South West
NET ZERO
HUB

Energy Local

A guide to 'Complex Sites' with case studies from Southampton City Council and Bath and West Community Energy.

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EXECUTIVE SUMMARY

Brief

This report has been commissioned by the South West Zero Hub (SWNZH).

Section 1 provides information on the concept of local electricity markets, specifically the benefits and risks associated with the 'complex site' mechanism.

To show the potential for the 'complex site' to benefit generation projects, this report has two case studies showing projects currently in development. Section 2 explores two Bath and West Community Energy (BWCE) wind and solar projects, and section 3 looks at Southampton City Council's (SCC) rooftop solar installations.

Thus, the report shows the application of the 'complex site' to two important and distinct situations: firstly, stand alone, grid connected generation supplying domestic properties and secondly, a property portfolio owner self supplying excess electricity from their rooftop solar installations to other properties in their own portfolio.

How to read this report

For anyone who is unfamiliar with the relevant terminology, or the national electricity system and markets, it is advisable to first read Appendix A, which provides a glossary and explains key terminology.

Section 1 summary

Background

For households, councils and businesses, the cost of energy and price volatility has caused fuel poverty, financial problems and forecasting difficulties.

This is a particular source of frustration when there are potential renewable energy sources in the local area which could help reduce costs.

Furthermore, a high proportion of the economic benefit of local clean generation commonly leaves the community. Any power not used on site – e.g. rooftop solar panel-generated power not used in that building - is usually bought by a Supplier at around a third of the price for which electricity is sold to neighbouring properties.

In recent years, the electricity transmission and distribution networks have also been placed under increasing strain. The system was not designed for intermittent small-scale renewable generation or rising demand at all times of day as transport and heating systems are increasingly electrified.

Local electricity markets can mitigate these problems as follows:

- As much power as practical is used locally.
- Demand customers can pay less for local generation.
- Demand is shaped to more effectively balance generation and power use in real time, and users are encouraged to shift away from power use at the typical peak time of 4-8pm, relieving strain on the network.
- Renewable power generators can receive a higher price when it is used locally.

The process of setting up a 'complex site'

The process of establishing a local electricity market based around a 'complex site' includes:

- Modelling potential financial outcomes;
- Navigating commercial and legal arrangements; and
- Ensuring compliance with complex regulation in the domains of electricity and finance, potentially including consumer protection.

This should only be done with assistance from trained advisers.

How a 'complex site' works

One type of 'complex site' allows a local group of electricity consumers and electricity generators, which are connected under the same primary substation[1] at the same voltage level, to be aggregated together into one site to effectively net off the local generation from the local demand that is used in the same half hour.

This enables a 'local electricity market' between the aggregated generators and consumers where they agree a price for the power used locally within their group.

A partner-licensed Supplier purchases any excess power from the generator(s) that is not consumed locally, via a Power Purchase Agreement (PPA), and supplies any power shortfall required by the group of customers – paid for on a more expensive 'time of use tariff' (TOUT).

[1] A substation that steps down voltage from 33kV to 11kV.

There are also some charges and levies that complex sites do not pay, although this could change in future (see below, and the 'DUoS, BUoS, TUoS and Levies' section on p30).

The arrangement incentivises demand customers to adapt their electricity use to when local generation is producing power. It also generally keeps more of the benefits of power generation in the local area.

Everyone involved must switch to the same Supplier, which provides all the billing and licensed responsibilities.

Supplier benefits include a lower cost of sale and 'stickier' customers who are less likely to switch suppliers. The arrangement also has the potential for smoothing the demand curve and reducing the risk of imbalance in the system. This matters to Suppliers because imbalance has cost implications.

The current legal framework

The Balancing and Settlement[2] Code (BSC) is a legal document which defines the rules and governance for the balancing mechanism and imbalance settlement processes of electricity in Great Britain. It regulates how power is bought and sold.

The code is overseen by not-for-profit organisation Elexon.

Key considerations for establishing a complex site

Constituent members of a complex site

A 'complex site' can comprise generators, households and non-domestic users. It can be set up if all the generators and consumption sites are owned by one organisation, e.g. a local authority connecting up solar generation mounted on council-owned land or mounted on its own buildings and supplying electricity to other buildings it owns elsewhere within the same primary substation area.

Meter Point Administration Numbers

Every generation site and consumer site individually exports or imports electricity and has its own Meter Point Administration Number (MPAN). By contrast, when a 'complex site' is established, the supply and demand of the multiple sites is aggregated together and then only the net electricity generation is exported or the net demand shortfall imported, entering half-

[2] 'Settlement' refers to the financial process where the cost of electricity consumed or generated is calculated and payments are made.

hourly settlement under one single import MPAN and one export MPAN. These are identification references which are currently linked to physical meters.

A proposed change to the Balancing and Settlement Code – currently named P441, see below and p27 – would allow for a virtual MPAN that is not connected to a particular physical meter. This would make it easier for customers to enter and leave a 'complex site' without affecting the remainder to the participants.

Generation voltage

Under the current regulatory regime, demand connected at LV (low voltage), such as most households, must be matched to generation connected at LV, and demand connected at 11kV (which is higher than LV) must be matched to generation connected at 11kV. Part of the proposed modification P411 would allow generation at 11kV to match demand connected at LV (or vice versa). This would allow demand users to benefit from larger electricity generation installations.

Status as licensed exempt supply and impact on levies and charges

As long as the generation in the 'complex site' is supplying less than 5MW to non-domestic or 2.5 MW to domestic customers, it is regarded as license exempt supply and is therefore not subject to green levies (e.g.Renewable Obligation Certificates (ROCs), Feed in Tariff (FITs), Contracts for Difference and Capacity mechanism.

There are then charges to use the system (for further information see the 'DUoS, BUoS, TUoS and Levies' section on p30). There are some savings from these charges in a complex site.

However, the savings outlined are transferred to the supplier and will vary from site to site. These are bundled up into a single price that the domestic customer is billed (i.e. the costs that contribute to the single p/kWh tariff and standing charge are not broken down.) However, it can be passed through directly for commercial customers.

For commercial sites all these charges depend on the size of the demand, the capacity and voltage of the connection and when they use power. It is not possible to give an example as each customer is different.

The charging regime that should apply in a 'complex site' is under review as part of P441.

Regulatory Risk

There is a risk that the 'complex site' regime or the licensed exempt supply rules could be removed from the Balancing and Settlement Code legislation.

Removing the complex site and licensed exempt regime would remove developing local electricity markets and the associated savings. There is also the potential that greater 'use of system' charges (DUoS, BUoS and TUoS) could be applied to all the power used. This would reduce the overall savings but not remove them entirely.

If both mechanisms are lost then only onsite or private wire solutions would be available as options for renewable generators to sell their power at higher rates than is achievable by simply exporting to the grid.

If the 'complex site' regime were, but the licensed exempt supply rules stayed in place, there would be higher 'use of system' charges (DUoS, BUoS and TUoS). It would also make it difficult for domestic households to participate in a local energy market and potentially provide them with less consumer protection.

Supplier benefits

Even though the local generator and demand customer benefit financially from this arrangement, suppliers also benefit because of:

-reduced risk and cost of imbalance in power purchased and sold;

-reduced risk of 'spill' which is where too much power is generated for demand at that time, causing a 'negative price' - in effect the supplier has to pay for the power to be used;

- a more predictable demand curve, which enables them to better 'hedge' which is buying blocks of power in advance at a cheaper rate; and

- greater customer loyalty, because those who are benefitting from a local electricity market are more likely to stay.

However, calculating an exact figure for these collective benefits is exceptionally difficult.

Factors affecting customer savings

The savings for suppliers are not automatically passed through to customers.

This depends on the negotiated pricing structure. A large local authority may have more negotiating power through a framework agreement. Different suppliers may take a different approach.

Under a local electricity market, the generator may receive a lower PPA price for excess power not used locally in the 'complex site' (which therefore has to be exported to the Supplier) compared with not being in a complex site.

However, the local electricity market price (or match tariff[3]) can be set above this PPA price, so the generator receives greater benefits if the power is used locally.

The match tariff should be set below the 'time of use tariff' which is the price demand users pay the Supplier for top-up electricity that has to be imported.

Within these parameters, the lower the price agreed between the parties to the local electricity market, the greater benefit there is for customers; the higher the price, the greater benefit there is for the generator.

Local organisations' role

Where the generator sites and consumer sites are not owned by a single organisation, Energy Local recommends that there is a membership organisation or contractual arrangement between the generators and demand sites to demonstrate who is included. A membership organisation removes the need for multiple contracts between generators and demand sites.

Under FCA rules, anyone establishing a cooperative has to agree a set of rules. Energy Local has previously agreed a set of rules for 'complex site' cooperatives, and new clubs can use this particular set of rules if Energy Local is the sponsor.

Anyone arranging a cooperative for setting up a 'complex site' can deal directly with the FCA if they wish.

A cooperative under the Energy Local set of rules provides a mechanism for negotiating prices and agreeing how power is shared out. If all sites are owned by the same legal entity, the formation of a cooperative is not necessary, but it must be clearly stated which sites are within the complex site, for the purposes of dealing with a supplier and other outside bodies.

[3] The match tariff is the price agreed between the generator and electricity demand customers for the power consumed within the complex site.

The process to develop a local electricity market

A 'complex site' normally involves generators and households/multiple customers so the process is as follows:

Mapping

Define the area covered by a primary substation on the distribution network and identify suitable generation and demand.

Modelling

Ensure that there is a reasonable chance of the demand matching a suitable percentage of the generation by modelling this half hour by half hour.

Recruitment

Recruit sufficient demand customers - It is important that they record suitable consents and that tariffs and arrangements are explained to people clearly. Where a local market is open to all in a particular area it is important that everyone is given the chance to participate.

Switching

Switch supplier, once sufficient customers have completed an expression of interest - They must be provided with a new estimated annual cost and asked for consent to have their half-hourly data used. For domestic customers this is also a good point to gather data on who needs to be on the priority services register. The process of gathering the data and sending it to the supplier varies.

It should be noted that for a local authority the situation is somewhat different as they are creating a local market within their own assets (unless they are providing power to other organisations). All the benefit can come from reduced electricity bills and they do not need to go through a consumer recruitment process in this scenario.

Maximising value of Power Purchase Agreements

Whilst there are many means to sell power for large generators, smaller generators exporting into the national market sell on a fixed price Power Purchase Agreement (PPA) with a licensed supplier, normally for a year but it can be for up to three years.

The value of power depends on the time of day and time of year. As a nation, we use more power in winter and during the day and therefore prices during the winter and day are higher.

Predictable and reliable power has a higher value than less predictable power as the supplier will be able to forecast how much more power they will need to buy to match the demand of the customers.

Hydro and wind that generally operate more in the winter have a higher value than south-facing solar that has highest output during the middle of the day and in the summer when demand is lower.

For very small-scale generation, such as rooftop solar, it is possible to have a Smart Export Guarantee (SEG) (rather than a PPA). These are generally credited to a supply contract.

The number of suppliers offering PPA contracts to small-scale generation has reduced since the energy crisis. The main suppliers offering contracts for small generators are OVO, Octopus, Good Energy, and 100Green. EDF appears to offer them for portfolios of small generators.

Power generation exported during the morning and evening peak will be more valuable.

This is particularly relevant for BWCE as they are considering using solar panels that produce power from both sides and erecting them vertically east-west. These produce more in the morning and evening than during the middle of the day.

New east-west facing vertical bifacial solar provides a different output profile (because it more effectively captures power during the morning and evening peak) but this is not really recognised yet by suppliers in PPA valuations as it is an innovative technology.

Battery storage is increasingly being used to offset peak supply prices and/or higher usage times, or to allow greater generation capacity to be installed where a connection is subject to a constraint. However, the difference in price of a standard PPA would not be enough in itself to justify the additional cost of a battery.

Constraints

Constraint refers to a situation where there is a limitation on how much generation can be exported or users can import due to the Distribution or Transmission network reaching its physical or operational limits.

One of the benefits of a local electricity market is that, by using power locally, it can prevent generators being constrained. This matters because constraint potentially reduces generators’ revenue.

How a proposed rule change could attract more suppliers to the local electricity market model

P441 is a proposed modification to the Balancing and Settlement Code that governs how power is bought and sold. It should increase interest among suppliers to partner with local electricity markets.

P441 aims to strengthen the regulatory position of when a 'complex site' can be used to net off local generation against demand. This should encourage more suppliers to provide the service, because there will be reduced financial risk in investing and adapting their services to support complex sites.

Energy Local is currently in discussions with Ofgem and Elexon as to how they can monitor the impact over time rather than sign off an immediate and permanent change to the Balancing and Settlement code.

Energy Local is also in discussion with several suppliers about offering the local electricity market service.

Section 2 summary - Bath and West Community Energy (BWCE)

1. Solar only

Bath and West Community Energy have a site that they would like to develop as a solar farm. To improve the overall output profile to one that is more valuable, they are considering:

- standard south facing panels
- standard panels with half east facing and half west facing.
- Bi-facial, vertically mounted panels with the panels facing east west.

The provisional energy output modelling showed that 'option 2 – standard panels with half east facing and half west facing' delivered little additional value, with lower overall output than option 1, so financial modelling for option 2 was not pursued.

Modelling

Option 1 (standard south facing panels) and option 3 (east-west facing, bifacial vertical panels) were both modelled, with and without constraint, in order to compare:

- the benefits of a 'complex site' with different numbers of households as opposed to the generator receiving a standard Power Purchase Agreement from a supplier.

- the different types of solar panel.

Key assumptions and parameters for modelling

Household usage

Based on domestic usage data sourced from Elexon, we estimated households' average usage across each half hour of the day and each day of the year.

Tariff used for 'no complex site' modelling

Flat tariff – This is used for the calculations for the scenario where there is 'no complex site' for comparison, to demonstrate the savings expected in a complex site. This a typical average market price.

As tariffs are falling from an all-time high, the model uses a conservative estimate of 25p/kWh for the 'flat tariff' (how much a household would pay for electricity from their supplier under a normal supply arrangement).

Please note this is different to the 'flat match' tariff – see below.

Tariffs used for 'complex site' modelling

'Deep Green' TOUT tariff – We are currently using a 'deep green' supplier at present for complex sites. In general, their prices are higher than the cheapest in market because they buy 100% renewable power. For the power that they sell into the complex site, a Time of Use Tariff (TOUT) has been used. Costs shown include the estimated standing charge.

Assuming that households do not shift their power to different times of day compared with the average daily demand profile, a typical flat tariff (see above) would be 17% cheaper than the 'Deep Green' TOUT, if there were no local generation.

Standard supplier TOUT tariff – We are anticipating that more suppliers will offer a service for complex sites. To model a comparison of such a scenario, we have therefore set out an assumed 'standard supplier' TOUT that is 16% cheaper than the 25p/kWh flat tariff (see above).

Match tariff - The match tariff is the unit rate agreed in the 'complex site' for the electricity used when it is generated locally. This is the price for the members within the complex site, and also the price that the generator would receive within the complex site.

The modelling demonstrates the difference in benefit between a (more expensive) 'deep green' TOUT and a (cheaper) 'standard supplier' TOUT. A TOUT varies in price during the day in time blocks.

More detail on the tariff modelling assumptions can be found on p51.

Power Purchase Agreement (PPA) price

The generator owner will have a Power Purchase Agreement (PPA) which pays for the exported electricity from a complex site. This is the remaining electricity not used within the complex site.

To provide calculations for 'no complex site', we have used 7.5p/kWh for a standard PPA.

Then for the 'complex site' modelling, we have used 7p/kWh for the exported PPA rate (because the export from a 'complex site' is likely to be of slightly less value than for all the generation). We have not differentiated between technologies.

All prices are exclusive of VAT.

Household consumption

We have used an average of 2700 kWh per annum for standard household consumption as the selected area is fairly affluent but environmentally aware.

Target benefits as a percentage

The models show the results of different scenarios (as compared with no complex site) for the:

- minimum number of households needed in the 'complex site' to provide at least a **7% benefit to the generator**
- maximum number of households such that there is at least a **7% benefit on average to each household**
- number of households to give **an approximate equal percentage benefit to households and the generator**

These were modelled for both 'deep green' and the notional 'standard supplier'.

An 'Equal Benefits' scenario – i.e. where the percentage benefit to the generator and the user is approximately the same - was also modelled where the match tariff was 50% of the supplier tariff. This can be found in the tables in the full report.

Modelling summary - solar

Table 1 sets out the number of households required under the 'complex site' arrangement to achieve the target percentage benefit of 7% for households and the generator, plus the respective.monetary benefits. This is a summary table of the ranges of benefits in different scenarios given in the main report.

Table 1 Summary of benefits in different scenarios - Solar

Scenario	Deep Green tariff			Standard Supplier tariff		
	Households needed	Household benefit	Generator benefit	Households needed	Household benefit	Generator benefit
South-facing solar-unrestricted	220-300	£61-73	£6,228-£9,886	160-5000	£169-214	£6,107-£63,026
South-facing solar - restricted to 650kW*	200-300	£61-£76	£5,781-£10,386	150-2200	£175-215	£5,969-£58,474
Vertical Bifacial – unrestricted**	190-380	£69-88	£5,644-£14,612	140-2500	£173-£218	£5,686-£66,214

Vertical Bifacial – restricted**	190-380	£69	£15,114	140-2500	£173-£218	£5,687-£66,363

*restricted export because of local distribution network constraint

**The impact of restriction/constraint is small

Considerations

The different scenarios, in terms of orientation or constraints, **do not make a large difference to the benefit to households.** It is a matter of a few pounds which is statistically insignificant.

The main difference in income for the generator is what can be exported over and above the local demand by selling to a supplier.

Other factors:

Impact of shifting: However, the model does not take into account 'shifting' in household electricity use to match generation. This is more likely with the vertical bifacial option (because it generates more in the peak morning and evening times). Under the scenario where demand shifts, the income from the 'complex site' could be greater.

Impact of 'constraint' on household numbers: The maximum number of households possible within the 'complex site' reduces if there is a constraint.

This reduces the maximum amount that the generator can earn by recruiting more households. However, this scenario with maximum number of households is much less attractive to the householders because they receive less benefit, particularly with 'deep green' and therefore it is unlikely to occur.

Finance modelling

Please note all investment decisions should be made with appropriate financial advice.

Four models have been created to show how the generation can be financed by income from the complex site.

Assumptions

-Capex and Opex were provided by BWCE.

-However, the Capex for vertical Bi-facial solar panels is uncertain due to being a new approach in the UK and the mounting and installation design not being finalised.

-The 'deep green' TOUT has been used as this is what is definitely available at present, and the solar farm could be built in the next year.

With these the assumptions, the following Capex and Opex in Table 2 were modelled

Table 2 Capex and Opex for models

Model	No. of member households needed	Capex	Annual Opex
South – Unrestricted	220-300	£1,270,962	£34,045
South – Restricted	200-300	£1,270,962	£34,045
Bi-Facial – Unrestricted	190-380	£1,269,800	£31,388
Bi-Facial – Restricted	190-380	£1,269,800	£31,388

Table 3 Income modelling, profit and potential Internal Rate of Return

	Total Project Costs	Total Project Profit	RoI	Percent Debt	Loan Interest Rate	Debt Coverage Ratio	IRR on PBT
South Facing Unconstrained **Complex Site**	£3,467,940	£2,953,020	-15%	50%	5%	116%	-2.7%
South Facing Unconstrained	£3,467,940	£2,718,180	-22%	50%	5%	102%	-4.3%
South Facing Constrained **Complex Site**	£3,467,940	£2,714,700	-22%	50%	5%	102%	-4.3%
South Facing Constrained	£3,467,940	£2,318,430	-33%	50%	5%	78%	-8.1%

	Total Project Costs	Total Project Profit	RoI	Percent Debt	Loan Interest Rate	Debt Coverage Ratio	IRR on PBT
Bi Facial East-West Facing Unconstrained **With Complex Site**	£3,386,006	£2,808,510	-17%	50%	5%	113%	-3.1%
Bi Facial East-West Facing Unconstrained **No Complex Site**	£3,386,006	£2,524,710	-25%	50%	5%	95%	-5.2%
Bi Facial East-West Facing Constrained **With Complex Site**	£3,386,006	£2,788,470	-18%	50%	5%	111%	-3%
Bi Facial East-West Facing Constrained **No Complex Site**	£3,386,006	£2,503,290	-26%	50%	5%	94%	-8.1%

South facing panels are not viable for equity holders at a 50/50 debt to equity ratio or interest rates but the complex site reduces the negative IRR by around half. The next step is to reduce OpEX, obtain a lower TOUT, and increasing equity with a complex site could make these sites viable.

There is value in the vertical bi-facial panels but additional risk and costs. It is recommended to seek grant funding to offset the risk for the first installation with vertical bifacial panels. If installed, aim to engage DNOs so the value of these panels is reflected in connection offers. Engage with structural engineers to ensure a robust design for installation of vertical bi-facial panels.

Developing a local electricity market increases income with all options.

2. Wind only/Wind & Solar

BWCE has a second site that is suitable for wind and possibly solar.

At this site there are practical and cost considerations:

- The wind turbine is 950kW, greater than the limit of 650kW for a cheaper LV connection, so would potentially need an 11kV connection.
- A ‘statement of works’ study for the transmission network would be needed if both wind and solar were installed (because solar and wind

combined are above the 1MW limit at which a statement of works is needed).

- Alternatively, to enable the solar and wind to be fitted without a statement of works, a battery would be required.
- Another alternative is to constrain export to 650KW and connect at LV.

The modelling suggests wind and solar fit together well to maximise the use of a connection, either with a statement of works or a battery. Combining wind and solar also makes the 'complex site' more attractive to the households.

The assumptions used for modelling were the same as for Solar only above.

Modelling summary – wind and solar

Table 4sets out the number of households required under the 'complex site' arrangement to achieve the target percentage benefit, plus respective monetary benefits.

Table 4 Summary of benefits in different scenarios - Wind and Solar

Scenario	Deep Green tariff			Standard Supplier tariff		
	Households needed	Household benefit	Generator benefit	Households needed	Household benefit	Generator benefit
Wind only - unconstrained	360-2400	£68-£228	£18,999-128,990	270 – 5,000	£186 - £269	£19,568 – £190,120
Wind & solar – unconstrained*	350 – 2,700	£67 - £273	£20,508 - £203,391	270 – 5,000	£189 - £281	£21,672 – £203,391
Wind & solar – constrained*	270-2200	£71-£287	£16,215-£122,200	200-5000	£180-£285	£15,866-£165,183

The benefits to households between 'wind & solar – unconstrained' and 'wind & solar constrained' are not hugely different as it is the peaks in generation that are constrained and this is power that is the most difficult to use within 'complex site' without a considerable level of switching.

The generator income is lower when the export is constrained to 650kW.

Use of a battery to avoid the need for a 'statement of works'

There have been conflicting reports as to whether inclusion of a battery and limiting the export from a connection is sufficient to avoid 'statement of works'.

To analyse the impact, a battery that was large enough to limit the export from solar and wind to 650kW was included.

A battery of greater than 400kWh is assumed – note that this is just a proxy for a battery with a high discharge rate due to the limitations of the model.

By storing the constrained wind and solar and selling at a different time, the generator can potentially increase its revenue.

A 400kWh battery (See Cost Projections for Utility-Scale Battery Storage: 2023 Update (nrel.gov)) would be around £160,000 at present day prices although the costs will vary depending on connection arrangement required. It is likely that by the time the wind turbine is installed, a battery would be nearer £120,000.

Finance modelling

We have used the 'Standard TOUT' as we hope to have more mainstream suppliers providing services for complex sites by the time this could be constructed.

Model	Member Size	Tariff	CAPEX	Annual OPEX
Solar & Wind Constrained	800	Standard	Wind: £2.4m Solar: £270k	Wind: £39,000 Solar: £6,802
Solar & Wind with Storage	800	Standard	Wind: £2.4m Solar: £270k Battery: £120k	Wind: £39,000 Solar: £6,802 Storage: £3,000
Wind Only Unconstrained	800	Standard	Wind: £2.4m	Wind: £39,000
Solar & Wind Unconstrained	800	Standard	Wind: £2.4m Solar: £270k	Wind: £39,000 Solar: £6,802

Please see full report for full context and considerations.

Table 5 Financial Headlines - Complex Site Comparison

	Total Project Costs	*Total Project Profit*	*RoI*	*Percent Debt*	*Loan Interest Rate*	*Debt Coverage Ratio*	*IRR on PBT*
Solar & Wind with Storage **With Complex Site**	£6,858,106	£9,463,930	38%	50%	5%	218%	4.6%
Solar & Wind with Storage **Without Complex Site**	£6,858,106	£8,460,000	23%	50%	5%	191%	3.0%
Solar & Wind Constrained **With Complex Site**	£6,627,106	£9,273,960	40%	50%	5%	222%	4.9%
Solar & Wind Constrained **Without Complex Site**	£6,627,106	£6,780,540	2%	50%	5%	152%	0.3%

	Total Project Costs	Total Project Profit	RoI	Percent Debt	Loan Interest Rate	Debt Coverage Ratio	IRR on PBT
Wind Only Unconstrained **With Complex Site**	£6,982,500	£9,466,440	36%	50%	5%	258%	6.8%
Wind Only Unconstrained **Without Complex Site**	£6,982,500	£7,354,950	5%	50%	5%	192%	3.1%

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In all cases, the complex site improves the income considerably and the combination of wind and solar will be beneficial to demand customers. Note however, there will be a challenge to recruit sufficient domestic customers. Recruiting some businesses would help create sufficient demand. Over time the premium for 'deep green' tariffs will fall and with a complex site, a solar farm should become viable.

2. BWCE Conclusions

In all cases a complex site:

- Increases the IRR dramatically.
- Helps balance demand to generation to alleviate network constraints.
- Helps justify use of batteries that will support more renewables to connect in a constrained network and balancing local demand to generation.

Section 3 summary - Southampton Local Authority

Southampton City Council has a range of building assets across the city with different levels of demand and suitability for solar.

By creating a complex site/local electricity market between their assets which are under the same primary substation, they can reduce their own costs and also help manage constraints on the network by using the power locally. This should also help justify installing more solar to maximise the size of arrays on roofs. As examples, there are three substation areas to consider – B,C, and D.

Unless the complex sites become very significant, they would not impact the buying (hedging) activity of LASER, which procures power for the council.

Modelling

Because the Council is 'selling to itself' the match price is assumed to be zero. It is unclear what sort of tariff the additional power would be purchased for under LASER. We therefore focused on the amount of power that could be netted off using a 'complex site' over and above that used by a building itself and how much power would then be left over.

We made existing data and assumptions on power prices and installation costs, which are set out in the full report.

Substations

1. Substation B

Buildings considered: **Banister Primary School, Sembal House, St Marks CoE School, West Park MSCP, The Civic, The Polygon School.**

In total, summing the total export versus the total generation, about 87% of the solar power is not used by the building it is installed on.

We modelled a 'complex site' to ascertain how much power could be used by other Council-owned buildings.

We found that the Civic Centre is well-suited as a consumer member in this scenario as its load profile matched very well with the available generation, using 95.75% of available exported power.

Table 6 Payback with and without a complex site

	Benefit from behind the meter with	Benefit from minimised solar arrays size (£)	Benefit with 'complex site' (£)

	maximum solar array size (£)		
	84,656	79,024	119,143
Number of years to pay back (division of income by capital cost)	7.8	7.7	5.6

Key conclusion

We recommend that a 'complex site' in Substation B should have the Civic Centre as the sole consumer member. This would enable almost all the power to be used, with a potential saving for the council modelled at £119,143.

The savings help justify installing larger PV arrays.

Substation B will give excellent benefit to the council and larger arrays are likely to pay for themselves, whether selling exported power via a SEG, or a 'complex site' arrangement with a PPA. There are further considerations set out in the full report regarding structural surveys and connection infrastructure.

2. Substation C

Buildings initially considered: Archaeology Storage Centre, Granville St Depot, ITEC Centre, Paget St Workshop & Courier, Start Point Northam, plus other council-owned housing and commercial buildings.

Summing the total generation including export for each building in substation C, 75% of the power is not used by the building it is installed on.

A 'complex site' reduces the imported power from 48% to 25%.

Table 7 benefits with and without a complex site

	Benefit from behind the meter with maximum solar array size (£)	Benefit from minimised solar arrays size (£)	Benefit with 'complex site' (£)
	20,562	9,029	38,711

Number of years to Payback, capital divided by income.	17.3	12.9	9.2

Key conclusion

The potential benefit to the council of using larger arrays and a 'complex site' is £38,711 in total (an increase of over £8,000 compared to the scenario without a complex site).

Even though, in this scenario, 63% of the solar power would still not be utilised, the 'complex site' will nevertheless improve the business case considerably and help justify the larger arrays.

However, there is still considerable power that could be used by other council buildings (including housing) or commercial buildings who could join the complex site, although more information about their usage profile is needed.

3. Substation D

Buildings considered: Bassett Green Primary School, Cantell School, Hardmoor Early Years Centre, Sure Start, Vermont School

These are all schools which tend to have the same usage profile and are therefore exporting power at similar times of day. Sixty-three per cent of power is not used by the building hosting it.

Table 8 Benefits with and without a complex site

	Total Benefit without a complex site	**Total Benefit With 'complex site' £**
	67503	98653
Years to payback, capital cost divided by income	7.0	6.8

Key conclusion

The total potential benefit of a 'complex site' for the council is £98,653, over £30,000 more than without a complex site.

The site with the highest export is also Cantell School. The optimum benefit of a 'complex site' came from combining Cantell School with Hardmoor Early Years Centre and Basset Green Primary.

There is still 56-57% of power imported (only 6-7% less) which shows that there is little diversity in school demand. There is a need for premises used at the weekend and primarily during school holidays to fit well with the export. The next step would be to establish if sports facilities held by the council fit this profile.

Southampton Conclusions

For council-owned buildings the use of a 'complex site' will

- Increase income and reduce payback
- justify expanding the size of solar arrays,
- benefit the network through more efficient use of power close to its generation.

FULL REPORT

SECTION 1

Background

Over the last few decades communities who have invested in or host local renewables have shown an increasing desire to get a direct benefit from using the power generated. Local authorities and businesses are struggling to cover costs and electricity price volatility is one key area that incurs high costs and uncertainty. Levels of fuel poverty have risen sharply even when there are sources of clean power very close by.

At the same time the transmission and distribution networks are under strain as more generation seeks to connect and we use more power as we decarbonise transport and heat. The networks were not designed to have this level of generation connected at distribution level nor the sustained demand that heat pumps and electric vehicle charging require.

Our national market for power is not designed for a scenario where there are many intermittent generators, which the increase in renewable power provides. However, there is also considerable potential for control of demand, which provides the opportunity to shape the demand curve and match it to local generation where possible, but this is not encouraged by our national market.

Many of the problems outlined above can be mitigated via local electricity markets where:

- as much locally generated power as practical is used locally
- renewable power receives a higher price when it is used locally
- demand customers pay less when they use power as it is being generated locally.

This incentivises balancing power locally and using the network more efficiently as well as helping to shape the demand curve for national suppliers.

Local electricity markets have been hard to achieve, but a key mechanism is a 'complex site'. This report studies this mechanism, its benefits, the financial case and two particular case studies with different types of generation.

The two case studies look at roof mounted solar, ground mounted solar, new bifacial solar panels and a wind turbine. They also cover the case of a non-domestic organisation (in this case a local authority) owning all the assets, and a community energy organisation partnering with local households and community amenities. Consideration includes the fact that costs of power, tariff structures and acceptable business models are different for domestic and non-domestic customers and organisations. The two case studies evaluate the viability of project with and without a complex site.

Structure of the Full Report

The first part of this report discusses the concept of local electricity markets, the benefits and risks associated with them.

The second part gives case studies of examples from Bath and West Community Energy.

The third part gives case studies of Southampton Local Authority installing solar.

Introduction to using 'complex site' to create a local electricity market

A 'complex site' is a way to take into account situations within the settlement process where the power recorded by a customer's meter may not be what is actually used by the customer. There could be situations where, for example, a meter records more than one user's consumption, where some parts of the electricity network are privately owned, or generation and demand are under different meters.

Settlement is the process that records how much power is bought and sold by suppliers and generators, and where it was used.

One type of 'complex site' allows a local group of electricity consumers and generators, which are connected under the same primary substation at the same voltage level, to net off the generation from the demand that is used in the same half hour. That is, the generation may not be behind the same meter as the demand that is using it.

This enables a 'local market' within this area which can facilitate lower cost power when it is used locally, and also increases income to the generator This is achieved by generators and demand users agreeing their own price for the power used locally with their group. The price for the power that is used within the 'complex site' gives the generator a higher price than a Power Purchase Agreement (PPA) export price (i.e. the price received by the generator for selling power to the national market) but is lower than supplier tariffs for demand.

The partner licensed supplier purchases the power from the generator that is not consumed locally, via a PPA, and supplies the additional power required for consumers – generally on a time of use tariff. Everyone must switch to the same supplier, who provides all the billing and licensed responsibilities.

In a complex site, "local" is as yet undefined[4], but is expected to be defined as fed from one primary substation on the distribution network.

Customer benefits include:

- Shelter from price volatility and reduction in bills.
- Supporting local generation and the local economy.
- Strength in numbers (in terms of influencing licensed suppliers and peer to peer support.

Generator benefits include:

- Greater income.
- Supporting the local economy.

Distribution network benefits include:

- Local balancing helps avoid constraints.
- Shifting power from peak times to run the network more efficiently and avoid network reinforcement.

Supplier benefits include:

- Lower cost of sale and 'stickier' customers who are less likely to switch suppliers
- Potential for smoothing the demand curve.
- Potential for reduced risk of imbalance.

The distribution system benefits from local balancing of generation and demand that helps reduce constraints. Note each site's usage is still recorded on their meter at the point of connection but they are incentivised to adapt their demand to when local generation is operating thus helping to manage constraints.

It is also envisaged that if the majority of the power used by customers is provided by the local generator, then the supplier can charge an administration fee for passing the payments from demand members to generator members.

This gives the opportunity for a new type of relationship between a group of customers and the supplier which is potentially a longer term, more collaborative relationship.

From the customer's point of view this arrangement is much 'fairer' than under a standard arrangement. Usually if local generation is not used on site when it is generated, it is bought by a supplier at around a third of the price for which it is sold to neighbouring properties.

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[4] Several 'complex sites' are already in operation, however there is an amendment to the Balancing and Settlement Code, P441, currently being considered which would formalise the rules and arrangements.

Customer do have work together and share power between themselves. There is therefore a degree of cooperation required. The tariff structure is more complicated that a simple flat tariff. For some vulnerable customers this may be too onerous. To date complex sites have not been implemented with prepayment smart meters removing option for this demographic to participate to date.

How it works

Relevant parties to the Balancing and Settlement Code

Data Central Collector (DCC): collects data from smart meters.

Data Collector (DC): collects data from meters themselves or from the DCC and validates it.

Data Aggregator (DA): aggregates data to send to settlement and other parties.

Meter Operator (MOP): installs and maintains meters.

Licensed supplier: buys and sells power.

A local electricity market via a 'complex site' operates by grouping all the demand customers and generation customers together. The import and export electricity is aggregated and enters settlement under one import MPAN and one export MPAN (these are identifier codes assigned to meters for export or import). (Note that a collection of MPANs could be owned by one organisation.)

The MPANs for the 'complex site' could be the generator's import and export MPANs, or they could be one of the demand customers' MPANs (if three phase). P441 (a proposed change to the Balancing and Settlement Code that regulates how power is bought and sold, see below) proposes these could be virtual MPANs not connected to a particular meter. This would make it easier for customers to enter and leave a 'complex site' without affecting the rest of it.

The generation in the 'complex site' is netted from the demand by the data collector each half hour before settlement. The net value of import and export enters settlement. The PPA price (i.e. that paid via a standard tariff for power in the national market) is only paid for the net export, i.e. that which is not used withing the complex site.

A **"match tariff"** is agreed between the generator and demand members for the power consumed in the complex site. This is the price paid by the demand customers for the power they use when it is generated by the local generator. This power does not enter settlement.

The Supplier provides a service to pass through the match tariff – this could be subject to a fee for the service.

The power imported by the demand customers (not from the local generator) is recorded by the import MPAN in the 'complex site' for settlement. The power used by individual users is recorded by their household/site meter. For domestic customers this is sold by the licensed supplier on a 3 or 4 band **Time of Use Tariff (TOUT)** and potentially with a weekend rate. That is, the price is different at different periods during the day. This encourages customers to move away from using power at the most expensive times of the day. The highest price is sometimes removed at the weekend as there is not the same peak in usage at the weekend. The TOUT also encourages households to shift power to match generation from peak times rather than off peak. Without the TOUT, a complex site is less attractive and beneficial to suppliers and distribution network operators. This will result in less benefit to customers. This price differential over the day will enable the Supplier to smooth their demand curve by encouraging customers to shift their use to when there is local generation, or spread it out during the day and night rather than having the typical peak demand between 4-8pm. At scale this could have an impact on Suppliers' hedging strategy (i.e. how they buy power in advance). This will also encourage users to shift power away from the peak loading time of between 4pm and 8pm when the network is most overloaded. This will reduce the cost to the network and the amount of reinforcement needed. Note that the price of power to a Supplier will vary from half hour to half hour and day to day and will be extremely high on a few days of the year. Setting 3 or 4 fixed time bands is risk sharing and encouraging efficient behaviour by customers whilst not being cost prohibitive.

The supplier needs to be able:

- to use two Market Participant IDs (MPID) to ensure that none of the meters are marked as de-energised for settlement purposes. MPID are codes used by suppliers to identify themselves in settlement (normally one is used). Note that even though two MPID are used, the charges remain the same for using the DC, DA and MOP services.
- to move meters from one MPID to another, this happens when a customer moves from one supplier to another. In this case the supplier is the same just using a different MPID. Even though it is still the same company, it acts here as if it were two parties.
- to operate half hourly settlement and have a data collector able to carry this out. In the case of SMETs meters (i.e. a domestic smart meter) this is elective half hourly.
- to use a Meter Operator (MOP) who can install all sizes of meters.
- to be able to instruct MOPs and Data Collectors (DC) to set up complex sites and send the correct summation of the data to settlement and MPANs

via the MOP. Note the contract for the service may be paid for by the demand and generator customers if they are commercial but it is the supplier who directs the MOP and DC.

- to either calculate different time of use tariffs and share out generation between demand customers, or use a third party to carry out this calculation (e.g. Energy Local). That is if there is insufficient generation to cover all the demand, allocate a share of what is available to each customer.
- provide billing on a half hourly basis taking into account the sharing out of generation.

Note that until this becomes mainstream, suppliers require a degree of 'handholding' to set up the new processes internally. In the case of LASER, this could be their role. Energy Local has been providing this role to date.

P441

P441 is a modification proposed to Elexon to change the balancing and settlement code (how we buy and sell power) to:

- more clearly define when a 'complex site' can be used
- enable a 'complex site' between generation connected at 11kV and demand connected at Low Voltage or vice versa.
- Enable 'Pseudo MPANS' (i.e. not linked to a particular meter) to be used to group the net generation and demand that enters settlement rather than use an MPAN connected to a particular meter (see below)
- Streamline processes regarding the Use of System charges as appropriate (see below)

It is hoped that this modification will give more licensed electricity suppliers the confidence to proceed with supplying to 'complex sites'.

Diagram of payments

The gross readings (i.e. without the generation taken off) from each of the demand customers are recorded by their advanced meter.

At present, either demand connected at LV is matched to generation connected at LV or demand connected at 11kV is matched to generation connected at 11kV. Part of the proposed modification p411 is to allow generation at 11kV to match demand connected at LV (or vice versa).

Figure 1. Structure of a complex site. The PPA price is paid to the generator on the net electricity exported. Consumers pay the supplier at the Time of Use Tariff (TOUT) rate for net electricity imported.

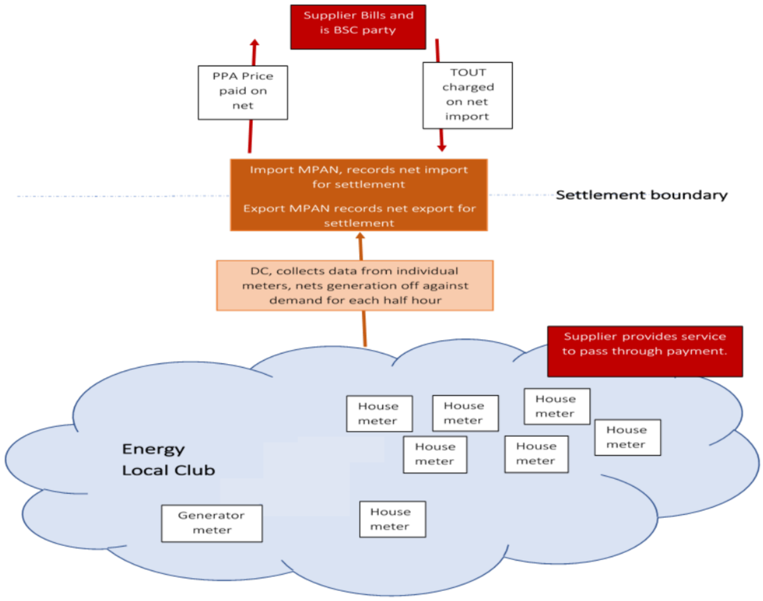

Figure 1: The total power used and generated within the 'complex site' is calculated each half hour. Generation is netted off against demand, and any generation not used in the 'complex site' goes into settlement, whilst any additional power needed by the 'complex site' comes from settlement.

Note that Figure 1 is drawn with domestic households and referred to as a club by Energy Local but the same arrangement can be used with non-domestic connections and can be owned by one organisation.

Note also that even if no generation is exported, there must be an export MPAN as each generator will have an export meter, and one of them must be used as the MPAN that all the others are 'associated' with, regardless of whether any generation enters settlement. At present the import and export MPANs are associated with a physical meter however it is proposed to use pseudo MPANs under P441.

The licensed supplier retains the license responsibilities. It can develop a new relationship with groups of its customers including helping them to manage their demand curve, reducing the risk of imbalance, and potentially co-investment in renewables.

DUoS, BUoS, TUoS and Levies

'Complex sites' can both avoid certain charges and potentially help reduce the size of these charges nationally if implemented at scale.

There are some charges that complex sites do not pay (this could change in the future). This can be justified as an incentive for behaviour that contributes to running a more efficient network and system. Charges are for the use of the distribution system (DUoS), transmission system (TUoS, also known as TUoS) and balancing the system nationally (BUoS).

Also, by balancing demand against generation locally, complex sites reduce constraints on both distribution and transmission in the network. By balancing locally they reduce the need to balance at a national scale. If delivered at scale, local energy markets will reduce overall costs for balancing and reinforcement. A small proportion of the saving could be used as a reduction in charges for 'complex site' properties to give an incentive for the right behaviour in a local energy market.

The power used locally is regarded as **licensed exempt supply**[5] (i.e. under 5MW non-domestic or 2.5MW domestic, it is not subject to the onerous requirements of licensed supply). As a result, it is exempt from green levies (Renewable Obligation Certificates (ROCs), Feed in Tariff (FIT), Contract for Difference (CFD) and Capacity Mechanism. On average, these make up around **30%** of a typical domestic bill with no intervention (such as local electricity markets)[6] , although these costs vary from day to day. The total cost varies on customer type and from year to year. Note a local electricity market reduces the size of the whole pie' it does not just avoid certain charges.

Balancing Use of Service charges (BUoS) are the costs to keep the amount of power available equal to that used at each instance, and Transmission Network Use of Service (TUoS) charges are the costs for operating the transmission network. **A 'complex site' does not pay the per kWh part of Balancing and Transmission Network Use of Service charges (BUoS and TUoS)** on the locally used power but does pay the Distribution Use of System (DUoS) charge.

The parts of the BUoS and TUoS charges that are made per meter per day are still incurred within a complex site. The costs to consumers vary depending on the amount of balancing required, capacity available, cost or rebate from contract for difference, and value of 'Triad events' (see below). This is not a fixed number and the final cost is only known a year or more after the event. Different customers pay different amounts. Therefore it is not possible to give one value.

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[5] The Electricity (Class Exemptions from the Requirement for a Licence) Order 2001- www.legislation.gov.uk/uksi/2001/3270/contents

[6] Imperial College London, Electricity Bill Charges | Breakdown of your bill components - electricitycosts.org.uk/electricity-bill-charges/, 7th February 2024.

At scale, the local balancing (where local generation is used by local demand) that occurs within this type of 'complex site' can reduce constraints and reduce the network reinforcement required including at the distribution level. It also provides balancing at a local level which reduces the amount of balancing required at a national level. It thus reduces the cost of running the system overall.

The value of the TUoS depends on where in the country and when the demand was using power. Generation near load centres is given a negative cost whilst that in remote areas pays more. Conversely demand in remote areas near generation pay less than in areas with low generating capacity. Part of it is paid per meter/annum and part on the power used. This is paid via the supplier to National Grid for demand customers and embedded generation (i.e. small scale).

For non-domestic half-hourly tariffs the locational charge is based on the kW peak during the three 'triad periods' in winter – i.e. the periods of highest usage at least 10 days apart. For domestic half-hourly or non-half hourly the charge is made for the consumption between 16:00 and 19:00 (measured or on a profile). Matching power and shifting from these times of day, (which is what the charges are designed to encourage) will reduce the usage and thus the charge. Note in the north of England and Scotland this charge is zero for demand customers. Also embedded generators (i.e. small scale) in the south of England receive a greater credit (via the supplier) but this is not paid on matched power in the complex site.[7] These charges are made via the supplier and passed on to the customer either explicitly for commercial customers or bundled into a tariff. For domestic customers, in total, **TUoS is around 7-10% of a domestic bill** but only a proportion of it is based on usage at peak times. Different commercial customers pay different amounts depending on their usage and voltage connection. As with BUoS it is not possible to give one figure for these charges and they vary from year to year.

BUoS is paid per MWh for each half hour that is recorded in settlement and therefore locally matched power reduces this as this power does not enter settlement. However, it is a relatively small amount of the bill.[8] This depends on the type of customer, balancing required in a year etc. Again it is not possible to provide one number.

Note all these charges are reduced by local balancing as this contributes to a more efficient use of the system and market.

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[7] National Energy System Operator (NESO), 'Final TNUoS Tariffs for 2023/24' www.neso.energy/document/275736/download
[8] 44939-TNUoS, BSUoS and Connection Charging Information.pdf (nationalgrid.com)

The savings outlined from not paying these charges come through to the supplier and will vary from site to site. These are bundled up and decoupled from the price that the domestic customer is billed (i.e. the costs that contribute to the single p/kWh tariff and standing charge are not broken down). However, it can be broken down and charged directly to some large commercial customers rather than bundled into the price but this will be rare for the participants in complex sites.

For commercial sites all these charges depend on the size of the demand, the capacity and voltage of the connection and when they use power. The range is considerable. It is not possible to give an example as each customer is different.

Note also that what charges should be made in a 'complex site' is under review as part of p441.

Regulatory Risk

There is a risk that the 'complex site' regime or the exempt supply regime is removed from the balancing and settlement code legislation. This would remove this mechanism for developing local markets and the associated savings. There is also the potential to insist on BUoS and full TUoS being paid on all the power used in a 'complex site'. This would reduce the savings but not remove them entirely as the benefit of matching power, reducing risk of imbalance and shaping the demand curve remain. If the 'complex site' regime were removed but not exempt supply this would result in higher BUoS and TUoS charges. It would also make it difficult for domestic households to participate and potentially provides them with less consumer protection.

If both mechanisms are lost then only onsite or private wire solutions would be available as options for renewable generators to sell their power at higher rates than is achievable by simply exporting to the grid.

Other Savings

The supplier gains in terms of:

- Reduced risk of imbalance (i.e. not having bought enough power or having bought too much), particularly at peak times. Suppliers must retain sufficient cash in reserve to be able to pay imbalance costs (the penalties for not having bought enough or having bought too much power). By shifting power from peak times (where the risk and cost is greatest) and matching demand to generation (to avoid export into settlement when the price is negative), the risk is reduced.
- Reduced cost of imbalance. These are costs that the supplier must pay if they have not bought enough power or have bought too much. Whilst normally the average cost of imbalance payments are around £50-£100

per MWh, in the worst periods prices can reach over £4,000/MWh. A supplier will normally only have an imbalance of around 2% of their total volume of demand but at periods of high imbalance costs this is a significant outlay. By shifting power from peak times and matching demand to generation, the risk is reduced.

- The spot price in Supplier Volume Allocation (SVA -i.e. where the power that supplier has bought is recorded) is the price that is paid in the last half hour of trading. To accommodate the small scale generation it is treated as negative power deducted from the demand in the supplier's volumes. If there is too much power the spot price can go negative. If the supplier has more generation than demand when the price is negative, it will have to pay for the power to be used (i.e. a negative price). There have now been several periods in the middle of summer days when spot prices have been between -£30-£50/MWh with it reaching a minimum of around -£64/MWh in 2023. By matching small scale generation to demand, the spill and the payments are reduced. By encouraging customers to match the usage to local power, the risk of 'spilling into SVA when the price is negative' is reduced.
- 'Hedging' is buying blocks of power in advance at a cheaper rate. The ability to shape the demand curve, predictability and shifting the demand curve enables suppliers to hedge as they have a better forecast and can reduce peak demand (for which it is difficult to buy hedged power in advance).
- Stickier customers – on average a customer that remains for over about 2 years provides a profit for a supplier. Before this point the cost of taking on a customer is not covered by the profit margin. Customers who are benefiting from a local electricity market are likely to stay with the supplier.

Putting a figure of the benefit of the above is very difficult to do and may only be possible at scale. It also depends on the position of the supplier and the condition of the market overall. Likewise, understanding the benefit of local balancing to the distribution and transmission network in avoiding constraint is difficult to calculate at present. Individual instances can be calculated but the impact at scale is harder to estimate.

Savings to the Customers

The above explains where there are savings to the supplier and the system. However, this is decoupled from the savings that customers see as a supplier may choose retain some of the savings via increasing other charges in theirpricing structure offered although we have not seen this to date to demand customers. A large local authority may have more negotiating power through a framework agreement such as LASER but the principles outlined below are the same.

The local price can be set between the PPA price for power not used locally and the time of use tariff provided by the supplier. Where the price is agreed within these parameters determines how the benefit is weighted to the generator or demand customers. Closer to the PPA price and customers benefit more, closer to the supply tariff and the generator benefits more. The price of power not used locally may receive slightly less than before setting up the complex site.

One supplier withheld embedded benefits for the power not used locally, whilst another examined the likely ‘spill’ from the ‘complex site’ and valued the generation accordingly. As the higher spill was when demand is lower, the price of the PPA was lower than the best in market.

Note that it is difficult to put a value on this price offered by a supplier as it is dependent on how much they are in need of power and the type of generation as well as market conditions. Suppliers may increase the standing charge in return for the service they are providing, particularly if they are selling little power into the members ‘complex site’ themselves.

Examples of prices are given at www,dashboard.energylocal.org.uk for the different clubs as well as approximate savings per club (each household can also see their own individual savings) - Table 9. Savings are between 10-30%.

Table 9. Current Energy Local Clubs and their tariffs

Club Name	TOUT p/kWh		Match p/kWh
Bridport	7am - 4pm	16.09	15.00
	4pm - 8pm	28.12	15.00
	8pm - 7am	15.27	15.00
Totnes	12am - 7am all week	19.00	15.00
	4pm - 8om weekdays	40.00	15.00
	All other times	32.00	15.00
Capel Dewi	7am - 4pm	16.74	12.00
	4pm - 8pm	27.14	18.00
	8pm - 7am	15.55	10.00
Crickhowell	7am - 4pm	16.74	14.00
	4pm - 8pm	27.14	22.00
	8pm - 7am	15.55	10.00
Llandysul	7am - 4pm	16.74	15.00
	4pm - 8pm	27.14	23.00
	8pm - 7am	15.55	12.00
Bethesda	7am - 4pm	16.53	12.40
	4pm - 8pm	18.25	13.70
	8pm - 7am	28.04	20.80
Corwen	7am - 4pm	18.25	13.00
	4pm - 8pm	28.04	13.00
	8pm - 7am	16.53	13.00
Machynlleth	7am - 4pm	18.25	10.00
	4pm - 8pm	28.04	14.00
	8pm - 7am	16.53	18.00
Roupell Park	7am - 4pm	24.43	6.30
	4pm - 8pm	24.43	6.30
	8pm - 7am	24.43	6.30

Local organisations' role

Energy Local recommends that there is a membership organisation or contractual arrangement with the generators and demand sites to demonstrate who is included. Energy Local sponsor rules for this to be a cooperative. These provide a mechanism for negotiating prices and agreeing how power is shared out. If all sites are owned by the same legal entity this is not necessary, but it must be clearly stated which sites are within the complex site.

The process to develop a local electricity market

Define the area covered by a primary substation on the distribution network and identify suitable generation and demand.

Ensure that there is a reasonable chance of the demand matching a suitable percentage of the generation by modelling this half hour by half hour. The percentage required depends on the price agreed. In general Energy Local aims to ensure around at least a **15% benefit for both sides**, however if the demand and generation is owned by the same organisation, all the benefit can be assigned to the demand or generation (e.g. the price for local power could be set to zero).

If all the demand is not owned by one organisation, those leading in setting up the local market must recruit sufficient demand customers. It is important that they record suitable consents and that tariffs and arrangements are explained to people clearly. Where a local market is open to all in a particular area it is important that everyone is given the chance to participate.

Once sufficient customers give an expression of interest they will need to switch suppliers. They are required to be provided with a new estimated annual cost and asked for consent to have their half-hourly data used. For domestic customers this is also a good point to gather data on who needs to be on the priority services register. The process of gathering the data and sending it to the supplier varies.

Energy Local provides a training programme, toolkit and online software for this process.

Note that for a local authority the situation is a little different as they are creating a local market within their own assets (unless they are providing power to other organisations). The price of the power can be zero and all the benefit can come from reduced electricity bills. They do not need to go through a consumer recruitment process in this scenario

Outlook for Power Purchase Agreements and maximising value

Electricity market context for small generators

Generation must try to get the best price it can within the context of the electricity market.

Power is traded up to half an hour before real time (up to ‘gate closure’). Suppliers buy power up to 2 years beforehand in blocks of 24 hours or 7 to 7 during weekdays as well as individual contracts with generators. Large generators sell into ‘Central Volume Allocation’ (CVA). Small generators up to 50MW are included in the ‘Supplier Volume Allocation’ (SVA) and are essentially regarded as negative demand. After gate closure the Electricity Systems Operator takes over to balance the system to ensure there is the exact amount of power and demand second by second. The contracts with generators and load required to balance the systems are paid for by ‘imbalance penalties’ when suppliers have bought not enough or too much power.

How contracts (Power Purchase Agreements - PPA) are calculated for generators for their power a year or a few months ahead of gate closure is key to how they receive income, so understanding how the power for a PPA is valued is important.

PPAs and how they are calculated

Whilst there are numerous means to sell power for large generators, for smaller generators, if they sell into the national market they sell on a fixed price Power Purchase Agreement (PPA) with a licensed supplier, normally for a year but it can be for up to three years. Forecasts for power prices do not extend further than 3 years and therefore this is generally the limit for a competitive PPA. There are options to have summer and winter prices or day and night prices within a PPA. It is also possible to have a PPA that tracks the spot price (price paid for power in the last half hour before gate closure). The PPA is the standard means for a generator to receive an income. Generators may also sell power ‘behind the meter’ but if they are exporting they should have a PPA.

The value of power depends on the time of day and time of year. We use more power in winter and during the day and therefore prices during the winter and day are higher. The value of different generators’ output is different. Predictable, reliable power has a higher value than less predictable power as the supplier will be able to forecast how much more power they will need to buy to match the demand of the customers. Hydro and wind that generally operate more in the winter or in the case of wind during the evening has a higher value than south facing solar that has highest output during the middle of the day and in the summer when demand is lower. Solar on buildings is generally of less value if the load that uses the solar before export (i.e. ‘behind the meter’) uses power at the most valuable times.

For very small scale generation such as rooftop solar it is possible to have a Smart Export Guarantee (SEG). These are generally credited to a supply contract. Some of these are still ‘deemed’ i.e. it is assumed that a percentage of the total is exported rather than metering the export.

The number of suppliers offering contracts to small scale generation other than SEGs has reduced since the energy crisis. The main suppliers offering contracts for small generators are OVO, Octopus, Good Energy, 100Green. EDF also appears to offer them for portfolios of small generators.

The level of detail that suppliers use when calculating a price for a PPA for a particular site varies. Some suppliers have one price per technology, calculated each day, others consider a year's worth of data and the overall reliability of the generator. These elements of risk (or lack of it) will be built into the price. Some will use granular forecasts for different times of day and year whilst others will use a single overall forecast.

Increasing the power that will be exported during the morning and evening peak will make generation more valuable. Likewise a battery will also help smooth power and provide a more reliable output at more advantageous times of day.

Difference in value due to time of day and time of the year

The value of power varies during the day and between winter and summer. This will be smoothed out to a fixed price (or fixed day and night, summer and winter). A supplier will take into account the forecast difference in prices and the probability that a generator will be operating at different times. Those that carry out a more detailed calculation will also take into account the risk of the generator not operating at all and its performance to date if known.

Difference between peak and off-peak prices, hedging and seasonal prices, and impact on PPAs.

Prices for power vary each half hour and depend on whether the power is bought in advance (hedging). It is important to have a mean to evaluate the variation in price to understand how a generator can gain more value. The 'System Buy Price' is a good proxy for the variation in power over the day if bought the half hour before gate closure.

This is particularly relevant for BWCE as they are considering using solar panels that produce power from both sides and erecting them vertically east-west (see page 52). These produce more in the morning and evening than during the middle of the day.

We analysed the 'System Buy Price' for spot prices over the last 8 years as a proxy for the value for power at different times of day.[9]

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[9] Market Domain Data ELEXON Portal, www.elexonportal.co.uk/mddviewer

Solar will not be operating during the night and therefore night prices are not relevant to it.

For each of the 8 years, the ratio of average peak (4pm-8pm) to the average for the rest of the 24 hours, and the ratio of average peaks to average daytime (8am to 8pm) was calculated. This was calculated for the whole year and during the summer (April-September). This should give an indication of the additional value of peak prices. The maximum peak price for the year was also identified. The results were not conclusive. On average the peak price to the rest of the day was about 12% higher, peak to daytime in summer was 14% higher and 16% higher for the whole of the year. However, the ratios vary widely and if the maximum peak prices happen in summer (due for example to a large outage) then summer peak prices may be larger than winter prices.

Likewise, if maximum prices do not occur during peak times, then this reduces the ratio.

More power is required in winter than in summer; between 2016 and 2023, 43-46% of power was used in summer compared to 54-57% in winter.[10] The South facing solar arrangement would only produce 24% of its power in winter (unless constrained) and 23% for the East-West facing bi-facial (unless constrained)

[10] Historic Demand Data | ESO (nationalgrideso.com)

Table 10. Average peak and off peak and daytime prices seasonally and ratios. This shows the different in prices between times of average peak price and base load price for different seasons. The maximum prices are also shown in the right hand side.

		all year peak vs off peak £/MW	Ratio	summer, peak vs off peak £/MW	Ratio	all year peak vs day £/MW	Ratio	summer peak vs day £/MW	Ratio	max peak all year £/MW	max summer £/MW
2016/17	**Peak**	56.18		60.68		56.18		60.68			
	off peak or day	49.78	1.13	50.98	1.19	45.33	1.24	47.54	1.28	1011.32	1011.32
2017/18	**Peak**	56.91		54.00		56.91		54.00			
	off peak or day	57.22	0.99	55.58	0.97	49.08	1.16	47.35	1.14	1509.80	172.28
2018/2019	**Peak**	63.23		69.17		63.23		69.17			
	off peak or day	67.71	0.93	74.16	0.93	56.92	1.11	62.33	1.11	191.37	191.37
2019/2020	**peak**	46.05		45.17		46.05		45.17			
	off peak or day	44.57	1.03	45.83	0.99	38.40	1.20	39.79	1.14	2242.31	160.00
2020/2021	**peak**	56.95		56.04		56.95		56.04			
	off peak or day	37.27	1.53	36.65	1.53	50.05	1.14	50.58	1.11	4000.00	849.82
2021/2022	**peak**	183.25		193.13		183.25		193.13			
	off peak or day	131.64	1.39	141.64	1.36	169.32	1.08	184.19	1.05	4037.80	4037.80
2022/2023	**peak**	217.01		264.74		217.01		264.74			
	off peak or day	221.61	0.98	273.20	0.97	187.11	1.16	232.28	1.14	1950.00	979.00
2023/2024	**peak**	91.50		96.26		91.50		96.26			
	off peak or day	94.36	0.97	96.31	1.00	78.16	1.17	80.67	1.19	300.00	300.00
Average ratio over the 8 years			1.12		1.12		1.16		1.14		

Whilst this analysis (Table 10) showed a trend of a small uplift for peak prices and higher prices during the day, the variability from year to year made the results inconclusive. A supplier is likely to use estimates for the next 1-3 years in providing a PPA price, taking into account the factors highlighted above. It may be that from a risk and credit point of view, to a supplier, there is more value in peak generation than this analysis would suggest but this is hard to quantify further. It also highlights that the need from a network point of view to have more embedded generation at peak times is not sufficiently highlighted in supplier price signals.

Domestic users increase demand when the weather is cold and windy (even if they have gas heating!) and reduce it when hot. This also devalues solar power. Overall, only 10.3% of the South facing solar will be produced during peak periods (4pm-8pm) and **14.6%** for east west facing bifacial. **This increases the value of the bifacial panels slightly** compared to conventional panels. Note there is not a significant consistent change in price in the early morning when east-west solar arrangement produces more power however there is some increase in usage.

Pricing by a Supplier for South facing and East West facing vertical bifacial solar.

One supplier built a model to show the benefits in terms of PPA price of vertical East West facing bifacial versus south facing standard solar panels. This gave a **7% uplift in fixed PPA price in total**, however half of this was due to benefits in terms of embedded benefits (i.e. an offset in Distribution Use of System charge for generation connected to the distribution network). The standard approach by another supplier was to use day and night blocks of pricing to calculate PPA prices that showed little impact but said that if more granular blocks were used there could be an uplift of 3-4% (this would need to be requested when quoting). Another did not seem to have a mechanism to evaluate new generation curves. Few other suppliers are offering PPA for small scale generation and others contacted did not respond. The market therefore would be likely to be limited initially.

Note: In comparisons of the selling power under a PPA and using a 'complex site' we have used a fixed PPA price across all the technologies and arrangements. Variations in price in both supply and generation tariff are too small to model until all prices are fixed for a particular scenario.

Use of a battery

Storage is increasingly being used to offset peak supply prices and/or higher usage times where solar is installed on roofs, or to allow greater generation capacity to be installed where a connection is subject to a constraint. The difference in price of a standard PPA would not be enough in itself to justify the additional cost of a battery.

Difference in peak and off peak for PPAs and supply tariffs.

From discussions with 100Green, if the true difference between the off peak and peak pricing for a demand customer were to be passed on to the demand customer, it would be at a ratio of about 5. This analysis shows that very little of this difference is represented in a fixed price contract for a small generator, regardless of when it generates, so **the difference between peak and off peak consumer pricing is due to other costs, such as costs to the network, balancing costs or of the risk of imbalance at peak times to the supplier.** A wind turbine is more likely to operate in the evening when more power is required than during the day so could be viewed more favourably in terms of price than solar but is likely to risk imbalance as it is intermittent which reduces the price offered. As a result, the difference in value to the supplier of power generated during peak vs off peak times has little impact on the price offered in a PPA for most technologies. The PPA price itself does not provide enough incentive to encourage different generation arrangements that would use the network more efficiently, such as the use of batteries. However, a local electricity market could be a means to benefit the network and gain some additional benefit to the supplier by shifting power use away from peak times whilst balancing consumption with local generation will reduce risk of imbalance for the supplier.

Complex site – PPA for power not used within it

A supplier will still need to provide a PPA for power not used within the ‘complex site’ (referred to as “spill”). The PPA price may be set in different ways and may be slightly poorer than the best in market. One supplier withheld embedded benefits whilst another examined the likely spill from the ‘complex site’ and valued the generation accordingly. If the spill is when demand is lower, the price of the PPA would be lower than the best in market.

Impact on managing constraints and liaison with DNOs

An increasing problem in the distribution and transmission network is that the network is overloaded either because of too much generation flowing upwards through the network or too great a demand for power. These two problems can occur at different times of the day on the same piece of the network. Referred to as constraints, the source can be due to a number of different reasons:

- Too great a voltage rise or fall. The voltage must be kept within an envelope of statutory limits, generation pushes the voltage up and demand pulls it down.

- The network has reached its thermal limit – i.e. it cannot carry any more power safely.
- The fault level is breached. When a fault occurs, the different components in the network and the protection must withstand a sudden rise in current. Generation contributes to the fault current level, if there is too much generation such that the potential fault current increase is too great it may breach the rated value that the network can withstand.

Local balancing can reduce both the power flowing up the network and the amount of power drawn down and thus can help to alleviate the first two issues, but it cannot contribute to the third.

Using a complex site, generation can be netted off against demand, this encourages balancing load against generation. This would mean that additional generation could potentially be used by local demand before a constraint, and therefore would not affect a constraint (if it is export only). This is a market led approach rather than DNO led and there is more value to the customer. Note that this is making better use of a constrained or non-firm connection. These non-firm connection offers are cheaper but generators could lose income when they are constrained off, the local electricity market helps mitigate this risk.

The points below came from a discussion with NGED of how a 'complex site' could potentially be used to allow generation to connect where there is a constraint. Alternatively, smoothing load in general to pre-emptively encourage the right behaviour to avoid constraints could be built into planning in future.

As DNOs look to harness flexibility, a local electricity market could be advantageous. There is more value to the customer in a 'complex site' arrangement than in a flexibility contract.

NGED have 'Active Network Management (ANM) Zones' where NGED may constrain the output from a generator when required. In an ANM zone at present NGED will subject new generation to potential constraint even if is on an existing generation connection with sufficient capacity, as the new generation will lose the diversity with which it was planned initially.

If a new load and generation are located under a constraint and the application is:

- made together,
- by the same organisation, and
- there is sufficient control to ensure that the demand balances the generation (or trips if this fails),

then this could be considered similar to a G100 connection. For example, where a new load and generation are co-located, the generation won't be subject to a potential constraint as long as a G100 control ensures it cannot breach an export limit, i.e. there is sufficient storage, load or the generation can be controlled to prevent excess export. However, there are rules about 'over planting' so that the capacity that can be connected is still limited. If there are 2 technologies they could be connected through 2 inverters but the export limiters on the 2 inverters must be coordinated and there needs to be one circuit breaker.

Where an upgrade to the network is required on the next voltage level up to the connection point for a new generator, the DNO has to give a timeframe for the work (under the Targeted charging review this cost was socialised across all users). A generator could connect with a potential constraint in this timeframe and use local balancing to ensure that it is not enacted. Likewise, if the upgrade is over the cost threshold and a generator could be subject to a constraint then they could use local balancing to avoid this.

From a DNO point of view, they could plan with the assumption that a 'complex site' will encourage enough local balancing, procuring flexibility from particular loads, and if this does not work upgrade the network as a last resort.

We have real time data from smart meters and we can also monitor the impact of a 'complex site' to encourage local balancing so that this can be considered within planning.

If there was a constrained connection, the constraint measurement could be at the point of constraint not at the point of common coupling. In the case of ANM arrangements, at present these tend to ensure that in the event of a N-1 (a standard to measure the size and impact of large faults) situation the network remains within statutory limits. These could be also used to avoid reverse power flow/voltage rise, or too much reverse power flow/voltage rise. If there was insufficient demand to prevent voltage rise above statutory limits or too great a reverse power flow it would be the generator that would need to turn down or switch off. The DNO would not need a contract with the load, this could just be an arrangement between the generator and load to match to prevent reverse power flow or voltage rise.

Constraint systems send a message to reduce power, if this does not happen it sends a message to switch off or a control engineer can trip it if necessary. NGED don't normally use active network management as described above for generators below 250kW.

NGED's policy is that for existing customers with generation connections (i.e. customers whose primary activity is the generation and sale of electricity), the connection agreement is for the generation profile agreed when they were connected. That is they should not add more generation that changes their export profile even if it does not breach the maximum export limit as this may cause other generators to be constrained. For example, adding a wind turbine to a solar installation may not increase the maximum export but it would change when maximum export occurred. Therefore any new installed generation capacity will consider the need for curtailment. This will not change with a 'complex site' but it can help avoid the curtailment being enacted.

In contrast existing customers with demand connections (i.e. customers whose primary activity involves the purchase and consumption of electricity) should be free to alter their usage profile within existing agreed capacity limits. They shouldn't be required to import power where demand can be met (fully or partially) by on-site generation, therefore only new export capacity will be considered when determining the need for curtailment. This is also why, to prevent a constraint, the generator would need to have a contractual arrangement with local demand rather than this being managed by the DNO.

Conversations with SSE distribution indicated that they were very interested in the concept of the 'social contract' of local balancing to prevent or help alleviate constraints on the network. That is, rather than a flexibility contract that involves bidding for particular times of day and amounts of load, the benefit of a local market is that is encourages the right behaviour and the idea of cooperation. They are interested in investigating the impact on a network that is not constrained initially.

Transmission constraints

There is a blanket ban on connection above 1MW for all distribution network connections due to transmission constraints in much of the South West, unless there has been a network study on the impact of the power flow at the Grid Supply Point (GSP) feeding the area. The GSP is the point where the distribution network is joined to the transmission network. This is for all connections of more than 1MVA of capacity not export. Network studies at the GSP will look at reverse power flow and fault level contribution.

In this case the operation is taken across a whole GSP even if power was matched locally, as a 'last on, first off' arrangement is used (i.e. the last generator to connect is the first one to be constrained or disconnected). This means that even if the generator is not exporting past its distribution or primary transformer it will still be tripped off first if 'last on'. There is no mechanism to take into account or reward local balancing that if carried out at scale could help mitigate issues at transmission level.

We have found it difficult to speak to NationalGrid directly regarding this both in this project and other projects. This makes it difficult to discuss alternative approaches but also understand the nature of the constraint.

Relevant network innovation projects

- SP Energy Networks (The DNO in North Wales, Merseyside and South Scotland) carried out a project with Energy Local studying the impact of local balancing via a local electricity market Bethesda Home Hub | ENA Innovation Portal (energynetworks.org).
- Pioneer Places Breaking Barriers to Net Zero in Bethesda and Blaenau Ffestiniog studies the increased viability of a whole systems approach to providing energy service and the role of a local electricity market in making this approach viable and subsidy free.
- A new project 'Community DSO' under Northern Power Grid is yet to start but aims to investigate the benefits of local balancing at the scale of a distribution transformer (i.e. 500 homes or less).

Energy Networks Association

All of the projects that are registered on the Energy Network Association site that focus on constraints and flexibility focus on either technical solutions, flexibility markets or the rearranging 'stacks' of who is turned off first in Active Network Management systems. This is also reflected in their strategy document and work through 'Open Networks'. There is no focus on how the supply market can support the distribution networks.

Suppliers providing the service and implications of P441

P441 is a proposed modification to the Balancing and Settlement Code that governs how power is bought and sold.

P441 aims to strengthen the regulatory position of when a 'complex site' can be used to net off local generation against demand. This should encourage other suppliers to provide the service as there is less risk to them investing in adapting their services to support complex sites.

We are currently in discussions with Ofgem and Elexon as to how they can monitor the impact over time rather than simply sign off a change to the balancing and settlement code. Two additional suppliers are currently considering offering the service and another is interested. Two of those on the LASER framework have indicated that they see no reason why they would not provide the service if P441 is adopted.

Case Studies

Two case studies, one for a local authority and one for Bath and West Community Energy, show how the economics improve for renewable generation but also benefit households or the costs for a local authority. This is true for solar or wind and solar combinations.

SECTION 2 – SCENARIOS FOR BWCE

Solar Only

South facing versus East West bi facial solar arrays with constraint – benefits of a local market.

Bath and West Community Energy have a site that they would like to develop as a solar farm. To improve the overall output profile to one that is more valuable (see graphs below for illustration), they are considering

- standard south facing panels
- standard panels with half east facing and half west facing.
- Bi-facial vertically mounted panels with the panels facing east west.

The following graphs give an estimate of the outputs from the different arrangements which demonstrates why there may be value in adopting a different panels arrangement. These were generated via a model developed by Energy Local. This can generate half hourly output for different orientations and angles of solar panels. The vertical east west bifacial solar panels were modelled using a combination of a weighted sum of output of east, west and south facing solar panels. The results were compared to recorded results. The output from the east/west bifacial vertical depends on their spacing and the reflectivity of the ground which affects the output in the middle of the day. The work above shows that there could be more value with greater output in the evening and this would match domestic customers habits within a complex site. In each case the MW peak capacity is about 1.1MW – how to compare the peak capacity of bifacial panels with standard panels is uncertain.

Figure 2 to Figure 4 show the east west orientated panels have little additional value in their output and the annual output is less, therefore this was not pursued.

Figure 2. Estimated outputs from South facing panels

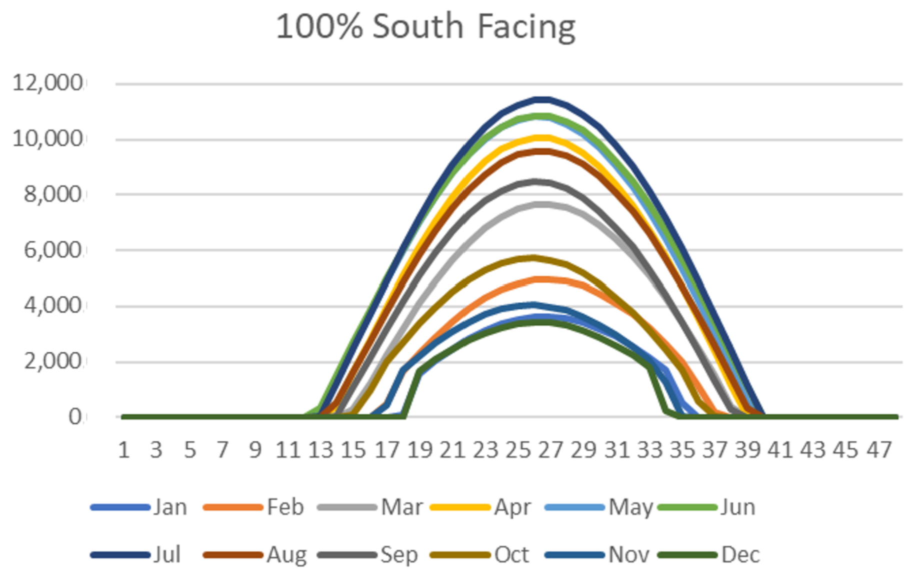


Figure 3. Estimated outputs from East and West facing panels

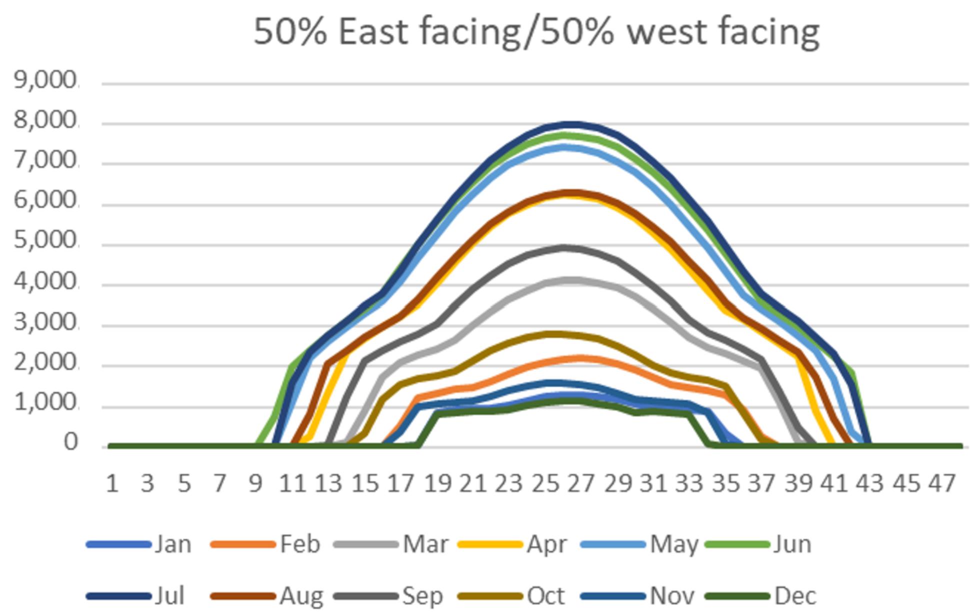
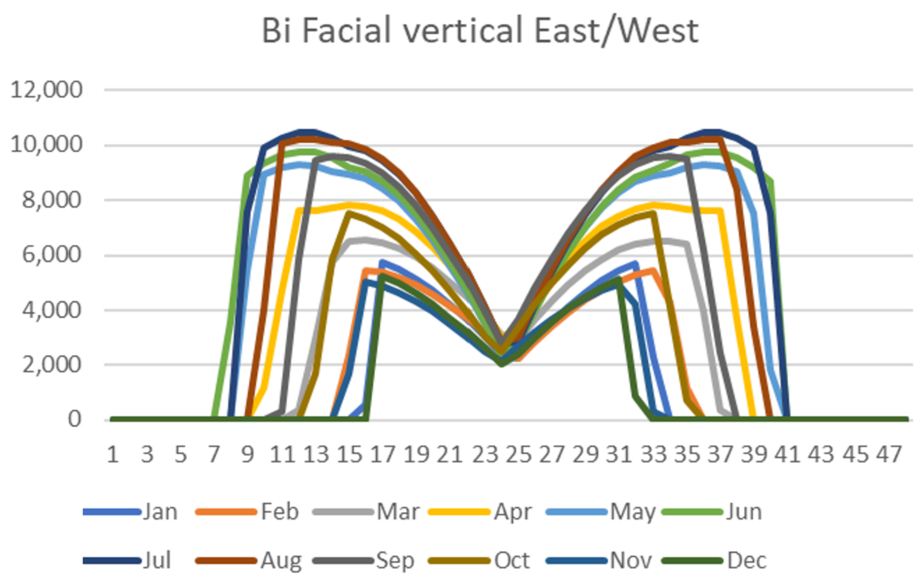


Figure 4. Estimated outputs from vertical bifacial panels



Modelling

The standard south facing and east-west facing bifacial vertical were modelled[11] in order to compare the benefits of a 'complex site' with different numbers of homes to receiving a standard PPA and different solar panels. For the available space, the kWp capacity with south facing panels was 1.18MW and 1.09MW with the bifacial vertical panels as these panels require greater separation.

Assumptions

The Default Period Profile Class Coefficients issued by Elexon are used to estimate the domestic profile[12]. This gives the average percentage of the total annual usage used in each half hour of the year for an average household.[12]

As tariffs are falling from an all-time high, the model uses a conservative estimate of 25p/kWh for the flat tariff that is used for comparison to savings expected in a complex site. 100Green is the supplier we are using at present.

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[11] Note that BWCE preferred the output from PVsol that gives hourly value to be used in the modelling as it is used by many in the industry. This gives less granularity. The curve produced for vertical bifacial east west facing solar is slightly different to that in academic papers, however there is no information on the ground surface assumed. As reflections are significant this will make a difference to the curve, however there is insufficient data to know which is the most accurate.

[12] ELEXON Portal spreadsheet of period default coefficients available for download from this website with login, www.elexonportal.co.uk/mddviewer

In general, their prices are higher than the cheapest in market because they buy 100% renewable power each half hour. For the power that they sell into the complex site, a Time of Use Tariff (TOUT) has been used. Costs shown include the estimated standing charge. Assuming that households do not shift their power to different times of day compared to the average daily demand profile, the flat tariff is 17% cheaper than the TOUT with no generation. For comparison a more 'standard supplier' TOUT was also modelled that was 16% cheaper compared to 25p/kWh flat rate.

The generator owner will have a Power Purchase Agreement (PPA) which pays for the exported electricity from a complex site. This is the remaining electricity not used within the complex site. We have used 7.5p/kWh for standard PPA (without a complex site) and 7p/kWh as the exported PPA rate with Energy Local (as the export from a 'complex site' is likely to be of slightly less value that for all the generation). We have not differentiated between technologies.

We have used an average of 2,700 kWh per annum for standard household consumption as the area is fairly affluent but environmentally aware. All prices are exclusive of VAT.

The Match Price is the unit rate agreed in the 'complex site' for the electricity used when it is generated locally. This is the price for the members within the complex site, and also the price that the generator would receive.

We have applied the following tariffs to each scenario (Table 11 and Table 12). We have used a 'standard supplier' Time of Use Tariff (TOUT) and a 'deep green' TOUT to demonstrate the difference in benefit between a (more expensive) 'deep green' tariff and a 'standard supplier' TOUT. A TOUT varies in price during the day in time blocks. 'Standard supplier' TOUT scenarios are modelled with a variable match (i.e. it is always 70% of the Time of Use tariff) and 'deep green' with a flat match (same during the whole of the day), as these scenarios produced the most advantageous outcomes. It was more beneficial to have a flat rate with 'deep green' as they do not have a peak rate in the time of use tariff at the weekend.

The flat tariff is from experience 'a happy medium' that gives a reasonable percentage benefit to both the generator and the demand customers but could be adjusted.

Table 11. Examples of Match Tariffs for the different times of day, as compared to the 'deep green' TOUT

Time	TOUT	Flat Match	Variable Match
12am – 7am	19p/kWh	12p/kWh	7.6 p/kWh
7am – 4pm	32p/kWh	12 p/kWh	12.8 p/kWh
4pm – 8pm	40p/kWh	12p/kWh	16 p/kWh
8pm – 12am	32 p/kWh	12 p/kWh	12.8 p/kWh
Weekend 7am – 8pm*	32p/kWh	12 p/kWh	12.8 p/kWh

*No peak time at the weekend.

Standing charge 65p/day.

Table 12. Examples of Match Tariff for the different times of day, as compared to the 'Standard supplier' TOUT.

Time	TOUT	Variable Match
8pm – 7am	16 p/kWh	11.2 p/kWh
7am – 4pm	16.9 p/kWh	11.8 p/kWh
4pm – 8pm	29.5 p/kWh	20.7 p/kWh

Standing charge 69p/day.

If the generation is connected at low voltage the maximum export is 650kW although up to 1MW capacity can be connected (above 1MW is difficult to connect due to constraints at transmission without a network study). Therefore, we have modelled the scenario of connecting up to 1MW connected at 11kV (i.e. unrestricted) and at LV with a 650kW export limit.

Note no demand shifting is assumed so this is 'worst case' for matching power and demand.

South Facing Scenario

Single Household

This scenario shows the maximum benefit to one household i.e. if they were the 1 member of the complex site. The household benefit (the difference between a flat tariff and the cost within a complex site) is not predicted to go beyond 14% in this scenario even if they had access to all the available power (Table 13):

Table 13. 1 household with maximum access to local power.

	No Complex Site	**With Complex Site**	**Benefit £**	**Benefit %**
'Deep Green'	£927	£801	£126	14%
'Standard	£927	£699	£228	25%

If there was 1 household in the 'complex site' in this scenario, local generation would account for 50% of their total demand and 0.11% of local power would be used. Obviously, this has little benefit to the generator.

The benefit is the same regardless of whether the export is restricted.

Multiple household scenarios

The Table 14 shows the results of different scenarios:

- minimum number of households needed in the 'complex site' to create benefit to provide at least a 7% benefit to the generator
- Maximum number of households such that each at least obtains a 7% benefit on average
- Number of households to give an approximate equal percentage benefit to households and the generator

These were modelled for both tariffs.

An 'Equal Benefits' scenario was also modelled where the match tariff was 50% of the standard price.

Table 14. Modelling results with the South Facing Unrestricted Scenario. Figures show costs and benefits per year.

		No 'complex site' £	With 'complex site' £	Benefit £	Benefit %	No. of households	% generation used	% of total demand
Minimum size 'Deep Green'	**Households**	927	854	73	8	220		41
	Generator	90,606	96,834	6,228	7		20	
Minimum size 'Standard tariff'	**Households**	927	713	214	23	160		43
	Generator	90,606	96,713	6,107	7		15	
Maximum size 'Deep Green'	**Households**	927	865	61	7	300		39
	Generator	90,606	100,472	9,866	11		26	
Maximum size 'Standard tariff'	**Households**	927	758	169	18	5000		15
	Generator	90,606	153,632	63,026	70		99	
Equal benefits	**Households**	927	743	184	20	750		72
	Generator	90,606	110,155	19,548	22		49	

The Deep Green tariff sees a range in 'complex site' size between 220 – 300 households, with benefits to households ranging from £61 - £73 and benefits to the generator ranging from £6,228 - £9,886.

The Standard Tariff sees a range in size between 160 – 5000, with benefits to households ranging from £169 - £214 and benefits to the generator ranging from £6,107 - £63,026.

South Facing Restricted Scenario

The same process was carried out for the scenario where the export is restricted to 650kW (Table 15). The maximum benefit to one household remains the same.

Table 15. Modelling results with the South Facing Restricted Scenario.

		No 'complex site' £	With 'complex site' £	Benefit £	Benefit %	Number of households	% generation used	% of total demand
Minimum size 'Deep Green'	Households	927	851	76	8	200		42
	Generator	82,801	£88,582	5,781	7		20	
Minimum size 'Standard tariff'	Households	927	712	215	23	150		43
	Generator	82,801	88,770	5,969	7		15	
Maximum size 'Deep Green'	Households	927	865	61	7	300		39
	Generator	82,801	93,188	10,386	13		26	
Maximum size 'Standard tariff'	Households	927	752	175	19	2200		18
	Generator	82,801	141,276	58,474	71		99	
Equal benefits	Households	927	734	193	21	2200		18
	Generator	82,801	101,303	18,502	22		99	

The Deep Green tariff has a range in member size of 200–300 households, with household benefit ranging from £61-£76 and generator benefits ranging from £5,781-£10,386.

The Standard Tariff ranges from 150 – 2200 households, with household benefit from £175-£215 and generator benefits from £5,969-58,474.

Vertical Bifacial Unrestricted Scenario

The process was repeated with the vertical bifacial panels.

Single household example

The table below shows the maximum possible benefit if there were only 1 household. This is 13%, presumably due to less output during the winter especially at peak time.

Table 16. Optimal scenario for 1 household with maximum access to local power.

	No 'complex site'	**With 'complex site'**	**Benefit/£**	**Benefit/%**
'Deep Green'	£927	£806	£121	13%
'Standard'	£927	£701	£226	24%

If there was 1 household in the 'complex site' in this scenario, local generation would account for 50% of their total demand and 0.12% of local power would be used.

Multiple household scenarios

The Table 17 shows the Deep Green tariff to be feasible with a 'complex site' size between 190 – 380 households. This is estimated to create household benefits ranging from £69 - £88, while benefits to the generator range from £5,644 - £14,612.

By comparison, the Standard Tariff makes it feasible to have a member size ranging from 140 – 2,500. This is estimated to create benefits to households ranging between £173 - £218 and benefits to the generator ranging between £5,686 - 66,214.

An equal benefit scenario with the Standard Tariff would have 2,500 member households and it is predicted this would save households £190 annually and increase generator revenue by £23,667.

Table 17. Modelling results for the Vertical Bifacial Unrestricted Scenario with a complex site

		No 'complex site' £	With 'complex site' £	Benefit £	Benefit %	Number of households	% generation used	% of total demand
Minimum size 'Deep Green'	Households	927	839	88	10	190		44
	Generator	84,157	89,802	5,644	7		20	
Minimum size 'Standard tariff'	Households	927	709	218	24	140		45
	Generator	84,157	89,844	5,686	7		15	
Maximum size 'Deep Green'	Households	927	858	69	7	380		41
	Generator	84,157	98,769	14,612	17		36	
Maximum size 'Standard tariff'	Households	927	754	173	19	2500		16
	Generator	84,157	150,371	66,214	79		99	
Equal benefits	Households	927	737	190	21	2500		16
	Generator	84,157	107,824	£23,667	28		99	

Vertical Bifacial Restricted

The impact on the export from the vertical Bifacial with a constrained export is small. The maximum benefit to one household is the same with or without a constrained export. The scenarios are in Table 18.

Table 18. Modelling results for the Vertical Bifacial Restricted Scenario with a complex site.

		No 'complex site' £	With 'complex site' £	Benefit £	Benefit %	Number of households	% generation used	% of total demand

Minimum size 'Deep Green'	Households	927	839	88	10	190		44
	Generator	84,157	98,557	15,114	18		20	
Minimum size 'Standard tariff'	Households	927	708	218	24	140		45
	Generator	84,157	89,844	5,687	7		15	
Maximum size 'Deep Green'	Households	927	859	68	7	380		41
	Generator	84,157	98,557	15,114	18		36	
Maximum size 'Standard tariff'	Households	927	754	173	19	2500		16
	Generator	84,157	150,520	66,363	79		99	
Equal benefits	Households	927	737	199	21	2000		20
	Generator	84,157	107,824	22,919	27		97	

Table 18 shows the Deep Green tariff to be feasible with a 'complex site' member size between 190 – 380 households. This is the same as the unrestricted scenario. The household benefit is expected to be £69 and generator benefit is expected to be approximately £15,114.

By comparison, the Standard Tariff is estimated to be feasible with a size between 140 – 2,500. This is the same range as the unrestricted scenario. Household benefit is expected between £173 - £218 while generator benefit is expected between £5,687 - 66,363.

Summary

The exact numbers are in the tables above. To summarise, the different scenarios, in terms of solar panel orientation or grid constraints, do not make a large difference to the benefit to households, a matter of a few pounds, which is statistically insignificant. The main difference in income is what can be exported over and above this from selling to a supplier. However, the model does not take into account demand shifting that will be more practical with the vertically bifacial option and therefore the income from the 'complex site' could be greater.

The maximum households possible within the 'complex site' reduces with a constraint imposed and this reduces the maximum amount that the generator can earn by recruiting more households. However, this scenario with maximum number of households is much less attractive to householders as they receive less benefit and therefore it is unlikely to occur.

Financial results

Using the results above, four models have been created to show how the generation can be financed by income from the complex site. Capex and Opex were provided by BWCE however, the Capex for vertical Bi-facial solar panels is uncertain as the mounting and installation would need to be designed. This includes operating costs for a complex site. The income includes that from a complex site. The 'deep green' TOUT has been used as this is what is definitely available at present, and the solar farm could be built in the next year.

1. South facing Standard PV Installation rated at 1,179 kWp with no export restrictions.
2. South facing Standard PV Installation rated at 1,179 kWp with an export restriction of 650 kW.
3. Bi-facial PV Installation rated at 1,087 kWp with no export restrictions.
4. Bi-facial PV installation rated at 1,087 kWp with an export restriction of 650kW.

Table 19. Headline Model Variables

Model	No. households Min Size	No. households Max Size	No. households Median	CAPEX	Annual OPEX
South – Unrestricted	220	300	260	£1,270,962	£34,045
South – Restricted	200	300	250	£1,270,962	£34,045
Bi-Facial – Unrestricted	190	380	285	£1,269,800	£31,388
Bi-Facial – Restricted	190	380	285	£1,269,800	£31,388

Capital Costs

NREL[13] breaks down CAPEX on commercial sized PV installs (not including network connection) as follows.

Item	£/Wp	
Inverters	£0.04	4%
BoS Equipment	£0.29	30%
Labour	£0.13	13%
Installation Overhead	£0.23	23%
Modules	£0.29	30%
Total[14]	£0.98	

A study in Nature 2023[15] puts the cost/W of vertical bifacial at £1.2/w vs £0.90 for tilted mono-facial panels. This indicates that the initial estimate of the vertical panels is broadly in line with current market prices and the finances described are valid. However, tilted south facing panels could be an overestimate and could be reduced to around £1.12m from £1.27m for 1,177kWp.

Operational Costs

As per studies cited above there is very little difference in OpEx between Vertical and Tilted panels. The main change is a reduction in cleaning costs for vertical panels vs tilted as vertical panels require less cleaning. However, this cost has a negligible effect on the overall OpEx. Online estimates[16] show panel cleaning costs ~50p per panel at ground level.

BWCE Estimates OpEx as

	Tilted	Bifacial
Rent	£6,613	£6,097
Ops & maintenance, inc reserve	£7,958	£7,337
Import electricity and comms	£3,134	£2,890
Insurance and audit	£2,977	£2,745
Asset management	£6,485	£5,979
Miscellaneous	£1,965	£1,812
BWCE Overhead	£4,913	£4,529

[13] https://atb.nrel.gov/electricity/2024/commercial_pv
[14] Grid connection costs are excluded.
[15] https://www.nature.com/articles/s41598-024-68018-1
[16] https://www.checkatrade.com/blog/cost-guides/solar-panel-cleaning-cost/

In addition to the above, the following assumptions have been used in the financial modelling from BWCE:

- Interest Rate – 5%
- 50/50 Debt/Equity Split
- 30 Year Loan Term
- Capital Repayment begins in Year 4 and is amortised over the next 27 years (note this longer than standard financial calculations)
- No grants have been claimed

A median number of households have been assumed (i.e. between the maximum and minimum numbers calculated above). For example South facing Unrestricted 'complex site' size is modelled as (220 + 300)÷2=260 members.

The tables below show the following metrics for each scenario:

Total Project Cost:
Capex + 30 years of Annual OpEx + 30y of Annual Interest and Capital Repayments

Total Project Profit:
30 years of Annual Gross Profits

Return on Investment (RoI):
(Total Profit – Total Costs)/Total Profit * 100

Debt Coverage Ratio:
PBIT/(Capital Repayments + Interest Payments) * 100. The lowest figure over the 30y project life is used. This ratio shows how much headroom there is to make capital interest payments after Operating Costs are accounted for. The closer to 100% the more exposed the project is to interest rate rises. Anything below 100% means the company does not have enough PBIT to cover its debt obligations.

IRR on PBT:
internal Rate of Return using Total Project Cost and 30 years of Profit Before Tax. The IRR on Equity will depend on how the projects Tax is calculated.

For completeness options without a complex site are included in Table 20. To show the improvement with a complex site. Table 21 shows the comparison of the bifacial options with a complex site to show how they compare (they are not viable without a complex site.

Table 20 Headline Financials Comparing Complex Sites with Non-Complex Sites

	Total Project Costs	Total Project Profit	RoI	Percent Debt	Loan Interest Rate	Debt Coverage Ratio	IRR on PBT
South Facing Unconstrained **Complex Site**	£3,467,940	£2,953,020	-15%	50%	5%	116%	-2.7%
South Facing Unconstrained **No complex site**	£3,467,940	£2,718,180	-22%	50%	5%	102%	-4.3%
South Facing Constrained **Complex Site**	£3,467,940	£2,714,700	-22%	50%	5%	102%	-4.3%
South Facing Constrained **No complex site**	£3,467,940	£2,318,430	-33%	50%	5%	78%	-8.1%

Table 21. Headline Financials for Complex Site using Bifacial solar panels.

	Total Project Costs	Total Project Profit	RoI	Percent Debt	Loan Interest Rate	Debt Coverage Ratio	IRR on PBT
Bi Facial East-West Facing Unconstrained **With Complex Site**	£3,386,006	£2,808,510	-17%	50%	5%	113%	-3.1%
Bi Facial East-West Facing Unconstrained **No Complex Site**	£3,386,006	£2,524,710	-25%	50%	5%	95%	-5.2%
Bi Facial East-West Facing Constrained **With Complex Site**	£3,386,006	£2,788,470	-18%	50%	5%	111%	-3%
Bi Facial East-West Facing Constrained **No Complex Site**	£3,386,006	£2,503,290	-26%	50%	5%	94%	-8.1%

Sensitivity analysis

For each scenario we show:

Debt Coverage vs % Debt

This shows how much headroom there is to make payments on the project's debt obligations. Any figure below 100% means the project does not have enough PBIT to pay its creditors

Sensitivity of Profit Before Tax (PBT) vs % Debt

This gives an idea of how much leverage a project could withstand and still remain profitable.

Sensitivity of PBT to Interest Rate

This shows how a change in interest rates will affect the profitability after Operations and Financing is taken into account.

Model 1: South facing Unconstrained

Figure 5. Debt Coverage vs % Debt in the South Facing Unconstrained Scenario

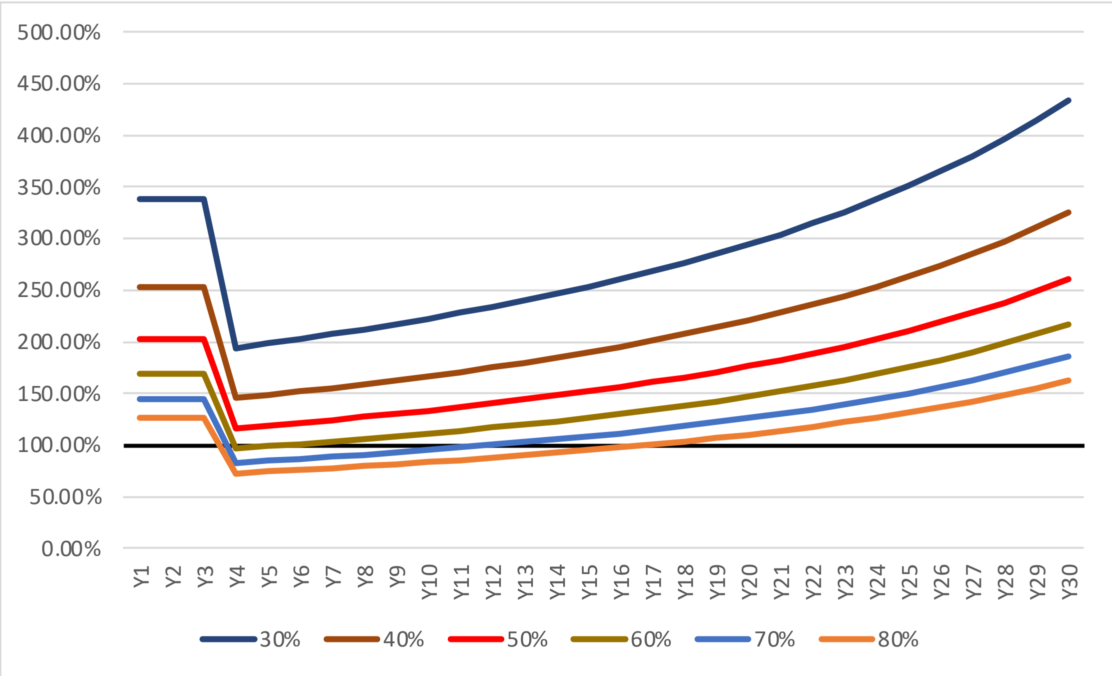


*Figure 6. As Above with **No Complex Site***

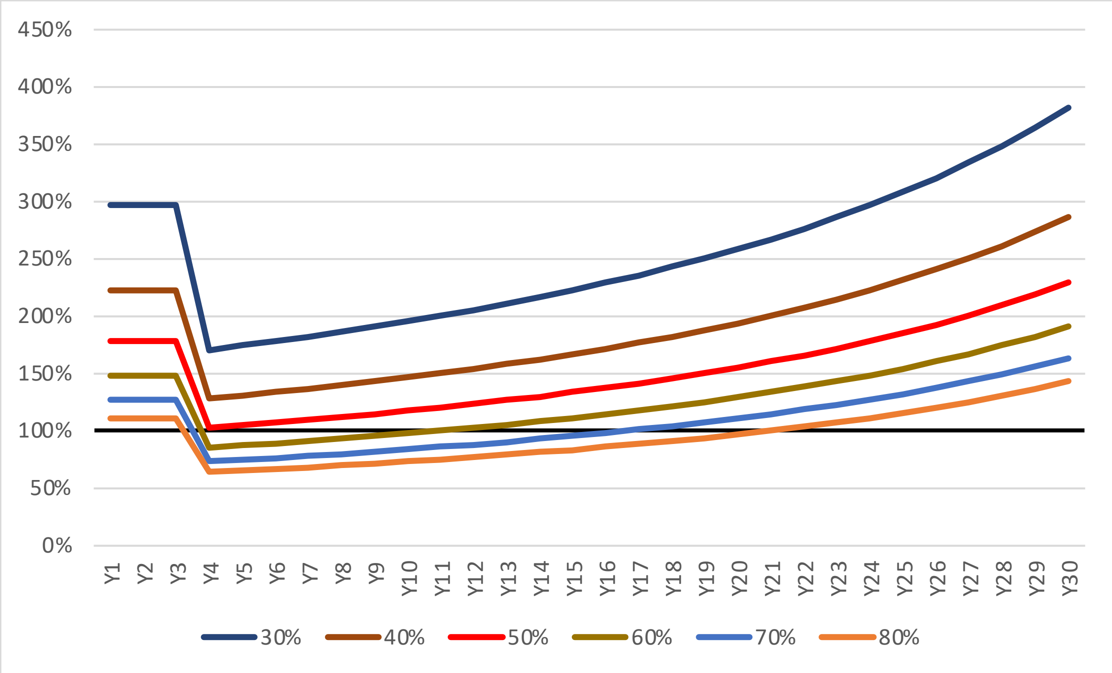


Figure 7. Sensitivity of PBT to % Debt in the South Facing Unconstrained Scenario

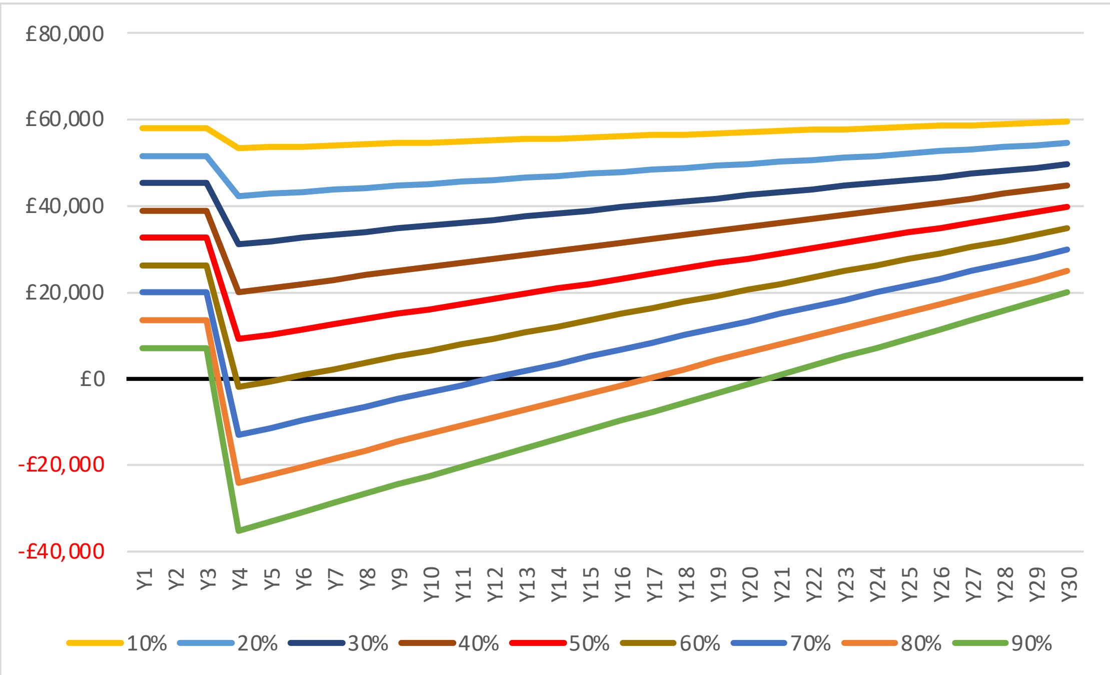


Figure 8. As Above with ***No Complex Site***

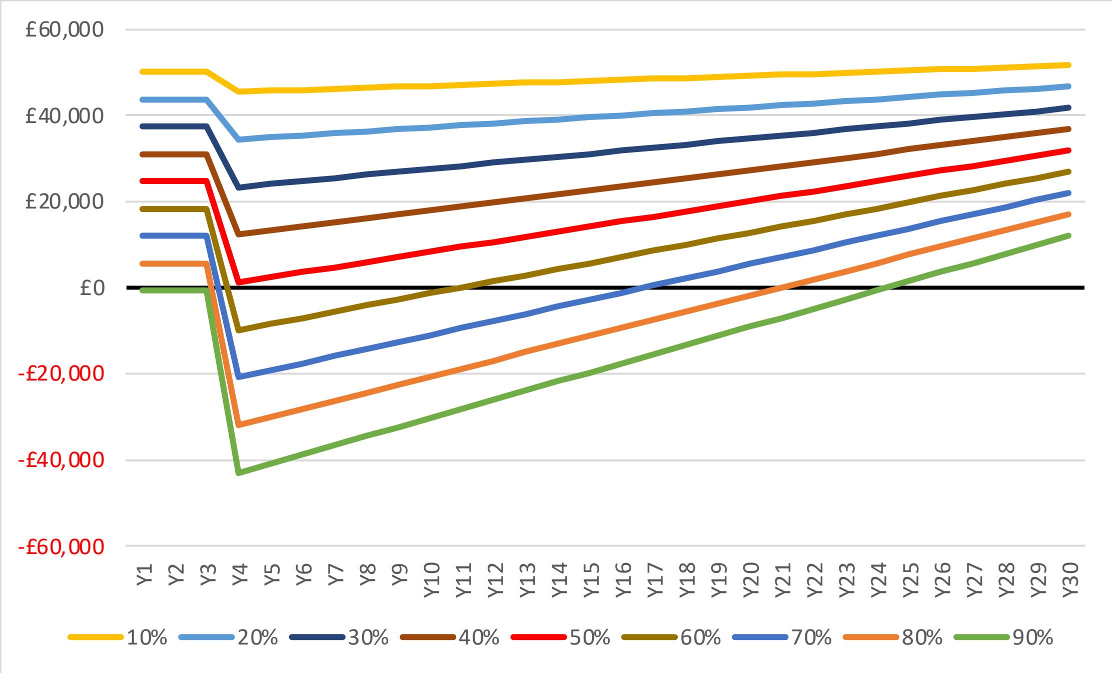


Figure 9. Sensitivity of PBT to Interest Rate in the South Facing Unconstrained Scenario

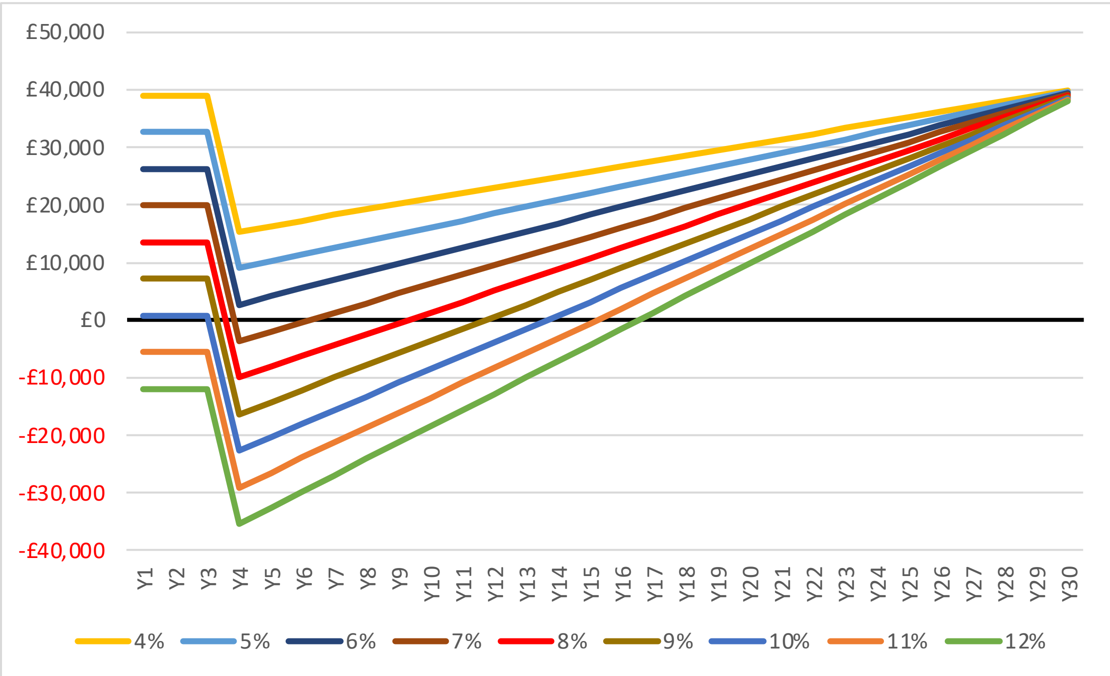
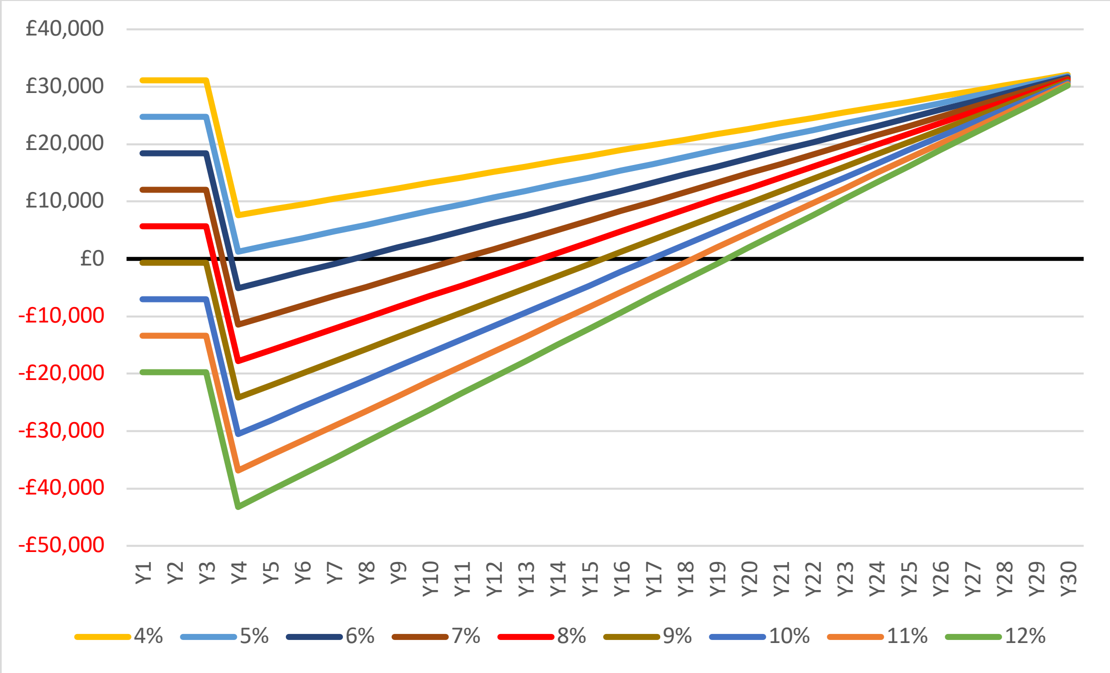


Figure 10 As Above with ***No Complex Site***



Model 2: South facing Constrained

Figure 11. Debt Coverage vs % Debt in the South Facing Constrained Scenario

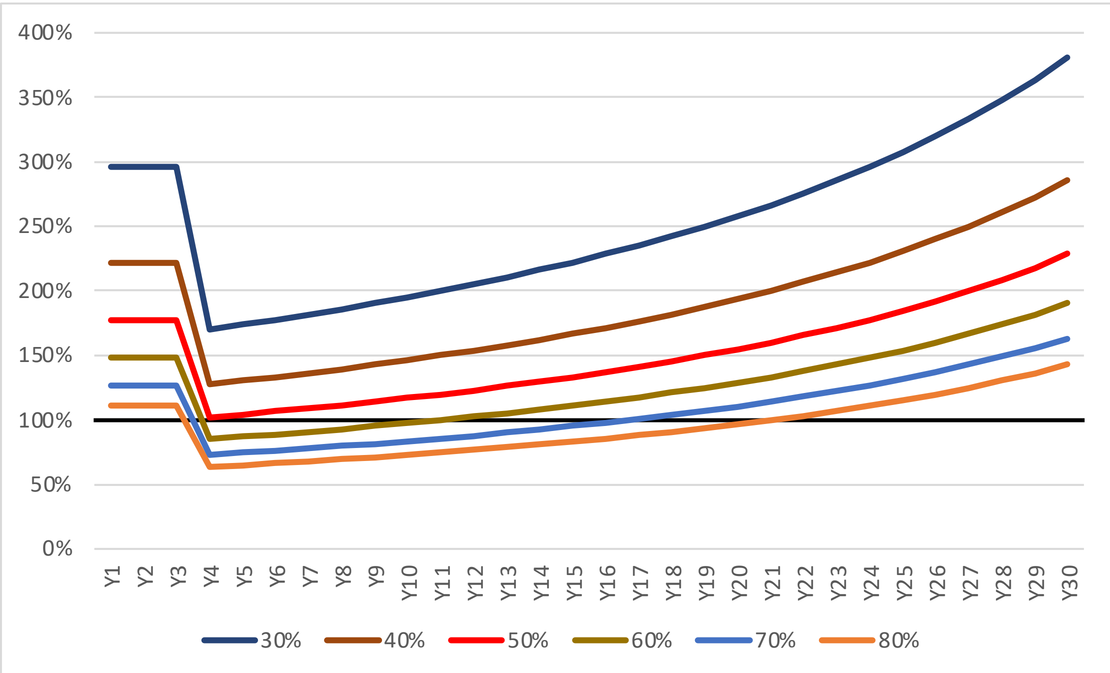


*Figure 12. As Above with **No Complex Site***

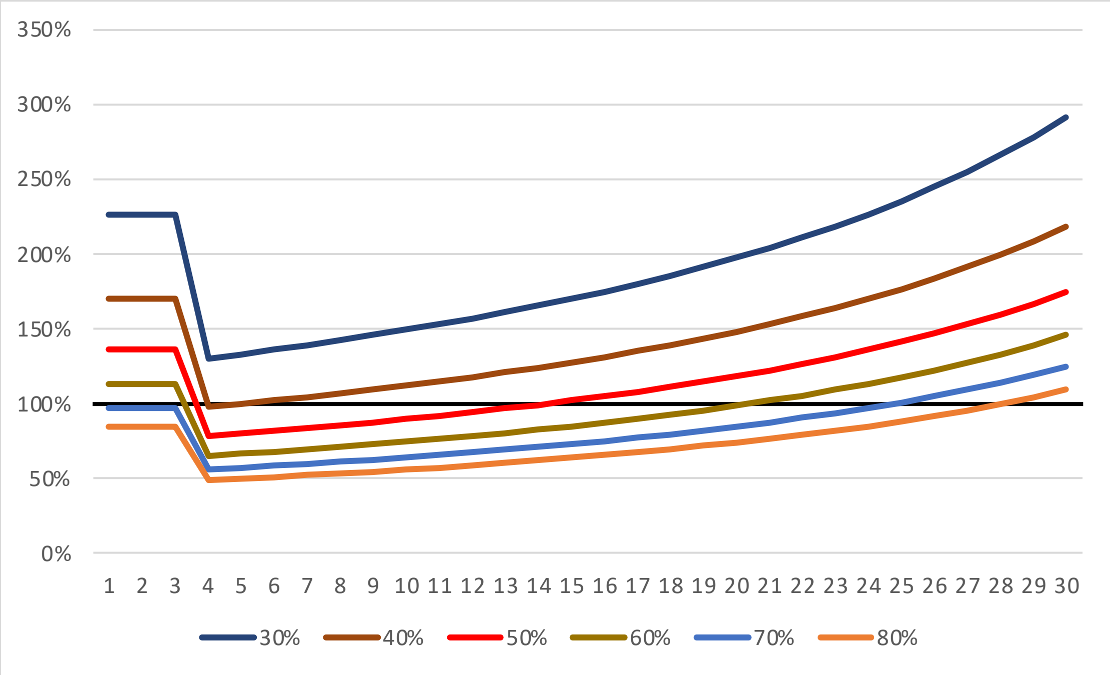


Figure 13. Sensitivity of PBT to % Debt in the South Facing Constrained Scenario

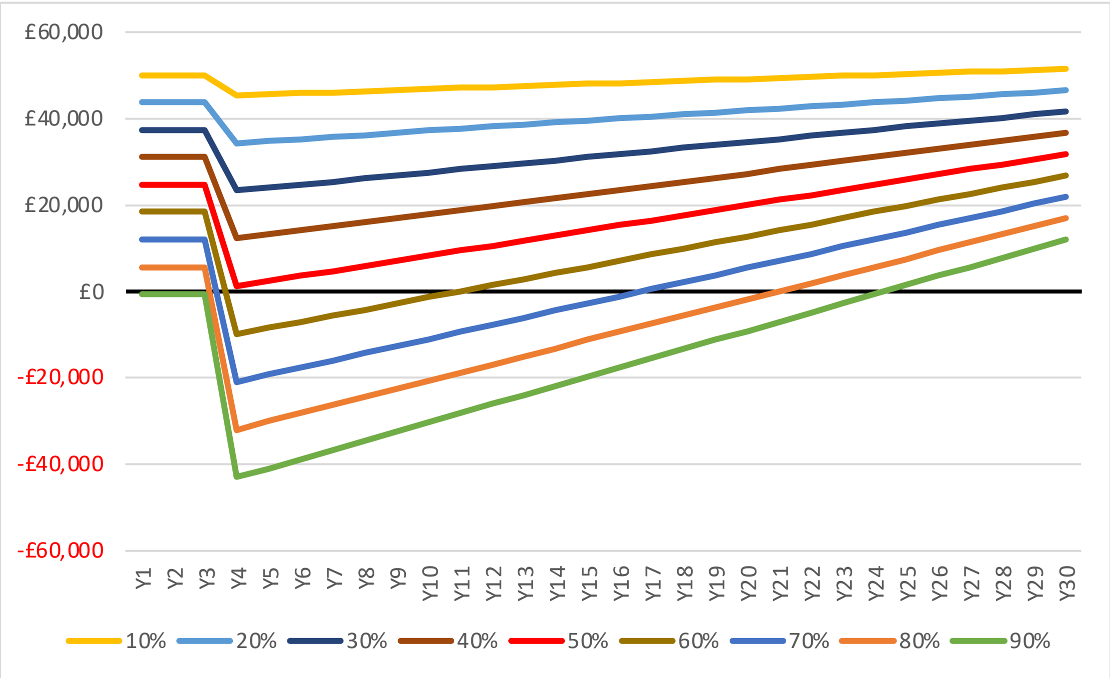


Figure 14. As Above with ***No Complex Site***

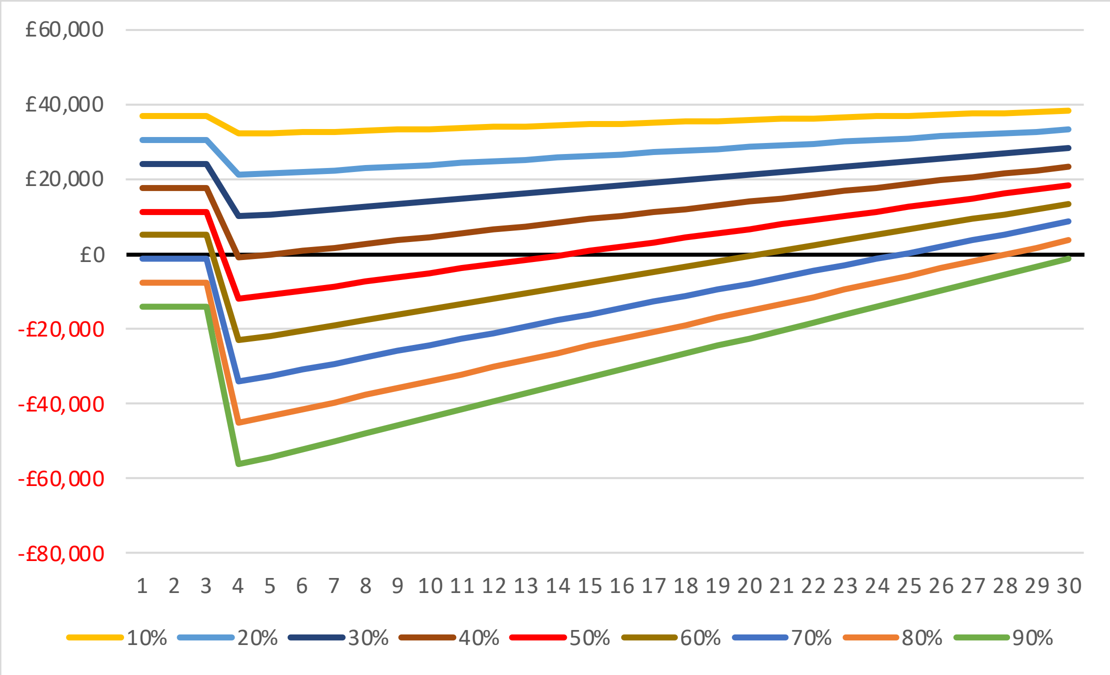


Figure 15. Sensitivity of PBT to Interest Rate in the South Facing Constrained Scenario

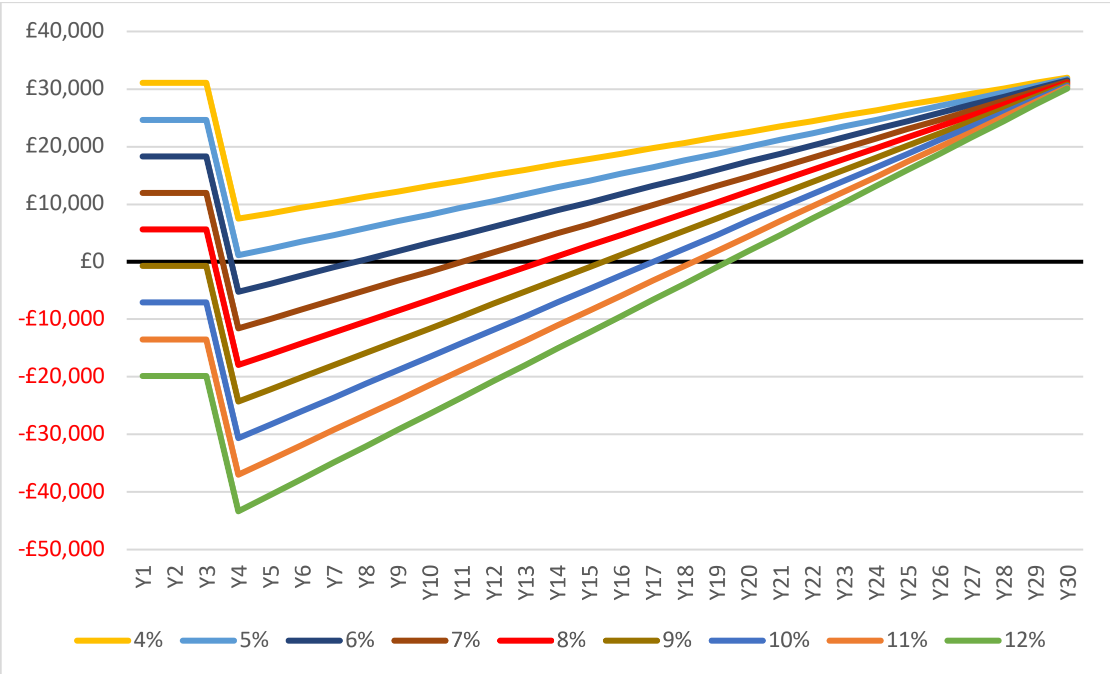
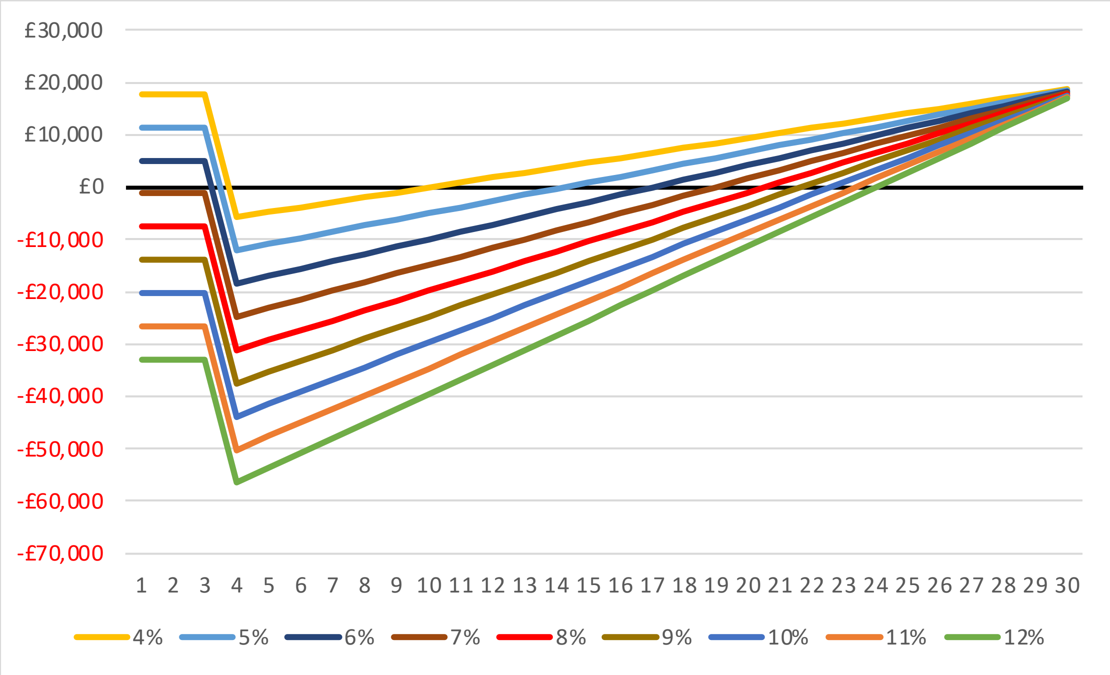


Figure 16. As Above with ***No Complex Site***



Model 3: Bi-facial Unconstrained

Figure 17. Debt Coverage vs % Debt in the Bifacial Unconstrained Scenario

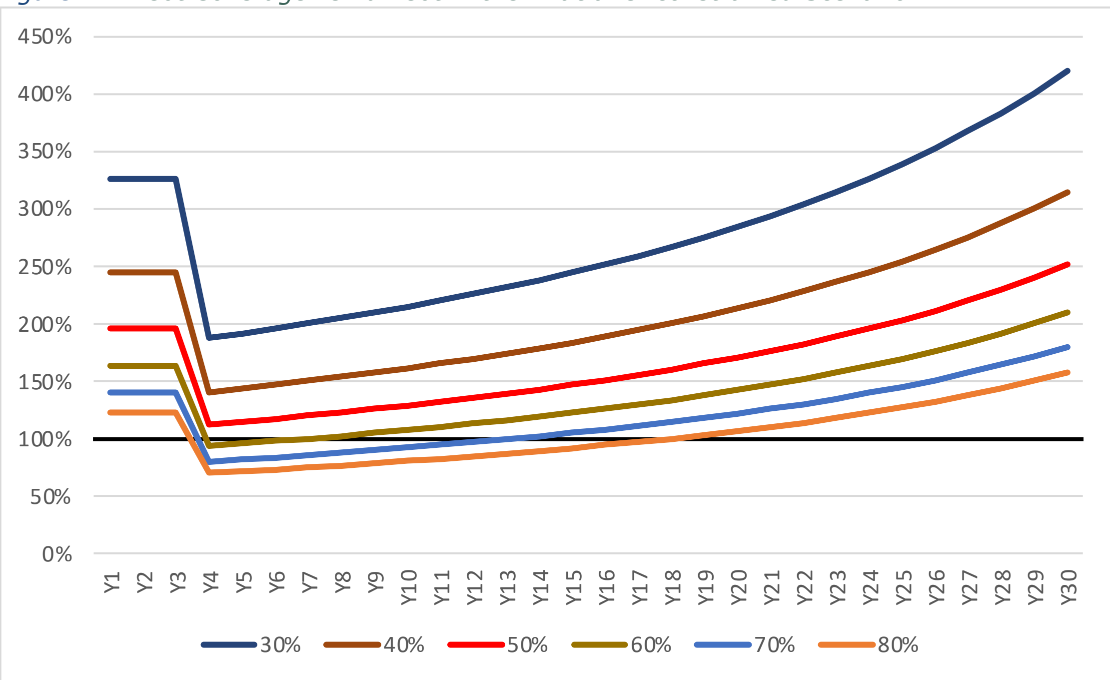


Figure 18: As above WITHOUT Complex Site

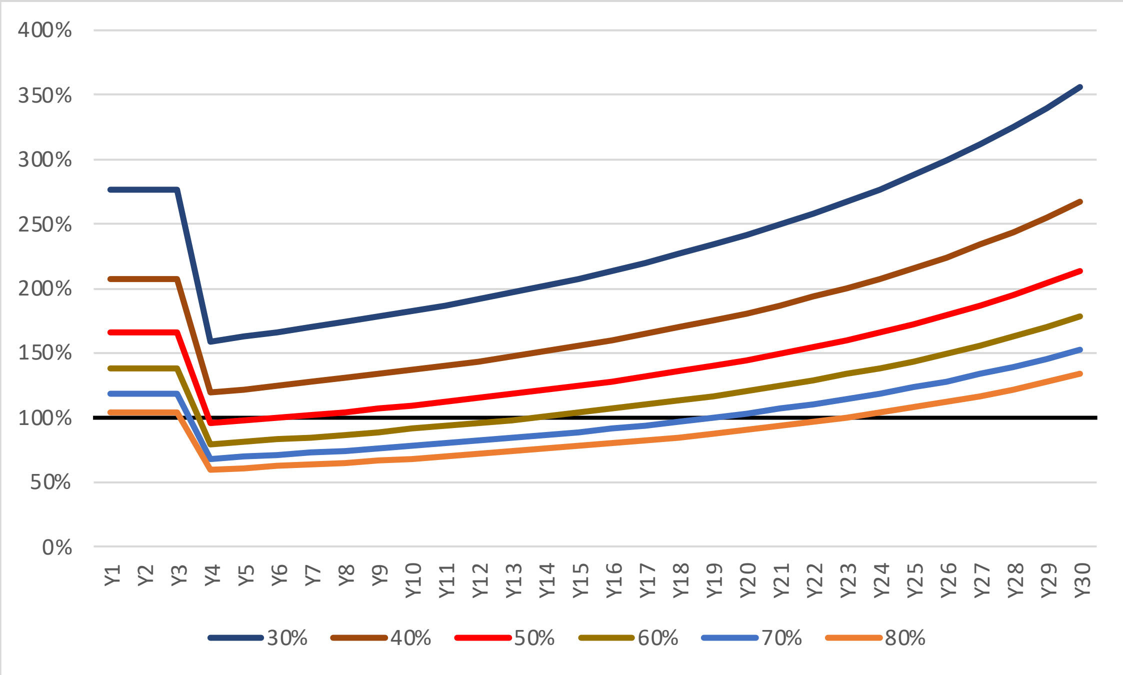


Figure 19: Sensitivity of PBT to % Debt in the Bifacial Unconstrained Scenario with Complex Site

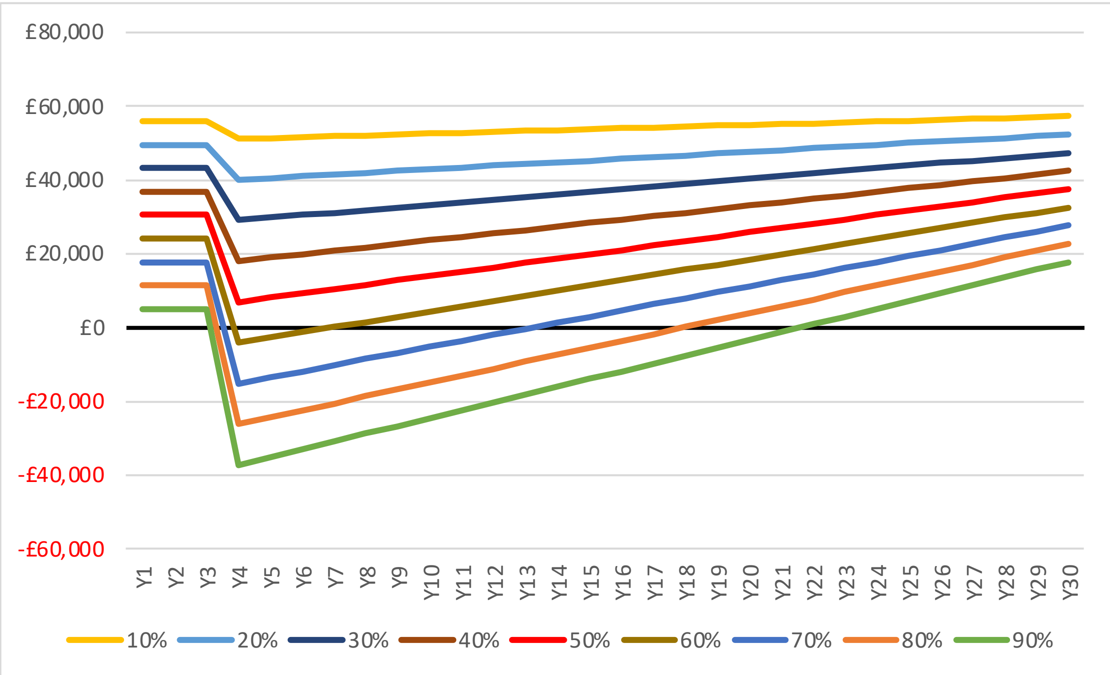


Figure 20:As above WITHOUT Complex Site

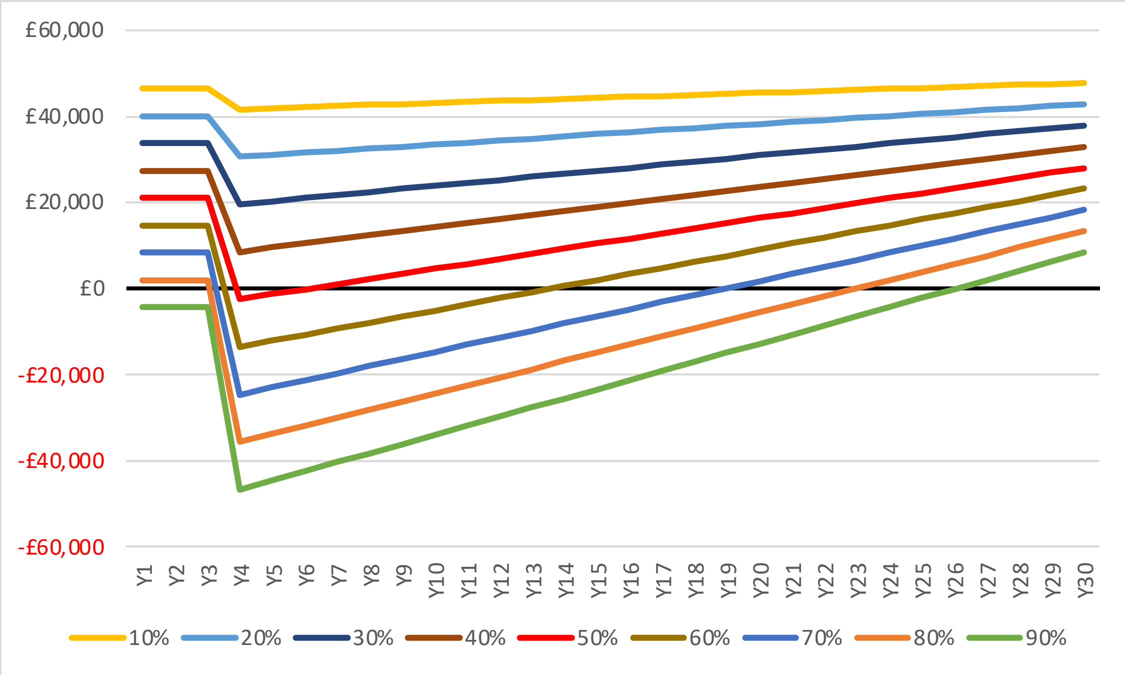


Figure 21. Sensitivity of PBT to Interest Rate in the Bifacial Unconstrained Scenario with Complex Site.

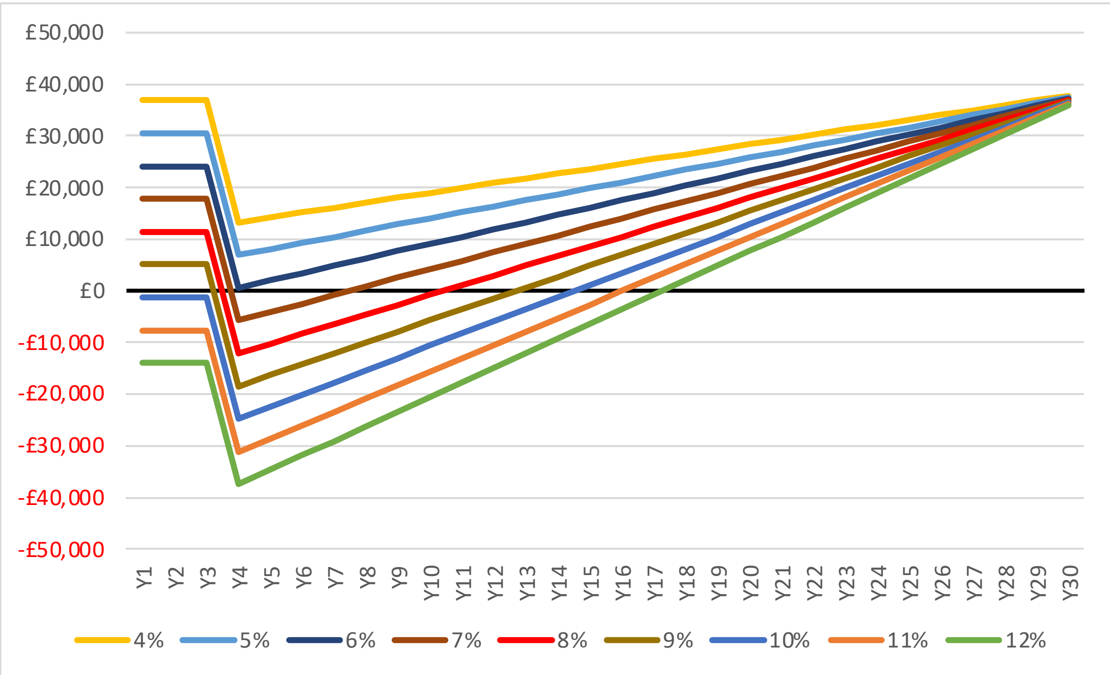
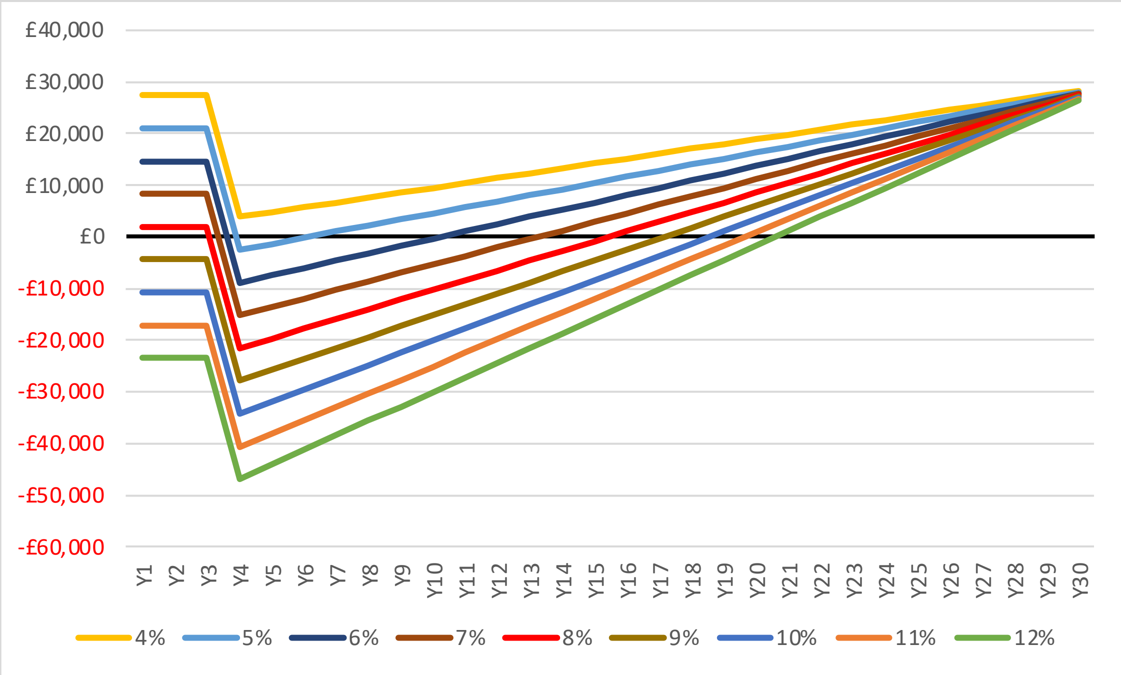


Figure 22: As above WIHTOUT Complex Site



Model 4: Bi-facial Constrained Scenario

Figure 23. Debt Coverage vs % Debt in the Bifacial Constrained Scenario

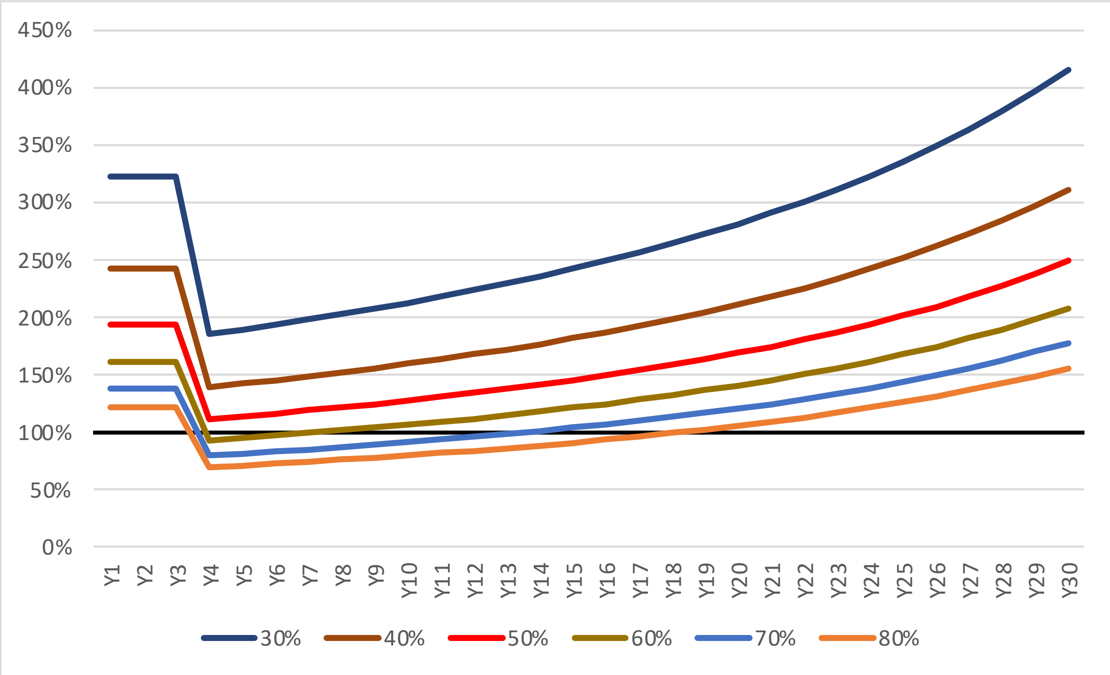


Figure 24: As above WITHOUT Complex Site

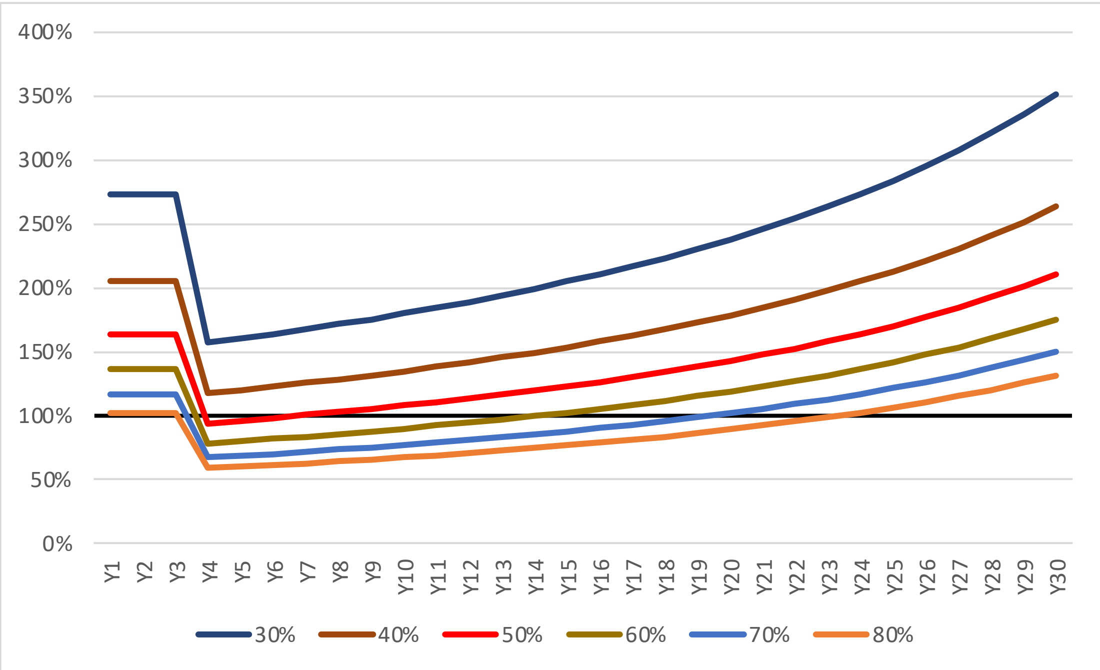


Figure 25. Sensitivity of PBT to % Debt in the Bifacial Constrained Scenario with Complex Site

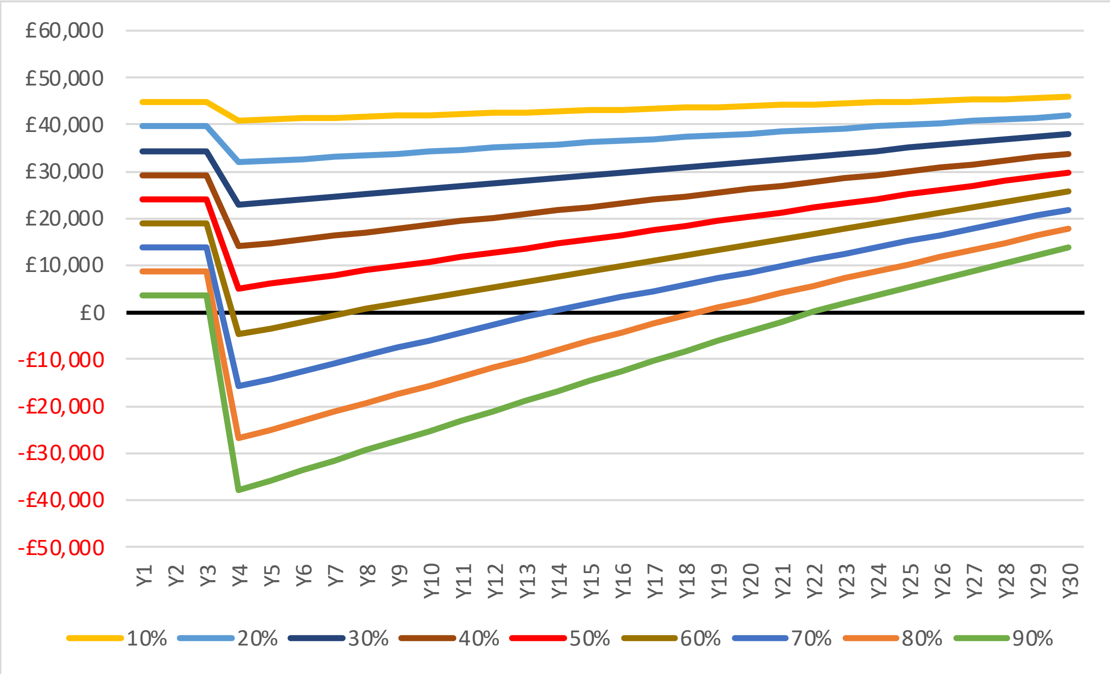


Figure 26: As above WITHOUT Complex Site

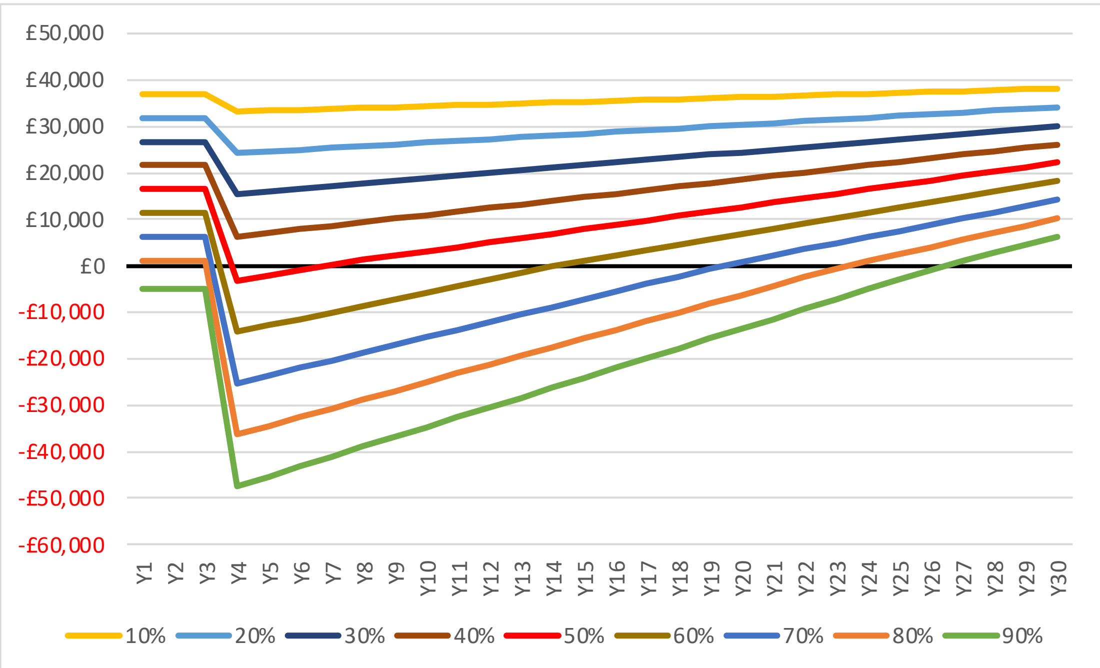


Figure 27. Sensitivity of PBT to Interest Rate in the Bifacial Constrained Scenario with Complex Site

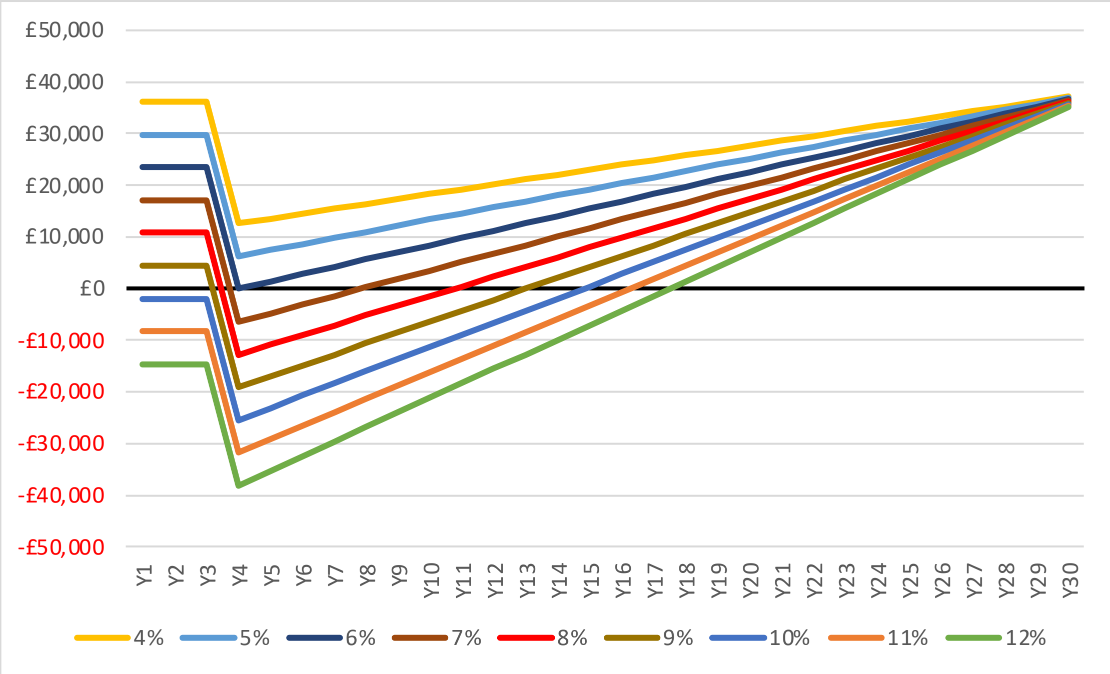
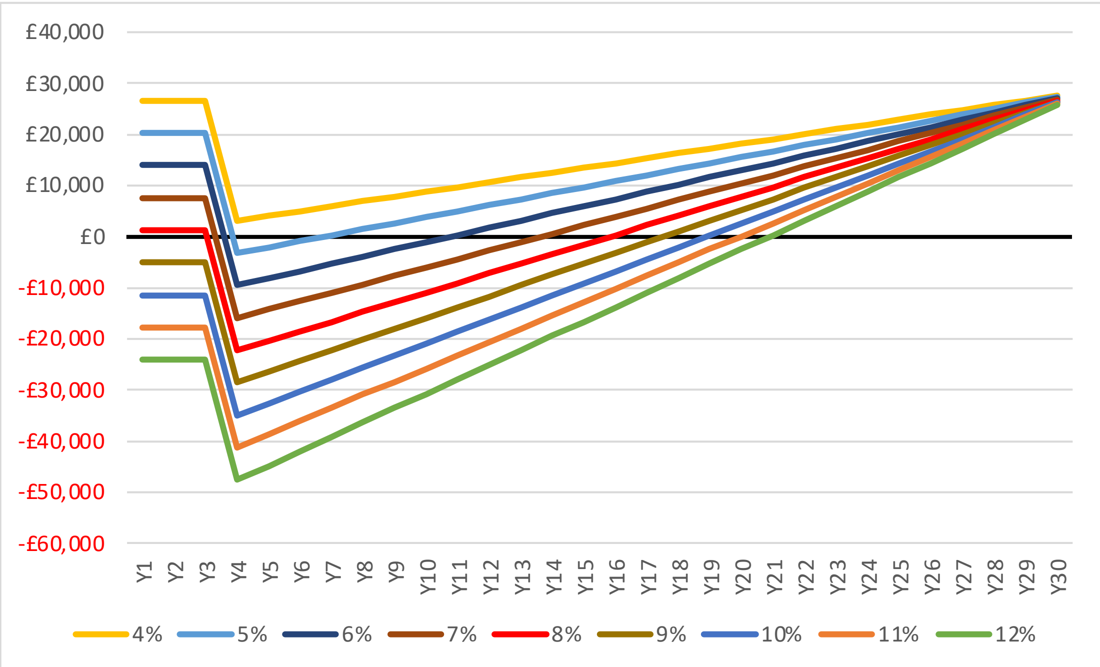


Figure 28: As above WITHOUT Complex Site



All models show a negative IRR meaning they are not viable but the complex site reduces the negative IRR by half.

The debt coverage ratio in all scenarios is low which points to the operational costs being too high. All the estimates of OpEx should be reviewed with special attention given to the 'Asset Management' and 'Operations and Maintenance' as from experience the costs quoted seem very high.

Introducing businesses who operate mainly during the day (ideally particularly during the summer) may increase the return and reduce the risk. A high match rate would improve the rate of return in all cases but there is then a greater risk that recruitment of demand customers would not be as high.

However, there are many different variables in the model and therefore the results here may be overly pessimistic.

The premium paid due for the 'Deep Green Tariff' reduces the benefit to households considerably. Note however in time these will fall. However, in every scenario using a Complex Site improves all the metrics used in sensitivity. With a complex site a project can bear more leverage and has better resilience to interest rate rises.

Note that 30 years is long period to calculate financial returns, and the normal period for PV is 20.

Bi-facial versus south facing

There are many different variables that make comparison difficult.

Bifacial generates at better times of the day to run the network efficiently but there is not significant recognition in the supply market.

There is less constraint with Bifacial vertical panels than with south facing panels and therefore it is possible to include more households before there is a considerable drop off in benefit for them due to the shape of the profile of the generation. Exactly how much the difference cannot be quantified at this point as the ground reflections and performance of the panels in the UK is not well understood. Overall, there is slightly less benefit to an individual household without shifting demand but it is not statistically significant.

The benefits of the profile overall to the distribution network of bifacial vertical panels is not really represented in the benefit to customers or the generator.

As vertical bifacial panels are innovative there are additional risks and costs including:

- Additional costs in designing the frames that would not be standard with new structural calculations.

- The frames would cost more as they will have to withstand a lot more loading than traditional frames and panels.
- As a result of the above and the fact that the technology is new, insurance is likely to be higher.

Many of the additional costs would only be possible to estimate once the structural calculations and designs of the frames have been carried out. Long term however these panels could become mainstream and have their worth better reflected in the supply market and by DNOs.

Next steps

South facing panels are not viable for equity holders at a 50/50 debt to equity ratio or interest rates but the complex site reduces the negative IRR by around half. In time, premium for 'deep green' will fall. The next step is to reduce OpEX, obtaining a lower TOUT, and increasing equity with a complex site could make these sites viable.

There is value in the vertical bi-facial panels but additional risk and costs. It is recommended to seek grant funding to offset the risk for the first installation with vertical bifacial panels. If installed, aim to engage DNOs so the value of these panels is reflected in connection offers. Engage with structural engineers to ensure a robust design for installation of vertical bi-facial panels.

Aim to develop a local electricity market to increase income with either option.

Wind and Solar Site

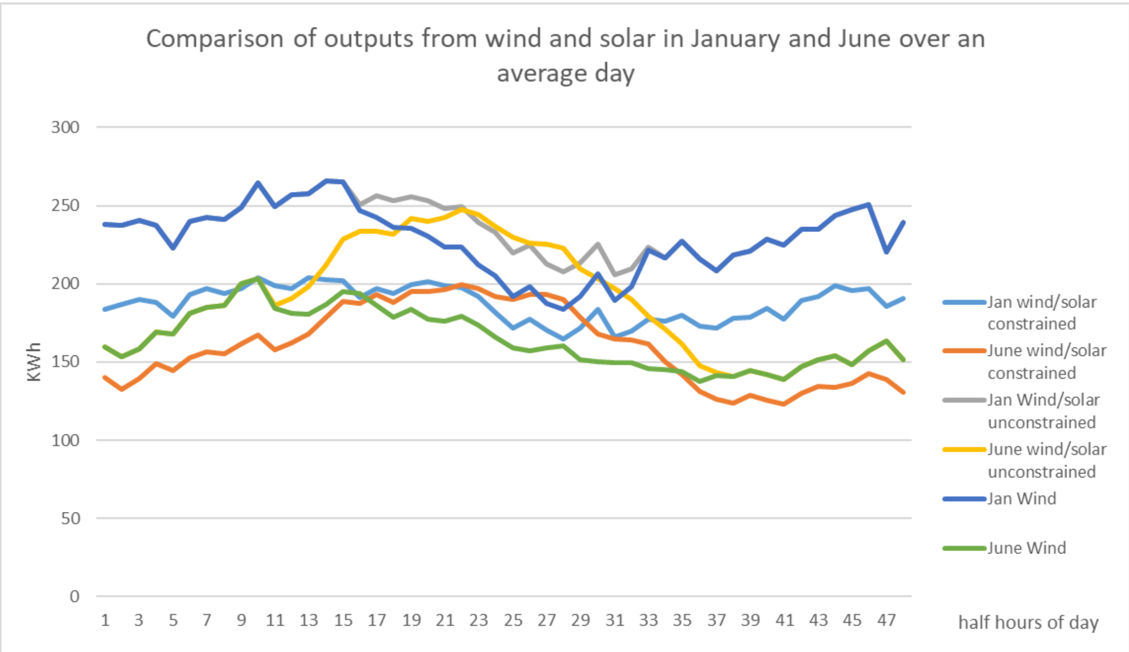
BWCE has a second site that is suitable for wind and possibly solar. The wind turbine is 950kW and therefore under the 1MW limit where a 'statement of works' network study is required for the transmission network however the wind and solar together would breach this limit without going through the costly and time consuming statement of works process. To enable the solar and wind to be fitted without a statement of works a battery would be required to prevent output being above 950kW at anytime.

A cheaper connection is possible if connected to LV but in this scenario the export would need to be restricted to 650kW as this is the maximum that can be connected at LV. If wind is installed alone, 19% of generation is curtailed. If 250kW of solar is included, there is little difference in the percentage of constrained power with wind alone or with wind and solar – 19% compared to 20% of the total output. This demonstrates how wind and solar fit together well to maximise the use of a connection (Figure 29).

The same assumptions as above were used for the comparison. We modelled with wind by itself and then wind and solar either constrained or unconstrained to compare the potential loss in income. If the output is above 650kW, the connection must be HV.

We then sized a battery to store the 20% of power that would be lost if the connection was constrained to an export of 650kW and enabling a connection without a statement of works.

Figure 29. Comparison of outputs from wind and solar, constrained and unconstrained, with just wind.



Wind Modelling – unconstrained

Single Household

Modelling for a single household shows the maximum benefits to one household if the 'complex site' only had that household. This is obviously not what would occur in reality.

It demonstrated that the household benefit is not predicted to go beyond 33% in this scenario even if they had access to all the available power (Table 22).

Table 22. Optimal scenario for 1 household with maximum access to local power

	No 'complex site'	**With 'complex site'**	**Benefit/£**	**Benefit/%**
1 Household 'Deep Green'	£927	£625	£302	32.56%
1 Household 'Standard supplier' TOUT	£927	£641	£286	30.89%

Multiple Household Scenarios

The same scenarios were modelled as in the case for the solar farm.

Table 23 shows the Deep Green tariff to be feasible with between 360 – 2,400 households. The household benefit is expected to range from £68 - £228 and the generator benefit is expected to be range from £18,999 - £128,990.

By comparison, the Standard Tariff is estimated to be feasible with between 270 – 5,000 households. Household benefit is expected to range from £186 - £269 while generator benefit is expected between £19,568 – £190,120.

An equal benefit scenario with the Deep Green Tariff would have 770 member households and it is predicted this would save households £178 annually (19% benefit) and increase generator revenue by £51,611 (20% benefit).

An equal benefit scenario with the Standard Tariff would have 760 member households and it is predicted this would save households £250 annually (27% benefit) and increase generator revenue by £71,105 (27% benefit).

Table 23. Modelling results for a 'complex site' with Unconstrained Wind

		No 'complex site' £	**With 'complex site' £**	**Benefit £**	**Benefit %**	**Number of households**	**% generation used**	**% of total demand**
Minimum size 'Deep Green'	Households	927	698	228	24.65	360		75
	Generator	262,676	281,675	18,999	7.23		21	
Minimum size 'Standard supplier'	Households	927	658	269	29.05	270		78
	Generator	262,676	282,244	19,568	7.45		16	
Maximum size 'Deep Green'	Households	927	859	68	7.30	2,400		45
	Generator	262,676	391,667	128,990	49.11		84	
Maximum size 'Standard supplier'	Households	927	741	186	20.04	5,000		26
	Generator	262,676	452,796	190,120	72.38		98	
Equal benefits 'Deep Green'	Households	927	749	£178	19.17	770		66
	Generator	262,676	314,288	£51,611	19.65		39	
Equal benefits 'Standard supplier'	Households	927	677	£250	26.92	760		66
	Generator	262,676	333,782	71,105	27.07		39	

Wind and Solar – unconstrained

Single Household

The benefit to one household is greater than with just wind due to the more constant output. (Table 24).

Table 24. Optimal scenario for 1 household with maximum access to local power

	No complex site	**With complex site**	**Benefit/£**	**Benefit/%**
1 Household 'Deep Green'	£927	£593	£334	35.99
1 Household 'Standard supplier'	£927	£632	£295	31.81

Multiple Household Scenarios

The same scenarios as before were modelled and are listed in the Table 25.

The Deep Green tariff is feasible with between 350 – 2,700 households. The household benefit is expected to range from £67 - £273 and the generator benefit is expected to be range from £20,508 - £203,391.

By comparison, the Standard Tariff is estimated to be feasible with between 270 – 5,000. Household benefit is expected to range from £189 - £281 while generator benefit is expected between £21,672 – £203,391.

Table 25. Modelling results for a 'complex site' with Wind and Solar Unconstrained

		No 'complex site' £	With 'complex site' £	Benefit £	Benefit %	Number of house-holds	% generation used	% of total demand
Minimum size 'Deep Green'	Households	927	654	273	29.49	350		83
	Generator	282,553	303,061	20,508	7.26		21	
Minimum size 'Standard supplier'	Households	927	646	281	30.28	270		86
	Generator	282,553	304,225	21,672	7.67		17	
Maximum size 'Deep Green'	Households	927	860	67	7.22	2,700		45
	Generator	282,553	427,938	145,385	51.45		87	
Maximum size 'Standard supplier'	Households	927	738	189	20.35	5,000		27
	Generator	282,553	485,944	203,391	71.98		99	
Equal benefits 'Deep Green'	Households	927	£724	£203	21.93	840		70
	Generator	282,553	343,409	60,855	21.54		42	
Equal Benefits 'Standard supplier'	Households	927	670	257	27.75	800		71
	Generator	282,553	362,189	79,636	28.18		41	

Wind and Solar – constrained

The benefits are not changed that much compared to the unconstrained scenario as the peaks in generation that are constrained are when it is hardest to absorb the power within the 'complex site' (Table 26).

Table 26. Modelling for a 'complex site' with Wind and Solar Constrained

		No 'complex site' £	With 'complex site' £	Benefit £	Benefit %	No. of house-holds	% generation used	% of total demand
Minimum size 'Deep Green'	Households	927	640	287	30.98	270		86
	Generator	226,018	242,233	16,215	7.17		21	
Minimum size 'Standard tariff'	Households	927	642	285	30.70	200		88
	Generator	226,018	241,884	15,866	7.02		16	
Maximum size 'Deep Green'	Households	927	856	71	7.69	2,200		46
	Generator	226,018	348,218	122,200	54.07		91	
Maximum size 'Standard tariff'	Households	927	747	180	19.4	5,000		22
	Generator	226,018	391,201	165,183	73.08		100	
Equal benefits 'Deep Green'	Households	927	713	214	23.09	750		72
	Generator	226,018	284,108	58,090	25.70		49	
Equal Benefits 'Standard tariff'	Households	927	662	265	28.57	600		76
	Generator	226,018	290,017	63,999	28.32		41	

Summary

Including solar as well as wind uses the connection well and the generation complements each other. This also makes the 'complex site' more attractive to the households. The income is reduced when the export is constrained to 650kW but there is a lower upfront capital cost of a connection to LV compared to HV and therefore the lower upfront capital needs to be weighed against a reduced income once quotes for HV and LV connections are received.

Use of a battery to avoid the need for a 'statement of works'

There have been conflicting reports as to whether inclusion of a battery and limiting the export from a connection is sufficient to avoid 'statement of works'.

To analyse the impact, a battery that was large enough to limit the export from solar and wind to 650kW was included. The sizing was such that no curtailment of generation was necessary. Note that this is the limit to connect at LV rather than to avoid 'statement of works' but if a battery is included, it is better to minimise the cost of connection by connecting to LV).

A battery of 400kWh maximum storage was sufficient to ensure that the export did not exceed 325kW in one half hour. However, a battery of this size may not be able to discharge sufficiently quickly or absorb spikes in power and therefore a larger battery greater than 400kWh is assumed – note that this is just a proxy for a battery with a high discharge rate due to the limitations of the model.

A battery allows the generation to be used rather than constrained. If a 'complex site' were included with a 'Standard tariff' tariff, with 800 households (i.e. as in the unconstrained case). By storing the constrained wind and solar and selling at a different time at 7.5p/kWh, the generator increases its annual income by £15,637 compared to the constrained case (storing around 712,000KWh of power that is used locally). Table 27 estimates costs of battery systems are around £400/kWh at present but are falling rapidly. A 400kWh battery[17] would be around £160,000 at present day although the costs will vary depending on connection arrangement required. It is likely that by the time the wind turbine is installed, a battery would be nearer £120,000. This would therefore not have a long payback. The discharge rate required is unknown but given the diversity of household and business demand, this will be much lower than that required by for example a car and additional power

[17] 85332.pdf (nrel.gov) accessed 7th August 2024.

can be drawn from the network. Guarantees for car batteries are now over 10 years and the requirements for a battery in this setting are much less and therefore it is likely that its lifetime will be similar to the rest of the equipment.

Note that the income could be increased as the model, at present, discharges as soon as possible to maximise the storage available but with a more sophisticated control system it could provide power at the most expensive times of day to benefit both the generation and demand customers. Further income could be achieved by providing ancillary services when the battery is not used for curtailment.

Table 27. Modelling results with wind and solar constrained and a battery.

	No 'complex site'	**With 'complex site'**	**Benefit £**	**Benefit %**
Households	£927	£651	£276	29.73%
Generator	£282,553	£315,396	£32,842	11.62%

Financial Case

As wind installations take longer to install we have used the 'Standard TOUT' as we hope to have more mainstream suppliers providing services for complex sites. The financial cases are compared to each other not between different tariffs. Opex and Capex based on figures given by BWCE (Table 28).

Table 28. Headline Modelling Variables

Model	Member Size	Tariff	CAPEX	Annual OPEX
Solar & Wind Constrained	800	Standard	Wind: £2.4m Solar: £270k	Wind: £39,000 Solar: £6,802
Solar & Wind with Storage	800	Standard	Wind: £2.4m Solar: £270k Battery: £120k	Wind: £39,000 Solar: £6,802 Storage: £3,000
Wind Only Unconstrained	800	Standard	Wind: £2.4m	Wind: £39,000
Solar & Wind Unconstrained	800	Standard	Wind: £2.4m Solar: £270k	Wind: £39,000 Solar: £6,802

CAPEX figures above are based on current estimates from discussions with wind developers and average solar installation figures from UK Government and Industry Reviews. Connection costs are not included. Battery prices are taken predicted costs in the next few years (reference above).

OPEX costs for Wind are taken from a UK government onshore wind review[18]. Solar OpEx costs were provided by estimates given to BWCE. Battery OpEx costs are taken from a US NREL report[19].

Wind OpEx Costs break down as per Onshore wind review:

Fixed OpEx	£22,000
Variable OpEx	£13,050
Insurance	£1,441
Use of System	£3,109

In addition to the above, the following constants have been used in the financial modelling:

- Interest Rate – 5%
- 30 Year Loan Term
- Debt to Equity Ratio 50%
- Capital Repayment begins in Year 4 and is amortised over the next 27 years (this is longer than standard)
- No grants have been claimed
- Inflation has not been included

[18] https://assets.publishing.service.gov.uk/media/643820ad8b86bb000cf1b1ea/onshore-wind-and-solar-pv-costs-review.pdf
[19] https://www.pnnl.gov/sites/default/files/media/file/Final%20-%20ESGC%20Cost%20Performance%20Report%2012-11-2020.pdf

Table 29. Financial Headlines - Complex Site Comparison

	Total Project Costs	*Total Project Profit*	*RoI*	*Percent Debt*	*Loan Interest Rate*	*Debt Coverage Ratio*	*IRR on PBT*
Solar & Wind with Storage **With Complex Site**	£6,858,106	£9,463,930	38%	50%	5%	218%	4.6%
Solar & Wind with Storage **Without Complex Site**	£6,858,106	£8,460,000	23%	50%	5%	191%	3.0%
Solar & Wind Constrained **With Complex Site**	£6,627,106	£9,273,960	40%	50%	5%	222%	4.9%
Solar & Wind Constrained **Without Complex Site**	£6,627,106	£6,780,540	2%	50%	5%	152%	0.3%

Table 30 Financial Headlines – with and without Complex Site

	Total Project Costs	Total Project Profit	RoI	Percent Debt	Loan Interest Rate	Debt Coverage Ratio	IRR on PBT
Wind Only Unconstrained **With Complex Site**	£6,982,500	£9,466,440	36%	50%	5%	258%	6.8%
Wind Only Unconstrained **Without Complex Site**	£6,982,500	£7,354,950	5%	50%	5%	192%	3.1%

Sensitivity Analysis

For each of the scenarios, a sensitivity to a change in return to shareholders equity vs debt ratio and interest rate.

Model 1: Solar & Wind with Battery Storage

Figure 30. Debt Coverage vs % Debt in the Solar, Wind and Storage Scenario - With Complex Site

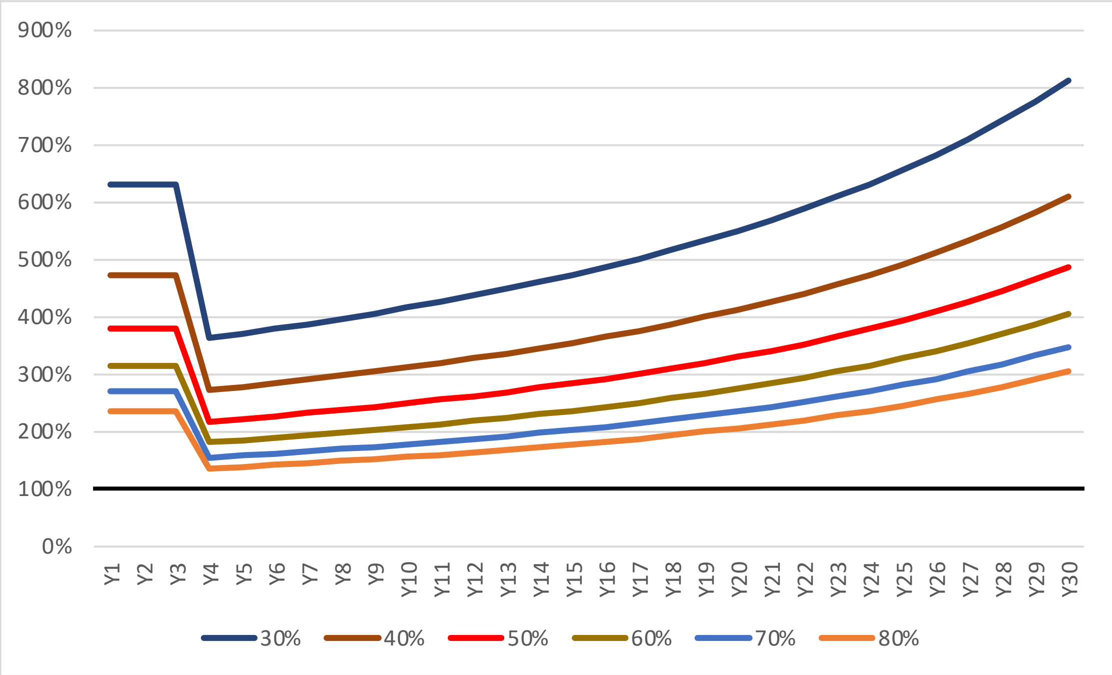


Figure 31. As Above WITHOUT Complex Site

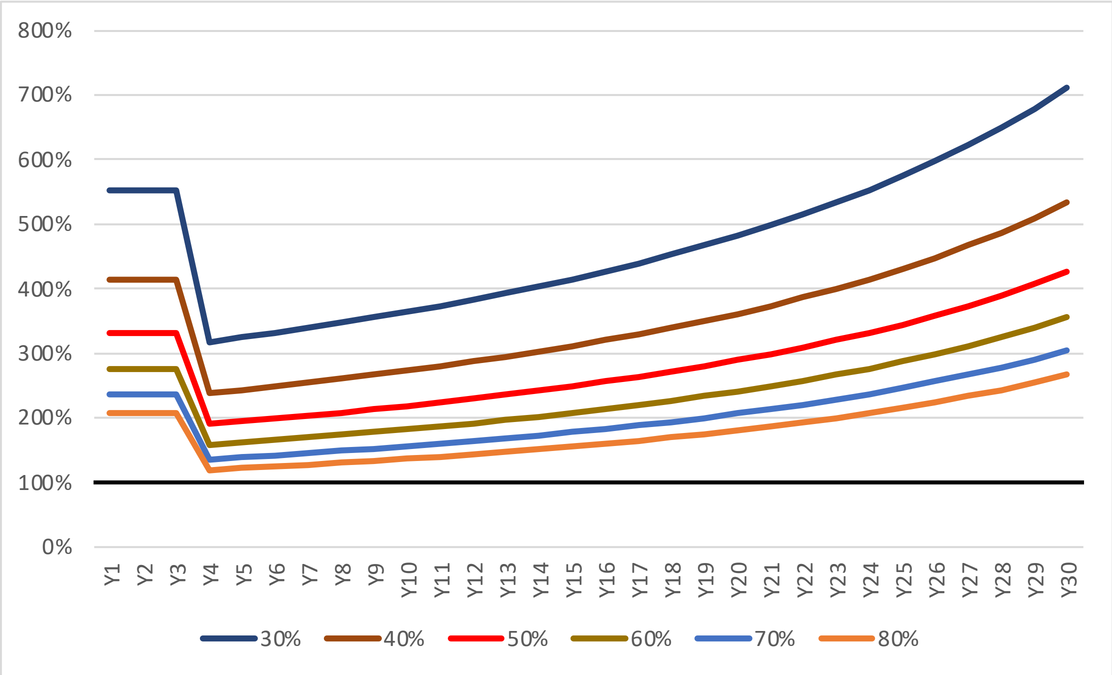


Figure 32. Sensitivity of PBT to % Debt in the Solar, Wind and Storage Scenario – With Complex Site

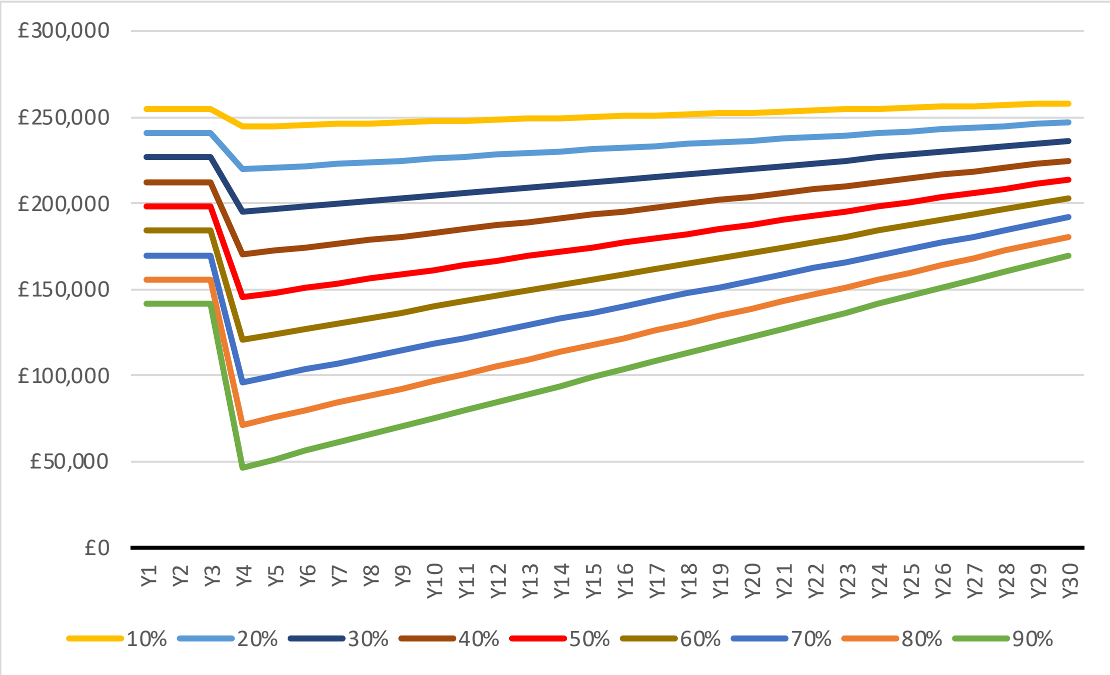


Figure 33. As Above WITHOUT Complex Site

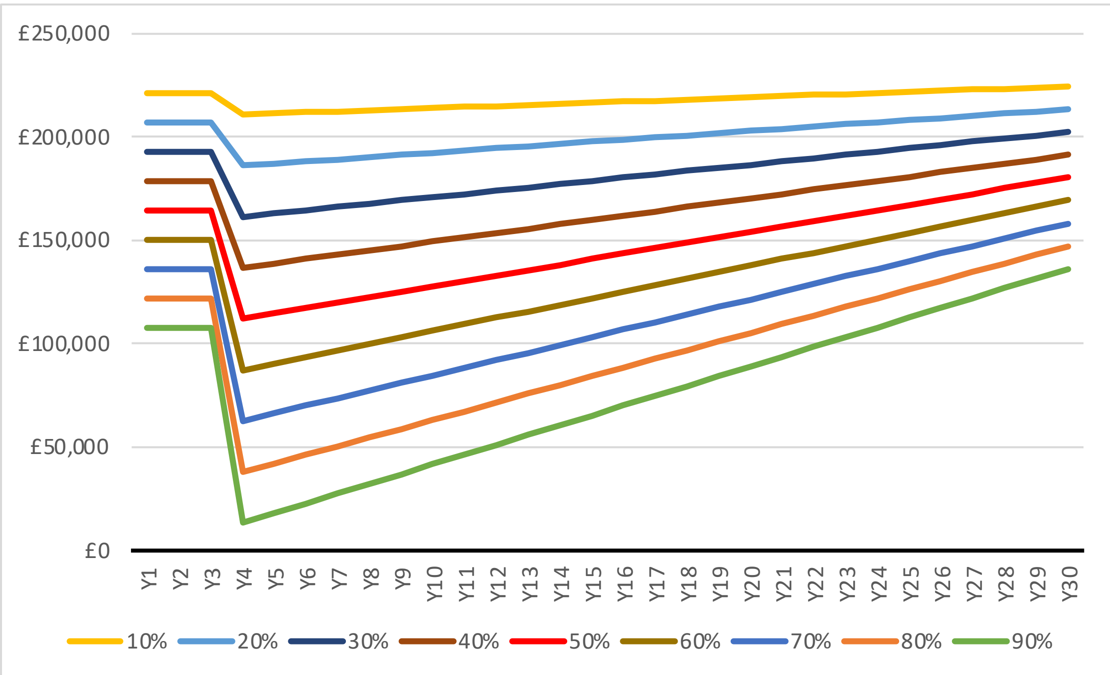


Figure 34. Sensitivity of PBT to Interest Rate in the Solar, Wind and Storage Scenario – With Complex Site

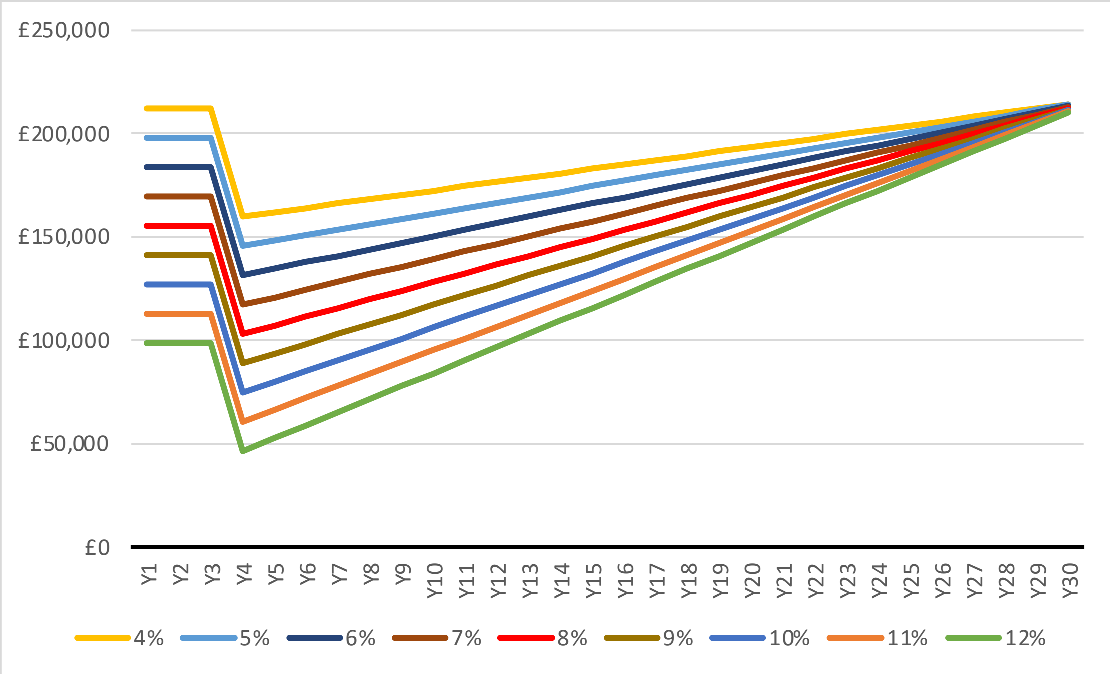
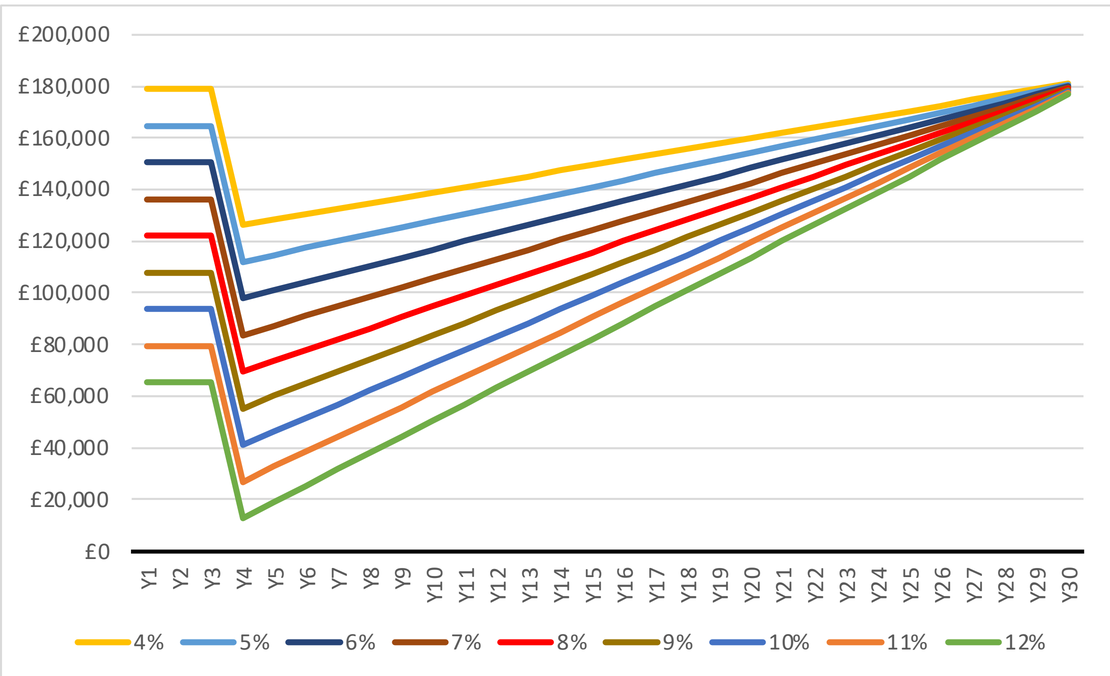


Figure 35. As Above WITHOUT Complex Site



Model 2: Solar & Wind - Constrained

Figure 36. Debt Coverage vs % Debt in the Constrained Solar & Wind Scenario – With Complex Site

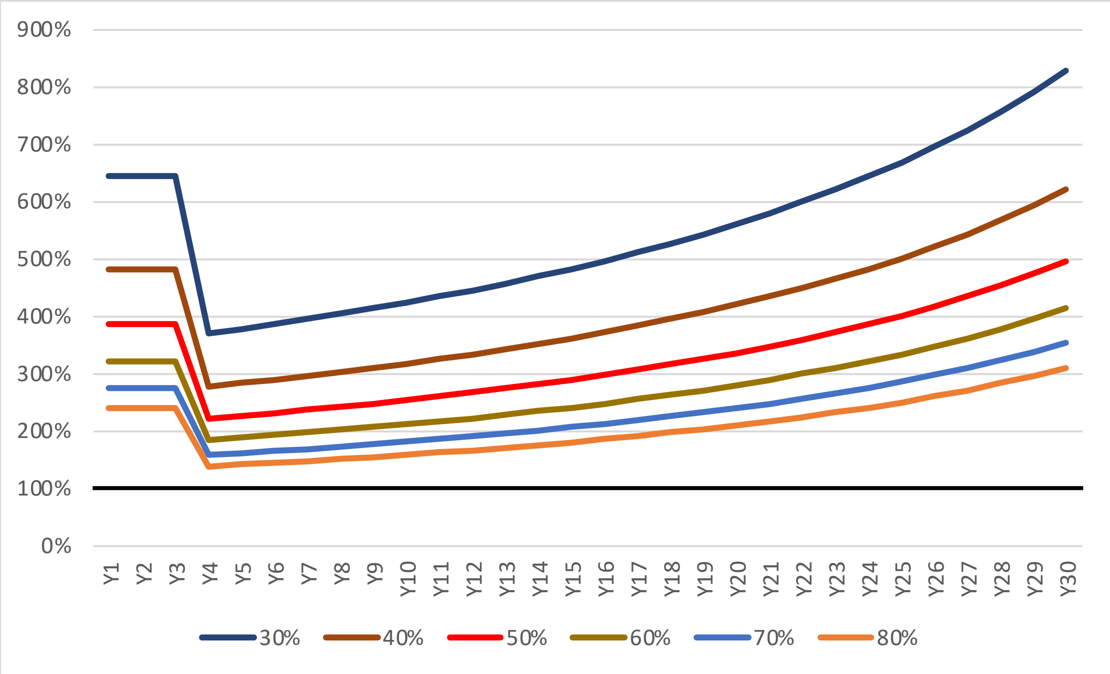


Figure 37. As Above WITHOUT Complex Site

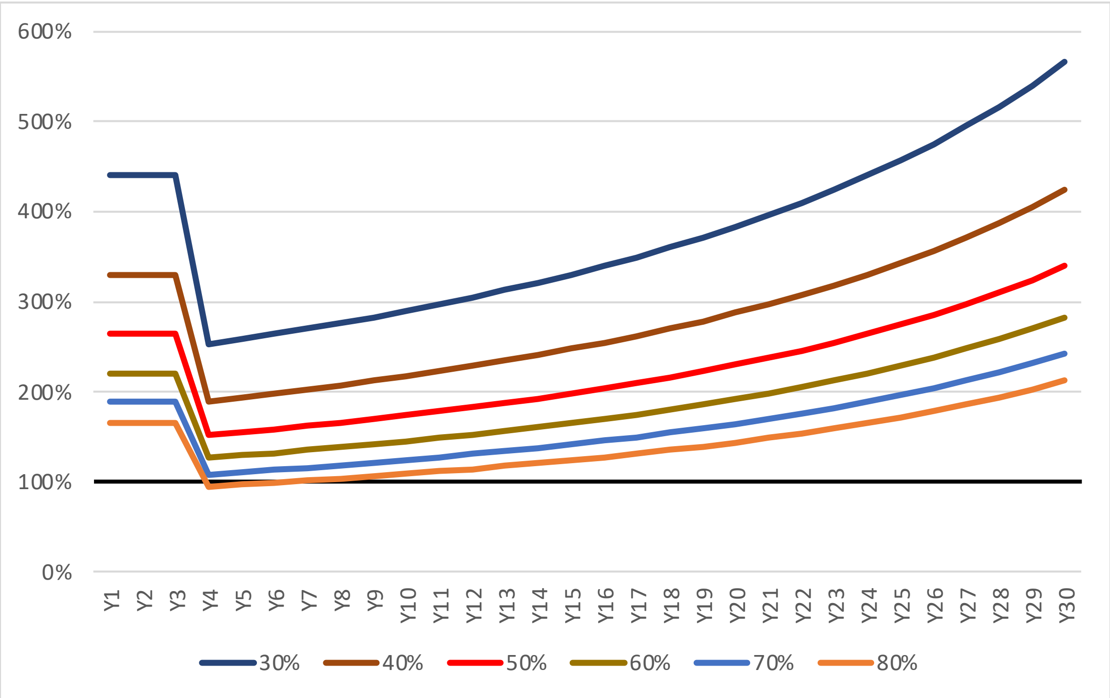


Figure 38. Sensitivity of PBT to % Debt in the Constrained Solar & Wind Scenario – With Complex Site

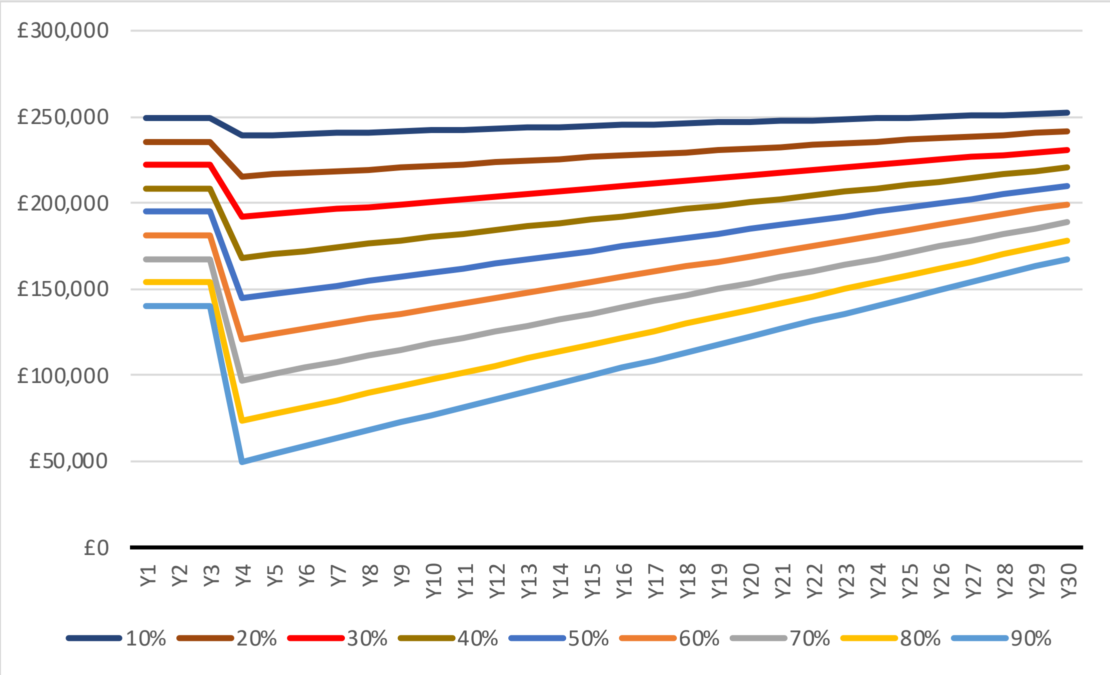


Figure 39. As Above WITHOUT Complex Site

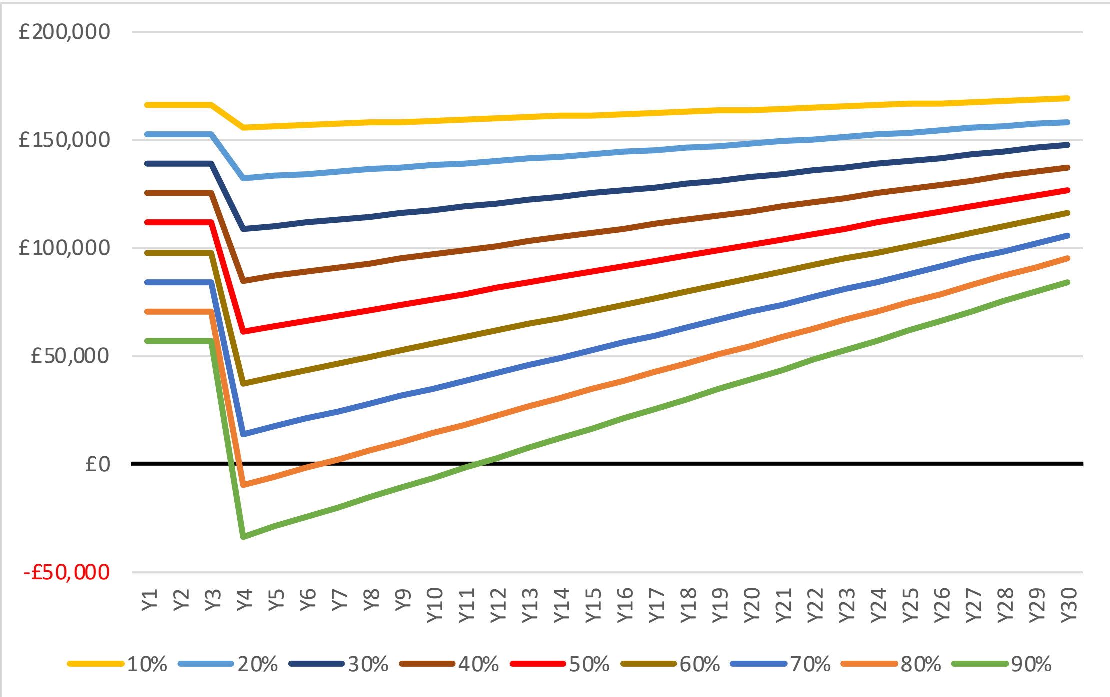


Figure 40. Sensitivity of PBT to Interest Rate in the Constrained Solar & Wind Scenario – With Complex Site

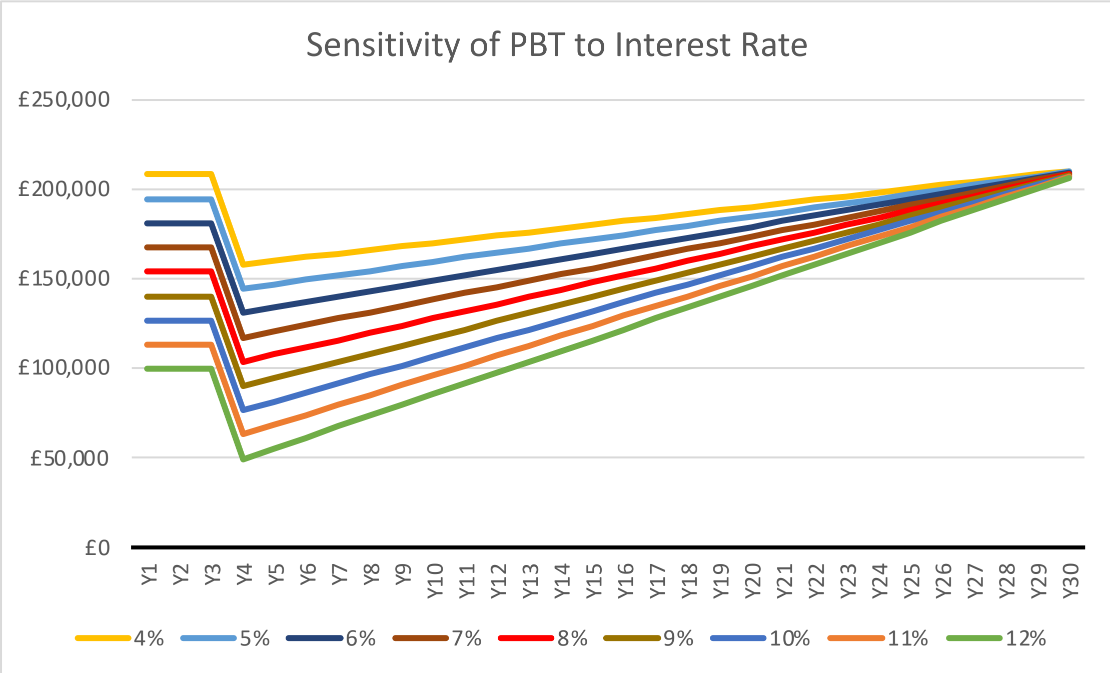
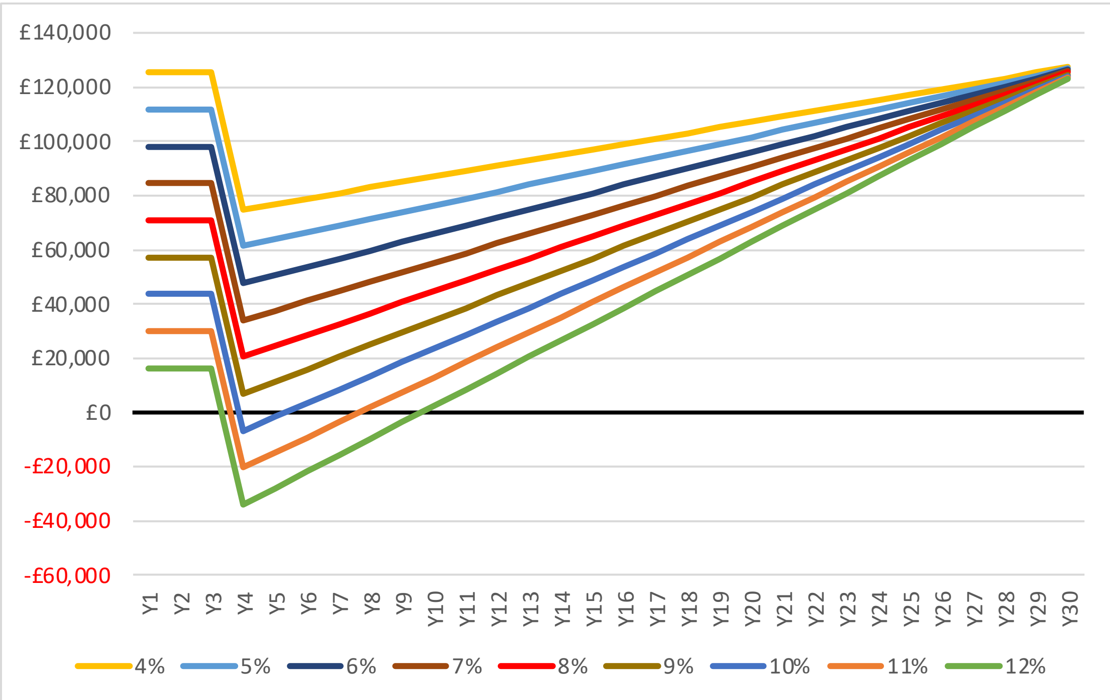


Figure 41. As Above WITHOUT Complex Site



Model 3 Wind Only Unconstrained with and without a Complex Site

Wind Only Unconstrained With Complex Site

Figure 42. Debt Coverage vs % Debt in the Unconstrained Wind Scenario – With Complex Site

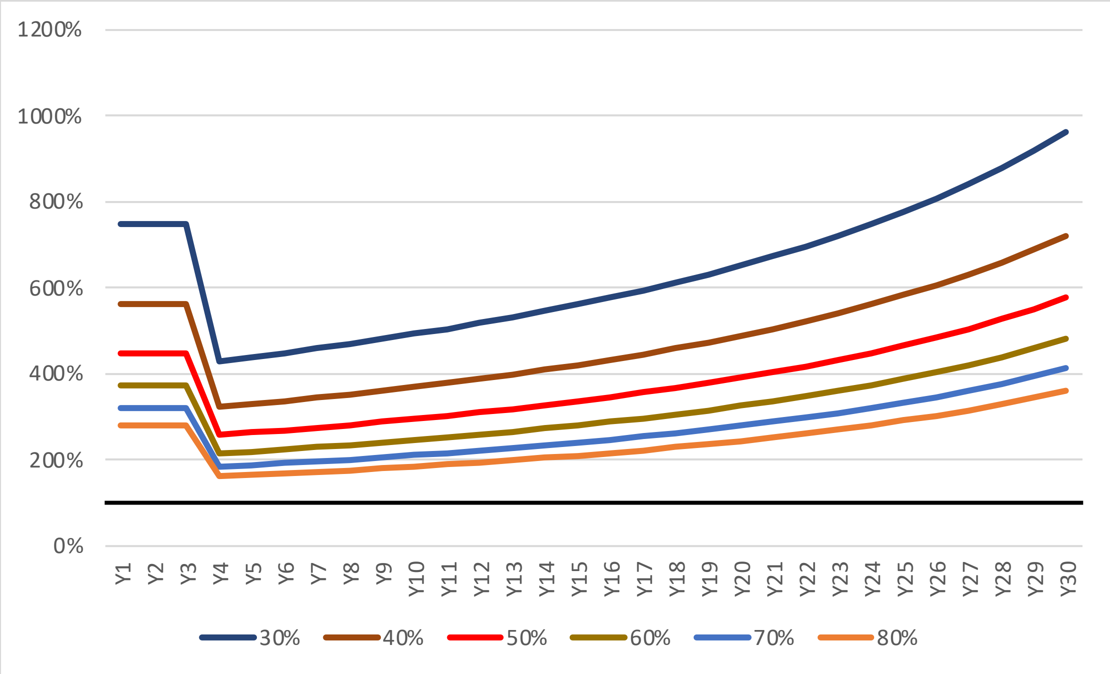


Figure 43. Sensitivity of PBT to % Debt in the Unconstrained Wind Scenario – With Complex Site

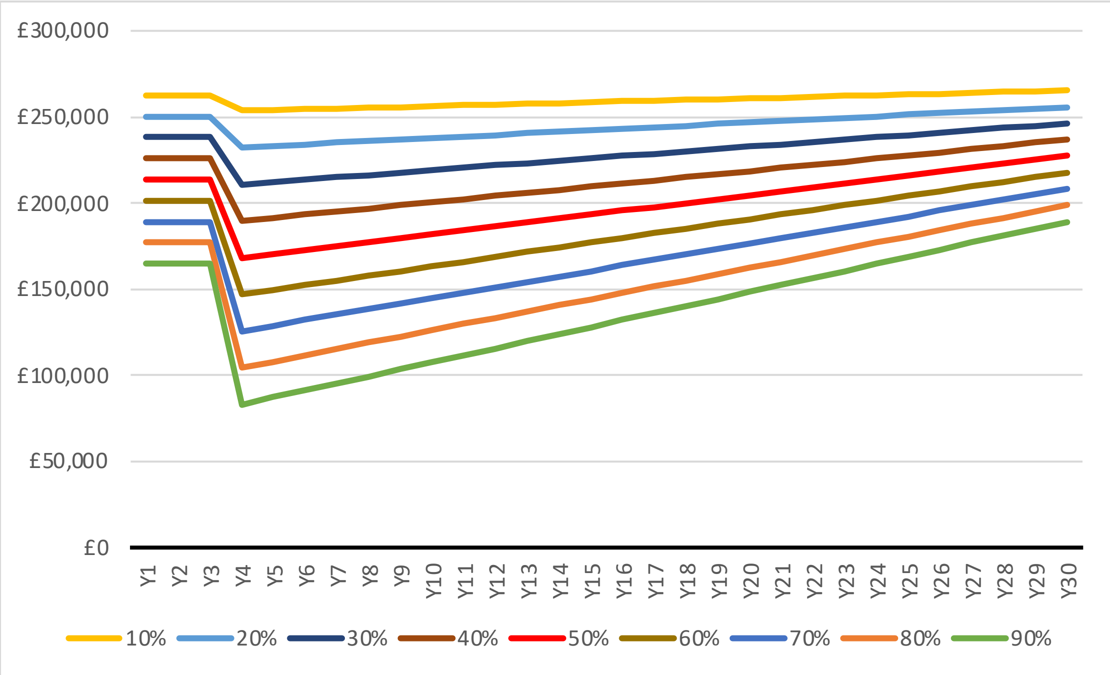
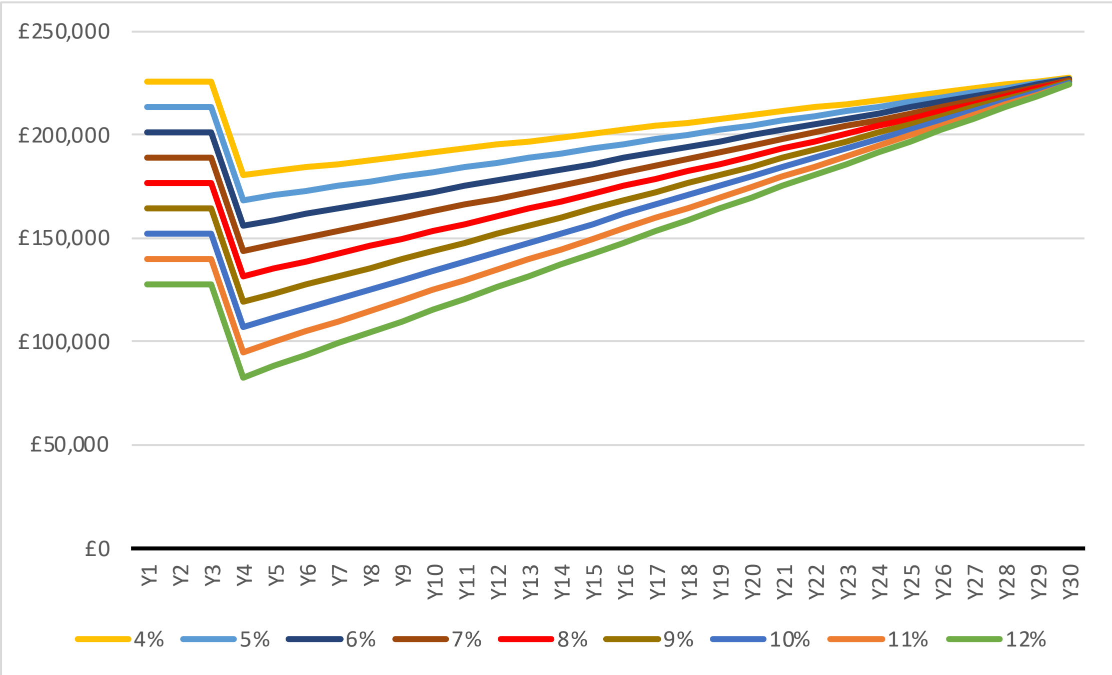


Figure 44. Sensitivity of PBT to Interest Rate in the Constrained Solar & Wind Scenario – With Complex Site



£250,000
£200,000
£150,000
£100,000
£50,000
£0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
Y8
Y9
Y10
Y11
Y12
Y13
Y14
Y15
Y16
Y17
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Y19
Y20
Y21
Y22
Y23
Y24
Y25
Y26
Y27
Y28
Y29
Y30
4%
5%
6%
7%
8%
9%
10%
11%
12%

Wind Only Unconstrained without Complex Site

Figure 45. Debt Coverage vs % Debt in Unconstrained Wind Scenario – Without Complex Site

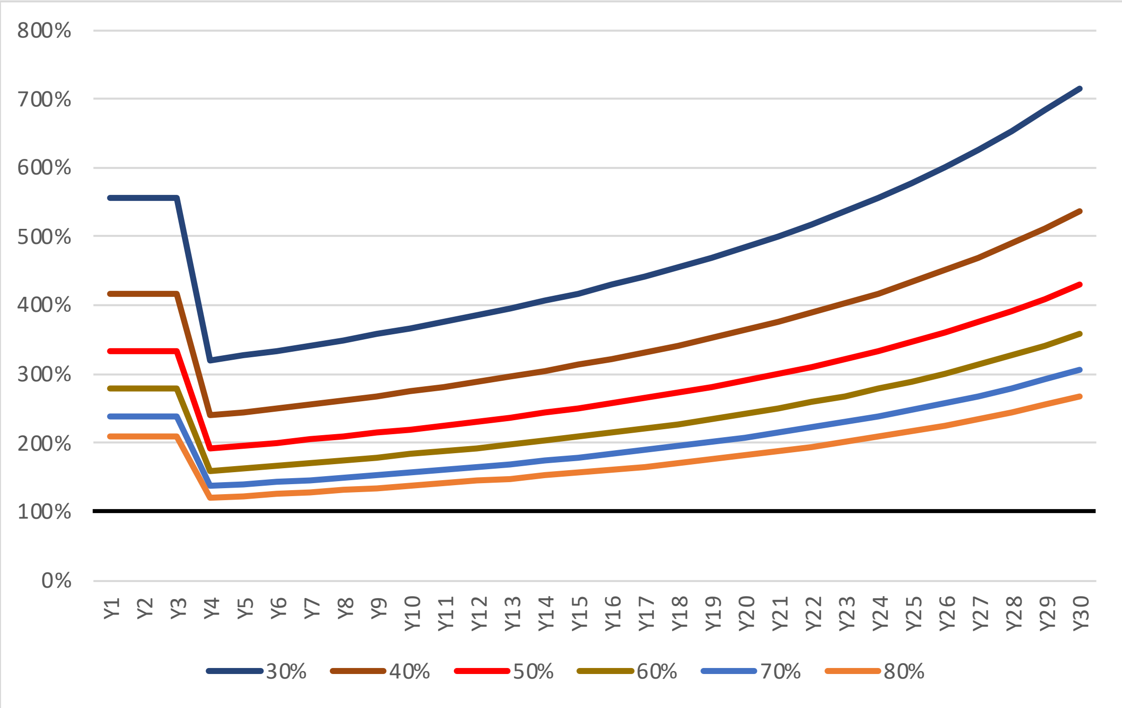


Figure 46. Sensitivity of PBT to % Debt in Unconstrained Wind Scenario – Without Complex Site

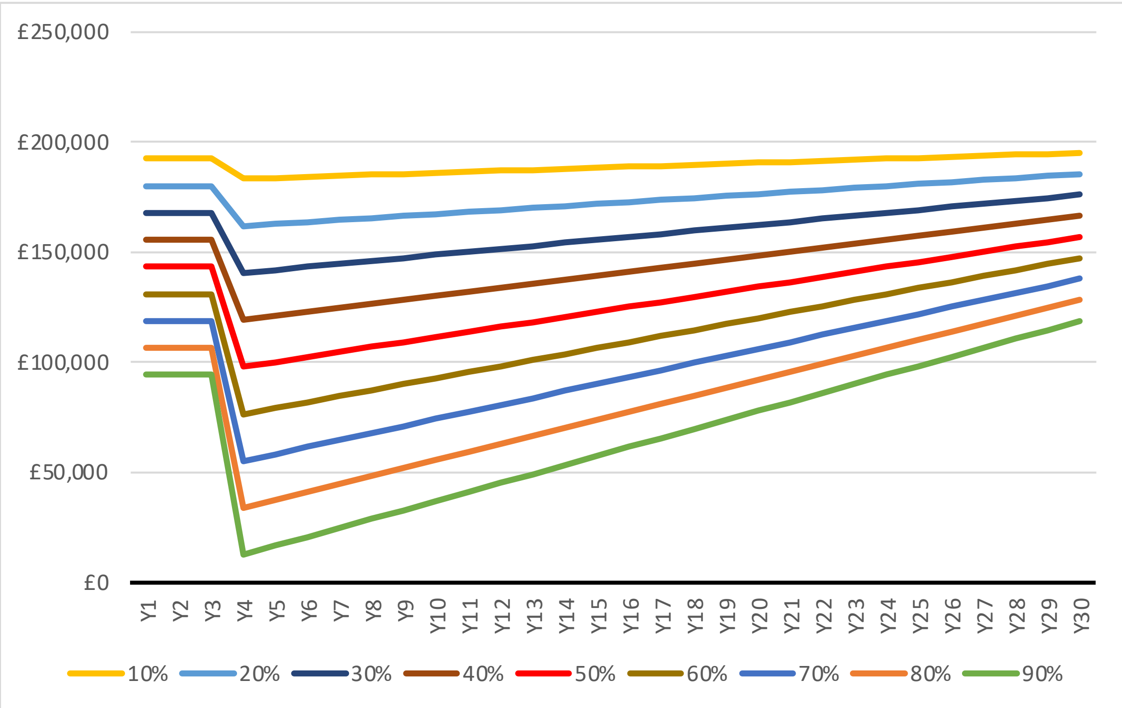
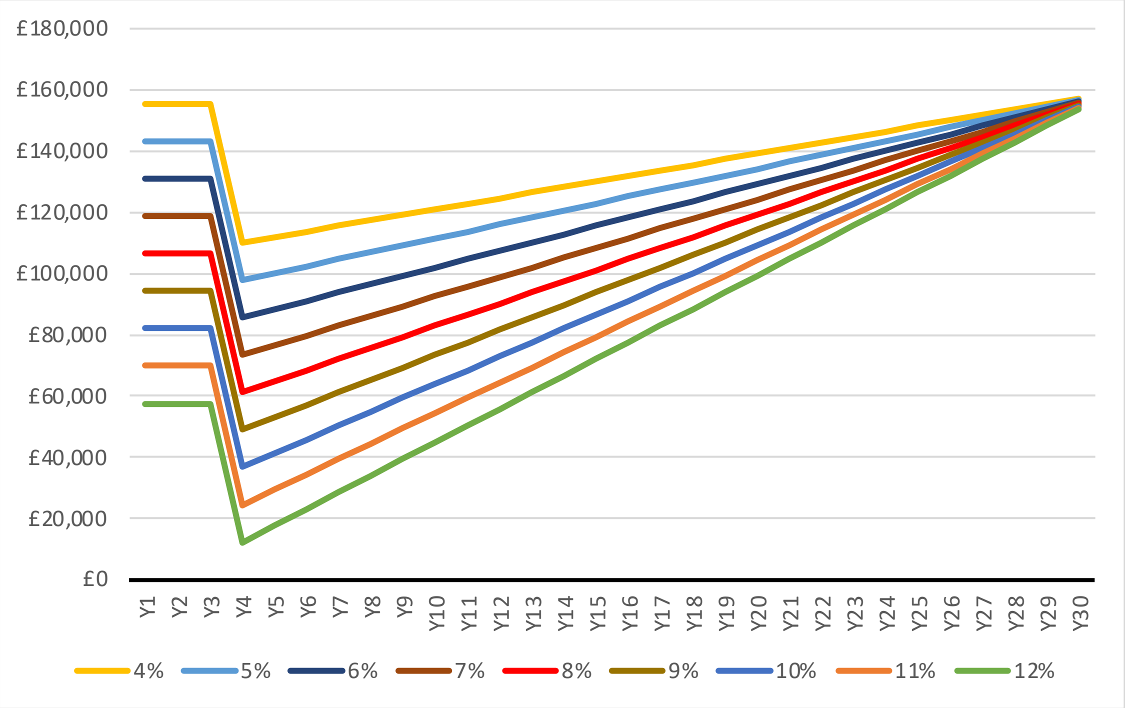


Figure 47. Sensitivity of PBT to Interest Rate in Constrained Solar & Wind Scenario – Without Complex Site



Conclusions

A wind only and a wind/solar hybrid model drastically changes the economics compared to solar alone although a higher match tariff may be possible with a lower TOUT in the case of solar alone.

In all cases, the complex site improves the income considerably and the combination of wind and solar will be beneficial to demand customers. Note however, there will be a challenge to recruit sufficient domestic customers. Recruiting some businesses would help create sufficient demand.

There is considerable benefit in using a battery to store power on a site that would be normally constrained. The storage scenario enables connection to the LV network in an area that would normally be constrained. The excess energy stored is enhanced when combined with a local electricity market as it creates revenues from energy that would otherwise be lost to site constraints.

The business case is strong when the generation is complemented with a complex site. The use of a club allows more leverage for a similar amount of risk and shields the project from rises in interest rates.

Next Steps

Get more accurate costs for wind, solar and storage to check the business model and decide on which combination and connection to use. These costs need to be refined before engagement with householders, business or suppliers to set up a complex site. There will be a period of studies required before a planning application and therefore plenty of time in which to engage with the community.

SECTION 3 – SCENARIOS FOR SOUTHAMPTON LOCAL AUTHORITY

Southampton City Council has a range of building assets across the city. Some of these are suitable to install solar panels but these are not necessarily where the demand is. By creating a local market for their own assets that do use significant power but are unsuitable for solar, they can reduce their own costs and also help manage constraints on the network by using the power locally. This should also help justify installing more solar to maximise the size of arrays on roofs.

LASER electricity purchasing arrangements and its implications

Southampton procures power through LASER. This is an organisation that buys power for a range of local authorities. It is able to buy 'baskets' of power from different generators ahead of use on a hedged basis (e.g. 2 years ahead) due to the volume they are buying. It uses four large suppliers on a framework basis. LASER can appoint a supplier outside of the first placed bidder if there are specific requirements from the local authority that the main supplier cannot provide. In terms of LASER's procurement, unless Complex Sites became very significant for a large number of its clients, it would not have a noticeable impact on the shape of the demand in the basket. Its key role would be to liaise between the supplier and the local authority during the contractual agreement to ensure the supplier can provide the services needed. In some circumstances LASER provides billing and holds debt until services are delivered. In this case, Energy Local could work with LASER to provide the system to allocate power used locally between buildings.

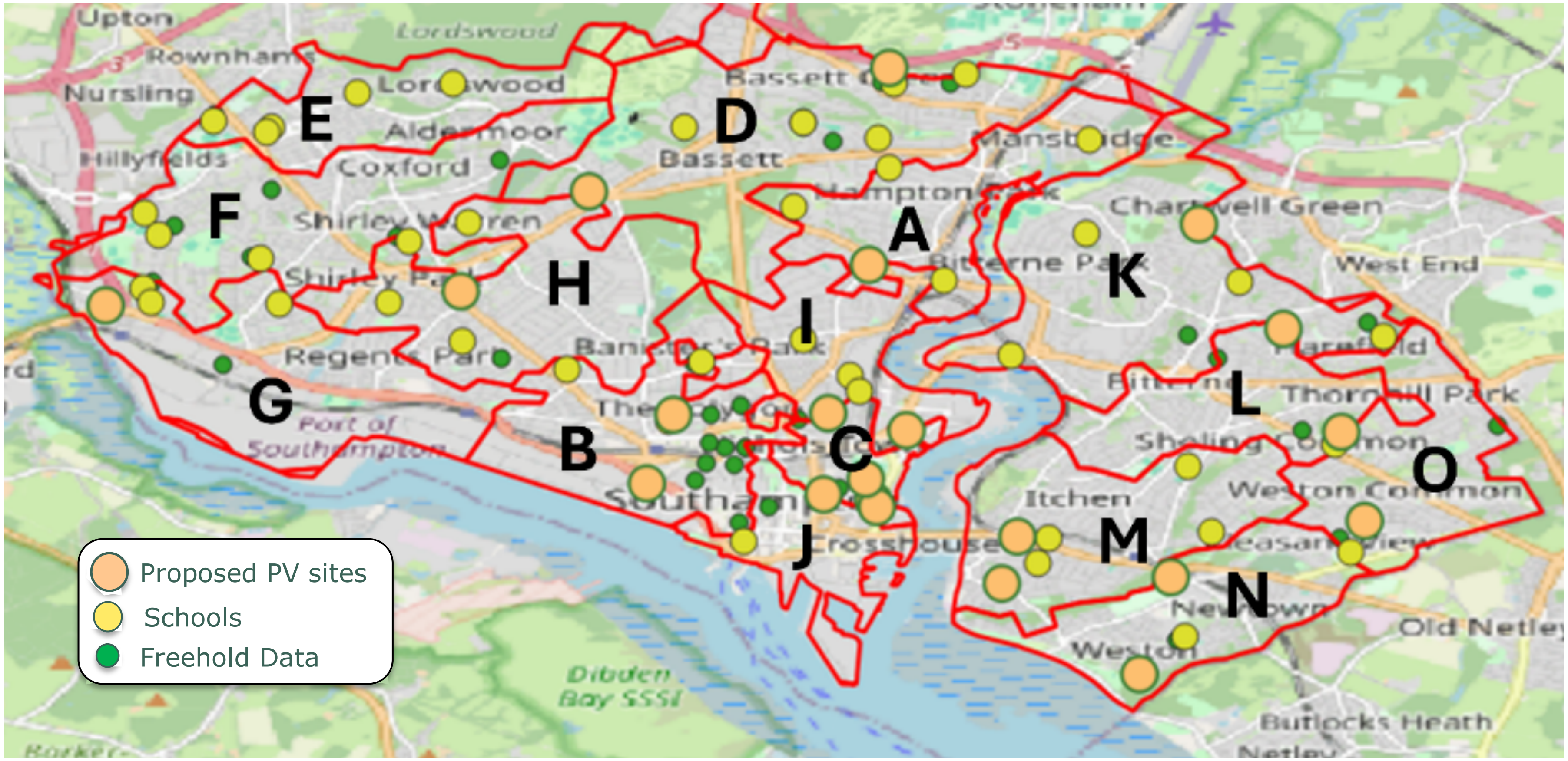
The are four suppliers on the framework at present; Eon/nPower, SSE, EDF and Total.

LASER has also negotiated that Southampton can receive an export rate (SEG) of 16.5p/kWh for the first year.

Proposed solar installations across the local authority, and first three substation areas

The potential solar sites and locations of local authority sites were plotted against the primary substation areas, B, C and D. To show the principle of modelling we took three substation areas marked as these looked the most promising with considerable number of solar sites and local authority buildings where the council pays the bills (freehold) or schools in the LASER contract.

Figure 48. Substation areas in Southampton



Modelling focused on buildings where the Council pays the bills directly, taking those with a demand profile that is predominantly during the day initially. Therefore, the focus is Substations B, C and D.

Modelling

Because the Council is 'selling to itself' the match price is assumed to be zero. It is unclear what sort of tariff the additional power would be purchased for under LASER. We therefore focused on the amount of solar power that could be netted off using a 'complex site' over and above that used by a building itself and how much solar power would then be left over.

To create a half hourly profile of the total generation that could be installed on each building, we estimated the angle and orientation of the roof and created a profile with a total annual output that was the same as that estimated in previous studies.

Where there was half hourly demand data, this was used in the modelling. Where there was no metered data, we estimated a profile from similar buildings and information about how the building is used.

Some sites include an additional scenario that models a smaller PV array to solely meet the building's load. These figures have come from scaling down the initial array and do not account for periodicity of generation. For sites where potential annual generation is already less than the annual consumption, this additional modelling was not conducted. Other sites were financial viable with the larger array even if the array produced more than was consumed by the building and the Council had decided to retain the larger array.

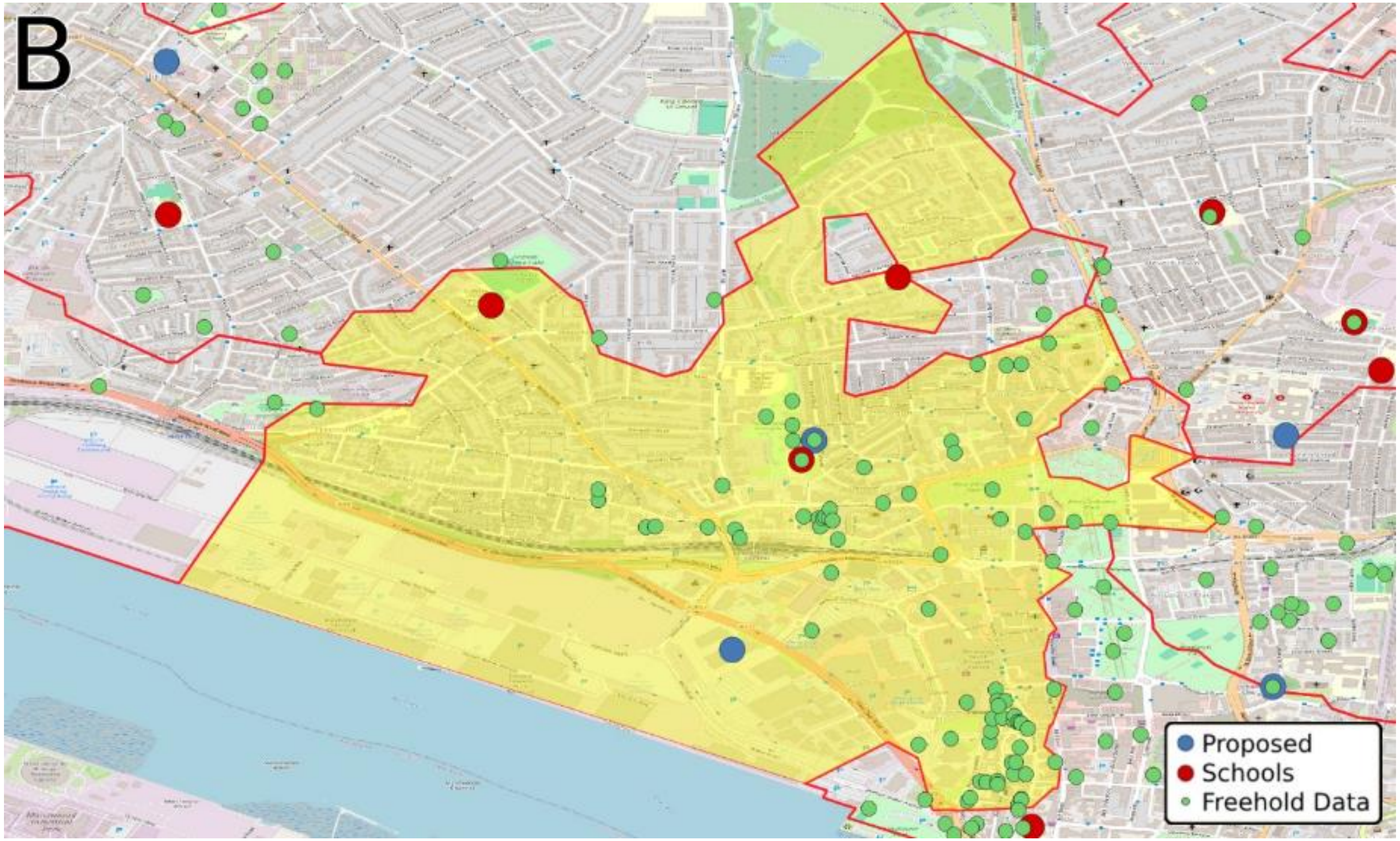
Note that the sites that are selected will likely be in Council hands long term.

It is assumed that on average the price of power long term for the council will be 23p/kWh, with the council being able to agree a SEG for export from a building which is higher than a PPA with a complex site. We have estimated that long term this will be 10p/kWh. As the match price is set to zero, it is assumed that any power used within the 'complex site' saves 23p/kWh.

It is assumed that cost of installation of the solar is £1200/kW. This is a high value but provides for additional works that may need to be done.

Substation B

Figure 49. Substation B Area highlighting council-owned freehold sites, school sites, and proposed PV sites



Onsite Solar Panel Usage

This section models the benefits of installing rooftop solar panels (Table 23). The annual demand and generation for each site are given in the table below along with an estimate of the amount of generation used by the building that it is installed on. This is compared to smaller arrays designed for just the use of the building where it is installed. The estimates given by the council for these small sites were fairly simplistic and therefore it is assumed that only 80% of the power is used on site and 20% is sold via a SEG.

Table 31. Projected savings from solar panels at each site in Substation B

		Maximised PV Scenario							Smaller PV to service building load only				
	Annual kWh Usage	**Annual Generation kWh**	**Annual Export kWh**	**Annual Remaining Import kWh. %**	**kWh used under the roof, % of usage**	**Under roof Savings (£)**	**Income from SEG (£)**	**Total Benefit (£)**	**Annual Generation kWh**	**kWh used under roof**	**Under roof savings (£)**	**Income from SEG (£)**	**Total Benefit (£)**
Banister Primary School	89,075	46,774	13,743	56,109 63%	33,031 37%	7,597	3,303	10,900	Full size array maintained				10,900
Sembal House	54,092	83,405	48,820	19,450 36%	34,642 64%	7,968	3,464	11,432	47,802	18,707 35%	£4,303	£1,497	5,800
St Marks CofE School	219,363	19,664	6,746	206,415 94%	12,948 6%	2,978	1,295	4,273	Full size array maintained				4,273

West Park MSCP	183,418	249,218	188,497	122,697 67%	60,720 33%	13,966	6,072	20,038	Full size array maintained				20,038
The Civic Centre	1,898,324	94,938	0	1,803,386 95%	94,938 5%	21,836	9,494	31,330	Full size array maintained				31,330
The Polygon School	52,179	88,944	10,113	31,928 61%	20,251 39%	4,658	2,025	6,683	Full size array maintained				6,683
Total	***2,496,451***	***582,943***	***267,919***	***2,239,985*** ***90%***	***256,530*** ***10%***	***59,002***	***25,653***	**84,656**	**547,340**	**240,594**	**55,338**	***23,685***	***79,024***

The Civic Centre achieves the highest financial savings from onsite panels, estimated at £21,836. Sembal House has the highest onsite usage percentage, consuming 34,624 kWh, which constitutes 64% of its total consumption. West Park MSCP has the largest export, at 188,497 kWh – i.e. it is a good site for solar but has little onsite usage.

Whilst the smaller arrays will cost less than the full size arrays the savings from the sites where the array could be reduced are reduced by 40%. Whilst the reduction in savings is not that great, it is generally cheaper to install larger arrays proportionately. It therefore makes sense to aim to justify installing the larger arrays and use the power via a complex site. Costs of setting up a complex site with one building owner are minimal.

Complex site Modelling

In total, summing the total export versus the total generation in Table 23, about 87% of the power is not used by the building it is installed on. Using a profile of the total generation exported from the buildings, we added one building at a time to a 'complex site' to ascertain how much power could be used by other Council owned buildings. Costs of setting up a complex site with one building owner are minimal.

Table 32. First site added to the 'complex site' in Substation B

Substation B	kWh extra local generation used by this site	Total kWh used by complex site	Proportion of local generation used
The Civic	256,594	256,594	95.75%

We found that the Civic is well-suited as a consumer member in this scenario as its load profile matched very well with the available generation, using 95.75% of available exported power.

This leaves a small amount of generation for other consumers. Due to the times of day the additional 4.25% of generation is available, these sites have very little impact on the proportion of local generation used.

Table 33. Additional sites modelled as consumer members and added consequentially to this scenario

Substation B	**kWh of extra local generation used in the 'complex site' by this building(s)**	**Total kWh used within the complex site**	**Proportion of local generation used**
The Civic + St Marks CofE School	164	256,758	95.81%
The Civic + Banister School	53	256,647	95.77%
The Civic + Polygon School	29	256,623	95.76%
The Civic + West Park MSCP	0	256,594	95.75%
The Civic + Sembal House	0	256,594	95.75%

This modelling showed that the Civic's load aligns well with the available generation and consumes a significant portion of it. As a result, adding additional sites only slightly increases the proportion of local generation used.

We recommend that a 'complex site' in Substation B should have the Civic as the sole consumer member. This would enable almost all the power to be used, thus saving the council a significant sum in total as in Table 26.

Table 34: Total benefits of the 'complex site' for Substation B

Benefit from behind the meter £	**Benefit from use in 'complex site' £**	**Benefit from SEG £**	**Total Benefit £**
59,002	59,001	1,139	119,143

The total costs are given assuming £1,200/kW.

Table 35 estimation of costs

Sembal *House*	**96**	**56**
St Marks *CofE School*	26.22	26.22
West Park MSCP	277	277
The Civic	111	111
The Polygon *School*	41.42	41.42
Total PV	551.64	511.64
Cost at *£1200/kWh*	**661968**	**613968**

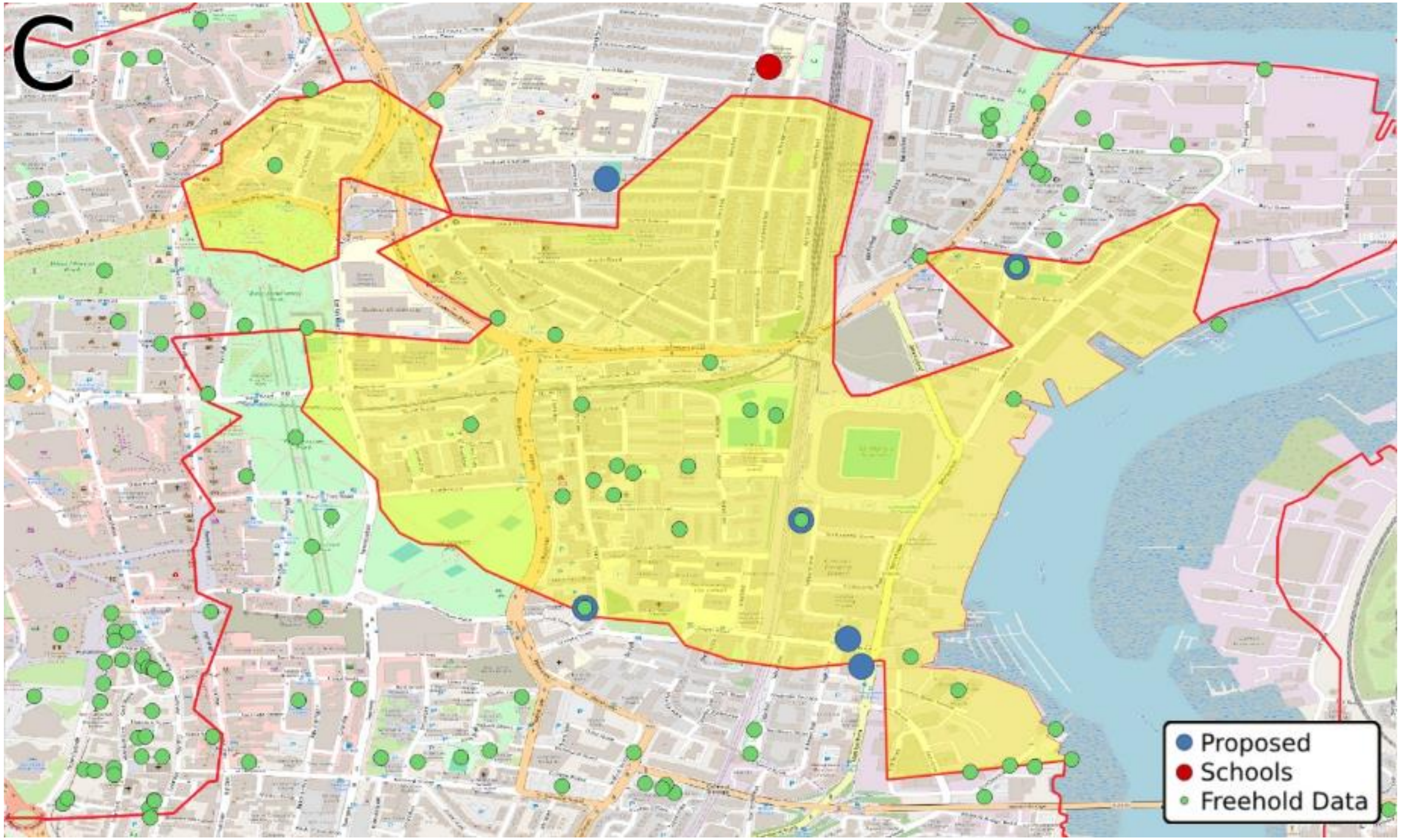
Comparing the three options, the benefits are in Table 36. The additional benefits of the larger arrays if just providing power to the building that they are mounted upon is small, however by using a 'complex site' the benefit is increased by over £34,000. This helps justify the larger arrays that will reduce strain higher up the electricity network by providing power close to where it is needed.

Table 36. Benefits of the three options for solar in Substation B

	Benefit from behind the meter with maximum solar array size (£)	**Benefit from minimised solar arrays size (£)**	**Benefit with 'complex site' (£)**
	84,656	79,024	119,143
Number of years to pay back (division of income by capital cost)	7.8	7.7	5.6

Substation C

Figure 50. Substation C Area highlighting council-owned freehold sites, school sites, and proposed PV sites



Onsite Solar Panel Usage

Table 37 below shows the benefits of installing rooftop solar panels. The annual demand and generation for each site are given along with an estimate of the amount of generation used by the building that it is installed on.

This is compared to smaller arrays designed for just the use of the building where it is installed. The estimates given by the council for these small sites were fairly simplistic and therefore it is assumed that 80% of the power is used on site and 20% is sold via a SEG.

The highest financial savings from onsite solar panels in Substation C come from Granville St Depot (£7,699).

Both the Archaeology Storage Centre and Graville St Depot have high percentages of onsite usage at 75% and 72% respectively.

The site with the highest export is the Archaeology Storage Centre at 110,653 kWh. This indicates an opportunity to use more power either in the buildings with PV if they are exporting power at different times to each other or in other council owned buildings.

Table 37. Projected savings from solar panels for the proposed PV sites

		Maximised PV Array							Smaller PV				
	Annual Electricity Use kWh	**Annual Generation kWh**	**Annual Export kWh**	**Annual Remaining Import kWh and %**	**kWh used under the roof, % of use**	**Under the roof Savings £**	**Income from SEG £**	**Total benefit (£)**	**Annual Generation kWh**	**kWh used under roof**	**Under the roof Savings £**	**Income from SEG £**	**Total Benefit (£)**
Archaeology Storage Centre	20,442	126,597	110,653	5,043 25%	15,399 75%	3,542	1,540	5082	17,819	2,169 11%	499	174	673
Granville St Depot	46,501	110,826	77,352	13,027 28%	33,474 72%	7,699	3,347	11,046	39,953	12,653 27%	2,910	1,012	3922
ITEC Centre	6,434	15,165	12,688	3,957 62%	2,477 38%	570	248	818	Full size array maintained				818
Paget St Workshop & Courier	30,513	13,802	2,844	19,555 64%	10,958 36%	2,520	1,096	3616	Full size array maintained				3616
Start Point Northam	31,362	No solar potential	None	31,362	0	0	0	0	No solar potential				
Total	*135,252*	*266,390*	*203,537*	*72,944 48%*	*62,308 52%*	*14,331*	*6,231*	*20,562*	*86,739*	*28,257*	*£6,499*	*£2,529*	*9029*

Complex site Modelling

Summing the total generation and export for each building in substation C, 75% of the power is not used by the building it is installed on. Using a profile of the total generation exported from the buildings, we added one building at a time to a 'complex site' to establish how much more power was used locally (Table 38).

Table 38. Sites modelled as consumer members and added consequentially to this scenario

Substation C	**kWh of extra local generation used by each additional building in the 'complex site' (kWh)**	**Total kWh used up by 'complex site' (kWh)**	**Proportion of local exported generation used within complex site**	**Annual remaining building consumption imported (kWh)**
Start Point Northam	20,067	20,067	10%	11,295
Paget St Workshop and Courier Service	11,776	31,843	15.8%	7,779
Granville St Depot	142	31,985	15.9%	11,184
Archaeology Storage Centre	0	31,985	15.9%	
ITEC Centre	566	32,551	16.2%	3,391
Total		*32,551*		*33,649*
Total of annual demand imported (not 'behind the meter' or in complex site)				25%

A 'complex site' reduces the imported power from 48% to 25%.

The additional financial benefit of a 'complex site' is in Table 30.

Table 39. Benefits of a 'complex site' for Substation C

Benefit from behind the meter £	**Benefit from use in 'complex site' £**	**Benefit from SEG £**	**Total Benefit £**
14,331	7,485	16,894	38,711

This is compared to the benefit of just on-site use and smaller arrays in Table 31. This shows the benefit is almost double when a 'complex site' is used. This helps justify the larger arrays and will take strain off the network at high voltages by providing more power locally.

Assuming £1200/kWp the cost of the two options for size of arrays installed is in Table 40 Size and cost of the arrays for substation C

Table 40 Size and cost of the arrays for substation C

Site	**Maximum**	**Reduced Size kW**
Archaeology Storage Centre	140	20
ITEC Centre	18	18
Granville St Depot (Chapel Road)	125	45
Paget St Workshop and Courier Service	14	14
Total	297	97

The annual benefit and payback is given in Table 41.

Table 41. Comparison of benefit and payback of the different options for solar in Substation C.

	Benefit from behind the meter with maximum solar array size (£)	**Benefit from minimised solar arrays size (£)**	**Benefit with 'complex site' (£)**
	20,562	9,029	38,711
Number of years to Payback, capital divided by income.	17.3	12.9	9.2

Additional buildings

There is still 63% of the power available. This could be used by other council buildings or commercial buildings who could join the complex site. However, for commercial buildings (i.e. independent and not part of the council estate) this would become complicated unless they could become part of the LASER contract.

Note that there are some domestic buildings where the landlord services are provided by the council under the LASER contract. Other buildings in the area that are Council owned are listed below although it is unclear which buildings are likely to remain in long term ownership.

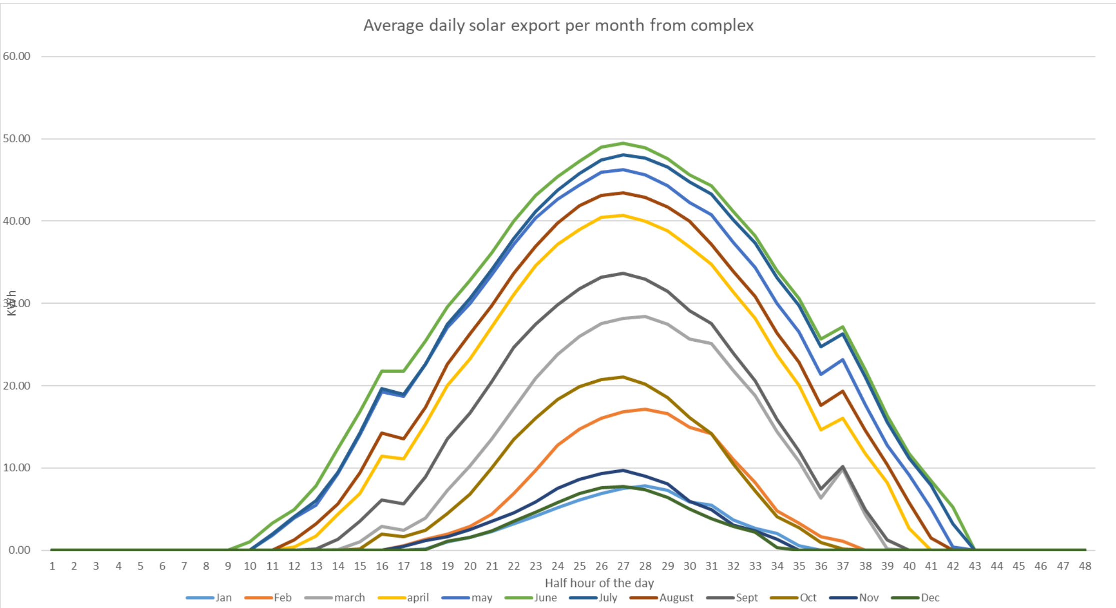
Table 42. Additional council-owned freeholds in Substation Area C

Description	**Site Type Description**
Albion Towers	Housing Blocks
James Street, Block 42 to 164 (evens) and Communal Centre	Housing Blocks
James Street, 093	Residential (RTB Flat - logged for lease purposes)
Kingsland Estate - all blocks	Housing Blocks (not included in asset count)
St Mary Street, 100F Central Housing Office	Housing Offices

Belvidere Hard	Mudland
American Wharf	Mudland
Chapel Wharf, SCH 005	Mudland
Crosshouse Road, The Crosshouse	Museums
Jonas Nichols Square Fountain	Museums
St Mary Street, 028 - 029, Church View	Offices
Melbourne Street Archaeological Store	Offices

However, the export from the ‘complex site’ peaks in the middle of the day (Figure 51) and therefore to be able to use this power the profile of additional buildings needs to be mostly during the day. The profiles of the buildings above are unknown but it is likely that the offices would benefit most if they are using power during the working day. Lighting and lifts in blocks of flats are less likely to benefit from solar. It is therefore difficult to model whether these would be beneficial to add but it is unlikely.

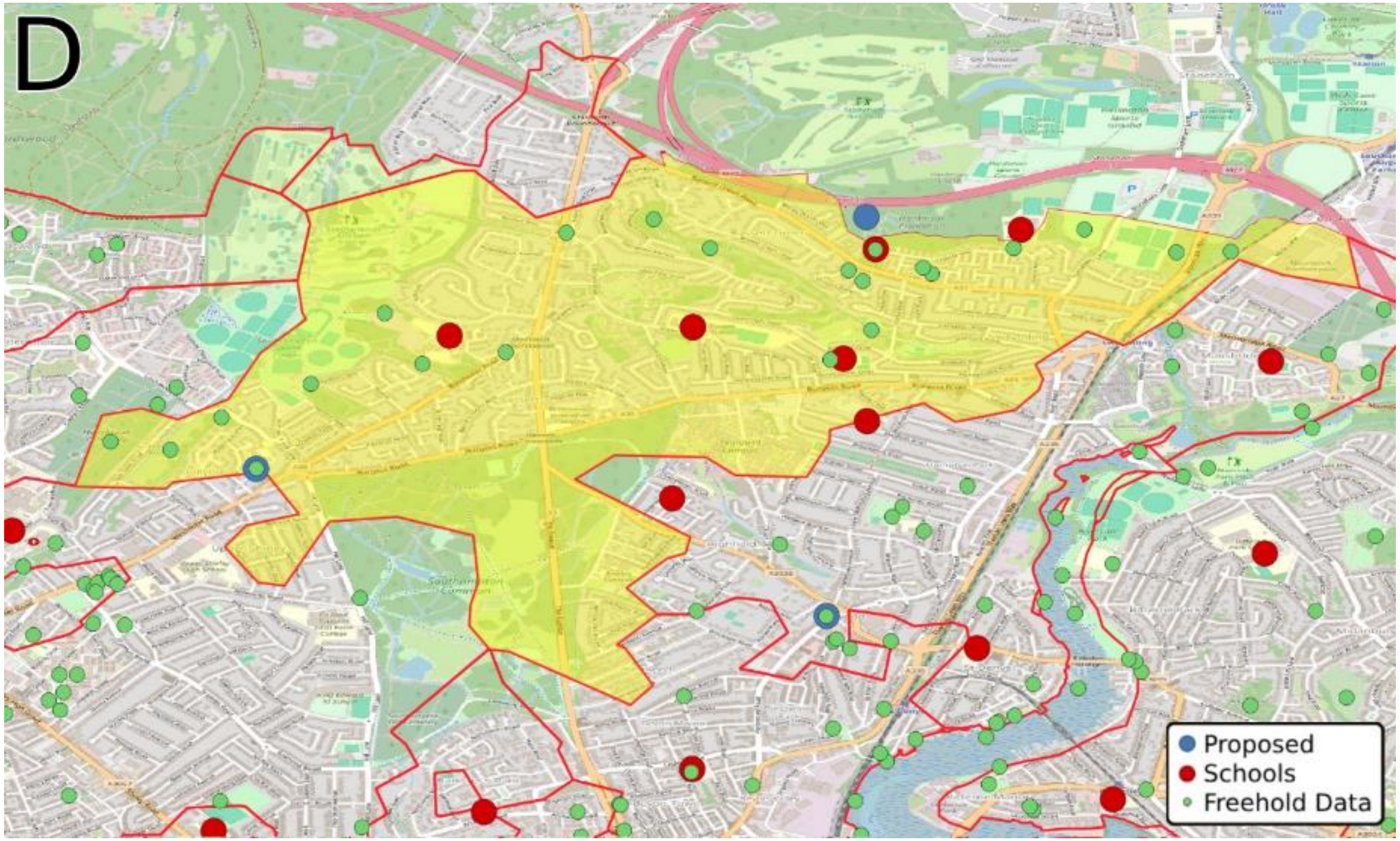
Figure 51 Average output from the ‘complex site’ in substation C.



Substation D

The modelled sites in this scenario are all schools. Freehold sites have been included to highlight other council-owned potential load consumers.

Figure 52. Substation D Area highlighting council-owned freehold sites, school sites, and proposed PV sites



Onsite Solar Panel Usage

Table 43. Projected onsite savings from solar panels at each school in Substation D

		Maximised PV Array							Smaller PV			
	Annual Electricity Use kWh	Annual Generation kWh	Annual Export kWh	Annual Remaining Import kWh, % of total	kWh used under roof, % of use	Savings under the Roof £	Income from SEG £	Total benefit (£)	Annual Generation kWh	kWh used under the Roof	Savings under the Roof £	Income from SEG £
Bassett Green Primary School	157,941	37,465	14,097	134,573 85%	23,368 15%	5,375	2,337	7,712	Full size array maintained			
Cantell School	531,905	305,994	73,865	299,776 56%	232,129 44%	53,390	23,213	76,603	Full size array maintained			
Hardmoor Early Years Centre	41,865	6,877	590	35,578 85%	6,287 15%	1,446	629	2,075	Full size array maintained			
Sure Start	24,282	12,510	4,283	16,055 66%	8,227 34%	1,892	823	2,715	Full size array maintained			
Vermont School	38,181	66,449	42,970	14,702 39%	23,479 61%	5,400	2,348	7,748	Full size array maintained			
Total	***794,174***	***429,295***	***135,805***	***500,684*** ***63%***	***293,490*** ***37%***	***67,503***	***29,350***	***96,853***				

The highest financial savings from onsite solar panels in Substation D come from Cantell School (£53,390). This is the most significant saving across all sites.

Vermont School has the highest percentage of onsite usage in this substation area at 61%.

The site with the highest export is also Cantell School at 73,865 kWh. The combined export from these sites is 135,805 kWh.

Complex Site Modelling

As there was significant power exported, we added each site as consumers to use the remaining electricity generated and to cover the remaining import. Sites were added in order of how much export they could use.

Table 44. Impact of adding sites consequentially as 'complex site' consumers in Substation D

Substation C	kWh of extra local generation used by each additional building in the complex site	Total kWh used by complex site	Proportion of the total local exported generation used within complex site	Annual remaining building consumption imported kWh
Hardmoor Early Years Centre	10,962	10,962	8%	24,616
Basset Green School	5,469	16,431	10%	118,142
Cantell School	1,565	17,996	13.3%	281,780
Sure Start	558	18,554	13.7%	15,497
Vermont School	0	18,554	13.7%	14,702
Total of annual demand imported, not behind the meter or in complex site		82,497		454,737 (57%)

The benefit of adding more consumer sites ends with the combination of Hardmoor Early Years Centre, Basset Green Primary and Cantell School. This would use approximately 17,996 kWh (13.3%) of available generation in the substation area. This is because the schools tend to have the same usage profile and are therefore exporting power at similar times of day. If all the above sites were added, this could increase to using 18,554 kWh (13.7% from 13.3%) of local generation so it is not worth adding these other sites for a 0.3% increase in consumption within the complex site.

The cost of the panels is given in Table 45.

Table 45 Cost of the solar panels for substation D.

Site	**kW**
Hardmoor Early Years Centre	7
Cantell School	412
Vermont School	92
Bassett Green Primary School	51
SURE START - Little Berries Hollybrook	15
Total	**562**
Cost at £1200/kWh	**£67400**

Table 46. The benefit of a 'complex site' with Hardmoor Early Years Centre, Basset Green Primary and Cantell School.

Benefit from behind the meter £	**Benefit from use in 'complex site' £**	**Benefit from SEG £**	**Total Benefit £**
67,503	17,996	27,011	98,653

Whilst there is not a huge increase in income, as there is no proposal to reduce the size of the arrays it is best to get as much value from them as possible.

	Total Benefit without a complex site	**Total Benefit With 'complex site' £**
	67503	98653

Years to payback, capital cost divided by income	7.0	6.8

There is still 56-57% of power imported (only 6-7% less) which shows that there is little diversity in school demand, and they do not fit well with solar as they are often closed at the weekend and during the summer. Sports facilities may be a good fit if they are often used in the summer and weekend. Again, the profiles of the potential additional buildings are in Table 47. There is a need for premises used at the weekend and primarily during school holidays to fit well with the export. We do not know the profiles of the additional premises so it is not possible to model if they would be beneficial.

Table 47. Additional council-owned freeholds in Substation Area D

Description	**Site Type Description**
Bassett Green Court, BLK INC 1 & BOILER ROOM	Housing Blocks
Ventnor Court, 001 - 060 Communal Centre	Housing Blocks
Ventnor Court, 061 - 122 Communal Centre	Housing Blocks
Red Lodge, Nursery	Depots
Stoneham Lane Land on West side	Outdoor Sport Facility
Family Hub Honeysuckle (formerly Sure Start Portswood, Bevois and Swaythling)	Family Hubs
Vermont Close/Overcliff Road, Recreation Ground	Sports Facilities

Next steps

Substation B will give an excellent benefit to the council. It is likely that the installations will pay for themselves with a favourable SEG. There is little difference in pay back for the reduced or larger array sizes and therefore it makes sense to install the larger arrays as this offers greater benefit with a complex site. Using a ‘complex site’ with almost all the power used at the Civic Centre will make a good business case and justify the larger arrays. This will also be beneficial for the network. For these sites, structural engineering checks are needed and then quotes for installation. These are large installations and therefore G99 applications for connections will be required. If the network is constrained at the primary substation level, Southampton City Council could accept a non-firm connection and accept they may be tripped off if voltage level or export through the primary substation is too high. This should be unlikely given the amount of power the Council could use below the substation.

With Substation C, the 'complex site' will improve the business case considerably and help justify the larger arrays. However, there is still considerable power that could be used by other council buildings. If the business case is not strong enough, considering including more assets within the 'complex site' should help. Structural surveys, quotes and G99 applications are needed as above.

Substation D demonstrates that schools are not a good fit for solar and have little diversity. However as there is no option to reduce the size of the arrays, creating a 'complex site' will improve the business case slightly. The sports facilities may be complementary to the schools use and solar generation. If the business case is not strong enough for the individual schools, the next step would be to establish if the sports facilities will be retained by the Council and what their demand profile is.

The next step would be to work with LASER to find a supplier on the framework willing to set this up and work with the supplier to ensure that the correct flows and billing is set up.

If only the minimum sized arrays are selected, their size needs to be checked to minimise export as the present estimation is very approximate.

Conclusions

Whilst some roof mounted solar exports at unusual times of day or only in some seasons, for most Council owned buildings using a 'complex site' will justify expanding the size of solar arrays and help reduce costs overall and benefit the network. A 'complex site' will also help ensure that the solar is used more efficiently and is less likely to be exported further up the network. Where there is diversity in load, the payback time is nearly halved. Where the demand is all schools there is little diversity in demand and therefore there is little additional power used and only a small difference in payback. For sites where the maximum size of array is to be installed anyway, the minimal cost of setting up a complex site and the risk is very low.

APPENDIX A - GLOSSARY

Acronyms

- **ANM**: Active Network Management - Systems used by Distribution Network Operators to manage network constraints.
- **BUoS**: Balancing Use of System - Charges for balancing the power system nationally.
- **BWCE**: Bath and West Community Energy - A community energy organization involved in renewable energy projects.
- **DCC**: Data Central Collector - Collects data from smart meters.
- **DC**: Data Collector - Collects and validates data from meters.
- **DA**: Data Aggregator - Aggregates data to send to settlement and other parties.
- **DNO**: Distribution Network Operator - Companies responsible for operating the distribution network.
- **DUoS**: Distribution Use of System - Charges for using the distribution network.
- **GSP**: Grid Supply Point - The point where the distribution network connects to the transmission network.
- **IRR**: Internal Rate of Return - A measure of the profitability of an investment.
- **kWp** – kilowatt-peak, which is a standard unit of measurement used to denote the peak performance capability of a solar photovoltaic (PV) system or an individual solar panel.
- **MOP**: Meter Operator - Installs and maintains meters.
- **MPAN**: Meter Point Administration Number - Identifier codes assigned to meters for export or import.
- **MPID -** Market Participant IDs
- **NGED -** National Grid Electricity Distribution, which is the regional electricity distribution division of National Grid.
- **NREL**: National Renewable Energy Laboratory - A U.S. laboratory specializing in renewable energy research.
- **PPA**: Power Purchase Agreement - A contract between a generator and a licensed supplier for the sale of electricity.

- **ROE**: Return on Equity - A measure of the profitability relative to shareholders' equity.
- **SEG**: Smart Export Guarantee - A scheme that pays small-scale generators for the electricity they export to the grid.
- **SMETs**: Smart Metering Equipment Technical Specifications - Standards for smart meters.
- **TUoS**: Transmission Use of System - Charges for using the transmission network.

Terminology

- **Balancing and Settlement Code (BSC)**: The code that governs how power is bought and sold in the electricity market.
- **Capex**: Capital Expenditure - The cost of developing or providing non-consumable parts for the product or system.
- **Constraint** - this refers to a situation where there is a limitation on how much generation can be exported or users can import due to the Distribution or Transmission network (see below) reaching its physical or operational limits.
- **Complex Site**: A setup where the power used on a set of meters is not entered into settlement as individual meters. In particular, in the context local energy, consumers and generators net off generation and demand within the same primary substation area, creating a local energy market.
- **Distribution networks**: Distribution networks take electricity from the transmission lines (see **Transmission network** below) and bring it to homes and businesses or other locations that use electricity.
- **Elexon** – This is a not-for-profit company, owned by National Grid Electricity System Operator. Its work includes administering the Balancing and Settlement Code, which is a legal framework governing how electricity is traded in the wholesale market.
- **Embedded Generation**: Small-scale generation connected to the distribution network.
- **Exempt licence scheme -** In the UK, the Electricity Licence Exemptions Scheme allows certain electricity generators, distributors, and suppliers to operate without holding a full electricity licence. This scheme is designed for small-scale operations. A particular case for supply is when the power supplied is under 5MW non-domestic or 2.5MW domestic, it is then exempt from green levies.

- **G100** - G100 is a technical standard in the UK electricity industry, specifically related to the connection of export-limiting devices to the distribution network. These devices are commonly used when electricity-generating installations (like solar PV or wind turbines) are connected to the grid, but the local network's capacity to accept exported power is limited. The goal is to use or store power on site to avoid overloading the local distribution network
- **Gate closure** - refers to the point in time by which all electricity market participants (like generators and suppliers) must finalise their contracts for buying or selling electricity for a given half-hour trading period.
- **Green Levies**: Charges on electricity bills to fund renewable energy and energy efficiency schemes. They include Renewables Obligation, Contracts for Difference, Feed in Tariff and others.
- **Hedging**: Buying blocks of power in advance at a cheaper rate.
- **Local Balancing**: Matching local demand with local generation to reduce the need for network reinforcement and national balancing.
- **Local Electricity Market**: A market where power is generated and consumed locally, reducing costs and increasing efficiency.
- **Match Tariff**: Under the Energy Local model, this is the price agreed between the generator and demand members for the power consumed within the complex site.
- **Negative price**: A negative price in electricity markets occurs when demand customers are effectively paid to consume or reduce production of electricity, rather than being paid to supply it. This unusual situation happens when there is excess electricity supply relative to demand, and the system cannot store or use all the generated power. Negative prices can arise in markets where there is a lot of renewable electricity or limited flexibility to adjust demand quickly.
- **Non-Firm Connection**: A type of connection where the generator may be disconnected or constrained if the network cannot take its full output.
- **Opex**: Operational Expenditure - The ongoing cost for running a product, business, or system.
- **Primary Substation**: A substation that steps down voltage from 33kV to 11kV (occasionally 132kV). General this feeds a few thousand households and businesses but can be up to the 100 000s.
- **Pseudo MPANs**: Virtual Meter Point Administration Numbers not linked to a physical meter, used to group net generation and demand.

- **Settlement**: The process of recording how much power is bought and sold by suppliers and generators and where it was used.
- **Spot price** - refers to the price of electricity before gate closure, usually within next half-hour. It reflects the current balance of supply and demand in the electricity market and fluctuates frequently based on factors like generation availability, consumer demand, weather conditions, and grid constraints.
- **Statement of Works**: A network study required for connections above a certain capacity to assess the impact on the transmission network.
- **Suppliers** – these are the companies that purchase electricity from generators and sell it to consumers. Their main responsibilities involve sourcing electricity from the wholesale market, managing customer accounts, billing, and ensuring customers have access to electricity.
- **Three phase and single phase** – Three phase connections have three connections to the 3 phases of an AC system, a single phase has just one (this is typically for domestic connections in the UK.
- **Time of Use Tariff (TOUT)**:A tariff system for power that has different prices for different times of year..
- **Transmission network -** In brief, transmission networks cover the long journey from where energy is produced to where it's needed in large quantities, while distribution networks take it a short distance to households, businesses and other power users. Transmission networks are like "motorways" which carry a huge amount of electricity over long distances. In England and Wales, the transmission network is operated by National Grid.
- **Triad Periods**: The three half-hour periods of highest demand on the electricity network during winter, used to calculate certain charges.
- **Vertical Bifacial Panels**: Solar panels that produce power from both sides and are mounted vertically, typically facing east and west.

References, sources and helpful links:

Energy Networks Association: Energy Networks explained – this explains the relationship between Transmission networks and distribution networks (www.energynetworks.org/energy-networks-explained/).

Elexon: Delivering the Balancing and Settlement Code (https://www.elexon.co.uk/

P441 Creation of ‘complex site’ Classes - Elexon BSC)

About Energy Local (https://energylocal.org.uk/about-us)