Analyzing solar installations: a catalyst or barrier to subsequent residential retrofits?

ABSTRACT

This study investigates the impact of solar photovoltaic (solar PV) system installations on subsequent energy retrofitting behaviour among residential dwellings in Ireland, particularly within the context of the nation's commitment to sustainability and renewable energy as outlined in the National Development Plan 2021-2030. Despite over 65,000 solar PV installations facilitated by the Sustainable Energy Authority of Ireland (SEAI), findings suggest that the installation of solar PV does not significantly encourage additional retrofitting actions when compared to alternative measures, such as attic insulation and heating controls. Using statistical methodologies, including chi-square tests and survival analysis, the study reveals that homeowners who adopt solar PV systems exhibit a minimal propensity to pursue further retrofits, with an average additional investment of only €200 per installation. While the results indicate a nuanced relationship influenced by dwelling type and energy building rating (BER), the hypothesis that solar PV serves as a "gateway" to broader energy efficiency improvements is unsupported. The findings emphasize the need for integrated energy strategies that encompass both renewable technology adoption and comprehensive energy performance upgrades to achieve Ireland's ambitious climate targets. This research underscores the importance of fostering holistic approaches to retrofitting that encourage homeowners to invest not just in renewable systems such as solar PV but also in measures that enhance overall energy efficiency such as dwelling insulation.

Keywords

Photovoltaics, residential, energy retrofit, energy efficiency

Acknowledgements

This research was conducted as part of my employment at Sustainable Energy Authority of Ireland, where I received funding and support for this work.

Introduction

The urgent need to address climate change has driven a global transition toward renewable energy, with solar photovoltaics (PV) emerging as a key solution. In Ireland, the National Development Plan 2021-2030 (Department of Public Expenditure and Reform, 2021) highlights the importance of solar PV in achieving the ambitious target of generating 70% of electricity from renewable sources by 2030, making solar energy a cornerstone of the country's sustainability strategy. Supportive policies, including feed-in tariffs and grants, have facilitated residential solar PV installations. A study in the UK found that feed-in tariffs significantly boosted the popularity of residential PV systems (Frances and Stevenson, 2019), a trend mirrored in Ireland with rising application rates (SEAI, 2024). Additionally, a social contagion effect may drive the adoption of solar PV, as individuals and communities influence one another, motivated by social norms, visibility, and peer effects (Graziano and Gillingham, 2014).

Despite the increasing interest in solar PV, several critical issues remain. Notably, the timing of solar electricity generation often does not align with residential energy demand, which typically peaks in the evening when solar output is low. While solar PV can reduce electricity bills and generate income through feed-in tariffs, it does not inherently improve a home's overall energy efficiency. Ideally, solar PV should be the final component in a series of energy efficiency measures (Haas et al., 1999), a consideration often overlooked in Ireland. In the UK, a dwelling qualifies for a solar PV grant only after achieving sufficient insulation in its envelope (Frances and Stevenson, 2019). This raises concerns about the opportunity cost of investing in solar PV instead of more impactful energy efficiency measures, such as insulation and heating system retrofits. Financial returns on residential solar PV investments in Ireland and the UK are estimated to extend beyond 20 years (Bergman et al., 2009; Ayompe, 2011). Even a recent Irish study, which accounts for feed-in tariffs and Sustainable Energy Authority of Ireland (SEAI) grants under ideal conditions (e.g., south-facing installation, no shading, clean panels), suggests a return on investment of at least 10 years (Ryan, Wheatley, and Saba, 2023). Furthermore, the demographic disparity in solar PV adoption is noteworthy, as installations are primarily undertaken by wealthier households (Lukanov and Krieger, 2020; Barbose et al., 2018), likely due to the high initial costs.

Research into the secondary benefits of solar PV indicates that homeowners often report lower overall electricity consumption as they become more efficient energy users (Frances and Stevenson, 2019) (DECC, 2010a). However, Haas et al. (1999) identified a more complex relationship: while larger energy consumers reduced their consumption after installing PV, smaller consumers tended to increase it. A Swedish study examining electricity consumption one year before and after solar PV installation found no significant change (Palm, Eidenskog, and Luthander, 2018), while Bepler, Matisoff, and Oliver (2018) reported a 28.5% increase in consumption following installation. Bergman et al. (2009) attributes these variations to the differences between habitual and deliberative behaviours, suggesting that changes in electricity usage often fall under habitual behaviour, which is challenging to modify.

Despite these concerns, proponents argue that, due to its relative ease of installation, solar PV may serve as a "gateway to retrofit", encouraging homeowners to pursue further energy efficiency measures. Those who install solar PV often report increased environmental motivation (Kastner and Stern, 2015), potentially leading to changes in deliberative behaviours, such as implementing additional energy efficiency measures (Bergman et al., 2009). Dobbyn and Thomas (2005) provide evidence of shifts in awareness, behaviour, and attitudes among individuals that gained microgeneration experience.

This study aims to empirically evaluate whether the installation of solar PV encourages further energy retrofitting, potentially establishing solar PV as a "gateway to retrofit".

Methodology

Data sources

Data on the installation of solar PV and other energy efficiency measures were collated from four active SEAI grant programmes (Better Energy Homes, Better Energy Communities, One Stop Shop and Solar PV) as well as two older programmes (Deep Retrofit and One Stop Shop Pilot). In addition, data on demographics, socioeconomic conditions and indicators related to community wellbeing were sourced from Central Statistical Office. This resulted in a dataset providing information on the retrofitting journey of Irish dwellings over time, where dwellings with multiple retrofits could be easily identified.

Analysis approach

The data described above were used to categorise dwellings that have solar PV installed into the following four categories:

1. **Solar PV followed by retrofit**. This category represents dwellings that first installed solar PV and later installed additional retrofit measures.
2. **Retrofit followed by solar PV.** This category represents dwellings fitting the opposite pattern whereby another energy efficiency measure was installed prior to solar PV installation.
3. **Solar PV and retrofit at the same time.** This category represents dwellings that installed solar PV and other energy efficiency measure/s at roughly the same time – the second retrofit measure was applied for between first measure's application date and completion date.[1]
4. **Solar PV only.** This category represents dwellings that only installed solar PV and did not apply for grants for any other energy efficiency measures.[2]

The above classification allows us to observe the frequency with which solar PV is followed by other retrofits but does not compare this against a counterfactual. For this reason, two counterfactual measures of attic insulation/roof insulation and heating controls were also chosen for comparison. The reasons for choosing attic insulation and heating controls as counterfactuals are threefold. First, they are common retrofit measures, giving enough data points for statistical analysis. Second, both of these measures are suitable for most of Irish dwellings. Third, they are relatively inexpensive to install compared with solar PV and can be considered "entry level" retrofits (see Table 1).

Table 1: Mean and median installation cost for the most common measures over the last two years.

Measure	Mean cost of works	Median cost of works
Attic insulation/roof insulation	2,623 €	2,150 €
Solar PV	13,299 €	11,100 €
Heating controls	4,363 €	3,750 €

Both attic insulation and heating controls were grouped into four categories in the same fashion as solar PV as described above. This allows for direct comparison of the likelihood solar PV installation is followed by further measures against the counterfactuals of attic insulation or heating controls being followed by retrofit.

After data cleaning and categorization, statistical analyses were conducted using multiple methods. Initial chi-square tests provided a straightforward interpretation of associations. Subsequently, survival analysis modelling was employed, focusing on time-to-event data to understand the influence of covariates on the timing of events, such as applications for additional retrofits. The Kaplan-Meier estimator (Kaplan and Meier, 1958) was utilized for non-parametric estimation of the time-to-event function, allowing for visual representation of event probabilities over time and group comparisons via log-rank tests. The Cox proportional hazards model (Cox, 1972) further examined the relationship between covariates and the hazard rate, providing hazard ratios to quantify the effects of predictors like dwelling size and deprivation index. Additionally, random survival forests, as proposed by Ishwaran et al. (2008), leveraged an ensemble of decision trees to capture complex interactions and nonlinear relationships in censored time-to-event data.

[1] Note that not all SEAI programs record completion date. In these cases, grant payment date was used instead.
[2] Note that homeowners could have installed energy efficient measures outside of SEAI programs, but these data are not available.

Results

Descriptive statistics

A total of 65,110 solar PV installations have been completed since the beginning of SEAI's grant programme of which 1,361 were later followed by additional retrofit projects, totalling 1,839 additional measures (see Table 2). The cumulative investment in these additional retrofits has reached approximately €13.0 million, indicating an average of €200 in further retrofits per solar PV installation.

As the SEAI PV grant has been present for 6 years, only the last 6 years of attic insulation and heating controls data are reported below for comparability.

A total of 33,935 attic insulation installations were finalized during the same period. Among these, 1,063 projects were followed by subsequent retrofits, totalling 1,196 measures and amounting to a total cost of €11.9 million or €350 in additional retrofits per attic insulation installation

Lastly, there were 24,225 installations of heating controls completed. In total 1,866 of these heating controls resulted in further retrofitting activities amounting to 2,393 measures, generating a total investment of €18.0 million. On average, each heating controls installation has led to an additional €740 in retrofits. For detail breakdown of measures following Heating controls installations see Table 2, Heating controls column.

Table 2: Breakdown of number of measures installed after initial retrofit shown for solar PV, attic insulation and heating controls over the last 6 years.

	Initial retrofit		
Type of measure installed at future date following the initial retrofit	solar PV (65,110)	Attic insulation (33,935)	Heating controls (24,225)
External wall insulation	178	124	123
Internal wall insulation	26	35	23
Cavity wall insulation	487	176	464
Heat pump	320	68	28
Doors	39	11	15
Windows	37	11	14
Other measures	21	2	3
Solar PV	-	664	1004
Attic insulation	641	-	719
Heating controls	90	105	-
Total	1839	1196	2393

The descriptive statistics above show that solar PV was followed by additional retrofit the least when compared with attic insulation and especially with heating controls. However, even though there have been a large number of solar PV, attic insulations and heating controls installed over the last 6 years, the level of subsequent retrofit is very small (Table 2). The amount of additional retrofitting happening at the same time is substantially larger, especially in the case of attic insulation (Table 3). Nonetheless, there are number of issues when looking at the descriptive data in this way. Firstly, it is unclear if solar PV is more or less likely to be followed by a retrofit at future date than attic insulation or heating controls. Secondly, those descriptives look at all the solar PV, attic insulation and heating controls installs in the last 6 years and for many of those, especially the recent ones, there hasn't been enough time to observe additional retrofit that might happen sometime in the future. This is especially problematic for solar PV which saw large increase in applications in the last 3 years (Figure 1). To address those shortcomings a series of chi-square tests was conducted next.

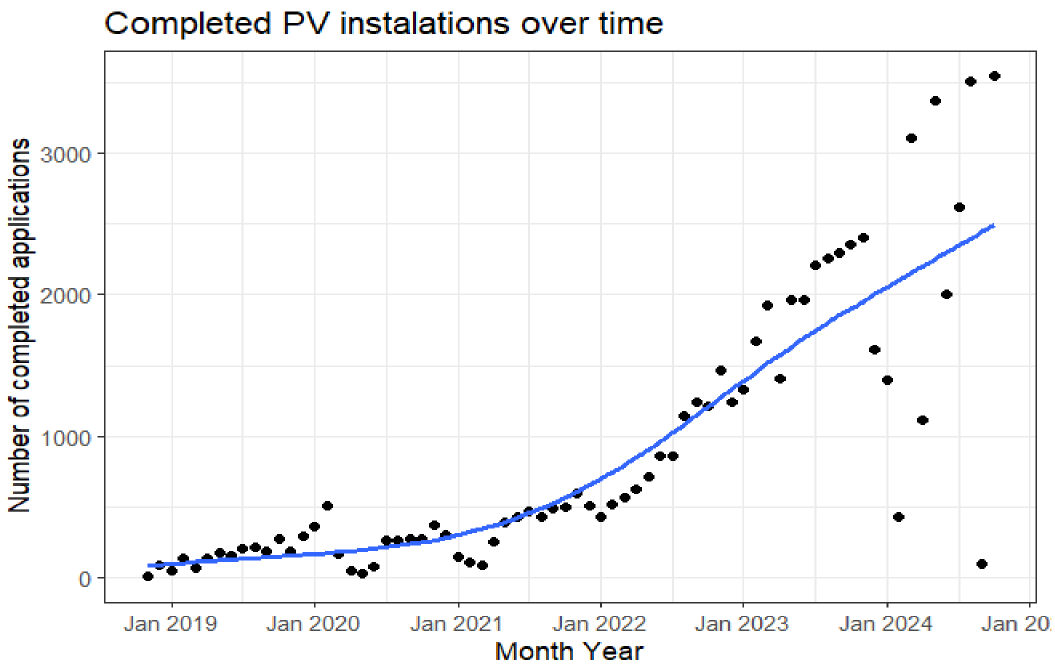

Figure 1: Graph of monthly completion of solar PV installs since inception of the solar PV programme.

Table 3: Breakdown of number of measures installed together (at the "same time") with initial retrofit shown for solar PV, Attic insulation and Heating controls during last 6 years.

	Initial retrofit		
Number of Measures installed with initial retrofit (solar PV/attic insulation/heating controls)	solar PV (65,110)	Attic insulation (33,935)	Heating controls (24,225)
External wall insulation	751	2,993	507
Internal wall insulation	209	1,866	356
Cavity wall insulation	1,179	13,817	395
Heat pump	1,722	3,266	-
Doors	863	1,747	43
Windows	808	1,712	43
Other measures	211	693	6
solar PV	-	1,740	219
Attic insulation	2,030	-	1,246
Heating controls	508	1,933	-
Total	8,281	29,767	3,084

Chi-square test results

To address the issue of unobserved future retrofits, the data were coded based on the number of retrofits occurring within a two-year period following the completion of a solar PV installation, attic insulation, or heating controls (collectively referred to as "Measure"). Data from the most recent two years were excluded from the analysis, as it remains uncertain whether additional retrofits will occur following installation made during that time. A two-year period was chosen to balance having enough time between the completion of the measure and any subsequent retrofits, while minimizing the exclusion of relevant data. This adjustment effectively reduces the available data from six years to four.

The category "retrofit followed by measure" follows the same two-year rule, but to avoid excessive data loss, retrofits from as far back as eight years are considered. The following rules apply:

1. A retrofit is counted as being followed by a Measure only if it occurred within two years after the Measure's completion and no retrofit occurred in the two years preceding the Measure.
2. A Measure is counted as being followed by a retrofit only if it occurred within two years after the completion of the retrofit.

Three sets of chi-square tests were conducted:

1. The first set of tests compared all four categories: “Measure is followed by retrofit,” “Retrofit is followed by Measure,” “Measure and retrofit at the same time,” and “Measure only.” The findings indicate that both solar PV vs attic insulation (X-squared = 16501, df = 3, p-value < 2.2e-16, Cramer’s V = 0.38) and solar PV vs heating controls (X-squared = 261, df = 3, p-value < 2.2e-16, Cramer’s V = 0.044) were significantly different in four categories (Table 4). However, it appears that the difference is mostly driven by “Measure and retrofit at the same time” category.
2. The second set of tests recoded the data into two categories: “Measure is followed by retrofit” and “Measure is not followed by retrofit,” the latter of which includes “Retrofit is followed by Measure,” “Measure and retrofit at the same time,” and “Measure only”. This test directly assesses whether a difference in the probability of additional retrofits exists between solar PV and attic insulation/heating controls. The findings found solar PV vs attic insulation (X-squared = 1.54, df = 1, p-value < 0.21, Cramer’s V = 0.006) and solar PV vs heating controls (X-squared = 0.75, df = 1, p-value = 0.39, Cramer’s V = 0.004) were not significant.
3. The third set of tests excluded the categories “Retrofit is followed by Measure” and “Measure and retrofit at the same time,” resulting in a dataset containing only “Measure is followed by retrofit” and “Measure only”. It was found that solar PV vs Attic insulation (X-squared = 627.94, df = 1, p-value < 2.2e-16, Cramer’s V = 0.091) was significant indicating that Attic insulation was more likely to be followed by retrofit than solar PV when multi-measure applications and “Retrofit is followed by Measure” of solar PV/Attic insulation are excluded. Solar PV vs Heating controls (X-squared = 0.65, df = 1, p-value = 0.42, Cramer’s V = 0.004) found no significant difference indicating that solar PV was no more likely to be followed by retrofit than Heating controls.

Table 4: Probabilities of a measure (solar PV/attic insulation/heating controls) being followed by retrofit in next 2 years displayed by 4 categories. Last 2 years of data are excluded to allow for two-year window to see if additional retrofit materializes.

Initial Measure	Probabilities of:

	Measure only	Measure and retrofit at the same time	Retrofit is followed by Measure	Measure is followed by retrofit
Solar PV	87.2%	5.3%	4.3%	3.2%
Attic insulation	28.0%	65.0%	4.0%	3.0%
Heating controls	87.1%	7.6%	2.2%	3.1%

The findings from the chi-square tests indicate that solar PV is no more likely to be followed by retrofit than attic insulation or heating controls. If anything, Attic insulation might be more likely followed by retrofit than solar PV when looking only at first-time standalone Measures.

However, there are number of limitations. The last two years of data were excluded to allow enough time to observe whether additional retrofit materializes or not. This is of particular concern for solar PV as majority of solar PV applications were only completed in last two years (see Figure 1) and hence many datapoints from solar PV were excluded. Also, this two-year window is limiting as it does not consider retrofits that happened more than two years after the initial measure. Moreover, the chi-square test does not allow to control for covariates such as dwelling type, dwelling size, deprivation index, Building energy rating, etc. To address these limitations survival analysis was explored next.

Survival analysis model results

This section presents the results of the survival analysis, which utilized a comprehensive dataset that includes 6 years of data for solar PV and 16 years for attic insulation and heating controls. The analysis employed two sets of survival models to assess the likelihood of additional retrofits following initial measures:

1. Using the full dataset, containing 160k attic insulations, 101k heating controls, and 65k solar PV installations.
2. Using a partial dataset from which the "Measure and retrofit at the same time" and "Retrofit is followed by Measure" categories were excluded, resulting in 15.7k attic insulations, 71.4k heating controls, and 44.4k solar PV installations. The purpose of this was to investigate whether solar PV installation is likely to be followed by subsequent retrofitting where it is a first-time, standalone measure.

Kaplan-Meier plots

Full dataset

Attic insulation is least likely to be followed by retrofit compared to solar PV and heating controls (Figure 2). Attic insulation shows a rapid initial uptake with minimal follow-up retrofits after two years, while solar PV and heating controls see a steady increase in follow-up retrofits showing almost a linear trend. However, the level of additional retrofit is limited to about 1% per year for solar PV and heating controls.

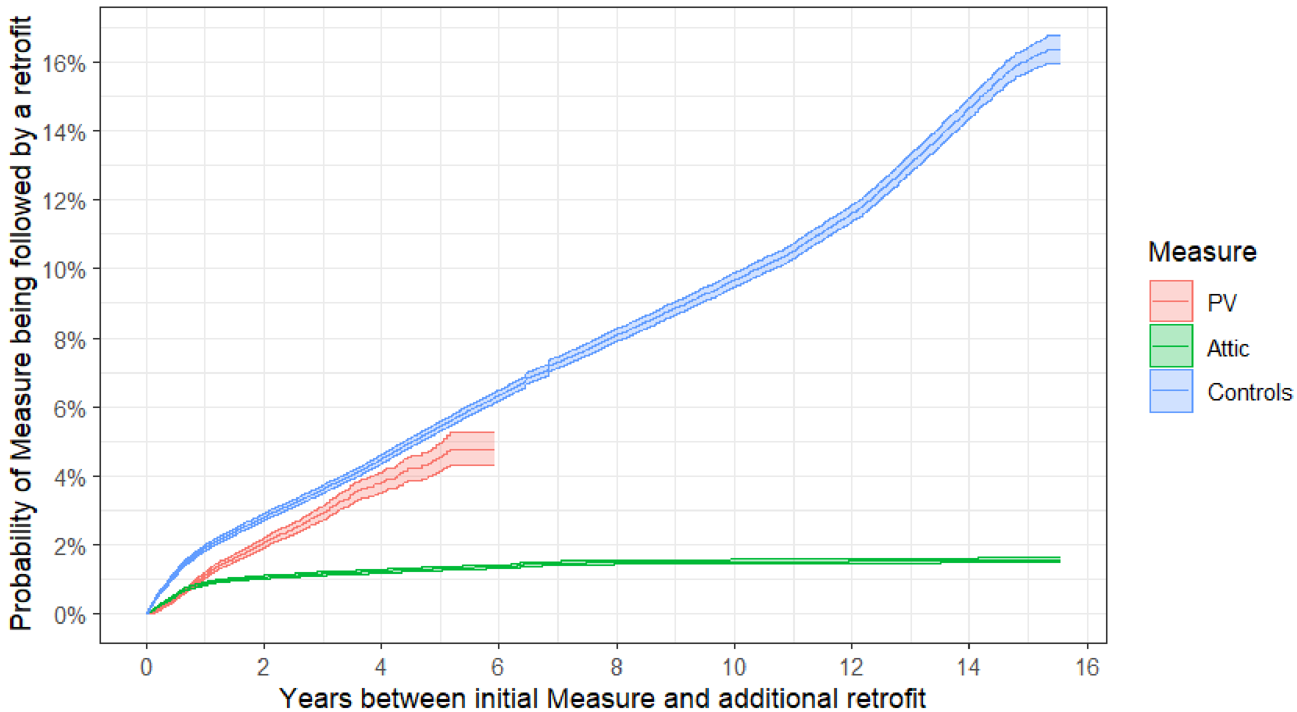

Figure 2: Kaplan Meyer plot showing probability of Measure being followed by additional retrofit over time (All Data).

Partial dataset

When considering only first-time standalone measures, attic insulation and heating controls are both more likely to be followed by retrofit compared to solar PV (Figure 3). There is a dramatic increase in the likelihood of attic insulation being followed by additional retrofits, resulting from the exclusion of a large number (about 80%) of attic insulation installations for this partial dataset. Attic insulation is primarily part of more extensive retrofits including multiple measures. The level of additional retrofit increased slightly but is still limited to about 1.5% per year for solar PV and heating controls.

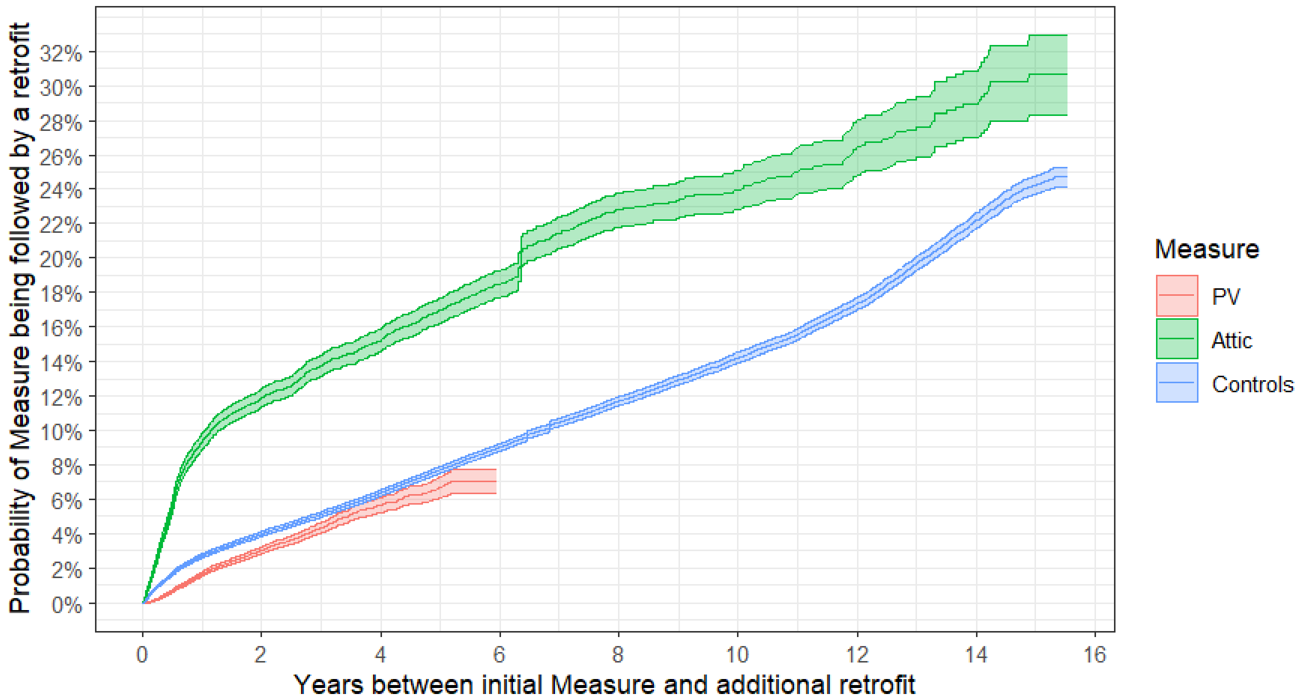

Figure 3: Kaplan Meyer plot showing probability of Measure being followed by additional retrofit over time (Partial Data).

Cox Model

Full dataset

The findings from the Cox model analysis indicate that all covariates are statistically significant due to the large size of the dataset (Table 5). It shows that solar PV is more likely to be followed by retrofit than attic insulation but less likely than heating controls, which aligns with the Kaplan-Meier plot. Moreover, a better BER after the initial measure increases the likelihood of applying for additional retrofits. Additionally, apartments and mid-terraced dwellings are less likely to seek additional retrofits than detached and semi-detached houses. The analysis also suggests that more affluent neighbourhoods and larger homes are more inclined to apply for subsequent retrofits, although the effect sizes are small as indicated by hazard ratios (exp(coef)).

Partial dataset

When considering only first-time standalone measures, attic insulation and heating controls both have a higher probability of additional retrofit when compared to solar PV (Table 6), controlling for covariates. Dwelling size and the deprivation index have a smaller influence when compared to full dataset, but other covariates follow the same pattern.

Table 5: Output from Cox model (All Data). Total number of datapoints – 330,680 with 13,726 of events (initial Measure being followed by a retrofit).

Covariate	coefficient	exp(coef)	se(coef)	z	Pr(>|z|)
Attic insulation	-0.8848	0.4127	0.0402	-21.983	< 2e-16 ***
Heating Controls	1.0638	2.8975	0.0356	29.872	< 2e-16 ***
Deprivation index	0.0236	1.0239	0.0029	7.974	1.54e-15***
Dwelling size	0.1526	1.1648	0.0276	5.516	3.46e-08***

Semi-detached	0.1082	1.1143	0.0209	5.156	2.52e-13***
Mid-terraced	-0.2678	0.7650	0.0372	-7.192	6.40e-13***
Apartment	-0.5259	0.5909	0.0710	-7.408	1.29e-13***
Unknown dwelling	-1.8973	0.1499	0.0650	-29.160	< 2e-16 ***
BER A	1.0214	2.7772	0.0462	22.076	< 2e-16 ***
BER B	0.6277	1.8734	0.0214	29.314	< 2e-16 ***
BER D	-0.2300	0.7944	0.0303	-7.571	3.71e-13***
BER EFG	-0.2038	0.8156	0.0498	-4.086	4.39e-13***
BER Unknown	0.2087	1.2321	0.0313	6.657	2.79e-13***

Table 6: Output from Cox model (Partial Data). Total number of datapoints – 131,484 with 13,726 of events (initial Measure being followed by a retrofit).

Covariate	coefficient	exp(coef)	se(coef)	z	Pr(>|z|)
Attic insulation	2.1863	8.9026	0.0403	54.202	< 2e-16 ***
Heating Controls	1.2125	3.3619	0.0372	32.588	< 2e-16 ***
Deprivation index	0.0059	1.0059	0.0029	1.991	0.0464*
Dwelling size	0.0774	1.0805	0.0282	2.746	0.0060**
Semi-detached	-0.1748	0.8396	0.0212	-8.229	< 2e-16 ***
Mid-terraced	-0.6613	0.5161	0.0374	-17.646	< 2e-16 ***
Apartment	-1.1039	0.3315	0.0711	-15.506	< 2e-16 ***
Unknown dwelling	-2.1529	0.1161	0.0651	-33.061	< 2e-16 ***
BER A	1.3854	3.9964	0.0477	28.993	< 2e-16 ***
BER B	0.9165	2.5007	0.0216	42.337	< 2e-16 ***
BER D	-0.4190	0.6576	0.0304	-13.757	< 2e-16 ***
BER EFG	-0.7156	0.4888	0.0502	-14.244	< 2e-16 ***
BER Unknown	0.2110	1.2350	0.0323	6.521	< 2e-16 ***

Random Forest Model

Full dataset

The random forest model does not generate regression outputs or dummy variables for categorical covariates, but it provides variable importance metrics (Table 7) that align closely with Cox model findings. A comparison of models suggest that the Kaplan-Meier and random forest models yield similar results, while the Cox model consistently shows a somewhat lower probability of additional retrofit.

Table 7: Variable importance as produced by random forest model (all dataset).

Variable	Importance
Type of measure	0.0935
BER following measure	0.0207
Dwelling type	0.0196

Dwelling size	0.0152
Deprivation index	0.0039

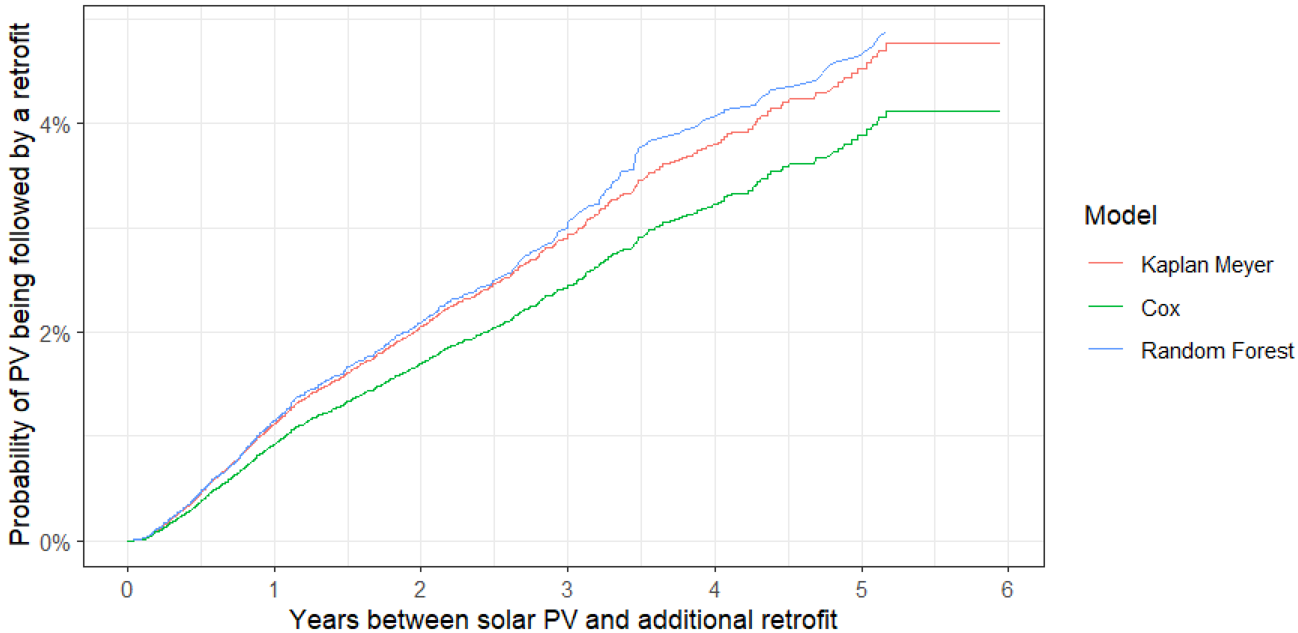

Figure 4: Comparison of predicted probabilities for solar PV by Kaplan Meyer plot, Cox model and random forest model (All data).

Partial dataset

The pattern of variable importance metrics (Table 8) for the partial dataset is comparable to full dataset findings. A comparison of models show that all three models are predicting very similarly for the first five years since following installation of the initial measure, diverging later.

Table 8: Variable importance as produced by random forest model (Partial data).

Variable	Importance
Type of measure	0.0679
BER following measure	0.0549
Dwelling type	0.0347
Dwelling size	0.0085
Pobal deprivation index	0.0045

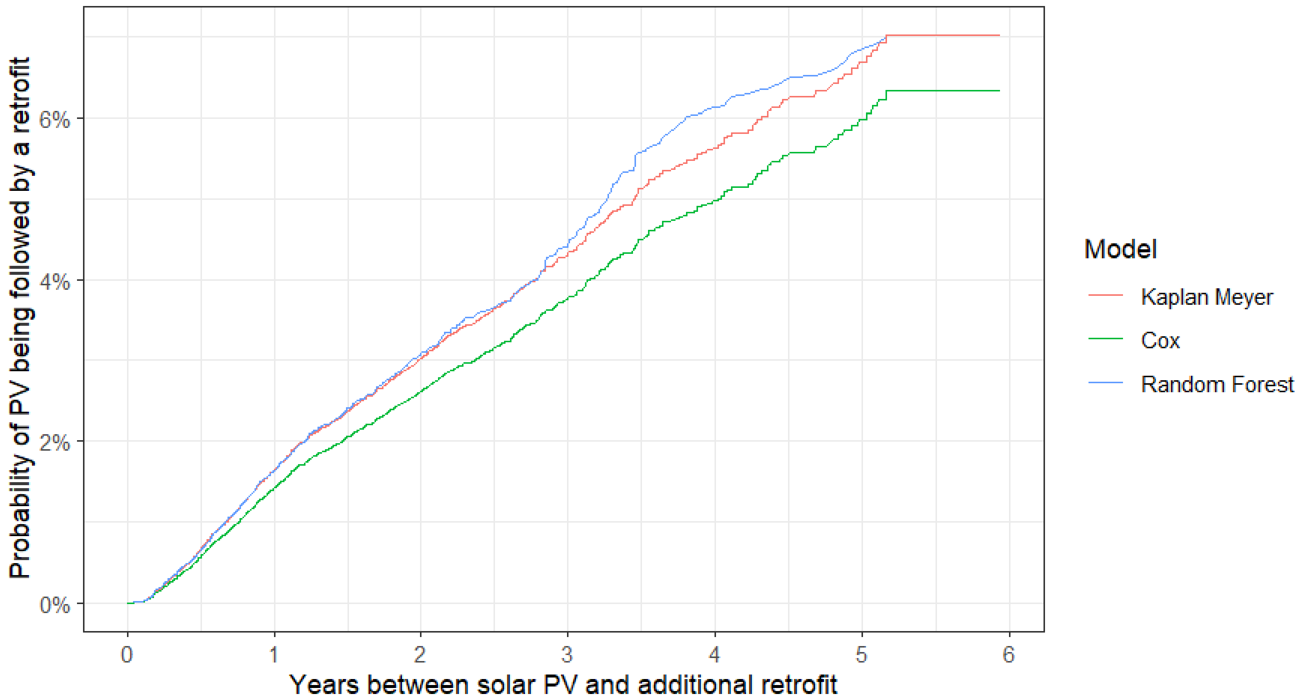

Figure 5: Comparison of predicted probabilities for solar PV by Kaplan Meyer plot, Cox model and random forest model (Partial data).

The survival analysis shows agreement across all three models suggesting that most important covariate affecting an increased probability of future retrofit is a dwelling's BER. Dwellings with a better BER are more likely to retrofit again compared to dwellings with a poorer BER. The impacts of the deprivation index and size of dwelling are least important. The probability of additional retrofit in a given year following the initial measure for solar PV only is between 1% (Figure 4) based on full dataset analysis and 1.5% (Figure 5) as given by the partial dataset analysis.

Discussion

This research explores the potential for solar photovoltaic (PV) installation to act as a catalyst for subsequent home retrofitting. The findings provide valuable insights into how the adoption of renewable energy technologies may influence broader residential energy retrofitting behaviours, particularly in Ireland, where the urgency around climate action necessitates transformative changes in home energy consumption patterns (DECC, 2024).

The data indicate that subsequent retrofitting activities are minimal compared to the extensive installation of solar PV systems. Of the 65,000 solar PV installations, only 1,839 have applied for further retrofits. Findings from survival analysis reveal that only 1-1.5% of solar PV installations seek additional retrofits each year. Similar trends are observed in the cases of attic insulation and heating controls, where additional retrofits are also relatively uncommon albeit to lesser degree. Furthermore, the results of the survival analysis demonstrate almost linear hazard functions (indicating the probabilities of additional retrofits) over time, suggesting that these retrofits occur at nearly constant rates.

The results from both chi-square tests and survival analysis indicate that solar PV does not inherently catalyse additional retrofitting to the same extent as other energy efficiency measures, such as attic insulation and heating controls. The tests reveal that heating controls are more likely to be followed by additional retrofits than solar PV, while attic insulation is more frequently installed as part of a package of measures. Reported increases in environmental motivations (Kastner and Stern, 2015) or shifts in awareness, behaviour, and attitudes (Bergman et al., 2009) following solar PV installation did not translate into additional retrofits. A meta-analysis by Kormos and Gifford (2014) may provide an explanation, as it found significant discrepancies between self-reported pro-environmental behaviour and actual behaviour.

Importantly, solar PV installations could be counterproductive, diverting resources from more effective measures such as insulation or heating retrofits. However, it remains unclear whether solar PV competes directly with these other measures. It is uncertain if homeowners who choose to install solar PV ever consider other, more effective retrofits. For instance, solar PV might only be considered against other types of expenditures (e.g., vacations), making it a more desirable option than forgoing improvements altogether. Further research is needed to explore this possibility.

Additionally, the research reveals that not only does the probability of an additional retrofit following a solar PV installation remain low, but significant differences are observed when controlling for variables such as dwelling type, size, and energy performance rating (BER). Detached and semi-detached dwellings with better BERs in more affluent neighbourhoods are correlated with higher additional retrofit probabilities, suggesting that energy efficiency investments may be more effectively pursued within specific dwelling contexts.

One limitation of the study is the lack of information regarding retrofitting measures undertaken outside of the SEAI programs. This potentially underestimates the overall impact of solar PV installations on home energy upgrades by failing to account for homeowners who may have pursued concurrent or subsequent retrofits without governmental grants. It is also important to note that a decision for additional retrofitting cannot be directly attributed to initial PV installation, as it is unknown when that decision was made and what factors influenced it. For example, financial constraints may lead homeowners to stagger their energy efficiency investments rather than pursue multiple upgrades simultaneously.

This paper highlights the dual nature of energy investments, emphasizing the need for a more comprehensive retrofit strategy that encompasses not only the adoption of renewable technology but also the necessity of improving the energy performance of dwellings through integrated energy efficiency measures. Without addressing the interplay between renewable energy adoption and home energy efficiency upgrades, the potential gains from solar technology may not be fully realized in reducing overall energy consumption and greenhouse gas emissions.

Conclusion

While this study provides significant data and analysis regarding the potential role of solar PV in stimulating retrofit behaviours, it also underscores the complexity of transforming residential energy practices. The findings indicate that simply installing solar panels is insufficient for a substantial shift in energy efficiency uptake. For policymakers, these insights emphasize the importance of fostering an environment that encourages holistic approaches to energy retrofitting. This involves integrating financial incentives, public education, and targeted outreach to guide homeowners through the lifecycle of energy efficiency, from initial installations to meaningful retrofitting across the home. Such a multi-faceted approach will be essential for achieving Ireland's ambitious targets for renewable energy adoption and emission reductions in the coming years, ultimately contributing to a more sustainable future.

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