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Indoor Air, Ventilation and comfoRt in Irish Domestic dwellings post DEep Energy reNovations-ARDEN

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ABSTRACT HEADING

Deep Energy renovation (DER) adopts a whole building approach and achieves much larger energy savings than shallow energy renovations that typically only included a small number (one or two) of upgrade measures. DER includes the installation of high levels of insulation, uses renewable energy technologies and minimises uncontrolled air leakage by achieving air permeability levels no greater than 5 $m^3/h.m^2$ to achieve building energy ratings (BER) of at least A3. It can also include the installation of mechanical ventilation in order to ensure an adequate level of controlled ventilation for the occupants.
The impact of energy efficient measures such as DER on indoor air quality (IAQ) is largely understudied internationally. Although research shows that improving the energy performance of a building improves indoor temperature and occupant comfort, the impact on IAQ is unclear. In this research project the air concentration of pollutants, $PM_{2.5}$, formaldehyde, carbon monoxide, carbon dioxide, BTEX along with temperature and relative humidity will be measured in a sample of homes participating in the Sustainable Energy Authority of Irelands Pilot DER programme. Post DER surveys will also include an assessment of the performance of the ventilation installed as part of the DER. Preliminary results from a sample of 8 homes post DER are presented here.

INTRODUCTION

Deep Energy renovation (DER) adopts a whole building approach and achieves much larger energy savings than shallow energy renovations. DER can include the installation of mechanical ventilation, high levels of insulation and uses renewable energy technologies, to achieve building energy ratings (BER) of at least A3 and building air tightness levels no greater than 5 $m^3/h.m^2$ SEAI, 2017 in line with NSAI Code of Practice for the energy efficient retrofit of dwellings Standard Recommendations (SR) 54.
Reduced building air permeability following energy renovations, which is necessary to improve the thermal efficiency of the building, may impact negatively on indoor air pollutants such as formaldehyde and radon if appropriate ventilation is not provided as part of the retrofit (Fisk et al., 2020, Du et al., 2019). It is clear that an energy efficient home provides measurable mental and physical health benefits, resulting from the economic benefits of reduced energy costs and increased indoor temperatures (Howden-Chapman et al., 2007; Thomson et al., 2013). However, the impact that the resulting indoor air quality (IAQ) has on health, post the energy retrofit needs further study (Fisk et al., 2020). If appropriate ventilation is not provided as part of the retrofit, if the ventilation systems are not used correctly by the occupants, or if occupant practices do not change (e.g. tobacco smoking) IAQ concentrations can often exceed levels before the energy retrofit (Broderick et al., 2017; Foldvary, 2017). Careful attention to training and educating homeowners on the new technologies installed as part of the DER is required to avoid an increase in pollutant concentration post renovation (Wells et al., 2015). Further to this, the updated Part F (Ventilation) of the Irish Building Regulations, which came into effect on 1st November 2019, requires that where new mechanical extract ventilation

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systems are installed as part of a Major Renovation as defined in Part L 2019, mechanical ventilation systems should be installed, balanced and commissioned by competent installers and that the systems should then be validated to ensure that they achieve the design flow rates (and minimum requirements of Part F of the Building Regulations) by an independent competent person.

In this research project, indoor air quality is measured in a sample of homes participating in the Sustainable Energy Authority of Irelands's DER Pilot programme. Post DER surveys will also include an assessment of the performance of the ventilation installed as part of the DER, a questionnaire survey will also be used to collect information on occupant comfort and how occupants use the energy saving features in their home.

METHODOLOGY

Ethical approval for the study was obtained from the Research Ethics Committee of the National University of Ireland, Galway. Homes who participated in SEAIs Pilot DER programme were recruited to participate in the study. Concentration data for the following Indoor air pollutants (IAPs) were measured in the living room and bedroom at one-minute intervals over a 48-hour period; CO, CO_2, $PM_{2.5}$, TVOC. Temperature and relative humidity measurements were also collected. Formaldehyde and radon measurements were also collected over 3-day and 3-month periods respectively. CO_2 concentrations were used to calculate steady state nighttime air exchange rates in bedrooms, participating homes were 1 to 2 years post retrofit at the time of sampling. Building air tightness (@50Pa) was measured in homes using the blower-door test (I.S. EN 1389: 2000). Outdoor $PM_{2.5}$ concentration data were available was obtained from local Irish EPA monitoring stations.

Table 1. Summary of the energy features installed as part of the DER in participating homes (AW= air to water heat pump, DCV= Demand Controlled Ventilation), n=7.

Approx building date	Pre BER	Post BER	Pre air permeability ($m^3/hr/m^2$)	Post air permeability ($m^3/hr/m^2$)	Heating source Pre retrofit	Heating source Post retrofit	Ventilation system
1998	G	A1	15.0	4.6	oil	AW	DCV
1998	G	A1	15.0	4.8	oil	AW	DCV
1985	E2	A3	7.8	3.0	peat	AW	DCV
1950	D1	A3	10.6	4.8	unoccupied	AW	DCV
1983	D2	A3	7.7	4.6	Oil, wood	AW	DCV
1999	D2	A3	10.2	3.8	oil	AW	DCV
1999	D2	A3	10.2	2.8	oil	AW	DCV
1999	D2	A3	10.2	4.6	oil	AW	DCV

RESULTS

Preliminary results: Post-DER IAQ assessments have been completed in 8 detached and semi-detached dwellings. Sampled homes had a minimum BER of A3, demand controlled ventilation was installed in all homes as part of the retrofit (Table 1). Post-DER fromaldehyde concentrations exceed the ATSDR long term health based guidance value in all homes sampled (Figure 1). 24-hour $PM_{2.5}$ concentrations exceed the WHO guideline value in 30% of homes sampled. Outdoor air pollution along with occupant activities during the surveys are likely reasons for the elevated $PM_{2.5}$ concentrations. Radon levels (Bq/m^3) exceed the National reference value of 200 Bq/m^3 in 1 out of 5 homes sampled. 24-

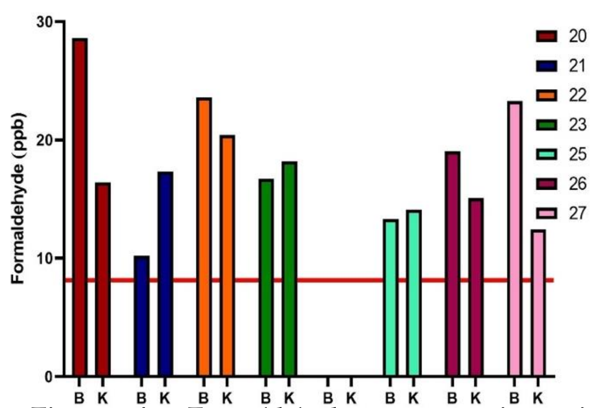

Figure 1. Formaldehyde concentrations in bedrooms and living areas over a 3-day period post-DER (B=bedroom, K=Kitchen/ Livingroom; red line– ATSDR indoor air quality guideline 8.14 ppb),

hour average CO_2 concentrations greater than 2000 ppm were recorded in one bedroom, which was occupied for most of the sampling period (Figure 2 – Home 20). Measured room ventilation rates in many of the sampled homes were less than 5 litres/sec/person. Nightime bedroom air exchange rates ranged from 0.5 to 1.2 air exchanges per hour.

CONCLUSION

Pre DER most of the participating homes relied in some way on fossil fuel based heating or cooking systems. Preliminary post DER assessments showed increases in some pollutants (Formaldhyde, $PM_{2.5}$, Radon, CO_2) above comparison guidelines in a few instances, some of these increased are likely due to occupant activities or outdoor air pollution events at the time of the survey. Post ventilation data for some homes were less than 5 litres/sec/person, however in many cases the homeowners reported problems with their ventilation system or there there were visible signs of underperformance i.e. dust deposits at the vents.

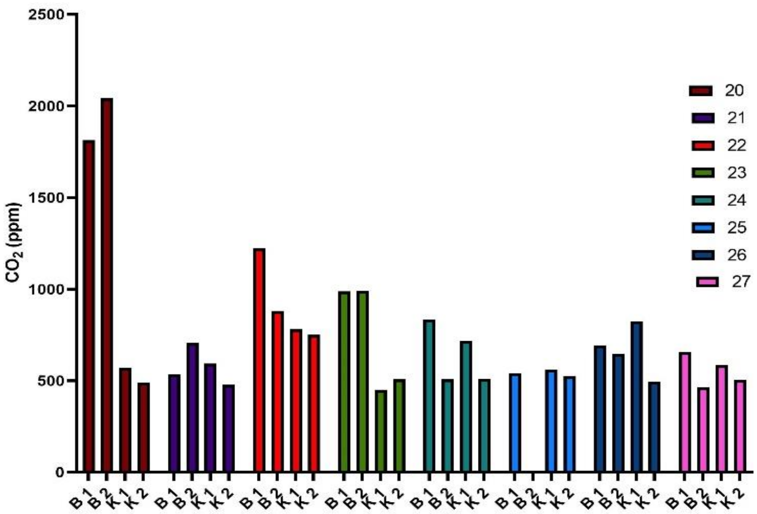

Figure 2: 24-hour average CO_2 concentrations in bedroom and living area post-DER (B=bedroom, K=Kitchen/Livingroom), n=8.

ACKNOWLEDGMENTS

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