RETROFIT EUROPE!
INNOVATION MEETS MARKET
SBE19 CONFERENCE
5—6 NOVEMBER 2018 – TU/e, EINDHOVEN (NL)

Effects of Fabric Retrofit Insulation on Temperature Take-Back

Macarena Rodriguez
Newcastle University
m.rodriguez@ncl.ac.uk

Carlos Calderon
Newcastle University
carlos.calderon@ncl.ac.uk

ABSTRACT

This paper presents a two-year-long empirical study on the effects of fabric retrofit insulation on temperature take-back in a high-rise social-housing building (23-storey block) in Newcastle upon Tyne (UK). The study has followed a quasi-experimental approach coupled with qualitative methods and examines whether temperature take-back has taking place; the saturation effect and the relationship between temperature take-back, physical factors and occupant's behavioural change. First, the evidence suggests that temperature take-back is not occurring and instead the saturation effect has taken place. Second, a maximum take-back temperature was achieved ranging from 20.85°C-24.81°C. The study also suggests that to evaluate appropriateness of retrofitted insulation measures, pre-intervention variables such as internal temperatures, heating system and building fabric performance should be taken into account.

Keywords: Energy, retrofit, temperature take-back.

---

1. INTRODUCTION

This empirical study stemmed from a query raised by a social housing provider to better understand the effects of building fabric retrofit on a deprived area.It is known that domestic energy demand is affected by factors which are complex and often poorly understood (Oreszczyn & Lowe, 2010), especially in social homes, in which energy demand could be far from energy models (Teli et al, 2016). Empirical information on temperatures in domestic dwellings is valuable in appraising energy conservation interventions as, for example, the benefits of an energy efficiency intervention can be taken as extra warmth and the reduction in energy consumption saving associated with that change (Milne & Boardman, 2000; Poortinga et al, 2018; Sorrell, 2007). This is known as temperature take-back (TTB).Previous studies have shown that: TTB ranged from 0.14°C to 1.6°C (Sorrell et al, 2009), 1°C rise in internal temperature increases the space heating consumption by 10% or more (Sorrell, 2007) and up to 100% of energy savings is lost through TTB with a mean around 20% (Sorrell et al, 2009). TTB is higher in low-income householders (Milne & Boardman, 2000; Sorrell, 2007) one suggested reason is that financial constraints would lead to very low pre-intervention temperatures (Milne & Boardman, 2000). TTB may also decrease owing to saturation effects when pre-intervention internal temperatures saturate (reaching 21°C)(Sorrell, 2007). This has been conceptualised as the saturation effect: the reduction in the level of service required (e.g. internal temperature) as the gap between that required service and thermal comfort level is reduced. Research studies have also theorised that half of the TTB is accounted by the physical factors[1] and the remainder by the occupant's behavioural change (Oreszczyn et al, 2006; Sanders & Phillipson, 2006; Sorrell, 2007).

Building upon previous research propositions and findings, this investigation primary research proposition is that TTB exists and can be observed. Thus, on a UK high-rise social housing building, this paper interrogates: whether TTB has taking place; the saturation effect; and the relationship between TTB, physical factors and occupant's behavioural change.

2. METHODOLOGY

This study has followed the so called physical paradigm approach, unlike the engineering approach, it is not based on theoretical models for estimating potential savings but on physical monitoring before and after building retrofit and does not predetermine occupant practices. In a fabric retrofit context, energy-efficiency intervention effects on energy demand can be determined measuring the change in energy service or energy input (Sorrell et al, 2009). Moreover, internal temperature is the preferred energy service demand variable to be observed (Love, 2014) and taken as a pathway towards measuring temperature take-back in retrofit insulation studies (Oreszczyn et al, 2006). This has been termed 'quasi-experimental' (Sorrell et al, 2009). This study has followed a quasi-experimental approach coupled with qualitative methods and follow a convergent research design rationale so that a more complete understanding of the phenomena emerges (Doyle et al, 2016).The applied quasi-experimental approach measures the change in internal air temperature (energy service) and space heating consumption (energy input) before and after retrofit in two high-rise social-housing buildings in Newcastle upon Tyne, UK: CPH as the target building, and The Hawthorns as the control building. The target building is a 23-storey block with 157 flats and underwent retrofit insulation (solid external wall insulation and double glazing windows) from September 2014 to February 2015 .

3. RESULTS AND DISCUSSION

Fig. 1 shows an increase in mean internal air temperatures (MIAT) of +0.46° (from 22.07°C-22.53°C) and Table 1 shows that the change in weather-normalised space-heating consumption following retrofit for the target building was −27% with a potential relative difference between target and control group of −34%. Thus, if only overall temperature figures are taken into account, it could be inferred that TTB has taken place as there is an increase in MIATfollowing the building fabric retrofit and the reduction in energy consumption saving associated with that change. In low-income households, in theory, this increase in temperature is likely due to an unmet demand for energy services, such as warmth, which needs to be satisfied. However, the results in the form of individual flat and qualitative data shows that the increase in MIAT is not homogeneous. Moreover, in terms of space heating consumption, less than half of the individual dwellings are experiencing a reduction of space heating consumption post-retrofit. Furthermore, the internal threshold temperature of recommended temperature for healthy environments (DCLG, 2006) (21.0°C in living rooms (WHO, 1987)) was achieved before retrofit (22.07°C) and the fabric efficiency upgrade increased the internal air temperature beyond that recommended threshold (22.53°C). In addition, there is a negligible decrease in energy saving when compared to average national consumption (DECC, 2013). Therefore, this paper argues that the saturation effect has taken place as suggested by Sorrell (2007). That is,temperature take-back decreases owing to saturation effects when pre-intervention internal temperatures saturate (approaching 21°C) (Sorrell, 2007). This implies that adding more energy efficiency measures (e.g. wall insulation, double glazing) to a household physical and heating system where indoor

[1]e.g. building fabric retrofitted insulation and heating systems

temperatures approach the maximum level for thermal comfort will yield a negligible decrease in energy saving consumption in absolute terms.

The empirical evidence also indicates that a maximum take-back temperature was achieved for the dwellings ranging from 20.85°C to 24.81°C.In addition there is a quasi-flat internal air temperature profile and small maximum temperature differences pre-and post-retrofit. A flat internal temperature profile may denote the absence of occupant-controlled heating periods, and heating period length changes as defined by the BREDEM-12 heating profile (Anderson et al, 2002). Consequently, this absence of pre- and post-retrofit heating periods suggest that the increase of standardised MIAT following the upgrade (+0.46°C) may be the result of unheated periods and it appears to be more related to building-related physical processes rather than switching the heating on by occupants (occupant behaviour).

4. CONCLUSION

The evidence presented in this paper is based on one specific, detailed, and contextualised case. The presented results suggest that, first, temperature take-back as extra warmth (or energy consumption savings) has not taken place. Second, an unintended saturation effect has taken place. This supports the assumption that temperature take-back decreases owing to saturation effects when pre-intervention internal temperatures saturate (approaching 21°C) in lieu of the hypothesis that low-income householders take the benefits of an energy efficiency intervention as extra-warmth rather than energy savings. Third, a maximum take-back temperature was achieved for the dwellings ranging from 20.85°C to 24.81°C. Fourth, heating behavioural factors appear to be less relevant than energy-efficiency improvements to explain the increased of standardised mean internal air temperature. However, it is unclear how much behavioural factors account for this and further research would be needed. The study also suggests that if these results were more broadly confirmed, future local guidelines to evaluate appropriateness of energy-efficiency interventions should take into account pre-intervention variables such as internal temperatures, heating system and building fabric performance, in order to suggest the best energy efficiency measure.

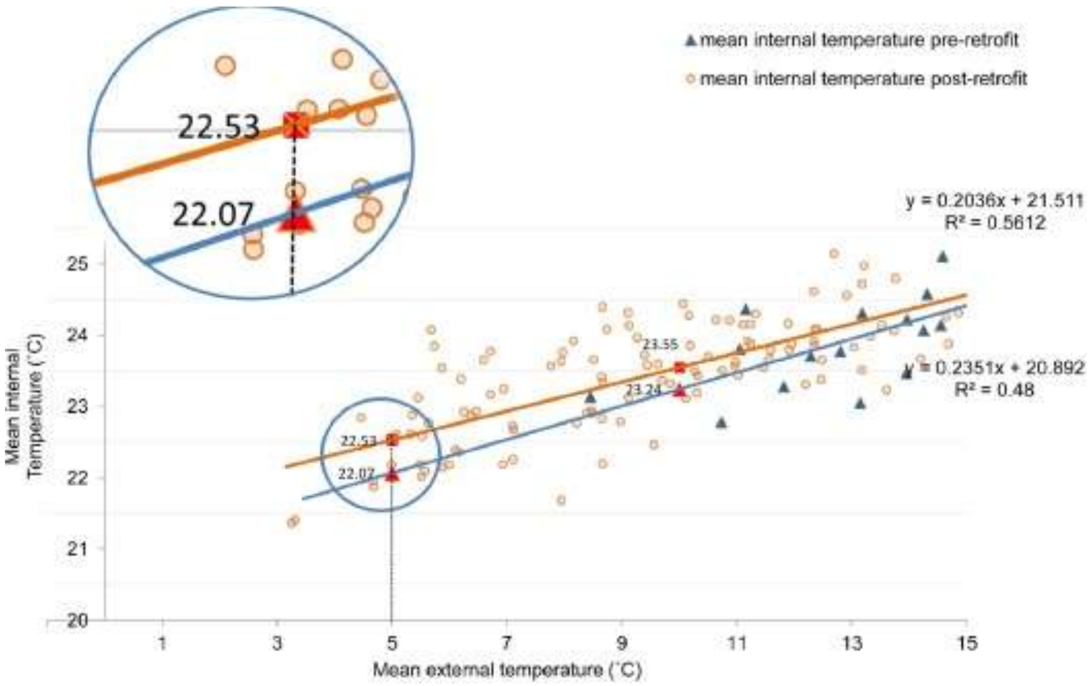

Fig. 1. Standardised mean internal air temperature of the target building, at 5.0 °C external temperature. Pre- and post-retrofit (n = 9).

Retrofit Status	Weather normalised space heating consumption percentage change		
	Target building ($WhK^{-1}m^{-2}d^{-1}$)	Control building (WhK^{-1} $m^{-2}d^{-1}$)	$\Delta(Target - Control)$ building(%)
Pre-retrofit	0.0184	0.0460	
Post-retrofit	0.0134	0.0494	
$\Delta(Pre - Post)$retrofit (%)	−27	7	−34

Table 1.Weather normalised space heating consumption percentage change in target building, control building, and relative to each other.

FURTHER READING

This paper is based on the following publication:

Effects of fabric retrofit insulation in a UK high-rise social housing building on temperature take-back.

https://www.sciencedirect.com/science/article/pii/S037877881734094X

REFERENCES

Anderson, B. R., Chapman, P. F., Cutland, N. G., Dickson, C. M., Doran, S. M., Henderson, G., Henderson, J. H., Iles, P. J., Kosmina, L. & Shorrock, L. D. (2002) *BREDEM-12 Model description: 2001 update*.Garston, Watford, UK.

DCLG (2006) *Housing health and safety rating system- guidance for landlords and property related professionals.* London: Department for Communities and Local Government.

DECC (2013) *The Future of Heating: Meeting the challenge.* London: Available online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf [Accessed

Doyle, L., Brady, A.-M. & Byrne, G. (2016) An overview of mixed methods research–revisited. *Journal of research in nursing*, 21(8), 623-635.

Love, J. (2014) *Understanding the interactions between occupants, heating systems and building fabricin the context of energy efficient building fabric retrofit in social housing*Ph.D. thesis. UCL.

Milne, G. & Boardman, B. (2000) Making cold homes warmer: the effect of energy efficiency improvements in low-income homes A report to the Energy Action Grants Agency Charitable Trust. *Energy Policy*, 28(6), 411-424.

Oreszczyn, T., Hong, S. H., Ridley, I. & Wilkinson, P. (2006) Determinants of winter indoor temperatures in low income households in England. *Energy and Buildings*, 38(3), 245-252.

Oreszczyn, T. & Lowe, R. (2010) Challenges for energy and buildings research: objectives, methods and funding mechanisms. *Building Research & Information*, 38(1), 107-122.

Poortinga, W., Jiang, S., Grey, C. & Tweed, C. (2018) Impacts of energy-efficiency investments on internal conditions in low-income households. *Building Research & Information*, 46(6), 653-667.

Sanders, C. & Phillipson, M. (2006) *An Analysis of the Difference between Measured and Predicted Energy Savings when Houses are Insulated* Centre for Research on Indoor Climate and Health, Glasgow Caledonian University; 2006., University;, G. C.

Sorrell, S. (2007) *The Rebound Effect: An Assessment of the Evidence for Economy-wide Energy Savings from Improved Energy Efficiency*.

Sorrell, S., Dimitropoulos, J. & Sommerville, M. (2009) Empirical estimates of the direct rebound effect: A review. *Energy Policy*, 37(4), 1356-1371.

Teli, D., Dimitriou, T., James, P., Bahaj, A., Ellison, L. & Waggott, A. (2016) Fuel poverty-induced 'prebound effect' in achieving the anticipated carbon savings from social housing retrofit. *Building Services Engineering Research and Technology*, 37(2), 176-193.

WHO (1987) *Health Impact of Low Temperatures*.Copenhagen.