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Tesla Powerwall 2

Is Tesla Powerwall 2 Right for Me?



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Scope

This guide is aimed at homeowners interested in installing the Tesla Powerwall 2.

The guide has been produced by Spirit Energy and is available for download from www.spiritenergy.co.uk.

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Additional Resources

You may also be interested in the following resources, available for download from www.spiritenergy.co.uk:

- **Guide to Residential Storage**

This is an in depth guide to battery storage, with a focus on the economics and on the technical aspects of storage.

- **Guide to Residential Battery Back-up**

This guide concentrates specifically on the use of battery storage to achieve grid back-up in a residential property.



1. Introduction

1.1 Is the Tesla Powerwall 2 right for me?

In the past 12 months, Tesla has generated unprecedented interest in home battery storage in around the world. Their latest product, Powerwall 2, has spearheaded a 50% drop in the cost per kWh of storage capacity, whilst achieving an aesthetic that wouldn't look out of place at Apple Inc.

This guide is designed to assist you in deciding if Tesla Powerwall 2 is right for your home.

It starts with a review of the benefits of battery storage in general, on the basis that a prior question for anyone considering Powerwall 2 has to be "is battery storage right for me?" It then sets out the key features and limitations of Powerwall 2, followed by a comparison of Powerwall 2 with alternative brands and battery chemistries.

1.2 Is battery storage right for me?

In the UK, hundreds of thousands of domestic and small commercial solar systems have been installed. Over the past two years, more and more of these systems are being retro-fitted with a complementary battery storage system to help maximise the benefits of solar PV generation. In several cases, the size of the original solar system is being extended.

Installing a battery affords the following potential benefits:

- **increased on-site use of solar** – with a correctly sized battery system, 65%-80% of solar generation should be used on site, thus reducing the owner's electricity bill;
- **emergency power supply in a power-cut (optional extra);**
- the ability to **buy electricity off-peak and store it for use at peak** – a real savings opportunity with the advent of smart meters and time-of-use tariffs such as the Green Energy 'TIDE' tariff;
- the potential to **increase on-site power output by around 20%** (useful when fast-charging an electric vehicle);
- potential to **access future opportunities including the export and sale of electricity at peak charge times, and the provision of grid balancing services;**
- **reduction in our collective carbon footprint** – by smoothing out the peaks and troughs of demand, battery storage negates the need for further investment in fossil fuel power plants.

In economic terms, with the correctly sized system, the **lifetime cost per kWh of stored electricity is below the current average domestic grid cost of around 16p per kWh**, and well below the **average expected cost over the life of a system of around 25p – 30p per kWh**.

In summary, there are many compelling reasons to install on-site storage. In fact with time-of-use tariffs, you can benefit from battery storage whether or not you have solar installed.

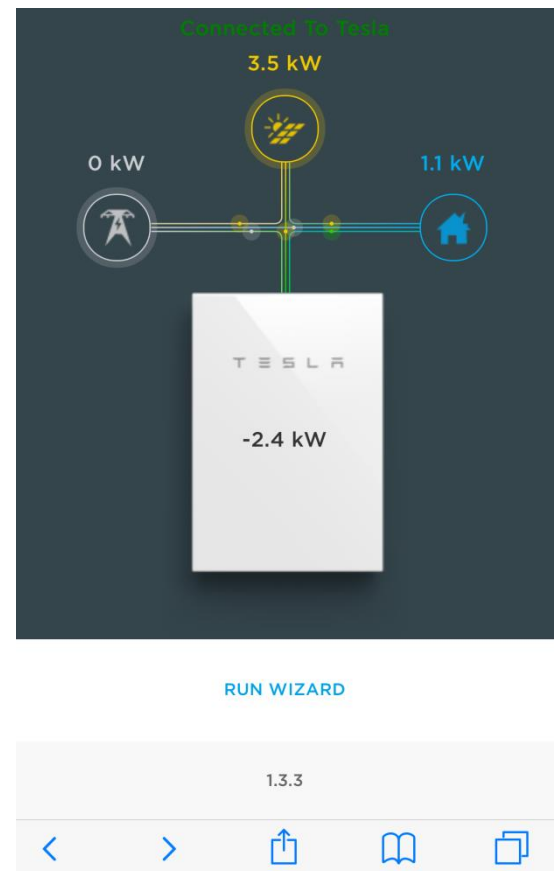


2. Powerwall 2 Features

2.1 Powerwall 2 at a glance:

The specification of Powerwall 2 is as follows:

Usable capacity:	13.5 kWh
Power output:	3.68 kW or 5 kW (subject to grid permission)
Round-trip efficiency %	>90%
Monitoring:	Tesla App
Warranty:	10 years
Mounting:	Wall- or floor-mounted, can be stacked
Location:	Indoor or outdoor installation
Dimensions (main unit):	H 1150 mm W 755 mm D 155 mm
Weight:	125 kg
Energy density (including inverter/charger):	100 kWh / m ³



Functionality

The system offers a range of functionality:

- ✓ on site storage of excess solar power;
- ✓ **(Q1 2018)** 'off-peak' charge and 'peak' discharge (i.e. timed charge and discharge);
- ✓ **(Q2 2018)** back-up.

Note that timed charge and discharge will be available to existing Powerwall 2 owners via a firmware update (delivered remotely). Back-up functionality will require a different gateway, and if back-up is a requirement, it is better to order it from the outset. Back-up can be installed retrospectively, but the original gateway will be redundant.



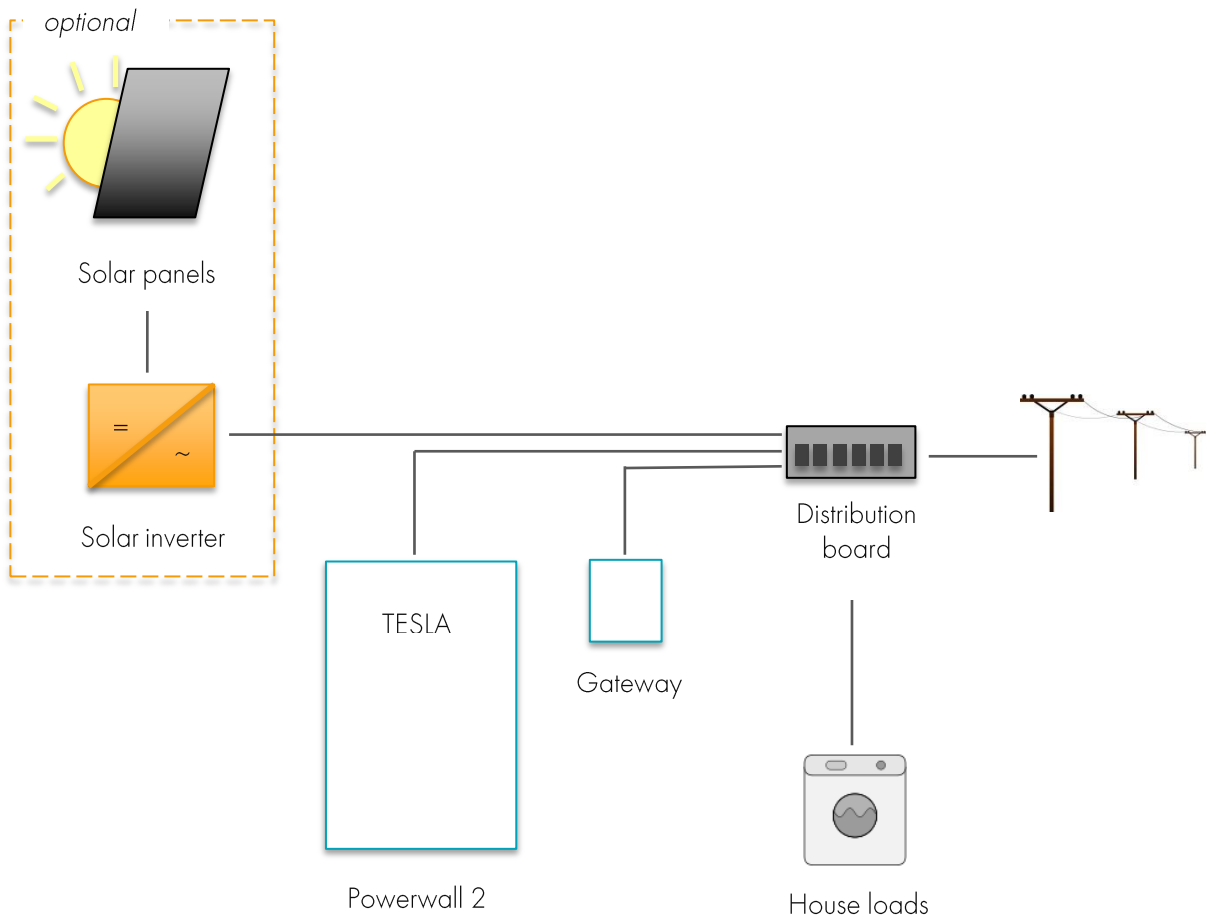
Installation

Powerwall 2 consists of the main unit (see picture on page 10) which houses the battery and inverter/charger, as well as a smaller "Energy Gateway" which measures the energy flows through the house and directs the battery to charge or discharge accordingly.

The gateway for a system without back-up is a small box (~250 mm x 250 mm) that is installed near the electricity meter. Whilst you can fit the units to suit, ideally the main battery unit should be relatively close to the gateway, otherwise the installation cost increases. The best scenario is an integrated garage with the meter and fuseboard inside. If there is no garage, the main unit usually goes on the outside wall as close as possible to the gateway and electricity meter. The installation typically takes up to a day for two installers.

With back-up, a larger gateway is required.

A typical schematic for the system is as follows:





DNO (grid) application

Unlike most other battery systems, Powerwall 2 has a special certification (G100) which allows it to be installed using something called 'G59 fast track' which as the name suggests is a fast track application process. Fast track applies provided **the system is not intended to be used for back-up, the power output is limited to 3.68kWp and any existing PV system is <4 kWp**. This can save up to £250 and weeks of delay which is a huge thumbs-up for Powerwall 2.

In order to be able to use the full 5kW alongside solar PV, or to install the system with more than 4kWp of solar, or with back-up, a normal G59 application must be made to the DNO. We can do this for you. There is no cost for applying, but there may be a cost of up to £250 to connect (and additional costs if the DNO decides upgrades are required).

If you connect at 3.68kW, and later receive permission for an upgrade to 5kW, we install suitably sized cables at the outset, and the upgrade can be managed by us remotely.

Timed charge and discharge

Across the nation, electricity demand reaches a high in the late weekday afternoons (4-7pm), and then falls to a low overnight. However, to date most domestic properties have paid a single rate electricity tariff which doesn't reflect the peaks and troughs of demand. Some domestic properties are on an Economy 7 (or Economy 10) tariff with a 'peak' rate 7-9 per kWh) and an 'off-peak' rate (15p -20p per kWh).

In January 2017, Green Energy UK introduced a 'TIDE' tariff with a banded tariff reflecting demand and supply across the nation and the true 'underlying cost' of electricity:

Time of Day	Cost per kWh
11pm – 6am (Mon-Fri)	4.99p
6am – 4pm (Mon-Fri)	11.99p
4pm – 7pm (Mon-Fri)	24.99p
7pm – 11pm (Mon-Fri)	11.99p
6pm-11pm (Weekends)	11.99p
11pm – 6am (Weekends)	4.99p

With the advent of smart meters, able to record half hourly electricity use, the market will gradually witness the introduction of many more such 'time-of-use' tariffs.

Clearly there are large savings (up to 20p per kWh under 'TIDE') to be made by buying electricity at night and using it in the day. Powerwall 2 will offer this functionality from Q1 2018. Existing owners can access the functionality via a remote firmware upgrade.



As mentioned already, you don't need a solar system to do benefit from time of use charge and discharge.

Back-up

From Q2 2018, Powerwall 2 will enable you to continue providing power to your home or business during power cuts. The system will switch automatically although the switch will not be to "UPS" (un-interrupted power supply) standard. Tesla claims that in general you won't notice the switch (except via a text from Tesla), but don't rely on the system if you have critical loads (e.g. medical) requiring seamless back-up.

You will need to specify a reserve percentage (e.g. 30%) and the system will always keep that percentage of the capacity in reserve for a power cut. This setting can be changed via the Tesla app.

Solar PV will still work in a power cut. When the batteries are full, the system will ensure that the solar inverters power down if there is no load to utilise the excess solar.

The sizing of the Powerwall 2 means that with full back-up power (5kW), with some judicious juggling, your life should continue undisturbed through the average power cut. That said, you should probably wait until the power comes on before using an electric dryer, and if you want to ensure you can continue to cook up a storm in the kitchen, it's probably best to install two Powerwalls.

If you reserve 30% of your battery (4kWh), then you should be able to watch TV, use your laptop and keep the lights and freezer working for almost four hours, whilst enjoying a few cups of coffee in the process.

Typical loads are as follows:

Kitchen

- fridge / freezer: 500W;
- kettle: 3000W;
- oven: 3650W;
- induction hob: 1500W;

Office and entertainment

- laptop: 50W;
- TV: 80W;

Lighting

- average lighting load 500W (2500W all lights blazing for a typical 4 – 5 bed house (LED));

Laundry / dishwasher

- dishwasher: 1250W;
- washing machine: 500W;
- electric clothes dryer: 4000W.



Note that if you try and run more than the 5kW load limit, Powerwall 2 will stretch to 7kW for a few seconds, but after that you will see some 'brown-out' behaviour, as indeed you would if you tried to import more than your 100A supply from the grid.

3-Phase connections

Most households run on a single phase connection (230V). If you have a 3 phase connection (400V), there are limitations to the system:

- There is no '3-phase' version and Powerwall 2. Thus if you have a 3-phase supply, you need to select one of the phases to install your Powerwall 2, and use it to power single phase loads connected to that phase. You can put a single unit (or several units) on each phase, but you cannot 'share' storage capacity across phases.
- Even if you install a Powerwall 2 on each phase, the back-up functionality will only allow loads to work on a single phase when the grid goes down.

Other considerations

Some people have installed an immersion heater diverter with their solar system which works in a similar way to battery storage, but sends the extra power to heat their water. Does this make a storage system unviable? Not usually, because on sunny days there will be plenty of spare power to charge both the battery and heat the hot water tank. Also, electricity is worth about 3x more than heat from gas so it makes more sense to charge a battery than heat your hot water.

Note that a battery storage system will usually 'respond' to excess solar much quicker than an immersion heater diverter, and thus the default position will generally be that excess power goes to the battery before it goes to the immersion heater.

If you have an EV charger and an Economy 7 tariff, you can use the timed charge / discharge functionality to prioritise the car charging and battery charging as required, and ensure that the battery doesn't discharge into the car at night.

2.2 Powerwall 2 highlights

- **Design and efficiency** The system uses a highly efficient battery and inverter (>90% AC in to AC out) combined with a battery management system controlling the state of charge, voltage, temperature and other parameters.
- **Quality control and safety** The system has been developed in-house by Tesla following their substantial experience from automotive battery technology. Every system undergoes extensive testing and inspection in their "Gigafactory" in the U.S. and the in-built management system incorporates an inherently multi-layered safety system.
- **10 year warranty** Unlike most battery manufacturers, Tesla prefers to talk in terms of years rather than cycles, cycles being a less easily understood concept than years. Thus Powerwall 2 is one of the few systems we have seen to have a 10 year warranty, guaranteeing the battery will retain 80% of its initial capacity if used for on site storage of excess solar only. That means that after 10 years, the Powerwall 2 should still be able to provide 10.8kWh of capacity. If the battery is used for timed charge and discharge, then, to guard against excessive cycling, the warranty is subject to the battery having had a maximum output of 37.8 MWh during the 10 year period.



- **Lowest lifetime cost per kWh** Powerwall 2 offers great value for money, giving one of the lowest “lifetime cost per kWh stored” on the market, well below the current cost of grid electricity.
- **Beautiful design, wall hung and weatherproof** Space is a consideration in residential properties, as indeed is aesthetic appearance. The design is modern and minimalist, designed to be seen, not hidden away out of sight. And the waterproof case means that it can be installed outdoors.
- **Flexibility** Tesla has designed a system that will allow AC-coupling with any PV system, or even without a PV system if used only for off-peak charging and backup. Furthermore, up to nine Powerwall 2 units can be installed together to help power systems of varying size (three per phase for 3 phase systems).
- **High capacity (kWh) and power output (kW)** Powerwall 2 has a total usable capacity of 13.5 kWh and a maximum power rating of 5kW. This is well above the size of competitor systems (even though they cost more...). That’s because as well as being geared to storage of excess power, Powerwall 2 is geared to the future: time of use charging. Tesla also ‘gets’ that most people wanting back-up would like their life to continue relatively undisturbed (see our section on back-up to understand the different load types). The system is also geared to ride the rollercoaster of the British weather system.
- **Reduced peak demand charges** Powerwall 2’s large usable capacity can be combined with Economy 7 tariffs to help reduce your electricity bill. By charging Powerwall 2 overnight from the National Grid on the lower tariff, daytime peak demands can be met through battery discharge rather than more expensive Grid import.
- **Grid back-up facilities** From 2018 Powerwall 2 will enable you to continue providing power to your home or business during power cuts. See above –you need the back-up gateway to benefit from back-up.
- **Increases power output of the average home by 20%** Most homes have a single phase 100A connection, limiting power consumption in the home to 100A. At 230 V, that’s around 23 kW. With a 5 kW continuous output from the battery, a full battery has the potential to ramp simultaneous power consumption by 20% for 2.5 hours. This may come in handy if yours is one of those busy households with a two hour window in which to wash the dishes, dry the clothes, cook dinner and charge the car... And if you’re running a home with two electric vehicles fighting to be charged, some sort of turbo-boost on the incoming grid power is going to be an absolute must.
- **Export Limitation Certification** Most battery systems require prior approval from the electricity grid (DNO) before they are installed. However, Tesla Powerwall 2 is one of the only systems to have a certification in place which allows it to be installed alongside existing or new solar PV systems up to 4 kWp with fast track approval. This not only saves up to £250 of application cost, but can also avoid weeks of delay and potentially avoid a connection refusal (although this is rare unless the solar PV system is very large).

2.3 Powerwall 2 limitations

- **3 Phase connections** Tesla wins hands down against the competition unless you have a 3 phase (400V) connection, in which case the system has a couple of limitations. In order to power all loads, you will need to connect a Powerwall 2 to each phase, and even then, the battery capacity will not be shared across phases, so you will need to ‘balance the loads’ across





the phases. That said, if you've only got a single phase solar system, you just need one Powerwall 2, with the solar and the battery installed on the same phase. You won't be able to power 3 phase loads with the system, and with a back-up system, only one phase will be operational.

- **Non UPS back-up** The back-up doesn't meet 'UPS' standards. So if you have loads needing a UPS (e.g. medical loads), don't rely on the Powerwall 2. For most of us, the non UPS back-up is a non issue: you just may have to reset the clock on the oven when a power cut happens.
- **Not ideal for off-grid properties** Tesla is philosophically opposed to diesel generation and so Powerwall 2 is not compatible with generators. It is therefore unlikely to be a suitable choice for a fully off-grid property, where some sort of generator is likely to be required unless the renewable energy system and battery are to be completely over-sized.





3. Tesla Powerwall 2 Road Test

We have compared Powerwall 2 to three other systems, one utilising the same battery chemistry (LG Chem RESU) and two market leading systems utilising lithium iron phosphate, which is generally considered to be a slightly superior but more expensive chemistry (Simpli-Phi and Sonnenbatterie). As with the Tesla system, the Sonnen system is an all-in-one unit integrating the charger and the battery. LG Chem RESU and Simpli-phi are batteries only; for the purposes of our analysis we have paired them with Victron chargers, although other chargers would be possible (with the potential to scale to very large systems, with and without UPS back-up, single-phase or 3-phase).

Our comparison is two-fold, including:

- 1) a head-to-head evaluation of the key system parameters, such as efficiency, warranties etc;
- 2) an economic comparison of performance for households with different sized solar system, different levels of consumption and different tariffs.

3.1 Head-to-head evaluation

	Powerwall 2	LG Chem	Simpli-phi	Sonnen
Battery chemistry	NMC	NMC	LFP	LFP
Size				
Minimum single unit storage capacity (usable capacity) kWh	13.5 (100% DoD)	2.9, 5.9 or 8.8 (90% DoD)	2.1 or 2.75 (80% DoD)	2
Single unit charge rate (kW)	3.68 or 5 (see DNO permission above)	1.68	Rated for 2 hour charge so choose kW to be ≤ 0.5 * kWh	1.5, 2 or 2.5
Single unit power output (kW)	3.68 or 5	2.5 or 4.5	Rated for 2 hour discharge so choose kW to be ≤ 0.5 * kWh	1.5, 2 or 2.5
Scalability	Up to 135 kWh (10 units) and 50kW.	Up to 12 kWh per phase.	Up to MW (very large systems).	Up to 16 kWh per phase

Tesla uses a larger building block than others and Powerwall 2 is not suitable if a small system is required. Powerwall scales to up to 50kW /135kWh.



	Powerwall 2	LG Chem (with Victron)	Simpli-phi (with Victron)	Sonnen	
Connection type, scalability, 3 phase options					
Connection type	AC-coupled	AC-coupled	AC-coupled	AC-coupled	
3-phase options	Yes – with limitations	Yes	Yes	Yes – with limitations	
Functionality					
Solar utilisation	Yes	Yes	Yes	Yes	
Off-peak charge, peak discharge	Available Q1 2018 (firmware upgrade for existing)	Available Q4 2017	Available Q4 2017	Yes	<i>Functionality rests with battery control system / inverter. Available with Victron Q4 2017.</i>
Grid services	Possibly will be implemented at small scale	Possibly will be implemented at small scale	Possibly will be implemented at small scale	Expect will be implemented	<i>Depends on inverter and control system.</i>
Back-up functionality					
Operation in power cut	Available Q2 2018	Yes	Yes	To be implemented	<i>Tesla claims back-up is seamless but it is not certified to UPS standard. Not the right solution where extensive 'islanded' (off-grid) use is expected, with generator input.</i>
UPS capability (seamless transition)	No	Yes	Yes	To be implemented	
Generator compatibility	No	Yes	Yes	To be implemented	



	Powerwall 2	LG Chem (with Victron)	Simpli-phi (with Victron)	Sonnen	
Efficiency, lifecycles, warranty, end-of-life recycling					
Round-trip efficiency	>90%	90%	93%	91%	
Expected number of lifecycles (and variation with depth of discharge, if known)	Tesla is proud to be different on warranty, preferring to state its warranty in terms of years rather than lifecycles.	6,000 at 90% DoD, >10 year lifetime (at 25°C).	20% DoD: 46,800 50% DoD: 18,240 80% DoD: 10,000. 100% DoD: 5,000	>10,000	<i>Tesla doesn't state any guarantee in terms of lifecycles.</i>
Warranty	80% of original capacity (so 10.8kWh) will be available after 10 years (self-consumption only) or 37 MWh output.	60% energy retention after 8.2, 16.1 or 24.3 MWh.	10 years. Cycles: 20% DoD: 40,000; 50% DoD: 16,000; 80% DoD: 10,000; 100% DoD: 5,000	10 years, 10,000 cycles.	<i>Lithium ferro phosphate (LFP) has a superior life expectancy to lithium manganese cobalt (NCM). At 300 lifecycles per annum, LFP is theoretically expected to last 30 years as compared to ~ 15 years plus for NCM. But it costs a lot more and who knows where technology / prices will be in 15 years!</i>
Expected life	> 15 years	> 15 years	30 years	30 years	
End-of-life recycling	Through manufacturer	Through manufacturer	Through manufacturer	Through manufacturer	
Operating conditions, energy density					
Indoor / outdoor?	Indoor / outdoor	Indoor / outdoor	Indoor	Indoor	
Operating conditions	-20°C to 50°C, up to 3,000 m altitude	-10°C to 45°C, up to 2,000 m altitude	-20°C to 60°C	5°C to 30°C	<i>NCM requires better ventilation and has slightly more expensive running costs as a result.</i>
Energy density (kWh / m ³)	100 (includes inverter/charger)	133, 158, 178	138	52 (includes inverter / charger)	



3.2 Economic comparison

We have looked at the economics of the four systems under two scenarios:

- **Scenario 1:** four bedroomed house with 4kWp solar system, annual use of 6,000kWh;
- **Scenario 2:** large property with 8kWp solar system, annual use of 8,000kWh.

We have presented the optimised system size alongside system cost and annual benefit.

Note that we have given two prices in each scenario, one with the VAT rate at 20%, which applies if the battery is not acquired as an integral part of a renewable energy (i.e. solar PV) system, and one at 5%, which applies if the battery is acquired as part of a renewable energy system (may be new or extension of an existing system).

Scenario 1

	Powerwall 2	LG Chem RESU	Simpli-phi	Sonnen
Large load, standard solar system: 6,000kWh load + 4kWp solar system.				
Functionality: storage of solar, off-peak charging with daytime discharge (cost per kWh: day 20p, night 9p).				
Optimised system size	13.5 kWh 5 kW	5.9 kWh 1.68 kW/2.5 kW	5.5 kWh 1.68 kW/2.5 kW	8 kWh 2.5 kW
System cost - inc VAT @ 20%	£7,000	£6,100	£7,450	£9,600
Inc VAT @ 5%	£6,125	£5,340	£6,520	£8,400
Solar utilisation without battery	51%	51%	51%	51%
Solar utilisation with battery	88%	81%	80%	86%
Total charged to battery	From PV: 1,450 kWh From grid: 2,468 kWh Total: 3,918 kWh	From PV: 1,182 kWh From grid: 1,019 kWh Total: 2,200 kWh	From PV: 1,120 kWh From grid: 935 kWh Total: 2,055 kWh	From PV: 1,369 kWh From grid: 1,515 kWh Total: 2,883 kWh



	Powerwall 2	LG Chem RESU	Simpli-phi	Sonnen
Total discharged from battery	3,526 kWh (~10% Loss)	1,982 kWh (~10% Loss)	1,910 kWh (~7% Loss)	2,624 kWh (~9% Loss)
Annual savings from battery – year 1	£418	£291	£286	£353
Annual savings from battery – 10 year average allowing for 5% p.a. electricity inflation	£526	£366	£360	£444

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Scenario 2

	Powerwall 2	LG Chem RESU	Simpli-phi	Sonnen
Large load, standard solar system: 8,000kWh load + 8kWp solar system.				
Functionality: storage of solar, off-peak charging with daytime discharge (cost per kWh: day 20p, night 9p).				
Optimised system size	13.5 kWh 5 kW	8.8 kWh 1.68 kW/2.5 kW	8.3 kWh 1.68 kW/2.5 kW	10 kWh 2.5 kW
System cost - inc VAT @ 20%	£7,000	£7,110	£9,700	£11,000
Inc VAT @ 5%	£6,125	£6,220	£8,490	£9,625
Solar utilisation without battery	37%	37%	37%	37%
Solar utilisation with battery	70%	65%	64%	67%
Total charged to battery	From PV: 2,537 kWh From Grid: 1,859 kWh Total: 4,396 kWh	From PV: 2,136 kWh From Grid: 1,106 kWh Total: 3,242 kWh	From PV: 2,035 kWh From Grid: 1,007 kWh Total: 3,042 kWh	From PV: 2,321 kWh From Grid: 1,287 kWh Total: 3,608 kWh
Total discharged from battery	3,957 kWh (~10% Loss)	2,920 kWh (~10% Loss)	2,827 kWh (~7% Loss)	3,284 kWh (~9% Loss)
Annual savings from battery – year 1	£553	£449	£443	£491
Annual savings from battery – 10 year average allowing for 5% p.a. electricity inflation	£695	£565	£557	£618



4. Conclusion

All credit to Elon Musk for having the vision to create a great product for residential storage, and for rolling out production at an unprecedented scale such that the price is affordable.

Overall, Tesla Powerwall 2 offers unbeatable value. Tesla has brought the payback time of battery storage to an acceptable level, and brought the lifetime cost per kWh stored to below the domestic grid cost per kWh.

The roll-out of time of use charging and discharging is in our view a game changer for the electricity market as a whole, allowing the smoothing of the peaks and troughs of demand without the need for further fossil fuel investment. With a smart meter installed, Tesla Powerwall 2 owners will be well placed to benefit from the energy market revolution, with or without solar PV.

The system is well sized, not only for time of use charging and discharging, but also for back-up. With a 5kW output rating, Powerwall 2 beats most of the competition in residential storage and ensures that life can go on reasonably undisturbed during a power cut, subject to some judicious juggling if the power outage persists.

Limitations lie in the areas of 3 phase connections (not relevant for most properties), seamless back-up (uninterrupted power supply) and the ability to work with a generator. The latter is really only relevant for off-grid properties, or properties experiencing recurring grid power outages.

For anyone wanting ultimate flexibility, longevity and seamless back-up capability, Simpli-phi combined with Victron would make a good alternative to Tesla. A lithium ferro phosphate system such as Simpli-phi or Sonnen should last longer than the Tesla system – but the Powerwall 2 has a life expectancy of more than 15 years, and none of us can predict where storage technology will be in 15 years. It is reasonable to expect that the 25-30 year life expectancy of LFP will necessitate a replacement charger at some point. This is going to be easier to achieve with Simpli-phi than with Sonnen, and if LFP is your chosen chemistry, we definitely recommend the Simpli-phi system over Sonnen. Simpli-phi is also the most robust in terms of toleration of extreme operating conditions – it is not surprising that Simpli-phi has been selected by the US military for use in challenging locations.

Overall we expect that Tesla's Powerwall 2 will be the system of choice for 90% of our residential battery storage customers.

If you'd like us to model the expected performance of Tesla Powerwall 2, or any other system, using your load profile and solar generation profile, please get in touch. Call us on 0118 951 4490, or email residential@spiritenergy.co.uk.