The Value of Solar Property

The financial benefits of a solar-powered future

Appendix one: Methodology

Contents

Summary

This document summarises the methodology used to demonstrate the financial value of solar property, as outlined in the Solar Energy UK Report *Value of Solar Property*.

Approach

This methodology document relates to two sets of financial costs: the cost of buying a home and the cost of running a home. The overall approach taken for this project was to combine existing sources of data to produce new evidence on the financial value of properties installed with solar. This included examining the impact on the equity value (in other words, sale price) of homes with solar technology installed, as well as the impact on the running costs of homes with solar installed, which are reduced because these homes can meet some of their own electricity demand.

The modelling for this research is described in more detail below. It was designed and carried out by sustainability consultancy Think Three, and the Department of Land Economy at Cambridge University.

The research was overseen by a Steering Group including current or former representatives of the Forster Group, the Green Finance Institute, Larkfleet Smart Homes, Loughborough University, the MCS Charitable Foundation, the National Federation of Roofing Contractors, PathTo2050, the World Wide Fund for Nature UK, and Viridian Solar. Please note that the Value of Solar Property report and its contents do not necessarily represent the views of any of these organisations.

Methodology: equity value

Overview

To examine the impact of solar installations on property value, an original dataset was developed to test if investment in the presence of an on-site solar PV system is associated with higher sales prices in residential properties in the UK.

Table 1 provides an overview of existing empirical studies on solar price premiums.

Most of the existing evidence was gathered in countries with more annual sunshine hours and potentially also larger homes and roof areas than the UK, which could have an impact on the observed average price premiums. Nevertheless, these studies can provide an indication of price premiums which might be expected in the UK.

Table 1: Previous studies and results

Authors	Location	Solar price premium
Best et al (2021)	Australia	4.0%
Lan et al (2020)	Queensland, AUS	2.4-4.3%
Ma et al (2016)	Queensland, AUS	2.3-3.2%
Qiu et al (2017)	Arizona, USA	17%
Dastrup et al (2017)	California, USA	3-4%
Hoen et al (2013)	California, USA	17k (USD)
Morris & Moore (2011)	Oxford, UK	Inconclusive
Scarpa & Willis (2010)	UK	£2831 (experiment-based)

As Table 1 indicates, estimates of the premium vary widely across studies. However, apart from the early, survey-based study in Oxford, solar panels appear to command a price premium relative to a set of comparable properties. A further important caveat when applying these findings to the UK is that many previous studies rely on evidence from relatively few observations. The present study resolves this problem by including a vast number of residential sales transactions from the English and Welsh housing market over the last decade, matched where possible with a comprehensive database of solar installations. It also contains a large number of control variables which allow for a like-with-like comparison between solar and non-solar properties.

Data

The original dataset for this study was created by combining three data sources, following the open-source data merging approach by Chi al (2021):

- Residential transaction data recorded by the Land Registry
- Energy Performance Certificates (EPCs) in England and Wales from 2011 to 2021
- The Microgeneration Certification Scheme (MCS) database.

The combination of Land Registry and EPC data captures information on approximately 80% of all sales that occurred from 2010 – 2021 (with approximately 5.7 million data points included in total), and contains vital property and residential area characteristics. As such it makes this study one of the largest that has ever been conducted, at the time of writing, on the capitalisation of renewable energy investments into house prices.

The MCS database includes information on the number, type, size and other characteristics of renewable heat and power generation systems installed on homes in the UK which have been accredited by MCS.

This dataset was then merged with the combined Land Registry/EPC data using address matching. Although address matching generally yields a lower matching success rate than methods using a unique identifier, this was the only practicable solution in the absence of a unique property or transaction identifier common to all three databases.

Properties in the sales transactions database were only considered as having solar technologies installed if the date of the sale occurred after the installation date recorded in the MCS database. In total, the analysis was carried out on 59,456 property transactions, the highest number of transactions which based on current data it is possible to investigate. This sample is extremely large, and means there can be a very high degree of confidence in the findings.

Model description

The standard method for investigating price determinants in any product market is hedonic regression analysis. The model specification is provided below.

- $ln\,(Pi) = \beta 0 + \beta 1\,(solari) + \beta 2\,(Ki) + \Sigma\beta 3(Xi) + \beta 4\,(time) + \varepsilon i$

Where:

- $ln\,(Pi)$ is the recorded transaction price in £ or per square metre for property i
- $\beta 0$ is the regression intercept
- $solari$ is a binary variable which takes a value of one if solar technology is installed and zero if not
- Ki is a set of control variables for the area as represented by Middle Super Output Areas (MSOAs)
- Xi is a vector of property characteristics for house i such as size, number of bedrooms and property type
- time is an annual binary fixed effect to control for housing market and macroeconomic conditions at the time of sale.
- $\beta 1, \beta 2, \beta 3$ and $\beta 4$ are vectors of parameters to be estimated
- εi is a random error term

House price values were also winsorized at 1% and 99% percentile to account for extreme values that could bias the regression coefficient estimates.

Results

Hedonic regression estimates

Table 2 details the estimation results for baseline hedonic models using the natural log of the sale price (1 and 2) and sale price per square metre (3) as the dependent variables.

Models 1 and 2 are identical apart from a control variable for the EPC rating of a property, which is only contained in 2. The reason for omitting the EPC rating in the baseline estimation is that the presence of on-site renewable energy forms part of the EPC assessment process. This means that where a property is registered as having a solar system installed on both the MCS and EPC database, it reduces the premium which can be attributed to it, as the same system is effectively counted twice. This means that the 0.9% premium produced under this model is almost certainly an underestimate. However, it provides a meaningful, conservative lower bound for the solar price premium.

Both estimations show a consistent premium of 0.9-2.0% for solar PV. These percentages are calculated based on an adjustment formula for logarithmic regression models. The R-squared value is extremely high, with 91-94% of the variation in house prices explained by the presence of PV, according to the models.

Table 2: Regression estimates for equity model

Variables	1 Sale price (log)	2 Sale price (log)	3 Sale price / sqm (log)
Solar PV (0.00103)	0.020***	0.009***	0.007***
Control sets (Y/N)			
EPC rating	No	Yes	Yes
Other on-site renewables	Yes	Yes	Yes
Property types	Yes	Yes	Yes
Extension count	Yes	Yes	Yes
Time of sale (YQ)	Yes	Yes	Yes
Location (postcode)	Yes	Yes	Yes
Observations	5,857,228	5,857,228	5,857,228
R-squared	0.942	0.942	0.916
Adjusted R-squared	0.930	0.931	0.900
Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1			

Hedonic regression estimates by quartile

Having established the average price effect of solar installations for the entire housing market in England and Wales over the observed time period, the models can now be re-estimated to investigate if the price impact of a solar PV installation differs between lower value and higher value properties. This is of particular interest as the underlying value of houses is subject to much greater variation across markets and regions than the value of solar installations. House prices in the most expensive region of the UK are almost three times higher than they are in the least expensive region, while the cost of a solar PV system is quite similar. Hence, it could be expected that the achievable percentage premium would be lower for a central London townhouse worth £3 million, compared with a terraced property in the Northeast of England worth £150,000.

Conducting this estimate on the segmented English and Welsh housing market, we find that the price premium is higher for lower-value properties, since solar installations of standard size make up a larger share of the overall house price in these properties (Tables 3 and 4). As previously, two versions of the model are described, controlling again for the presence or not of solar technology on the property's EPC.

Table 3: Hedonic regression estimates for each house price quartile (EPC controls model)

Variables	1st price sale price (log)	2nd price sale price (log)	3rd price quartile sale price / sqm (log)	4th price quartile sale price (log)
Solar PV coefficients	0.0142	0.011	0.00643	0.00133
Standard errors	0.00221	0.000927	0.000852	0.0012
Adjusted % premium	1.54%	1.15%	0.69%	0.19%

Table 4: Hedonic regression estimates for each house price quartile (No EPC controls model)

Variables	1st price sale price (log)	2nd price sale price (log)	3rd price quartile sale price / sqm (log)	4th price quartile sale price (log)
Solar PV coefficients	0.027	0.016	0.01	0.005
Standard errors	0.0022229	0.0009255	0.0008503	0.0012013
Adjusted % premium	2.85%	1.66%	1.05%	0.56%

Table 5 summarises the findings for the house price quartiles for the English and Welsh housing market between 2010 and 2021.

Table 5: house price quartiles for the UK housing market, 2010 - 2021

Quartile	Price range	Indicative price premium (%)
1	£0 - £137,000	1.54% - 2.85%
2	£137,000 - £205,000	1.15 – 1.66%
3	£205,000 - £315,000	0.69% - 1.05%
4	£315,000+	0.19% - 0.56%

As is clear, there is a price premium across all parts of the market, and the figures discussed in the Value of Solar Property report reflect the lower bound of the range above.

To ascertain the indicative change in equity value for the properties included in the case studies produced for this research, the potential range of change in equity value associated with each quartile of the housing market was applied to the known average price of each property type, based on data from the UK House Price Index (HPI), as of March 2021.

For example, in March 2021 the average price of a terraced house in the East Midlands region was £163,765. This places it in the second quartile, which has an indicative PV price premium of 1.15% - 1.66%. The indicative change in value for such a house is therefore 1.15% - 1.66% of £163,765, or £1,891 - £2,722.

However, it should be noted that this is only an indicative range, and that any change in value for a specific type of house in a specific region may differ from these global estimates, which are based on a quartile distribution of the English and Welsh housing market.

The analysis was not carried out for data on Scottish properties because of a lack of bulk, standardised data available on property transactions. Given assumed similarities in the behaviour of the Scottish housing market, which also includes many properties adjacent to the border with England, it does not seem unreasonable to assume that the presence of PV on properties in Scotland affects prices in the same way. However, care should be taken, as with all figures.

Repeat sales analysis

The hedonic analysis shown above controls for a large number of value drivers, but it still cannot be ruled out that some minor drivers were missed. These could be problematic if any such value drivers are systematically correlated with the presence of solar PV. To confirm the overall findings, a repeat sales analysis was also performed.

This analysis takes repeat measurements of transactions for the same property at two points, and works out a growth rate. This is then compared against a hypothetical appreciation if the property had grown in value in line with the regional house price index. The repeat sales analysis was performed on a sample of 23,319 properties that met all the conditions: installation of PV solar panels between two recorded sales transactions, no change in recorded extensions to property, no change in recorded number of habitable rooms, and no change in total floor area. The latter conditions are important as the growth rate may be overestimated if properties that have solar panels installed were also more prone to being extended.

Table 5 shows that the median annual price growth rate of these properties is 62 basis points above the index predicted value. This means that properties that have solar technology installed outperform the general benchmark index of the region in which they are located. To test this more formally, a paired t test was also performed which shows that these two indicators are statistically significantly different. More information on this is available on request.

Table 5: Compound annualised return before and after sale

Percentile	Actual	Index-predicted	Difference
25%	2.16%	1.94%	0.22%
50% (median)	4.18%	3.55%	0.62%
75%	6.08%	5.36%	0.72%
Standard deviation	0.032	0.022	N/A
Variance	0.001	0.000	N/A
Skewness	0.646	0.034	N/A
Kurtosis	6.565	2.800	N/A
Observations	23,319	23,319	N/A

Methodology: running costs

To examine the running cost savings of a solar system, the project developed a fully user-modifiable financial model. The model is based on real-world cost data sourced from and checked with representatives of the solar and finance industries. The model allows more than 15 input variables for a solar or solar and storage system to be altered. These include:

- The type of solar system (for example, PV or PV with a battery), and the direction in which it is facing.
- The size of the PV system array.
- The location of the property.
- The type of property – detached, semi-detached, mid-terrace, end-terrace or bungalow.
- Whether gas or electricity is used as a heating fuel.
- The financing used to pay for a system: cash, loan, or mortgage (including where the installation cost is covered by a third party, such as a housing association) and on what terms (loan interest rate and length of loan).

The model uses these variables to calculate a variety of outputs relating to the system, including its expected annual yield (electricity generation), and how these relate to its capital and operating costs. In turn, the model produces a range of standard metrics to assess the financial performance of the solar system. The metrics include the net present value of the system over its lifespan, return on investment, and internal rate of return. The model also provides specific information on, for example, the value of grid imported electricity displaced by the presence of a solar system, and the value of payments received under the Smart Export Guarantee. These figures are intended to help inform the user of the economic performance of the whole system, including all the elements generating a financial cost or benefit.

Three versions of this model were produced. One focuses on simplifying the inputs and outputs for consumers. The second and third versions have greater flexibility and allow a wider variety of inputs to be altered. The second, industry-focused model provides solar professionals with the opportunity to alter very detailed information on system installation parameters. The third, lender-focused model provides lenders, such as banks, with more detailed information on metrics to help assess the financial performance of a system.

Contact Solar Energy UK for more information on these models.

Inputs

Summary

Table 3 shows the input variables which can be altered as part of the model developed.

Table 3: Running cost model input variables

Input title	Description	2 Sale price (log)
System type	The type of technology installed	• Solar PV • Solar PV + battery
Region	The location of the property on which the system is installed	• All UK postcode regions
House type	The type of property on which the system is installed	• Detached • Semi-detached • End of terrace • Mid-terrace • Bungalow • Apartment
Heating fuel	The type of energy used to heat the property	• Gas • Direct electric heating (e.g. storage heating) • Heat pump heating
Occupancy archetype	The amount of time occupiers spend in the property	• Home all day • Home half the day • Out all day
Property occupier	The relationship of the occupier to the property	• Existing homeowner • Renter • New home buyer
System description	Expected lifespan Number of PV panels (in other words, the size of the system, assuming a standard wattage per panel)	• No of years • Number of panels
Generation	• Orientation of the system • Roof pitch (degrees from horizontal) • Shading impact	• N; NE / NW; E/W; S; SE / SW • 0; 10; 30; 45; 90 • None; very little modest; significant; heavy
Storage	Battery lifespan (years)	• 5; 10; 12; 15; 20
Prices	Electricity price SEG price	• 15 – 23 p / kWh • 0 – 12 p / kWh
System financing	Type of loan Loan interest rate Loan term	• Loan or mortgage • % • Number of years

The following sections explain the significance of key input variables in more detail.

Region

The region or location of the property where the solar PV system is installed has an impact on the level of generation. This is because of difference in the annual irradiation levels. For example, systems in the south of England will tend to produce more power on a cumulative annual basis than systems in the north west of Scotland for a given capacity.

House type

The type of house can have an impact on potential returns, because of the energy consumption levels associated with different properties. For example, detached properties tend to have more occupants and therefore tend to have higher electricity usage than terraced properties which are typically smaller and have fewer occupants. So the occupants of a detached house which meets 50% of its power demand will, all other things being equal, save more money on their energy bills than a smaller, terraced house which also meets 50% of its power demand (because the smaller house will have lower demand in the first place).

This is further the case because of the significant difference between the cost of buying electricity from the grid and the income received under the Smart Export Guarantee for selling electricity to the grid, which is much lower. This means it is financially and environmentally beneficial to use as much of the generation from any onsite solar system as possible in the home.

The model developed for this research uses assumptions for energy consumption profiles based on standard energy use data from government agencies and departments. Input variables in the model can be altered if necessary to provide more specific assessments of energy consumption based on known property parameters (including, for example, the floor area of a property, and its assumed number of occupants).

Heat source

Most homes in the UK are heated using gas boilers. At present, these are more cost effective than electric heating. This is because the retail cost of gas is currently about three to four times less per kilowatt hour than electricity. However, there are some properties which are not connected to the gas grid, and instead use electricity to provide space heating and hot water, with higher electrical consumption as a result. Some properties may also use a heat pump to provide the space heating and hot water demands of the home more efficiently than, for example, electric panel heaters and a hot water immersion cylinder.

The model distinguishes between these three cases to acknowledge the relationship between different demand profiles for electricity. As such a property which generates its own electricity, and uses electricity to heat the home would avoid and displace a higher electrical consumption rate and potentially save more money.

Figures for electrical consumption using electricity to heat homes are taken from Typical Domestic Consumption Values (TDCVs). These are industry standards for the annual gas and electricity usage of typical domestic consumers.

Occupancy

Energy consumption levels vary with the number of occupants in a household, and how much time they spend in the property over the course of the day. The model uses three occupancy archetypes to distinguish between households that are occupied:

- For the whole day
- For half the day
- For none of the day

These occupancy archetypes represent different lifestyle and working arrangements, and correspondent to the standard methodology used in the MCS Self-consumption Guide to assess energy usage.

These archetypes have an influence on the levels of energy used within the home and how much of this is met by any onsite solar generation, which impacts on the financial performance of such a system.

Occupancy archetypes are particularly relevant in the context of the Covid-19 pandemic, and what this may mean for the future of working arrangements. As technology and remote system access make flexible working more feasible, home occupancy levels may increase, with a commensurate increase in electricity consumption, and hence impact on the costs and benefits of investment in a solar and storage system for the home.

System lifespan

System lifespans have an important function in determining investment return. The longer something lasts, the greater its potential to generate returns for a given upfront capital investment.

The estimated lifespan of a solar PV system is typically 30 years, although the trend for system lifespans is increasing. Typical 'string' inverters may last 10 – 15 years. The lithium-ion batteries typically sold at present for domestic energy storage usually come with 10-year warranties and with good maintenance should be expected to last at least this length of time. The lifespan will depend on the number of charge and discharge cycles used and the depth of those charges.

The consumer model makes the following standard assumptions for the lifetime of the main components making up the system.[1] These may well prove to be conservative, and hence if anything the financial performance of the case studies included in this research may improve with longer lifespans.

- PV panels – 30 years
- Inverters – 10 years
- Batteries – 10 years

1 Note the 'Industry' and 'Lender' versions of the financial model allow the user to vary the lifespans to suit their specific requirements or designs, or simply understand the potential changes to the cost-benefits with systems with longer lifespans.

System Parameters

Other assumptions that affect the costs and benefits of a solar system relate to its design parameters, and geographical information. Key factors that have a bearing on the expected electricity yield from a solar PV system include:

- Orientation of the panels: the direction in which the property roof faces. In the northern hemisphere, panels that face south are ideally orientated. However, solar systems which face east or west can still produce significant amounts of power, and advances in technology mean they can also be installed facing north, albeit with correspondingly lower yields.
- Pitch: the angle at which panels are installed. Most roof pitches in the UK tend to have an angle of 30-50 degrees, which is ideal for solar PV installations. Solar panels can be installed on flat roofs where they are typically laid at an angle of ~10 degrees from the horizontal to allow rainfall to fall away. Panels can also be installed vertically, on walls, although the drop in yields is significant.
- Shading of the solar panels. Adjacent buildings, chimneys, trees, satellite dishes, and other objects which cast shade on solar panels, whether intermittently or continuously, will affect output. Avoiding shading is a priority for solar PV design.

Electricity Smart Export Guarantee price

The two sources of financial benefits for consumer solar systems are the avoided cost of grid electricity (because the onsite solar system is meeting part of the property's electricity needs), and the income received under the Smart Export Guarantee for selling any surplus electricity produced back to the grid.

Although the retail price of electricity is relatively consistent across the UK, there are differences according to tariff and location. The model allows users to select an assumed electricity and SEG price for the system, and calculates costs and benefits accordingly.

Relating to this, note that the model developed for this research used the MCS-accredited self-consumption methodology for domestic solar PV systems with and without battery storage. This concerns how much self-produced electricity it is assumed that a battery system will store in a given property.

As noted, at present it is preferable to utilise as much generation from a solar PV system as possible, since the value of the electricity which is offset as a result is higher than the value offered for selling any generation not used in the property. The SEG market is expected to develop in future as licensing arrangements and technology support the development in consumer electricity trading.

Outputs

Table 3 shows key outputs provided by the consumer model. They are intended to provide a snapshot of the costs of installing and maintaining a PV or PV and battery system specified by the model user, the potential savings in electricity costs the system will derive over its life, and the overall merits of the investment accounting for capital and operational costs over the lifetime of the system.

Table 3: Key running cost model outputs

Output area	Description	Output detail
Capex	The capital costs associated with the system specified using the input variables	• Total module costs • Total installation cost • Total module costs / kWp • Total installation cost / kWp
Opex	The operating costs associated with maintaining the system specified using the input variables	• Total annual operational and maintenance costs • Annual operational and maintenance costs / kWp • Replacement component costs
Savings	The financial benefits which the system specified using the input variables could be expected to produce	• Annual avoided electricity costs • Annual income from Smart Export Guarantee payments • Cumulative (lifespan) avoided electricity costs • Cumulative (lifespan) income from Smart Export Guarantee payments
Income	The net savings which the system specified using the input variables could be expected to produce	• Annual income (savings net of costs) • Cumulative (lifespan) income (savings net of costs)
Net Present Value	Lifetime investment metrics for the system specified using the input variables, accounting for all costs and savings.	• Net present value • Return on investment • Internal rate of return • Simple payback: number of years before the initial investment is recovered
Net Present Value (with loan)	Lifetime investment metrics, where a system is financed using a loan or mortgage, for the system specified using the input variables, accounting for all costs and savings.	• Net present value • Return on investment, as a percentage of the initial investment • Internal rate of return • Simple payback period: number of years before the initial investment is recovered • Overall payback period (see section 4.3) • Loan costs
Generation	The expected electricity which the system specified using the input variables could be expected to produce	• Annual kWh • Lifetime kWh • Lifetime CO2 savings

Payback period

The payback period is the breakeven point for an investment. It is often given in years. For example, a £1,000 investment which generates £500 in returns each year would have a payback period of two years. After this, the investment has paid for itself.

In this report, we have provided two payback periods. One is based purely on the running cost savings produced by a solar system. For example, a £4,000 solar system which generated £500 per year in running cost savings would have an eight-year payback period.

The second version of the payback period has been calculated by combining this figure with the increase in equity value which could be realised if the property were sold. This has been calculated by deducting the increase in sales price produced by installing a solar system from the initial installation cost of that system.

For example, if installing a £4,000 solar system on a property led to a £2,000 increase in the value of that property, then the net installation cost of the solar system would also be £2,000. If the system generated £500 per year in running cost savings, it would therefore have an effective combined payback period of four years. Note that this would likely apply only in the scenario where the property was sold and the increase in equity realised, and as with the other financial performance indicators provided in this report, the value of a solar installation to a specific property depends on a wide range of factors.

This second version of the payback period is referred to as the 'Overall payback period' in the case studies below.

Sensitivity analysis

This section provides an illustrative example of how the financial performance of a solar system varies according to system and geographical changes.

The following assumed system characteristics were used to conduct a sensitivity analysis:

- Semi-detached property located in the Midlands
- Gas heating
- 3.06 kWp solar system
- Financed using a loan at 6% with a term of five years
- 20p / kWh electricity price
- 8p / kWh SEG price

The table below shows the impact of two different variables on the net present value (NPV) of the system: the direction in which a PV system faces, and the angle at which the panels are installed.

Impact of orientation and tilt on system net present value					
Tilt (degrees from horizontal)	Orientation				
	N	NE/NW	E/W	SE/SW	S
0	11,268	11,268	11,268	11,268	11,268
10	10,035	10,192	11,185	11,709	12,063
30	7,387	8,309	10,427	12,276	12,767
45	5,279	6,860	9,360	11,765	**12,920**
90	**1,070**	2,720	5,448	7,483	7,901

The table is shaded so that better financial performance is indicated with green, and worse financial performance is indicated with red. The best and worst financial performance figures are in bold.

As is clear, the impact on NPV from poor orientation and tilt is significant. For example, changing the orientation from SE/SW to E/W at 45 degrees reduces the NPV by 20%. However, panels laid at 0 degrees are within 13% of the optimum NPV, which is why even a 'north-facing' flat roof system can generate financial returns (as a panel laid flat is effectively not facing in any direction). The best financial performance is produced by a south-facing system installed at 45 degrees. This would generate a lifespan NPV of £12,920.

Sensitivity analyses relating to a wide range of variables are available from Solar Energy UK on request:

- Differences in electricity and Smart Export Guarantee prices
- Occupancy rates and heating fuel
- Solar panel and battery lifespans and degradation rates
- PV module and battery costs
- Mortgage and loan rates and terms
- Maintenance costs

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