ISSN 2616-5872 Vol.5, Issue 8: 1-9, DOI: 10.25236/AJEE.2023.050801

The mitigation potential and barriers for climate change in UK housing: A rapid evidence assessment

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Abstract: *Global warming is becoming an increasingly serious problem for the whole world, and all countries are looking for effective ways to reduce the emission of carbon dioxide to control the rise of temperature. The UK has set a net zero target of achieving net CO2 emissions of zero by 2030, which is difficult to achieve on current progress, especially since the UK has no effective measures to reduce emissions in the heating of houses. The purpose of this report is to identify the potential for reducing emissions in the housing heating in the UK, to identify suitable solutions and possible obstacles to implementation, and to make reasonable recommendations for proposed solutions.*

Keywords: *Climate Change, Global Warming, Carbon Emission, Net-Zero, House Heating*

1. Introduction

1.1 Background

Global warming is now becoming a serious problem. The Sixth Assessment Report (AR6) shows that human influence can be a major driver for rising temperature [6]. The Paris Agreement has needed most countries to help control the global temperature anomaly under 1.5°C. Many countries have designated their net-zero target to control emissions from human influence. The UK has also adopted lots of strategies to reduce emissions in several areas such as electricity supply and those strategies have been effective [1]. Data also shows that electricity products have reduced emissions by 74% to date and UK emissions are falling at a rate of 13 MtCO2 per year [2]. However, if the current rate of reduction is maintained, the UK is unlikely to achieve its designated net zero target by 2050 [14]. The Sixth Carbon Budget also points out that almost no low-carbon resources are used for house heating. This suggests that there is still significant scope and potential for reducing emissions from housing in the UK. The purpose of this Rapid Evidence Assessment (REA) report is to explore the mitigation potential from house in UK and identify some effective strategies, and to assess the various barriers to implementing these strategies.

1.2 Research question

The research question (RQ) according to the topic is about the mitigation potential and the barriers in UK:

What is the mitigation potential in housing in UK and what are the barriers?

The Sixth Carbon Budget (CCC, 2020) has shown that while housing have not been effective in reducing emissions to date, it can also be argued that housing has significant potential in reducing emissions.

There are many strategies to reduce emissions in housing. In the housing sector, house renovation and the use of heat pumps are the two most common strategies (Ürge-Vorsatz et al., 2009; Qu et al., 2021).

This report has looked specifically at the policies adopted by the UK. The Net zero strategy (UK government, 2021) mentions that for housing, the UK is focusing on installing heat pumps and retrofitting homes. The Net Zero Strategy (UK government, 2021) also mentions that for housing, the UK is providing funding for heat pumps and retrofitting schemes, as well as providing cheaper electricity and gas bills through a balanced policy[13].

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The aim of this report here is to examine the potential that retrofits and heat pumps can reduce the emissions in UK. As the UK has not achieved significant results in reducing emissions from housing in the last thirty years[2], this report also explores what the barriers to implementing these strategies (house retrofit and heat pumps) might be. Because the barriers of developing strategies differ from country to country, four areas are examined here: technology, policy, finance, and social, and further discussion of what might be done to overcome these barriers.

This report therefore examines, firstly, how much mitigation potential that house retrofitting, and heat pumps have in the UK; secondly, what the barriers to implementing house retrofitting, and heat pumps are; and finally, how these barriers can be overcome. This report is structured to address the research question by the following three questions:

RQ1: How much mitigation potential that house retrofitting and heat pumps have in UK?

RQ2: What are the technical, political, financial, and social barriers to implementing the strategies?

RQ3: How to overcome the barriers?

This report will then first describe the methods used to obtain evidence from the reference literature and to assess the strength of the evidence. This will be followed by a discussion of the findings on the research questions based on the evidence obtained, and finally by a summary of the results and findings and new recommendations for the current abatement situation.

2. Methodology

2.1 Conceptual Framework

The conceptual framework is formulated according to the research question this report focuses on.

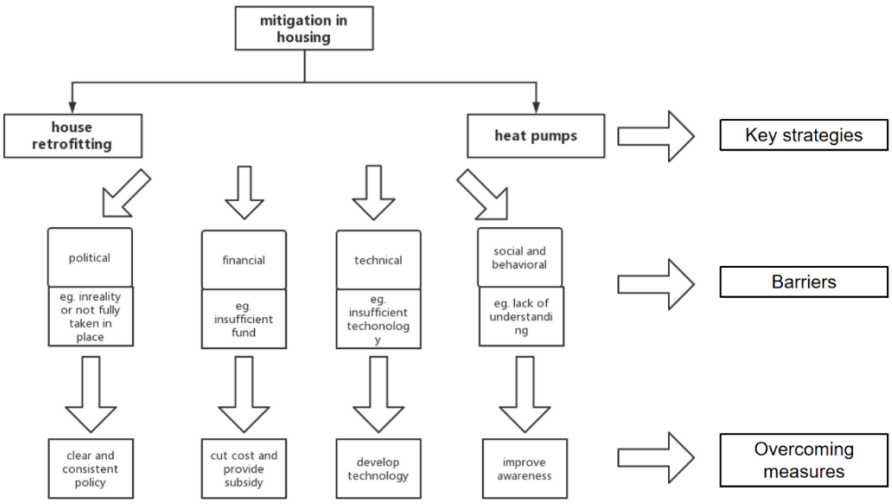

Figure 1: Diagrammatic representation of the conceptual framework in this REA

The main point of this report is on the barriers to implementing these strategies. There are four main barriers to consider here:

1) Technical: Whether better technologies within the house can match the needs of the society, and whether existing technologies can meet net zero targets.

2) Political: Whether these policies are in place or whether they match the needs of society.

3) Financial: The renovation of houses with new energy sources requires not only adequate technical support, but also sufficient financial support.

4) Social and behavioral: Several social factors contribute to the barriers.

2.2 Description of search

This report follows the conceptual framework process (Figure.1). The literature engines and the key

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phrases that used for searching evidence have been shown below (Table.1):

Table 1: The list of the research engines and journals used in this report, and the search key phrase when searching evidence

Search engines	Google Scholar
	Science Direct
	Web of Science
Search key phrase	'House retrofit' and 'UK'
	'Mitigation' and 'Housing'
	'Mitigation' and 'Heat pump'
	'Heat pump' and 'UK'

The evidence is limited to 'since 2010' and 'English only'. The selection process is followed by 'title – abstract – introduction – full context'. Finally, this report concludes with a selection of 20 out of 44 pieces of evidence.

2.3 Assessment of evidence

The methodology for assessing the strength of evidence is based on the assessment methods (Appendix.1. Fig.3 and Fig.4) from Simon et al. (2017). Here Table 2 and 3 is a simplified method used in this report. The other method used to assess the barriers to implementation is to collate the barriers mentioned in the articles and classify them into four categories. From this to determine which type of barriers was mentioned most often. It is also important to look specifically at which specific barriers are present in each of these four categories and how many times each is mentioned.

Table 2: The criteria of the strength of evidence based on Simon et al. (2017).

Criteria	Score
Barriers mentioned: 'High score' (3): All four areas of barriers are mentioned; 'Middle score' (2): Many barriers are mentioned, but not all four areas; 'Low score' (1): Only one aspect of barriers is mentioned	(1-3) * 2 Out of 6
Solutions mentioned: 'High score' (3): all barriers are related to detailed overcoming strategies; 'middle score' (2): Only part of the solution is mentioned; 'Low score' (1): No mention of overcoming strategies	(1-3) * 1 Out of 3

Table 3: The score range of the strength of evidence based on Simon et al. (2017) [12].

Score range	Strength	Marker
7-9	Strong	+
5-6	Moderate	=
3-4	Weak	-

3. Results and discussion

3.1 Mitigation potential

Of the 20 articles on housing, 15 mention the perception of the housing's potential to reduce emissions. Qu et al. (2021) states that buildings account for 30% of total energy consumption and 20% of total greenhouse gas emissions in the UK. Iibrahim and pelsmakers (2018) also demonstrates that building emissions account for 27% of UK greenhouse gas emissions. However, the UK has been doing a poor job of reducing emissions from housing[7]. For example, Gupta and Gregg (2020), Lingard (2021) both mentions that the UK has a long history in the housing sector but the energy efficiency of housing is low[4][10]. The housing sector has huge mitigation potential for the UK's designated carbon reduction targets and the ambition to reach a net zero target by 2050.

Studies concluded that house renovation contributes significantly to emissions reduction [1][5][8]. Alabid et al. (2022) states that with a simple centralized retrofit, the energy consumption can be reduced by 84%. Gupta and Irving (2014) studies the emissions reductions from specific house retrofits and they

ISSN 2616-5872 Vol.5, Issue 8: 1-9, DOI: 10.25236/AJEE.2023.050801

found that the retrofit for a specific house could lead to a 94% reduction in energy consumption in the neighborhood. If stringent emission reductions were made to housing and developed to every sector, then 96% of the reduction target compared to 1990 GHG emissions could be achieved[8].

The installation of heat pumps in house renovations is also an effective way of reducing emissions. Heating currently accounts for over 40% of the final energy consumed in most UK homes, businesses, and industries. Heat pumps offer higher efficiency in electricity generation than conventional fueled boilers and have about a third of the carbon footprint of fueled boilers [16]. Gupta and Irving (2014) also show that there is a significant reduction in carbon emissions from heat pumps compared to fuel boilers and replacing 80% of current conventionally fueled boilers could lead to an 80% reduction in the UK's carbon emissions target in the housing sector.

In addition to the two main mitigation potentials of reducing energy consumption and greenhouse gas emissions, there are other potentials for house renovation and heat pumps. Firstly, the payback period for renovation is short, with the cost of the investment being recovered within 20 years, which is a very short time for most of houses to be renovated in UK. Secondly, improved air quality and warmer homes can make a huge contribution to human well-being [3].

3.2 Barriers

Table 4: Number of different kinds of barriers in each paper, the assessment score and marker are included in the rightmost column.

	Barriers			
Paper	Political	Financial	Technical	Social and behavioral
Alabid et al (2022) 9(+)	2	3	2	2
Pan et al (2011) 8(+)	2	7	2	0
Wang et al (2022) 7(+)	0	2	2	1
Gupta et al (2020) 6 (=)	2	1	1	1
Jing et al (2022) 7(+)	0	0	1	1
Wang et al (2022) 6(=)	1	1	1	1
Bobrova et al (2021) 6(=)	3	0	0	1
Schaffrin et al (2015) 6(=)	1	2	0	2
Ibrahim et al (2018) 3(-)	0	0	2	0
Li et al (2022) 5(=)	1	0	2	0
Kokoni et al (2021) 5(=)	0	3	2	2
Gupta et al (2014) 5(=)	1	0	1	0
Ivanova et al (2020) 4 (-)	0	0	1	0
Lingard et al (2021) 4(-)	1	0	1	0
CREDS (2019) 3(-)	1	0	0	0
CREDS (2021) 3(-)	1	1	0	0
Total	16	20	18	11

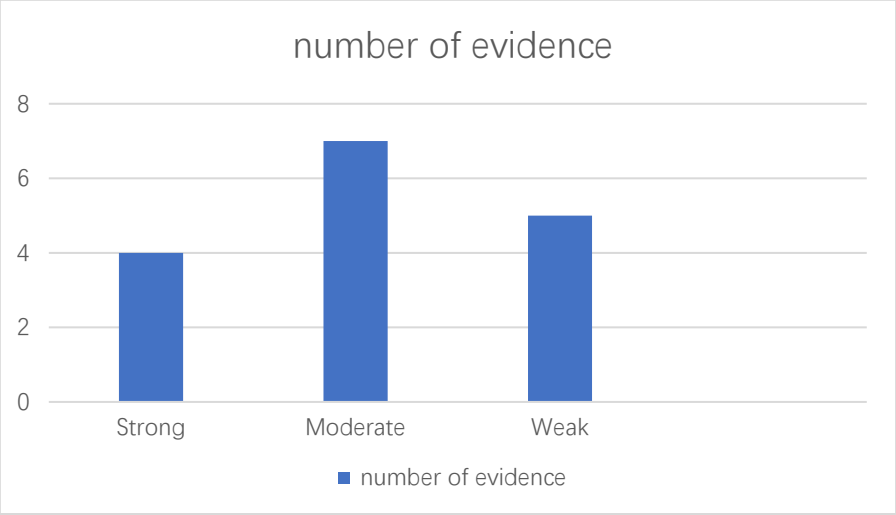

Figure 2: Number of evidence for different strength

ISSN 2616-5872 Vol.5, Issue 8: 1-9, DOI: 10.25236/AJEE.2023.050801

Among those evidence, the financial barrier can be the most serious barriers when implementing these strategies (Table 4). After assessment of strength for each evidence, 10 pieces of evidence are assessed as 'Moderate quality' while 4 are assessed as 'Strong quality' and 5 as 'Weak quality' (Fig.2).

3.2.1 Political barriers

Table 5: Different barriers for political reasons

	Political barriers					
paper	No clear policy (specific for different house)	Inadequate housing information	Uncertainty about the government subsidies	Insufficient policy diversity	gaps in electricity supply	Over-reliance on heat pump
Alabid et al (2022)	■	■				
Pan et al (2011)	■		■			
Gupta et al (2020)	■		■			
Wang et al (2022)			■			
Bobrova et al (2021)	■	■		■		
Schaffrin et al (2015)				■		
Li et al (2022)	■					
Gupta et al (2014)					■	
Lingard et al (2021)						■
CREDS (2019)	■					
CREDS (2021)	■					
Total	7	2	3	2	1	1

In the case of policy barriers, this evidence can be summarized into five further types (Table.5), and the most serious barriers are listed below:

(1) The lack of clear government policy and the lack of policy diversity. There is no clear government policy to implement strategies for housing nowadays, and the diversification of government policies for different house retrofitting options is not enough.

(2) The government subsidies. The unclear size of government subsidies for house retrofits and heat pump installations, as well as the lengthy process of applying for subsidies make house builders and houseowners are not willing to retrofit the house and use new heat systems.

(3) The lack of house information. The existing housing guidance and information are insufficient to implement a viable carbon reduction plan.

Another two types of barriers are gaps in electric supply and over reliance on heat pump. The first one shows that the use of heat pumps increases the consumption of electricity, which needs new policies to balance the use of electricity. The second one is that the current over-reliance on heat pump installations to meet emission reduction targets may lead to a risk of overheating in housing.

3.2.2 Financial barriers

Financial barriers have been divided into seven categories (Table.6). The three most serious categories of barriers are:

(1) The high cost of retrofitting, which is unaffordable for most low-income households in the UK.

(2) The high cost of new heating systems. New heating systems are too expensive to install and house builders will be unwilling to go with new heating systems without clear government subsidies.

(3) For high-income and low-income households, the high-income group will be more willing to retrofit their homes if the energy pricing is the same, while low-income households may not be able to afford the same energy pricing. This is an inequality for households with different incomes.

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Table 6: Different barriers for financial reasons

	Financial barriers						
Paper	no reliable method of cost assessment	cannot afford renovation costs	less awareness and understanding	New heating systems cost more	No sales advantage	Mismatch with current system (more cost)	Pricing inequality
Alabid et al (2022)	■	■	■				
Pan et al (2011)	■		■	■	■	■	■
Wang et al (2022)				■		■	■
Gupta et al (2020)		■					
Wang et al (2022)		■					
Schaffrin et al (2015)		■					■
Kokoni et al (2021)		■		■			■
CREDS (2021)				■			
Total	2	5	2	4	1	2	4

3.2.3 Technical barriers

Technical barriers were divided into six categories in the various pieces of evidence (Table 7), of which the following three were mentioned most notably:

(1) The houses in UK have a long history with old building materials, there is a technical need to use different retrofitting techniques for different house types, and the current retrofitting techniques cannot match all house types.

(2) The existing heating system is associated with fueled boilers, retrofit technology needs to consider how to modify the existing heating system and match it to the new heat pump and warming materials, which requires more thorough consideration of retrofit technology.

(3) Heat pump systems use electricity, which makes their electricity consumption have different peaks in different seasons and fluctuate greatly from season to season. Techniques need to take the fluctuations into account as well.

Table 7: Different barriers for technical reasons

	Technical barriers					
Paper	Neglecting ventilation	no adaptation program for all houses	Reluctance to innovate technology	Mismatch with current system (more complex)	High fluctuations in energy consumption	Risk of overheating
Alabid et al (2022)	■	■				
Pan et al (2011)			■	■		
Wang et al (2022)				■	■	
Gupta et al (2020)		■				
Jing et al (2022)				■		
Wang et al (2022)					■	
Ibrahim et al (2018)				■		■
Li et al (2022)		■			■	
Kokoni et al (2021)		■			■	
Gupta et al (2014)					■	
Ivanova et al (2020)		■				
Lingard et al (2021)		■				
Total	1	6	1	4	5	1

3.2.4 Social and behavioral barriers

Social and behavioral barriers were divided into four categories in the various pieces of evidence (Table.8). The most serious barrier is about the limitation of the understanding of emission reduction.

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Because homeowners and home builders lack the awareness of the importance of reducing emissions and knowledge of retrofitting, most people still rely on existing heating systems, and some may not even support retrofitting. Secondly, 50% of people in the UK choose to rent their homes [9], and the requirements of tenants do not consider the need to reduce emissions. Even if houseowners want to educate tenants about the importance of reducing emissions, this would be against the interests of the tenants, making it difficult to reduce emissions in the home.

Table 8: Different barriers for social and behavioral reasons

	Social and behavioral barriers			
Paper	Neglection of indoor health	less awareness and understanding	Dependence on users to maintain flexibility	Different benefits for tenants
Alabid et al (2022)	■	■		
Wang et al (2022)			■	
Gupta et al (2020)		■		
Jing et al (2022)		■		
Wang et al (2022)			■	
Bobrova et al (2021)		■		
Schaffrin et al (2015)	■			■
Kokoni et al (2021)		■		■
Total	2	5	2	2

3.3 How to overcome barriers

For economic barrier, which is the most serious barrier. There are two issues that need to be addressed. Firstly, the inability of low-income residents to afford the cost of retrofitting. Wang et al. (2021) suggest that government can help residents to retrofit and provide incentives as well as subsidies. For the inequality of different incomes, Gupta and Gregg (2020) suggest bespoke funded projects to satisfy different classes of households. Secondly, the cost of a new heating system is too high. Gupta and Gregg (2020) states that the simultaneous renovation of many houses and the purchase of materials in bulk can reduce some of the costs, or using low-cost electricity [15].

3.4 Discussion

3.4.1 Limitations of evidence

Lingard et al. (2021) mention that low-carbon heat pumps are now being over-relied upon. The excessive use of low carbon heat pumps to meet emission reduction targets can lead to the danger of overheating houses (Lingard, et al., 2021). However, there is little evidence to mention what type of heat pump should be used better, and only one mentions Air Source Heat Pumps (ASHP) which is one of the best choices [11]. However, knowledge of new heat pumps is limited. Future research could focus more on the use of heat pumps in relation to the health of houses, enabling heat pumps to better reduce emissions for houses. Meanwhile, there are few mentions in those evidence of some irresistible factors such as COVID-19. Only one mentions that the use of house retrofitting to stimulate economic development, job creation and the development of technology after the COVID-19 (Gupta and Gregg, 2020). Future research can take COVID-19 more into account to see how more progress can be made in the face of these uncertain and irresistible factors.

3.4.2 Suggestions

This report also has some suggestions for policymakers, companies, and the public to improve the emission reduction in housing. Here the overcoming methods are also divided into four categories:

(1) Political: The government needs to establish a clear policy for reducing emissions from housing and set standards for emission reductions. The scale and process of government subsidies should be made public.

(2) Finance: The government adjusts energy prices, and the renovation company bears part of the renovation costs. Make new heating systems and retrofits affordable for low-income households.

(3) Technology: Vigorously develop innovative technologies.

(4) Social and Behavioral: Raise public awareness of the importance of national emissions reduction plans and attract more investors and supply chain partners.

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4. Conclusion

For the UK's ambition to reduce emissions, the housing sector has great potential to help achieve the net zero target by 2050. The most prominent barrier now is the economic barrier. This requires different funding programs for households of different incomes and lower costs for new low carbon heating systems. There are many barriers to mitigating in housing, but with clear policies, a well-funded subsidy system, innovative technologies and public support, the UK is well placed to reduce emissions from housing and reaches its net zero target by 2050.

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ISSN 2616-5872 Vol.5, Issue 8: 1-9, DOI: 10.25236/AJEE.2023.050801

Appendix. 1 Assessment method from Simon et al. (2017)

ASSESSMENT CRITERIA	WEIGHTING & SCORE
Conceptual Framing Measures the extent to which the study acknowledges existing research and constructs a clear hypothesis and/or conceptual framework for investigation. Highest score (3) 'no concerns': study identifies wide range of existing research and clearly frames the study with a research question or hypothesis. Middle score (2) 'some concerns'. Lowest score (1) 'major concerns': provides little review of previous research; lacks a clear research question or hypothesis.	(0-3) x 1 Out of 3
Appropriateness Measures the appropriateness of the study design and its methodology (e.g., quantitative, qualitative, quasi-experimental, longitudinal). Highest score (3) 'no concerns': study clearly demonstrates how its design suits the research question or hypothesis. Middle score (2) 'some concerns'. Lowest score (1) 'major concerns': study provides no explanation as to how its design suits the research question or hypothesis, or the explanation given is not considered plausible.	(0-3) x 1 Out of 3
Validity Measures the credibility of the research and the extent to which the study presents results that effectively and meaningfully measure effects and accurately describes these relationships. Highest score (3) 'no concerns': study clearly and credibly measures the relationships it sets out to measure. Middle score (2) 'some concerns'. Lowest score (1) 'major concerns': study employs measures that do not capture effects or key relationships in a credible way.	(0-3) x 2 Out of 6
Reliability Measures the extent to which the measures used in the study are stable and capable of producing consistent results. This includes a consideration of any explanation given to sampling (i.e., what choices were made when sampling and why). Highest score (3) 'no concerns': study demonstrates it applies consistent (i.e., stable) measures that, when repeated, it would produce the same results. Middle score (2) 'some concerns'. Lowest score (1) 'major concerns': study appears to lack consistent measurement techniques.	(0-3) x 2 Out of 6
ASSESSMENT SCORE	**18**

Figure 3: The assessment criteria and score matrix. (Reprinted from Figure 7 of Simon et al. 2017)

Study Quality	Abbreviation	Score	Definition
High	↑	14-18	Comprehensively addresses multiple principles of quality
Moderate	→	10-13	Some deficiencies in attention to principles of quality
Low	↓	6-9	Major deficiencies in attention to principles of quality

Figure 4: The strength of evidence and definition. (Reprinted from Figure 8 of Simon et al. 2017)