England [45]. Although households owned by the elderly make up the single largest group living in fuel poverty, almost one-third consist of families with children or those with single parents.

The causes behind a resurgence of fuel poverty relate to the energy intensity of British homes and rapidly rising energy prices more than any inherent failure with WF. Household energy bills in the UK are dominated by a winter heating season which, due to the country's colder climate, requires 20,000 kWh per year for space heating for a typical 3 bedroom domestic house [49]. From 1996 to 2012, Fig. 4 shows that domestic energy prices increased by over 220 percent [14], with gas prices rising 15 percent alone from 2011 to 2012 [50]. Every 1 percent rise in fuel prices results in approximately 40,000 households entering fuel poverty [51]. As the Department for Energy and Climate Change was forced to admit, "For several years, prices have been the most influential factor in movements in fuel poverty. Prices have risen at a rate well above that of income [52]." Unfortunately, analysts expect fuel poverty to worsen in the future. Deutsche Bank has projected that with expected energy price rises of 25 percent by the end of 2015, a quarter of the country could fall into fuel poverty [50]. This combination of low household incomes, higher fuel prices, and higher penalties for nonpayment will make it exceedingly difficult to contain fuel poverty, let alone eradicate it [53].

All the while, rather than increase the budget for WF, the government curtailed it. In a review of government spending in 2010, the government committed itself to a "smaller, more targeted" WF scheme and cut its budget by two-thirds to a total of £210 million for 2011 to 2013 and restricted eligibility to fewer households [37]. The WF scheme was replaced by the Affordable Warmth element of the Energy Company Obligation in 2013. The Energy Company Obligation will be funded by energy companies and there will no longer be a national government funded program to tackle fuel poverty in England. This is unfortunate, to say the least, given that the nonpartisan Centre for Sustainable Energy estimated it will cost at least £4.6 billion, rather than the meager few hundred million pounds currently allocated, to deliver energy efficiency improvements to all poor households that need them [54]. As the *Lancet* warned, "the decrease in budget allocated to the Warm Front scheme for 2011–2013 is therefore unlikely to meet demand, even allowing for reduced eligibility [14]." The 2012 Hills Review of fuel poverty projected that under current trends there will be more than 9 million households in fuel poverty, representing more than 43 percent of all households in the United Kingdom, by 2016 [55].

a. Top panel: Domestic energy prices in the UK and the Retail Prices Index, 1996 to 2012



b. Bottom panel: Average annual standard credit bills for typical consumers (£2013 prices)

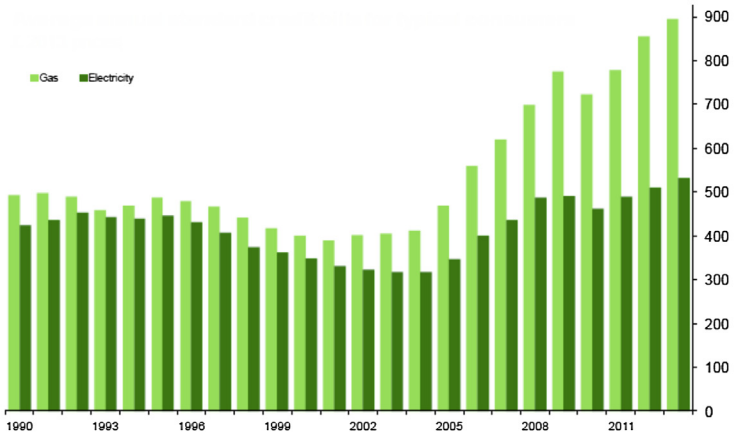


Fig. 4. Domestic energy prices in the United Kingdom.

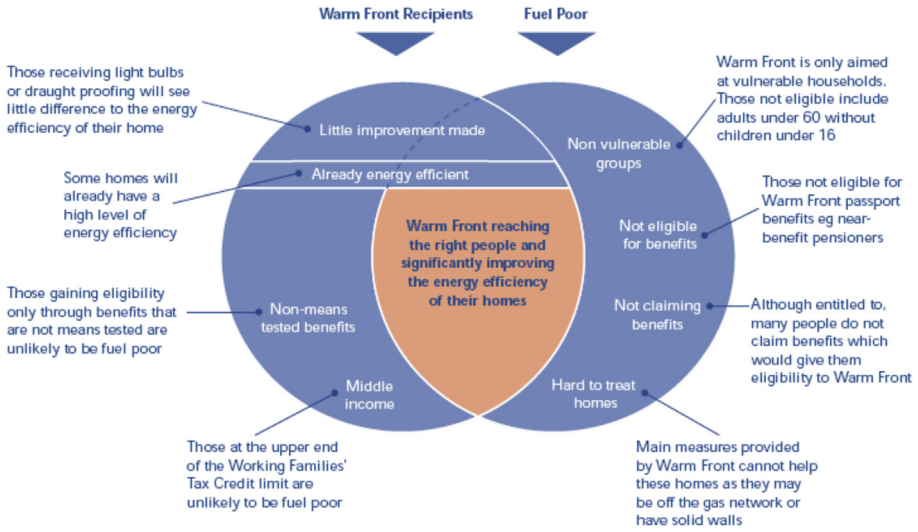


Fig. 5. Explanations for poor targeting and gaps in coverage under England's Warm Front scheme.

5.2. Limited cost effectiveness

A second class of challenges concerns the cost effectiveness of WF. One major obstacle was the requirement that homes still pay for a proportion of the energy efficiency work being done when it exceeds the maximum grant level—WF grants do not always cover all of the costs of the work. The average household contribution required in 2007 and 2008, for example, was £581, and roughly one-quarter of applicants that winter were asked to contribute to the cost of upgrades [36]. This meant that more than 6000 households withdrew from the scheme and a further 16,000 households did not finish their application or put their application on hold for more than a year. Thus, WF hasn't reached everybody it needed to, mitigating its cost-effectiveness.

Furthermore, though the section above on benefits showed how the WF saved households money and energy, it may not be the most cost effective way to mitigate greenhouse gas emissions. Presuming it saved about 1.5 tons of carbon dioxide per household per year, and the WF scheme abated carbon dioxide at a cost of about £50 per ton.[5]

5.3. Faulty targeting

The WF scheme had difficulty identifying fuel poor homes and likely disbursed a significant proportion of its assistance to homes that were not technically in fuel poverty. Tom Sefton from the London School of Economics calculated that in 2002, oddly, only 42 percent of fuel poor households received assistance under WF and that 75 percent of those participating were not, in actuality, fuel poor [56]. Two years later Sefton repeated his analysis and found that "just less than one in five Warm Front recipients are fuel poor prior to receiving a grant … most recipients – around four in five - are probably not fuel poor [57]." In other words, WF grants were skewed towards low income households, but not necessarily fuel poor households [13]. The recent 2012 Hill Review similarly noted that fuel poverty is difficult to distinguish from "more general problems of poverty [55]."

Targeting difficulties within the WF scheme have been confirmed by two separate evaluations conducted by the National Audit Office. The first estimated that "around a third of the fuel poor may be ineligible and up to two thirds of eligible households may not be fuel poor." It cautioned that the heating and insulation measures under the Scheme would be insufficient to move households out of fuel poverty in at least 20 percent of the cases, and that only 14 percent of WF grants reached the least efficient homes [35]. The second evaluation warned that "57 percent of vulnerable households in fuel poverty do not claim the relevant benefits to qualify for the Scheme [36]." Commentators on the internet have joked that, as a result, the scheme should have been renamed the "Lukewarm Front."

Fig. 5, using data from the National Audit Office, presents the most likely explanations behind this faulty targeting and shows that the problem is a mismatch between fuel poor households and eligibility for WF. WF relies on self-selection for participation, which means many homeowners will not know about the program, or may not consider themselves fuel poor. For example, surveys have shown that only 5 percent of homeowners will report that they cannot afford adequate heating when in fact more than 12 percent cannot [58,59]. The implication is that people don't want to report themselves as fuel poor, or they believe that they are in fact not fuel poor. The elderly commonly have trouble discerning temperature, and may feel comfortable at temperatures unhealthy for them [29]. Other low income households will spend significantly less on fuel than required and suffer cold homes as a consequence. Under the current definition of fuel poverty these households won't always show up as fuel poor because they aren't spending 10 percent of their income on energy services. In other cases, low income households may already be energy efficient, meaning they didn't really need assistance under the scheme. In still other cases, they may decline to participate in the WF scheme out of fear of bothering their landlord, or they may want to avoid the transaction costs and inconvenience of having somebody installing equipment in their home.

5.4. Rising fuel consumption

A significant number of WF homes, even though they saved their occupants money, did not necessarily consume less fuel. Put another way, a large difference exists between the fuel savings modeled and expected by WF planners and actual fuel

[5] The WF Scheme helped 127,930 homes in calendar year 2011, meaning it saved about 3,837,900 tons of carbon dioxide over a 20 year period at a cost of £195 million, resulting in an abatement cost of £50.81. This estimate is done independently and using different data (and methodology) than the ones above estimating various returns on (social) investment or payback periods for efficiency upgrades.

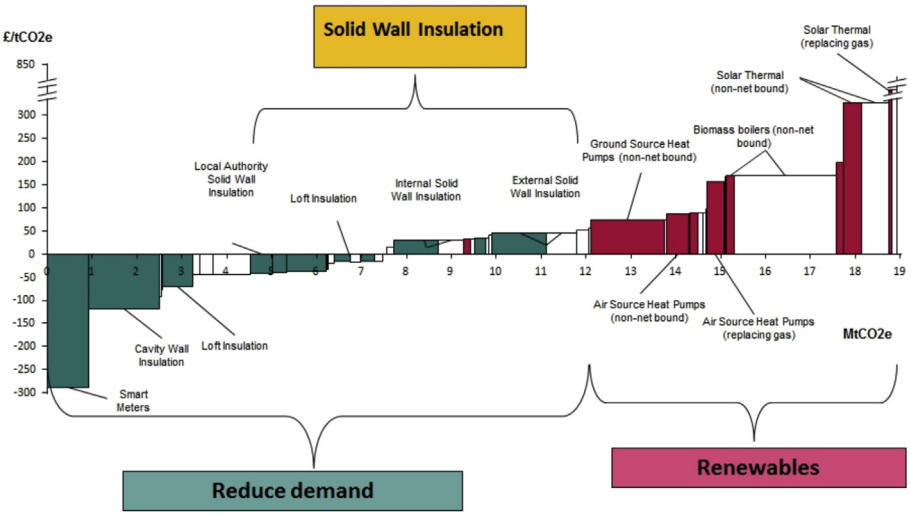


Fig. 6. Carbon cost abatement curve for various household options in the United Kingdom, 2012.

consumption among participating homes. Research undertaken by the Warm Front Study Group found that WF homes did not always exhibit reduced fuel consumption [46]. Counter to intuition, rather than seeing up to a 60% reduction in energy use after participating in WF, the authors found that on average total fuel consumption per household actually rose for a small sample of homes examined.

One reason for higher fuel consumption in the post intervention dwellings can be attributed to the "take back" or comfort factor. Households "take back" the benefits of improved energy efficiency as increased warmth and comfort rather than as fuel savings particularly following the installation of a new heating system [60]. Other reasons for this rising fuel consumption may relate to contractors trying to keep costs low and implementing slipshod work quickly, or to contractors trying to meet the requests of clients to keep costs low and on budget. Another albeit unconfirmed factor could be contractors taking advantage of elderly and vulnerable customers unable to distinguish high quality work from low quality. The Warm Front Study Group, for example, utilized infrared images of 85 WF dwellings and found missing areas of loft insulation in 13 percent of the cases and in cavity walls in one-fifth of the cases. Another reason is higher monitored ventilation rates than predicted, caused by gaps created by retrofitting that allowed heat to escape and because occupants of warmer homes are more likely to open windows to let "fresh" air in, mitigating energy savings [46].

6. Conclusion: lessons and policy implications

Even though it ceased to exist after 2013, the Warm Front's approach towards addressing fuel poverty reveals six noteworthy lessons for other energy analysts, planners, and policymakers.

First, WF demonstrates the truly massive financial benefits to investing in energy efficiency. Presuming that the numbers from the Department of Energy and Climate Change are accurate, every £1 invested into Warm Front produced as much as £1 to £36.3 in benefits over a 20 year period. This calculation, though simple, is potentially conservative, as it includes monetized energy savings and average annual increases in income per customer identified, but it excludes indirect savings related to reduced health care expenditures, avoided excess winter deaths, and longer lives for those living in more efficient homes. WF reminds us that energy efficiency programs can pay for themselves quite quickly, producing measurable benefits that far exceed costs. The Department of Energy and Climate Change reaffirms this conclusion with their most recent carbon cost abatement data shown in Fig. 6, which shows that a variety of household energy efficiency measures are the "cheapest" and "best" investments society can make if they want to mitigate emissions of greenhouse gases [61].

Second, the WF program, though it faced some major obstacles, underscores the necessity of having strong political leadership for addressing fuel poverty. Although it did not engender enough political commitment to prevent the recent rise in English fuel poverty, WF was the product of energy planning at the highest levels of the UK government, including the efforts of a 1999 Inter-Ministerial Group on Fuel Poverty, the Warm Homes and Energy Conservation Act in November of 2000, and a 2001 formal government Fuel Poverty Strategy. Managed by the Department for Environment, Food, and Rural Affairs, WF received additional support from a fuel poverty indicator produced through an English House Condition Survey and Census data, and a staggering £3.2 billion in government funding. With this level of support, the WF scheme was able to assist more than two million homes in improving the efficiency of their dwellings and creating the economies of scope and scale needed to drive costs down, performing installations cheaper than other private contractors.

Third, the somber barriers confronting WF remind us how difficult eradicating fuel poverty can be. Though the absolute number of fuel poor households in the UK would undoubtedly have been higher without WF, the scheme stopped lowering the national rate of fuel poverty in 2004 and since then the percentage of homes in fuel poverty has *tripled* to the point where it afflicts roughly one in five throughout England, a number that could rise even further by 2016 to almost *half* of UK households. Some of the culprits behind this rising rate of fuel poverty were outside of the scheme's control, such as prices for electricity and natural gas that have rapidly increased compared to incomes. Others, however, can be blamed on the government, such as drastic reductions in the WF budget. And the sensitivity of the number of households in fuel poverty to increases in the price of fuel suggests that energy efficiency might need to come *second* as a priority to government efforts to keep fuel prices low; indeed, WF's largest contributions towards reducing fuel poverty coincided with a fall in the retail price of energy, which dropped to a twenty year low in 2003.

Fourth, the current situation in England—rising prices, rising rates of fuel poverty—illustrates the intractability of eradicating

fuel poverty without both ensuring that household incomes are improved along with their energy-efficiency. One implication to this finding is that electricity restructuring and liberalization may be incompatible with attempts to abolish fuel poverty—the first wants people to pay competitive market costs for energy, the second says they shouldn't have to pay full costs if it comes to represent a disproportionate share of their income. The replacement to the Warm Front scheme, the Green Deal, is so far suffering from a similar problem. The Green Deal is a commercial low-interest, pay-as-you-save private loan scheme for domestic energy upgrades, the idea being that consumers can pay back their loans through their fuel bills, with payments always being smaller that the resultant real time savings, free of government expenditures. Yet few companies have signed up to offer loans as part of the Green Deal and very few customers have formally participated in the scheme. In short, "paying" for energy efficiency and relying on market approaches seems incommensurate with actually addressing fuel poverty.

Fifth, times of fiscal austerity create competing and contradictory pressures within government; as fuel prices rise, governments tend to have less revenue and curtail public spending, yet cutting back during these times means less support for helping the poor at precisely the moment they need it the most. The government has also incentives which counteract addressing fuel poverty and investing in efficiency. Every year, for example, £2.8 billion is spent on winter fuel payments to pensioners at Christmas, typically a lump sum of £250 per household—yet only one quarter of these expenditures were actually spent on energy efficiency improvements [17]. This annual amount is equivalent to the *entire* ten year budget of WF, and if it was instead invested into WF the government might have achieved its target of eliminating fuel poverty entirely. Some even accuse the UK government of intentionally passing fuel poverty costs onto the consumer to relieve the government's tax system and budget [55]. Yet another implication is that, given the sensitivity of fuel poverty to fuel prices, the government's goal of mitigating climate change (which could cost money and raise prices) can potentially exacerbate the numbers of households in fuel poverty (which need prices to drop rather than rise) if those homes are unable to implement efficiency measures to offset increased prices.

Sixth, and lastly, the WF reminds us how vital human behavior can be in determining whether energy efficiency interventions succeed or fail. Social attitudes and attributes such as pride and identity played significant roles in mitigating the ability for the WF scheme to meet its targets. The WF scheme was based on self-selection, meaning homeowners had to apply themselves for assistance. Between 42 and 57 percent of vulnerable fuel poor households did not take advantage of the WF scheme. The largest reason behind this refusal to participate is simple: people either did not consider themselves fuel poor or, if they were, did not want to admit it. Fuel poverty takes a severe toll on households, and as such it may have become stigmatized to the point where households feel that classifying themselves as "fuel poor" or even just "poor" is insulting. The repercussion is that future measures for tackling fuel poverty must be group specific, and find ways of convincing families that are frustrated, angry, and scared that they can save energy without sacrificing their social identity or pride.

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References

[1] Department for Energy and Climate Change. Connecting with communities The Warm Front Scheme Annual Report 2010/11 (London: DECC, 2011), available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48168/2747-warm-front-annual-report-2010-2011.pdf.
[2] O'Sullivan Kimberley Clare, Howden-Chapman Philippa L, Fougere Geoffrey M. Fuel poverty, policy, and equity in New Zealand: the promise of prepayment metering. Energy Res Soc Sci May 2015;7:99–107.
[3] Middlemiss Lucie, Gillard Ross. Fuel poverty from the bottom-up: characterising household energy vulnerability through the lived experience of the fuel poor. Energy Res Soc Sci March 2015;6:146–54.
[4] Sovacool BK. What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. Energy Res Soc Sci March, 2014;1:1–29.
[5] Sovacool BK. Energy studies need social science. Nature July 31, 2014;511(7511):529–30.
[6] Sovacool BK, Dworkin MH. Global energy justice: problems, principles, and practices. Cambridge: Cambridge University Press; 2014.
[7] Sovacool BK, Dworkin MH. Energy justice: conceptual insights and practical applications. Appl Energy March 15, 2015;142:435–44.
[8] Sovacool BK. Energy & ethics: justice and the global energy challenge. Basingstoke UK/New York USA: Palgrave Macmillan; 2013.
[9] Sovacool BK, Brown MA. Competing dimensions of energy security: an international review. Annu Rev Environ Resour November, 2010;35:77–108.
[10] Liddell Christine, Morris Chris, McKenzie SJP, Rae Gordon. Measuring and monitoring fuel poverty in the UK: national and regional perspectives. Energy Policy October 2012;49:27–32.
[11] Liddell Christine. Fuel poverty comes of age: commemorating 21 years of research and policy. Energy Policy October 2012;49:2–5.
[12] Liddell Christine. The missed exam: conversations with Brenda Boardman. Energy Policy October 2012;49:12–8.
[13] Moore Richard. Definitions of fuel poverty: implications for policy. Energy Policy October 2012;49:19–26.
[14] O'Brien Mary. Policy summary: fuel poverty in England. Lancet December, 2011. available at: http://ukpolicymatters.thelancet.com/?p=1603.
[15] Howden-Chapman Philippa, Viggers Helen, Chapman Ralph, O'Sullivan Kimberley, Barnard Lucy Telfar, Lloyd Bob. Tackling cold housing and fuel poverty in New Zealand: a review of policies, research, and health impacts. Energy Policy October 2012;49:134–42.
[16] Bradshaw Jonathan, Hutton Sandra. Social policy options and fuel poverty. J Econ Psychol 1983;3:249–66.
[17] Boardman B. Fuel poverty. Int Encycl Hous Home 2012:221–5.
[18] Herrero Sergio Tirado, Urge-Vorsatz Diana. Trapped in the heat: a post-communist type of fuel poverty. Energy Policy 2012;49:60–8.
[19] Boardman B. Fixing fuel poverty: challenges and solutions. London: Earthscan; 2010.
[20] Boardman B. Fuel poverty: from cold homes to affordable warmth. London: Belhaven; 1991.
[21] Boardman Brenda. Opportunities and constraints posed by fuel poverty on policies to reduce the greenhouse effect in Britain. Appl Energy 1993;44:185–95.
[22] Brunner Karl-Michael, Spitzer Markus, Christanell Anja. Experiencing fuel poverty. Coping strategies of low-income households in Vienna/Austria. Energy Policy October 2012;49:53–9.
[23] Falagas ME, Karageorgopoulos DE, Moraitis LI, Vouloumanou EK, Roussos N, Peppas G, et al. Seasonality of mortality: the September phenomenon in Mediterranean countries. Can Med Assoc J 2009;181:484–6.
[24] Shaw M. Housing and public health. Annu Rev Public Health 2004;25:397–418.
[25] Wilkinson Paul, Smith Kirk R, Joffe Michael, Haines Andrew. Global perspective on energy: health effects and injustices. Lancet 2007;370:965–78.
[26] Jenkins DP. The value of retrofitting carbon-saving measures into fuel poor social housing. Energy Policy 2010;38:832–9.
[27] Liddell Christine, Morris Chris. Fuel poverty and human health: a review of recent evidence. Energy Policy 2010;38:2987–97.
[28] Marmot Review Team. The health impacts of cold homes and fuel poverty. Friends of the Earth; May 2011.
[29] Ormandy David, Ezratty Véronique. Health and thermal comfort: from WHO guidance to housing strategies. Energy Policy October 2012;49:116–21.
[30] Anderson Will, White Vicki, Finney Andrea. Coping with low incomes and cold homes. Energy Policy October 2012;49:40–52.
[31] Walker Gordon, Day Rosie. Fuel poverty as injustice: integrating distribution, recognition and procedure in the struggle for affordable warmth. Energy Policy October 2012;49:69–75.

[32] Critchley Roger, Gilbertson Jan, Grimsley Michael, Green Geoff, Warm Front Study Group. Living in cold homes after heating improvements: evidence from warm-front, England's home energy efficiency scheme. Appl Energy 2007;84:147–58.
[33] Gilbertson Jan, Stevens Maryjane, Stiell Bernadette, Thorogood Nicki. Home is where the hearth is: grant recipients' views of England's home energy efficiency scheme (Warm Front). Soc Sci Med 2006;63:946–56.
[34] Department of Food and Rural Affairs. The UK fuel poverty strategy. London: Defra; 2001 [November].
[35] National Audit Office. Warm Front: helping to combat fuel poverty. London: The Stationery Office; 2003. available at: http://www.nao.org.uk/report/warm-front-helping-to-combat-fuel-poverty/.
[36] National Audit Office. The warm front scheme. London: The Stationery Office; 2009. available at: http://www.nao.org.uk/report/the-warm-front-scheme/.
[37] Guertler Pedro. Can the green deal be fair too? Exploring new possibilities for alleviating fuel poverty. Energy Policy October 2012;49:91–7.
[38] Watson Chris, Bolton Paul. Warm front scheme (House of commons, science and environment social and general statistics section. August 21, 2013. available at: http://researchbriefings.files.parliament.uk/documents/SN06231/SN06231.pdf.
[39] U.S Department of Energy. Weatherization assistance program: executive summary. Washington, DC: DOE; November, 2009. available at: http://waptac.org/data/files/website_docs/briefing_book/wap_programoverview_final.pdf.
[40] Department of Environment. Food and rural affairs. fuel poverty in England: the government's plan for action. London: DEFRA; 2004.
[41] Department of Energy and Climate Change. Process evaluation of the Warm Front scheme. London: DECC; March 28, 2014. available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/322901/Warm_Front_Evaluation_Report.pdf.
[42] Warm Front Evaluation Team. Warm Front evaluation (London school of hygiene and tropical medicine. 2006. available at: http://www.shu.ac.uk/research/cresr/ourexpertise/warm-front.
[43] Hong Sung H, Gilbertson Jan, Oreszczyn Tadj, Green Geoff, Ridley Ian, The Warm Front Study Group. Field study of thermal comfort in low-income dwellings in England before and after energy efficient refurbishment. Build Environ 2009;44:1228–36.
[44] Oreszczyn T, Hong SH, Ridley I, Wilkinson P, The Warm Front Study Group. Determinants of winter indoor temperatures in low-income households in England. Energy Build 2006;38(3):245–52.
[45] Gilbertson Jan, Grimsley Michael, Green Geoff, For the Warm Front Study Group. Psychosocial routes from housing investment to health: evidence from England's home energy efficiency scheme. Energy Policy October 2012;49:122–33.
[46] Green Geoff, Gilbertson Jan. Warm Front, better health: health impact evaluation of the Warm Front scheme (center for regional, economic, and social research. May, 2008. available at:http://www.apho.org.uk/resource/view.aspx?RID=53281.
[47] Shortt Niamh, Jorun Rugkasa. The walls were so damp and cold' fuel poverty and ill health in Northern Ireland: results from a housing intervention. Health & Place 2007;13:99–110.
[48] Department for Energy and Climate Change. Annual report on fuel poverty statistics. London: National Statistics; 2013. available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199833/Fuel_Poverty_Report_2013_FINALv2.pdf.
[49] Bahaj AS, James PAB. Urban energy generation: the added value of photovoltaics in social housing. Renew Sustain Energy Rev 2007;11:2121–36.
[50] Vukmanovic Oleg. Quarter of homes seen in fuel poverty by 2015. Reuters News Service; October 10, 2011.
[51] Illsley Barbara, Jackson Tony, Lynch Bill. Addressing Scottish rural fuel poverty through a regional industrial symbiosis strategy for the Scottish forest industries sector. Geoforum 2007;38:21–32.
[52] Department for Energy and Climate Change. Annual report on fuel poverty statistics. London: National Statistics; 2011. June. available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48138/2181-annual-report-fuel-poverty-stats-2011.pdf.
[53] Davies M, Oreszczyn T. The unintended consequences of decarbonising the built environment: a UK case study. Energy Build 2012;46:80–5.
[54] Roberts Simon. Energy, equity and the future of the fuel poor. Energy Policy 2008;36:4471–4.
[55] Hills John. Getting the measure of fuel poverty final report of the fuel poverty review. Department of Energy and Climate Change; March 2012. available at: http://sticerd.lse.ac.uk/dps/case/cr/CASEreport72.pdf.
[56] Sefton T. Targeting fuel poverty in England: is the government getting warm? Fisc Stud 2002;23(3):369–99.
[57] Sefton Tom. Aiming high: an evaluation of the potential contribution of Warm Front towards meeting the Government's fuel poverty target in England. CASEreport 28. Centre for analysis of social Exclusion. London, UK: London School of Economics and Political Science; 2004. available at: http://eprints.lse.ac.uk/28322/.
[58] Price Catherine Waddams, Brazier Karl, Wang Wenjia. Objective and subjective measures of fuel poverty. Energy Policy October 2012;49:33–9.
[59] Dubois Ute. From targeting to implementation: the role of identification of fuel poor households. Energy Policy October 2012;49:107–15.
[60] Hong Sung H, Oreszczyn Tadj, Ian Ridley for the Warm Front Study Group. The impact of energy efficiency refurbishment on the space heating fuel consumption in english dwellings. Energy Build 2006;38:1171–81.
[61] Monzani Dan. Green deal legislation & finance: UK energy efficiency financing. London: Department of Energy and Climate Change; February 2012.