CLIMATE TARGETS VERSUS LONGTERM PERFORMANCE - HOW EFFECTIVE IS B2 RETROFIT IN THE RACE TO 2030?

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CLIMATE TARGETS VERSUS LONG-TERM PERFORMANCE: HOW EFFECTIVE IS B2 RETROFIT IN THE RACE TO 2030?

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Ireland's Climate Action Plan details a roadmap of measures that align with the European Union's ambition to achieve a net-zero target carbon emissions by 2050. It seeks to play a key role in delivering energy efficiency in Ireland and follows a Europe wide approach to reduce energy consumption across the building sector. In this context, Ireland has introduced the National Retrofitting Scheme which has set a goal of retrofitting 500,000 existing homes to a Building Energy Rating (BER) of B2 by 2030. The route to attaining this rating is dependent on the pre-works BER of individual properties. This research paper followed a structured approach to assess the potential long-term effects of shallow retrofit to dwellings that required minimum intervention to achieve the required standard. It is demonstrated that scenarios exist where shallow retrofit (a) is insufficient to enhance the quality of the indoor environment, (b) may promote conditions for condensation and mould growth, and (c) can reduce indoor air quality. These findings have significant health and wellbeing impacts for occupants and have implications for the policy framework.

Keywords: dwelling performance; retrofit; indoor environment; indoor air quality; condensation risk

INTRODUCTION

Ireland's Climate Action Plan (CAP) 2021 (Department of Communications, Climate Action and Environment, 2021) seeks to play a key role in delivering energy efficiency in Ireland and follows a Europe wide approach to reduce energy consumption in a building sector that represents 40% of total energy usage. In this context, the National Retrofitting Scheme (NRS) has set an ambitious goal of retrofitting 500,000 existing homes to a Building Energy Rating (BER) of B2 or cost optimal equivalent by 2030 (Sustainable Energy Authority of Ireland, 2022a), equating to almost 30% of all residential buildings in Ireland (Sustainable Energy Authority of Ireland, 2022c).

This approach aligns with the ambitious plans of the European Green Deal (European Commission, 2019) which emphasizes the need for the EU and its Member States to engage in a 'renovation wave' of both public and private buildings. Currently, 33,108 dwellings have been retrofit to a BER of B2 or better since January 2021 (Sustainable Energy Authority of Ireland, 2024). The CAP requires the equivalent of 120,000 dwellings retrofitted to the required standard by 2025 with the remainder (75,000 per

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annum) achieved by 2030 (Department of Communications, Climate Action and Environment, 2024), therefore requiring hundreds of thousands of homeowners to make the decision to invest in decarbonising and making their dwellings more efficient.

Currently, there exists no single policy or measure that can affect the required increase in the rate of retrofit. However, the residential built environment has set sectoral emission ceilings of 29.3 Mt CO2e and 23.5 29.3 Mt CO2e for periods 2021-25 and 2026-30 respectively (Department of Communications, Climate Action and Environment, 2024). Realising these goals requires an urgent reduction in the use of fossil fuels and an immediate improvement in energy efficiency in buildings. To this end, a focus on energy efficiency first has become the key principle in relation to the built environment and is included in the 2023 Energy Efficiency Directive for the first time as a policy requirement (European Union, 2023).

There are approximately 140,000 local authority (LA) owned social housing stock (Department of Housing, Local Government and Heritage, 2022) in the Republic of Ireland with plans to retrofit 36,500 within the next decade (Department of the Environment, Climate and Communications, 2022b). This working paper seeks to evaluate the impact of BER/cost optimal focussed retrofit within LA owned dwellings and is part of a wider body of research that utilises post-occupancy data to explore if the implementation, execution, and performance of retrofit strategies that utilise a uniform approach to the retrofit of non-uniform existing dwelling stock could create un-intended consequences for both the dwelling and the dwelling occupants.

LITERATURE REVIEW

The precursor to the NRS was the Deep Retrofit Pilot Programme, which was introduced in 2017 and managed by the Sustainable Energy Authority of Ireland (SEAI). A fabric first approach to deep dwelling retrofit was promoted, with all participating dwellings achieving a Building Energy Rating (BER) of A1-A3 and an airtightness of ≤ 5 m3/hr/m2 (Sustainable Energy Authority of Ireland, 2022b). The programme investigated the challenges and opportunities presented by deep retrofit in Ireland with the outcomes used to inform the approach to large scale retrofit, culminating in the introduction of the NRS. The NRS addresses barriers to undertaking energy retrofits reported by homeowners and those working in the industry and sets out a package of supports designed to

make it easier and more affordable for homeowners to undertake home energy upgrades (Sustainable Energy Authority of Ireland, 2022a). This represents an important step in the delivery of the National Retrofit Plan (NRP) which has previously set out how retrofit targets are to be achieved (Department of the Environment, Climate and Communications, 2022b).

There is an obligation to ensure that retrofit measures that are designed to improve performance do not adversely affect the quality of the indoor environment. Previous studies have demonstrated that this may happen (Shrubsole *et al.,* 2014; Jonge *et al.,* 2019; Sarran *et al.,* 2023; Yang *et al.,* 2020; Fisk *et al.,* 2020). This body of research provides post occupancy insight, enabling adjustment where required to enhance our overall retrofit approach.

B2 or Cost Optimal Requirement

The European Performance of Buildings Directive (EPBD) requires each member state to set minimum energy performance requirements for buildings and building elements, requiring a cost-optimal study to define the energy performance required (European Union, 2023). This requires cost-optimal calculations and a gap analysis for residential buildings using the Dwelling Energy Assessment Procedure (DEAP) (Sustainable Energy Authority Of Ireland, 2023), which is the approved calculation methodology and software for calculating the energy performance of buildings, meeting the requirements of the EPBD. The study accounts for the capital, operational, maintenance, and carbon costs of various energy efficient solutions and renewable technologies. Regulation 244/2012 supplements the EPBD and requires that the national minimum energy performance requirements should not be more than 15% lower than the outcome of the cost-optimal results of the calculation taken as the national benchmark (European Commission, 2012). A BER of B2 is considered the benchmark for excellent energy performance and home comfort (Sustainable Energy Authority Of Ireland, 2021) relating to a primary energy performance of less than 125 kWh/m2/yr. This is the minimum energy performance requirement that should be achieved in so far as this is technically, functionally and economically feasible. For the majority of existing dwellings, the energy performance requirement is within 15% of the cost optimal primary energy level as required by the cost optimal guidance (Department of Housing, Local Government and Heritage, 2020).

Local Authority Energy Efficiency Retrofit Programme Requirements

The LA Energy Efficiency Retrofit Programme (EERP) was introduced in 2021 and is expected to run for ten years to align with CAP goals. Funding is made available on an annual basis and is allocated based on previous targets being met and local authority forecasts for each current year (Department of Housing, Local Government and Heritage, 2022). Eligible retrofit works include attic/cavity wall insulation or external wall insulation, windows and doors replacement, heat pump installation and ancillary and associated works. Funding may be re-distributed between local authorities to ensure that that overall retrofit targets are achieved (Department of Housing, Local Government and Heritage, 2022).

Local Authority Funding Allocation

In respect to dwelling retrofit, applicable LA properties in the Republic of Ireland are conditioned by a funding ceiling for energy efficiency works, allowing maximum available grants ranging from €42,350 for mid-terrace and apartment type properties to €48,850 for end of terrace/detached/semi-detached properties (Department of Housing, Local Government and Heritage, 2022; Department of the Environment, Climate and Communications, 2022a). Each LA is required to choose a mix of properties across a range of BER's, allowing for homes which need significant expenditure to be balanced out by those needing lesser spend, ensuring that targets are achieved within the funding envelope provided. An inappropriate choice of properties in this regard may result in local authorities having to support the programme from their own resources. Furthermore, only properties which will achieve a post works BER of B2 or cost optimal equivalent are permitted to be included in the local authority's annual programme of work. Works which are not eligible, overdesigned, over specified and/or bring the homes to a rating beyond that which is absolutely necessary will not be financially supported (Department of Housing, Local Government and Heritage, 2022).

METHOD

As previously mentioned, it is critical that retrofit measures are carried out correctly and sequentially, to prevent against a chain relationship of causes/effects leading to fabric or energy related performance gaps. This research will evaluate participating retrofit dwellings in both winter and summer through a performance in use perspective. This will be achieved by evaluating (a) the performance of the external wall element and (b) the ventilation strategy in each dwelling. These parameters have been chosen as they serve to demonstrate optimal building performance, which is the central tenet of this study. This working paper will present the primary data that is relevant to open a discussion into the long-term impact that the current retrofit strategy in LA owned dwellings may have for the dwelling and the dwelling occupants.

Devices

Airthings Wave Plus data loggers were utilised to measure carbon dioxide (CO2), temperature, humidity, volatile organic compounds and radon levels within participating dwellings. Omega 8 Channel Handheld Thermocouple Thermometer data loggers were utilised to monitor and log the internal surface temperature of external walls.

Dwelling Typology

This study focussed on dwellings that were retrofit under the EERP to a BER of B2. Each dwelling was initially assessed on an individual basis so that the required BER rating would be achieved post retrofit works. Dwelling ID no. 4 was not retrofit prior to this study, therefore acting as a control property against which achieved improvements could be considered. Table 1.0 details the retrofit measures that were applied to each property. It is notable that certain measures were existing and represent the staged approach to dwelling insulation and energy improvements that were implemented, within LA properties, until the commencement of the EERP programme. It also confirms that, in line with the funding allocation ceiling, only measures that brought each dwelling to a B2 rating were considered.

Table 2 details the designed reductions in regulated energy use (space heating, water heating, ventilation, lighting) that are expected to be achieved in each dwelling resulting from the retrofit works. Each property will benefit from a significant improvement on the BER primary energy value. It also states the results of the post-works airtightness test that was conducted as part of this research study.

Table 1: Participant Dwellings - Retrofit Measures

ID	Replacement of uPVC external doors and windows Y/N	Type of external wall insulation used **FFCB** - Full fill cavity bead **FFMW** – Full fill mineral wool **EWI** - External wall insulation **N** – None **E** – Existing measure **N** – New measure	Attic level insulation Y/N	Floor insulation Y/N	Ventilation system **E** – Existing measure **N** – New measure	Heat pump or Gas Boiler **E** – Existing measure **N** – New measure
1	Y	FFMW - E	Y	N	DCV - N	HP - N
2	Y	FFCB - E	Y	N	Passive - E	HP - N
3	Y	EWI -N	Y	N	Passive - E	HP - N
4	N	N/A	Y	N	Passive - E	GB - E

Table 2: Participant Dwellings - Listed Improvements

ID	pre-retrofit BER	pre-retrofit energy use - kWh/m2/yr	post-retrofit BER	post-retrofit energy use - kWh/m2/yr	pre-retrofit airtightness test result - m3/hr/m2	post-retrofit airtightness test result - m3/hr/m2	Occupancy
1	C2	188.81	B1	79.68	n/a	8.32	2 adults 2 children
2	D1	252.12	B1	83.92	n/a	6.83	1 adult
3	C3	212.8	B1	75.61	n/a	12.16	1 adult
4	D1	226.87	n/a	n/a	9.46	n/a	1 adult 3 children

RESULTS AND DISCUSSION

Table 3 lists the CO2 measurement range captured during the monitored period. The designation (A) has been given to the main utilised living area whilst (B) refers to the master bedroom in each dwelling. The data was segregated into percentage occurrence of specific ranges in parts per million (ppm) to understand the overall performance of the monitored spaces in respect to the dilution of this specific pollutant.

Table 3: % occurrence of CO_2 measurements per monitored space

CO_2 (ppm)	1A	1B	2A	2B	3A	3B	4A	4B
< 700	7.71	2.09	99.14	81.60	67.83	42.71	82.47	56.15
>= 700 < 1000	16.91	7.62	0.84	18.29	23.40	24.32	13.01	32.08
>= 1000 < 1500	49.30	23.94	0.01	0.11	8.61	23.60	3.88	11.77
>= 1500 < 2000	23.61	30.08	0.00	0.00	0.16	7.96	0.61	0.00
>= 2000 < 2500	2.44	28.19	0.00	0.00	0.00	0.61	0.04	0.00
>= 2500 < 3000	0.03	7.61	0.00	0.00	0.00	0.80	0.00	0.00
> 3000	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00

Dwelling 1 appears to have a significant issue with ventilation despite having a demand-controlled ventilation (DCV) system installed. The system installed in the dwelling is designed to react to human occupancy patterns, thereby reducing thermal loss via over-ventilation during unoccupied periods. Further research will have to consider the reason behind this specific case, but it is noteworthy that it has previously been demonstrated that systems that are controlled by sensors to save energy, have been noted as potentially problematic (Sloan Brittain *et al.,* 2021; Jonge *et al.,* 2019).

It is demonstrated that the monitored levels of CO2 dwellings in 2/3/4 are broadly similar. All three dwellings are passively ventilated but only 2 and 3 have been retrofit as part of the EERP works. However, it does demonstrate that the retrofit measures do not appear to adversely affect the indoor air quality (IAQ) in respect to this specific occupant created pollutant within single occupancy passively ventilated LA dwellings.

However, as CO2 generation depends on the number of occupants, their size and level of physical activity, exact correlations between CO2 and other indoor pollutants can only be drawn if they are generated at a rate that depends on the same factors (Emmerich and Persily, 2003). Further data was collected in respect to radon and volatile organic compound levels, both non-occupant created pollutants. This data will be analysed to assess the suitability of the ventilation strategy dwelling as this working paper develops. Table 4 lists the relative humidity (RH) measurement range whilst Table 5 lists the temperature measurement range captured during the monitored period.

Table 4: % occurrence of relative humidity measurements per monitored space

Relative Humidity (%)	1A	1B	2A	2B	3A	3B	4A	4B
< 40	0.00	0.00	27.90	12.65	42.36	5.20	0.13	0.00
>= 40 < 50	4.20	0.00	60.97	82.11	52.03	42.25	13.83	4.68
>= 50 < 60	51.97	8.28	11.44	5.24	5.60	52.55	56.90	37.57
>= 60 < 65	36.87	24.56	0.00	0.00	0.00	0.00	23.31	39.42
>= 65 < 70	6.23	52.52	0.00	0.00	0.00	0.00	5.52	16.66
>= 70 < 75	0.69	14.52	0.00	0.00	0.00	0.00	0.28	1.67
> 75	0.04	0.02	0.00	0.00	0.00	0.00	0.03	0.00

Table 5: % occurrence of temperature measurements per monitored space

Temperature (°C)	1A	1B	2A	2B	3A	3B	4A	4B
< 12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28
>= 12 < 13	0.00	0.00	0.00	0.00	0.00	0.00	0.34	4.93
>= 13 < 14	0.00	0.00	0.00	0.00	0.00	0.13	3.08	14.50
>= 14 < 15	0.00	0.00	0.00	0.00	0.00	1.01	9.33	23.17
>= 15 < 16	0.00	0.00	0.00	0.00	0.00	2.11	15.61	25.54
>= 16 < 17	0.19	0.00	0.00	0.00	0.00	4.30	19.91	19.50
>= 17 < 18	3.56	2.39	0.11	0.00	0.00	11.46	19.80	9.40
>= 18 < 19	16.64	16.75	0.93	0.64	0.54	37.71	13.74	2.88
>= 19 < 20	19.43	36.84	13.60	12.15	12.15	32.35	9.22	0.10
>= 20 < 21	21.84	35.83	71.24	25.76	25.76	9.70	5.22	0.00
>= 21 < 22	25.02	7.55	13.35	37.88	37.88	1.22	2.86	0.00
>= 22 < 23	11.63	0.43	0.77	22.05	22.05	0.00	0.77	0.00
>= 23 < 24	1.51	0.00	0.00	1.62	1.62	0.00	0.10	0.00
>= 24 < 25	0.19	0.00	0.00	0.00	0.00	0.00	0.01	0.00
> 25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The constantly high ambient internal temperatures that are realised post-retrofit are to be expected and similar findings of those other studies (Coggins *et al.,* 2022), however it is noteworthy that recommended internal temperatures of 17 - 19 ◦C for bedrooms (Chartered Institution of Building Services Engineers, 2021) are routinely exceeded.

Dwelling 1 has significant levels of RH above the 60% range. Whilst this is not an issue in respect to RH, it becomes a cause for concern when it is viewed in conjunction with the high internal temperatures demonstrated in Table 5 and the low internal surface temperature of an external wall within the dwelling demonstrated in Figure 1. These results demonstrate an issue that the chosen catalogue of retrofit measures has inadvertently created. RH is the amount of water vapour present expressed as a percentage of the amount needed for saturation at the same temperature.

Raising the temperature without changing the amount of moisture in the air reduces the RH, as warmer air can hold more moisture than colder air. The opposite occurs when the temperature falls. This can pose a significant problem when external walls are subjected to cooler external temperatures, which can subsequently decrease the cross-sectional temperature of the wall, creating a cooler internal surface. This is demonstrated in Figure 1 and will result in localised cooling of internal air causing RH levels to rise, inevitably leading to a moisture dump, resulting in condensation and subsequent mould growth on this surface. Dwellings 2 and 3 (Figures 2 and 3) show significant potential for the same result to occur, should similar conditions occur. It is considered that condensation occurs in Dwelling 4 (Figure 4), however this is the control property that has not yet been retrofit and as, such, can be expected.

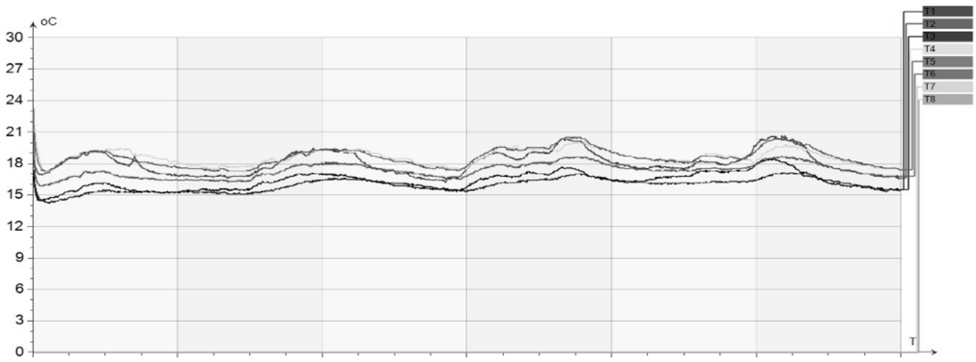

Figure 1: Dwelling 1: Internal surface temperature of external wall

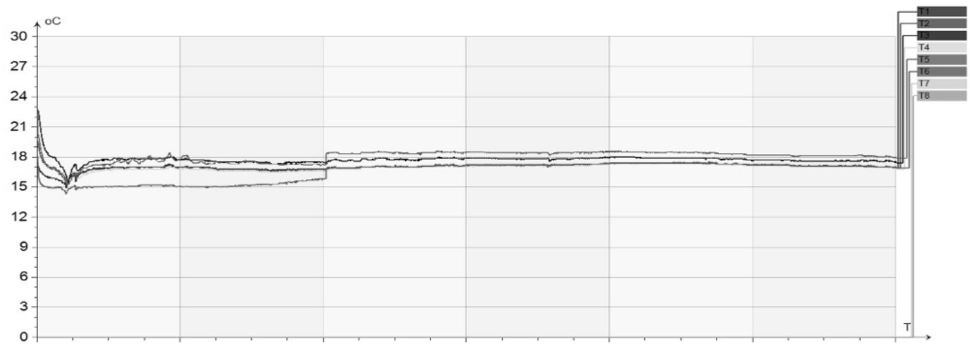

Figure 2: Dwelling 2: Internal surface temperature of external wall

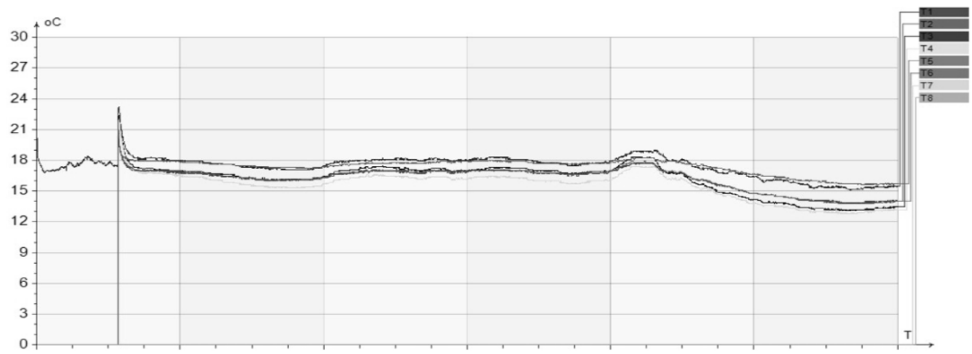

Figure 3: Dwelling 3: Internal surface temperature of external wall

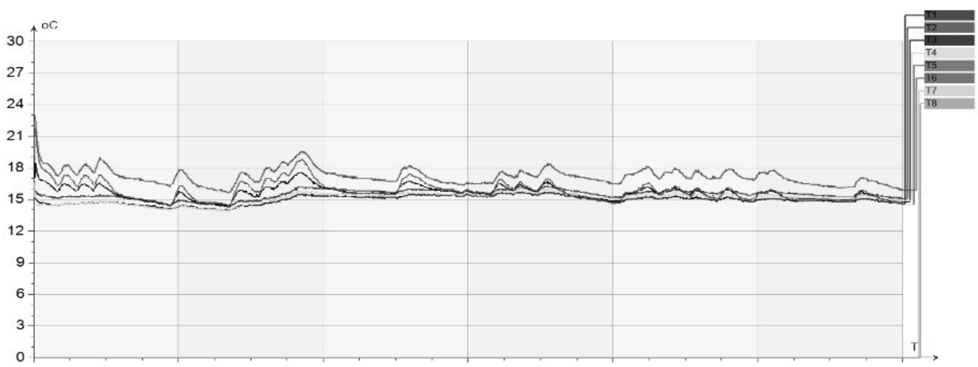

Figure 4: Dwelling 4: Internal surface temperature of external wall

CONCLUSIONS

This paper seeks to open a discussion into the long-term impact that the current retrofit strategy in local authority owned dwellings in Ireland may have. It is demonstrated that the catalogue of retrofit measures that are applied when upgrading local authority owned properties to a BER of B2 or cost optimal equivalent have the potential to create un-intended consequences for both the dwelling and the dwelling occupants. The primary data requires further in-depth analysis and consideration, however there are specific physical dwelling properties that will promote conditions for condensation and mould growth and will reduce indoor air quality within the dwellings under review.

It is noteworthy that the EERP scheme requirements, the funding ceiling, and the countrywide retrofit targets define the overall approach and play a significant part in the preliminary results of this paper. The stated position that (a) works which are not eligible under the scheme, (b) works that are overdesigned or over specified, and/or (c) works that bring the homes to a rating beyond that which is absolutely necessary will not be financially supported preclude LA's from considering any measures that result in achieving a rating greater than B2, irrespective of the rationale for doing so.

The financial cost associated with dwelling retrofit ensures that retrofit measures become locked-in for a significant period. The current approach to retrofitting LA owned properties promote the adoption of retrofit techniques that achieve the required BER rating as opposed to focussing on optimisation of dwelling performance. It is critical that the EERP scheme be modified to allow significant flexibility where required, to enhance the overall retrofit approach and preserve the quality of the dwelling stock for current and future dwelling users.

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