Ebook: How to size your solar battery energy storage system (BESS)

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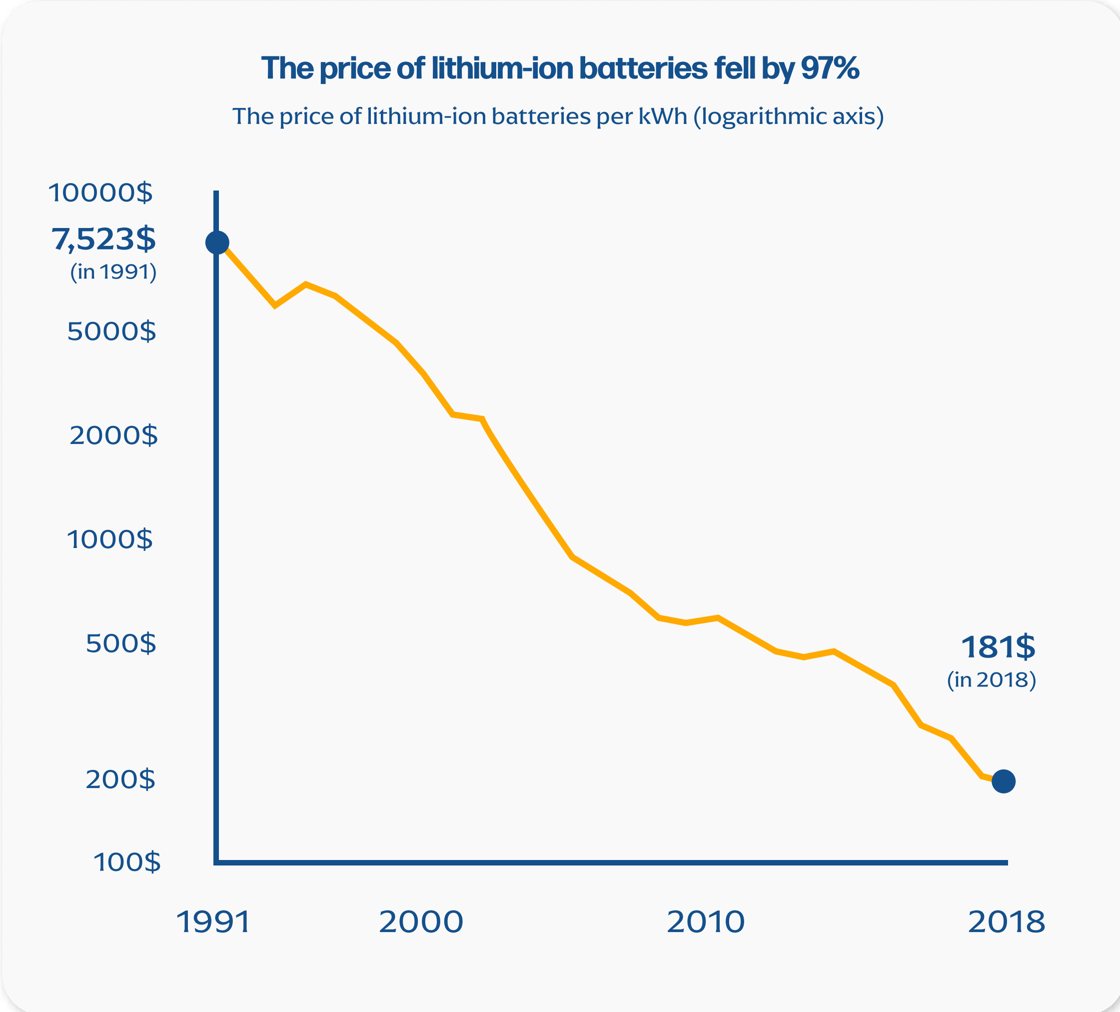
Battery energy storage systems (BESSs) are key to integrating large amounts of solar and wind generation into power grids. They can store excess output, supply power during peak periods, and connect isolated or off-grid communities.

More utility-scale solar projects around the world will need to be hybrid projects that pair photovoltaic systems with batteries. And an increase in manufacturing capacity has brought down the cost of lithium-ion BESSs in the past 10 years, making widespread rollout viable.



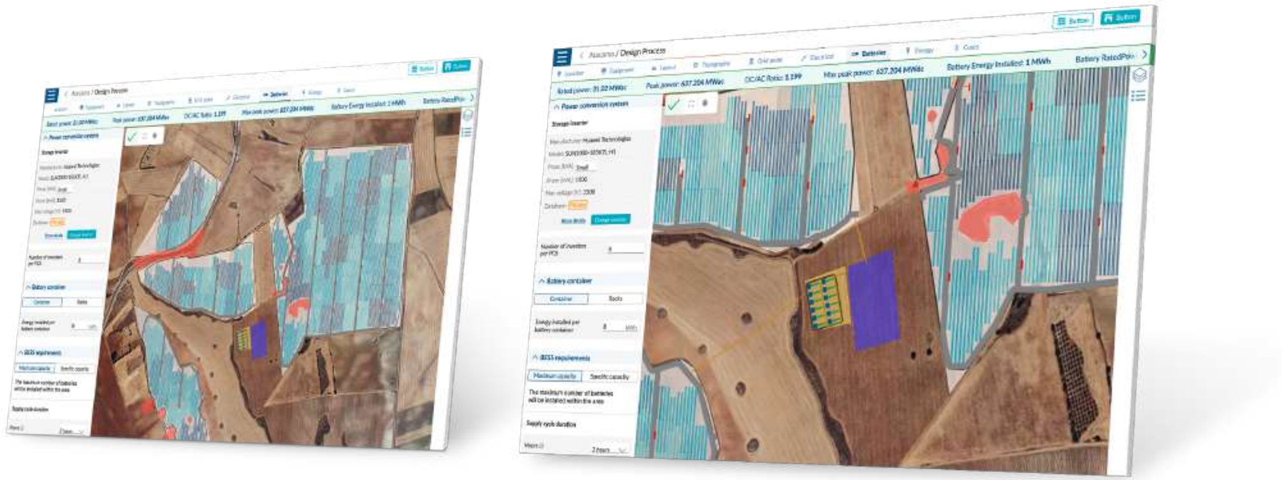
Source: Our world in data

When designing a BESS, the most challenging engineering work is in establishing the appropriate size for the system and determining whether it will generate a positive return on investment.

RatedPower's software now includes functionality to automate and speed up the feasibility study process for identifying viable utility-scale PV projects with BESS.

This guide looks at the process of sizing up batteries for a PV plant looking at three specific criteria in detail:

- Services provided
- Profitability
- Tender recommendations or requirements



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How does a battery storage system work?

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The batteries used in energy storage are **electrochemical devices that charge from a power plant or grid and then discharge energy to supply electricity or other grid services as needed.**

Hybrid solar and storage systems charge during the day when the sun shines and supply electricity when the sun is not shining. Modern BESSs typically include an inverter to convert the DC current solar panels generate into the AC current that powers equipment and appliances.

Energy storage systems incorporate software that uses algorithms to coordinate electricity generation and control systems that determine when to discharge the battery.

Type of solar battery systems

The first choice to be made in designing a solar storage plant is the basic architecture, including how the battery will be integrated into the PV system.

There are two main types of architecture: alternating current (AC) and direct current (DC).

Alternating current (AC)

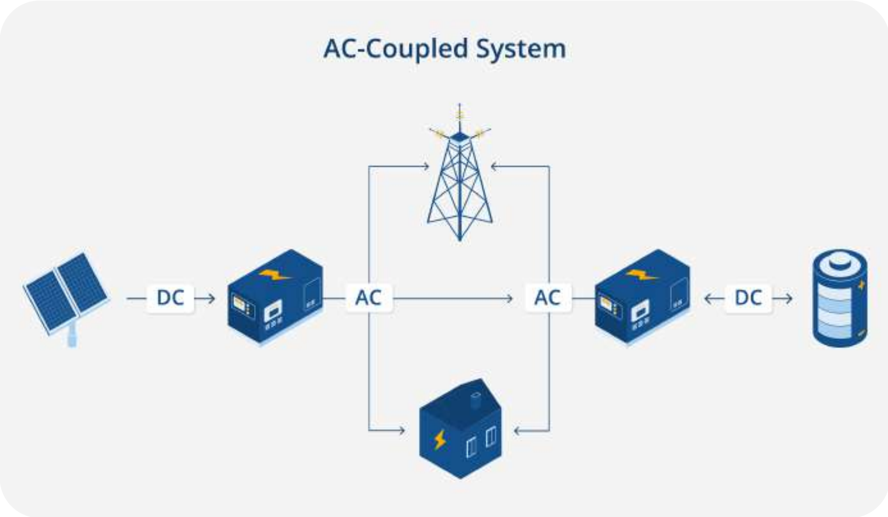
Direct current (DC)

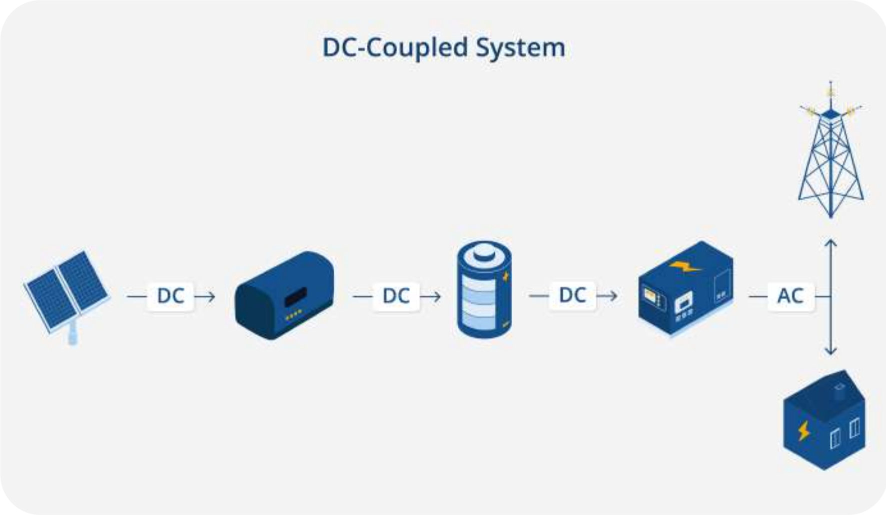
AC current flows rapidly on electricity grids in both directions, while DC currents flow in just one direction. As solar panels generate DC current and batteries store DC but appliances use AC current, the current must be converted using inverters.

AC-coupled systems are the preferred options for larger and utility-scale plants.

That's because AC-coupled systems are more **flexible** (working with any type of inverter), **resilient** (as multiple inverters can be built in), and **versatile** (AC-coupled systems enable batteries to charge from the grid as well as the solar panels and the grid).

For a more in-depth analysis of the pros and cons of AC-coupled vs DC-coupled BESS systems, see our dedicated guide here.





What to consider when sizing BESS

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A number of **factors need to be considered when sizing a BESS**: the application, the economic profitability of the BESS, the market scenario, energy transition policies, and more.

In this guide, we'll look at **three of the most critical considerations:**

- **Services provided**: are you looking to maximize the energy output, for example?
- **The economic profitability:** are you looking for the most cost-efficient solution?
- ... and the **tender recommendations or requirements:** are you bound by certain stipulations that are outside of your control?

Sizing a BESS based on services provided

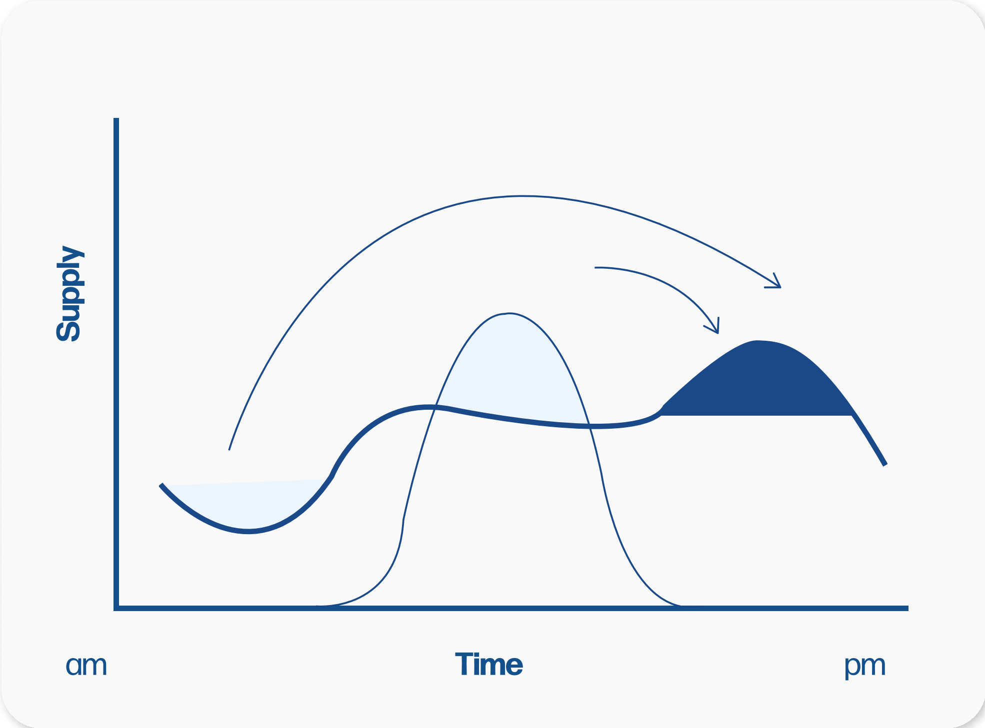
One of the main case uses for BESS are dispatch strategies concerning energy flows. Predictive dispatch strategies aim to optimize load flows looking to consider future load scenarios and how that will impact the overall life-cycle and size of the BESS.

Peak shifting is used in this specific case – a process that involves proactively managing overall demand to eliminate short-term demand spikes, which set a higher peak.

This process lowers and smooths out peak loads, which reduces the overall cost of demand charges.

In the graph, the light blue areas indicate periods of battery charging: first, in the consumption valley, and second, when solar generation exceeds demand. The dark blue area indicates the battery discharge period; when the previously stored electrical energy is used to cover higher peak demand.

In this example, the utilization of renewable solar energy produced is maximized. In turn, the cost of supply from the grid is minimized, since we store energy when the price is low and use it when it is high.



Source: Figure 1. Peak shifting applied to solar generation and typical demand profile [Source: SaltX Technology. (2016). "Peak Shifting Graph,"]

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How to size a BESS with peak shifting and shaving

When sizing a BESS based on peak shaving, you should **overlay a graph of the grid consumption and a graph of the plant production during a specific period of time**. This way it is possible to locate peak demands across the duration.

This sizing calculation requires the maximum load value to be defined – this will be based on the production information of the plant and consumption of the network, from which the plant stops injecting directly into the network. This power, obtained from the difference between the maximum load limit and the surplus production of the plant, will be the power injected into the battery system:

$$P_{carga} = P_{PV} - Carga_{Máx}$$

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Where:

- Pcarga is the power that will be charged to the battery [MW]
- Ppv is the power generated by the PV plant [MW]
- Carga max is the maximum load value defined by the user [MW]. Above this value, the exceeding power produced by the plant will be injected into the BESS.

If you overlap the hourly production profile of the plant with the hourly consumption profile of the network, **there will be periods in which the plant is producing above the consumption of the network – and that excess power is lost because you cannot inject, you unbalance the network.**

There will be other times when the plant is not producing or produces less than the consumption of the network at that time (for example, at night). This is where the battery plays an important role because it can be charged at times of excess production and discharged when the consumption of the network is higher. This way you avoid production losses and give constant support to the network.

Other strategies might be considered based on BESS capabilities for providing ancillary services. As an example, for primary frequency regulation to the grid (PFR), **lithium-ion batteries can be used because of their fast response**, as faster discharge cycles are needed to reset the frequency to its operating value.

Because of this, to be able to quickly discharge the battery and subsequently return it to its previous state of charge (SOC), **a different dispatch strategy might be considered**. Alternative dispatch strategies will have an impact both on the battery lifetime and economic feasibility analysis.

Sizing a BESS based on economic profitability

Profitability is an important factor not only for BESS sizing, but for any application when developing any project, including the PV plant sizing. After all, we could apply the first criterion, based on the maximum peak demand that we would like our system to cover, but it might not be economically feasible. **If this is the case, a detailed financial analysis is carried out to decide if the system is economically profitable.** Returning to the example above, if a 10 MW and 2 hours of supply duration is not economically feasible, we would reduce the battery size (down to 5 MW, e.g.) until we see profitability.

Essentially, the costs of the battery should be calculated by taking into account:

- The initial, upfront investment
- The replacement costs at the end of the battery's lifetime
- Estimated energy prices, in hours or days.

This way, **you can work out how economically viable it is to have the biggest battery you can get versus a smaller battery that allows you to save up excess energy** and sell it afterward at peak price times.

In this instance, you want to ensure that the money you'd make from selling the excess energy saved is worth the cost of the battery.

Sizing a BESS based on tender recommendations or requirements

Including a BESS in your PV plant design can help make tender bids more successful; the more sustainable you can make the design and the better the integration of renewable energies into the grid, the higher your score will be (depending on the country).

In Spain, for example, a BESS that's sized at 5% of the total power installed in the PV plant would be looked upon very favorably and receive high scores. To follow that logic when sizing the BESS, if developing a 20 MW project, a 1 MW BESS would give us the maximum rate regarding storage.

If sizing BESS in relation to tender recommendations or requirements, then the size of the battery would depend entirely on the country and the necessities outlined in the tender itself.

5%

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How to size up a BESS

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Rated Power's pvDesign software allows you to design an AC-coupled BESS. When choosing the location for storage, analyzing the costs and benefits of different locations will help you identify the optimal placement to meet the needs of the system. **By defining the parameters of the system, you can easily generate a basic engineering report.** Here are the factors you need to define.

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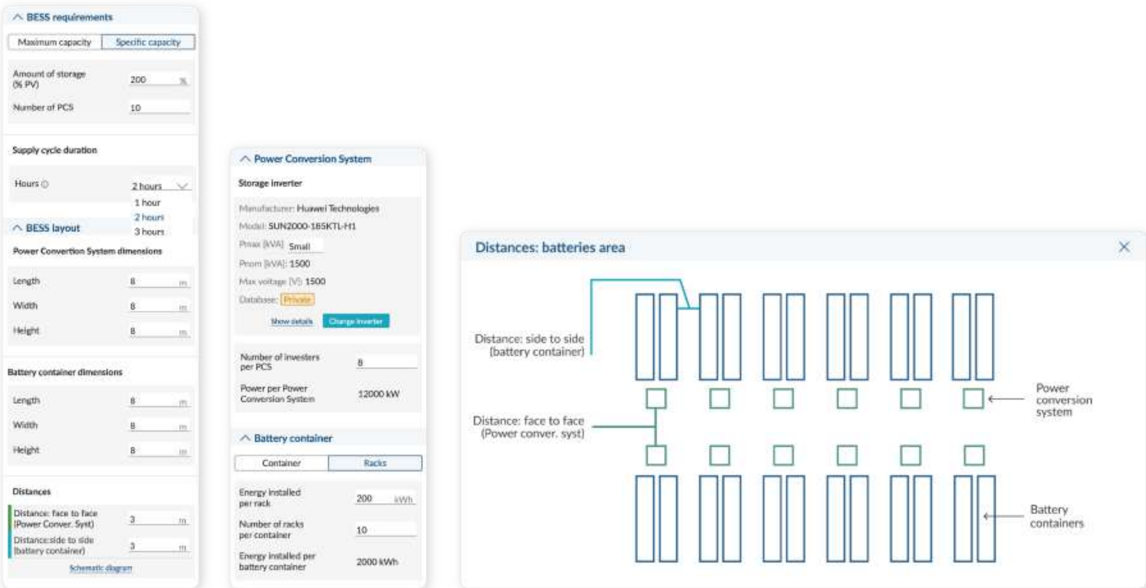
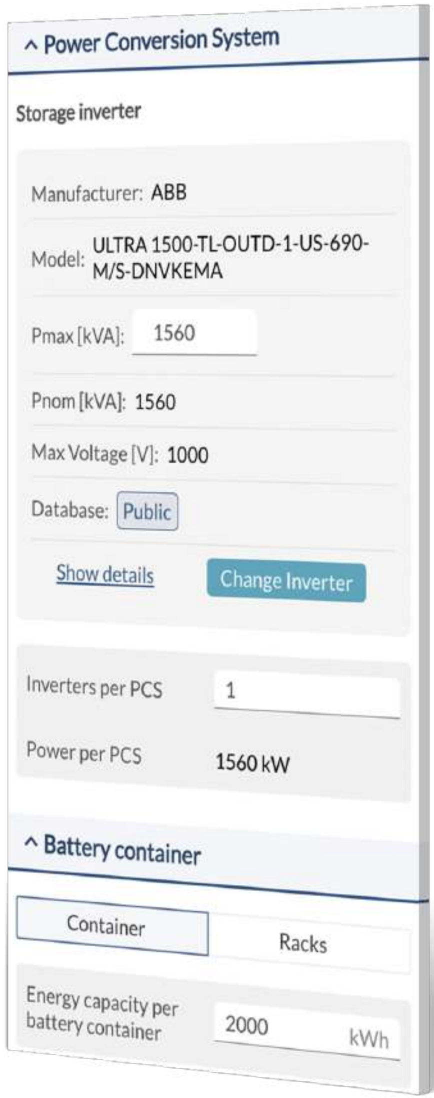


1. Determining the space required

It's important to start with a battery area for a hybrid solar storage system. The size of the user-defined area will determine the space available to install the storage system. The MV point will be the interconnection point between the battery area and the substation.

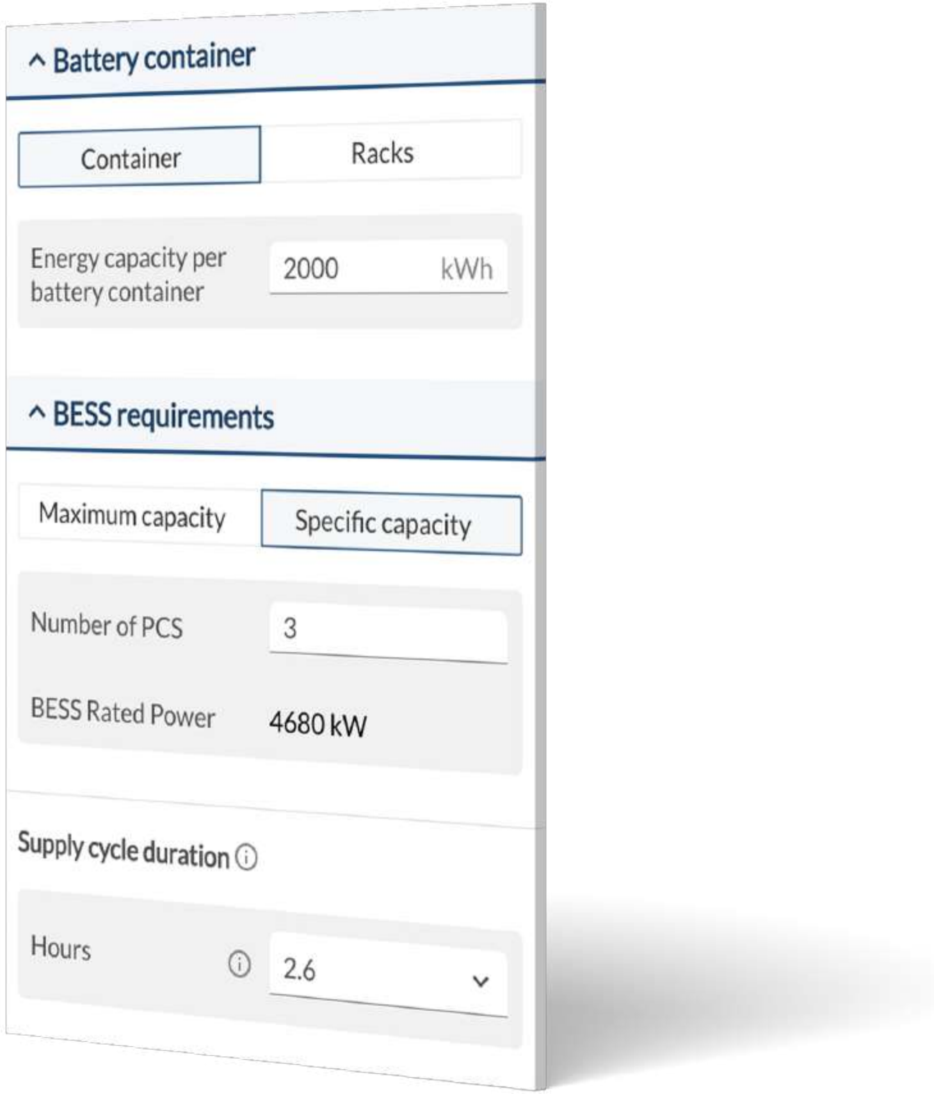
2. Minimum BESS unit

The minimum unit for the BESS is defined by the inverter type and the number of inverters. For example, if an inverter has a power of 1000kVA, and there are two



inverters in the Power Conversion System (PCS), the power of the PCS is 2000kW.

For the battery container, pvDesign assumes the storage system is modular. You can specify the capacity of a battery container or set the capacity of a single battery rack and the number of racks to include per container. **pvDesign will then install the appropriate number of containers based on the system requirements.**



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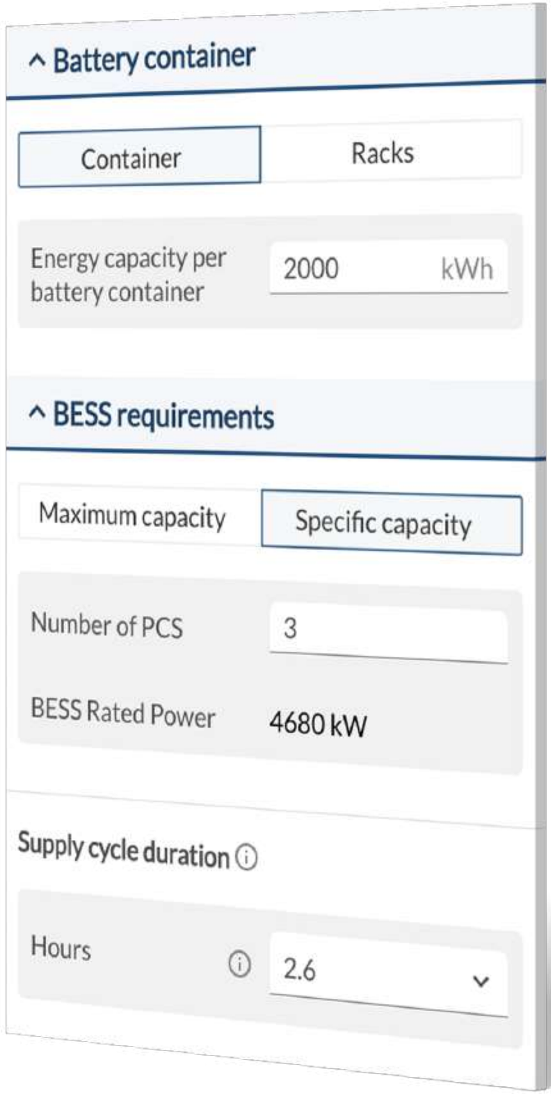
3. Power and capacity requirements

Once the PCS and container capacity are determined, you need to define the power requirements. **In pvDesign you can establish both the power requirements and the supply hours of the BESS.**

In the BESS requirements section, you can choose between maximum capacity or specific capacity. The maximum capacity option will install the maximum possible power in the area defined for the battery system.



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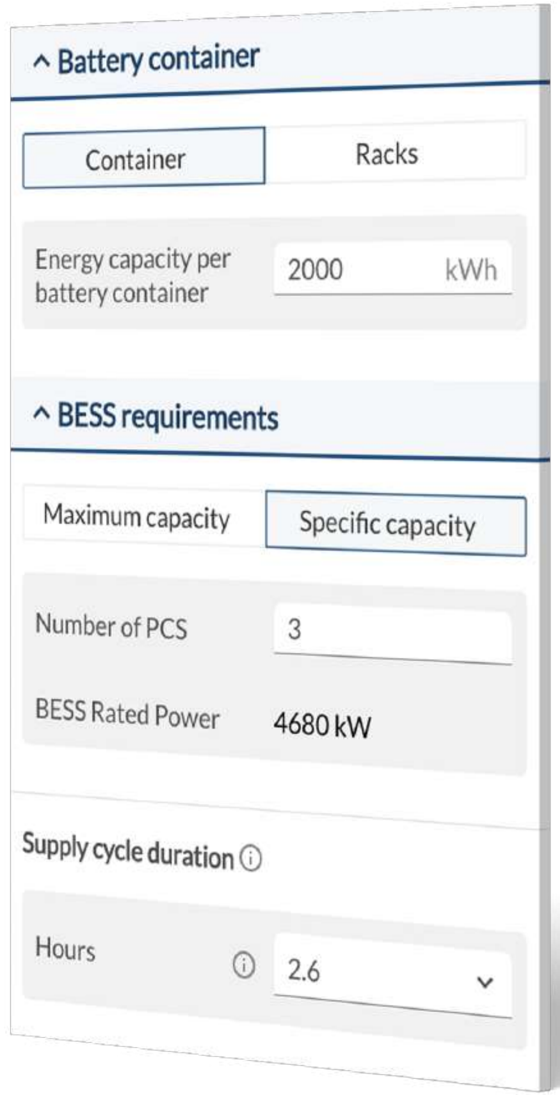
You can then determine the battery's supply duration. The duration of the supply cycle is calculated by dividing the capacity in MWh by the rated power in MW.

For example, with a 2000kW PCS and a 3000kWh container, the length of time it will take for the battery to complete a full charge or discharge cycle will be 1.5 hours. If you connected two 3000kWh battery containers to the same PCS, the system would have a three-hour supply time.



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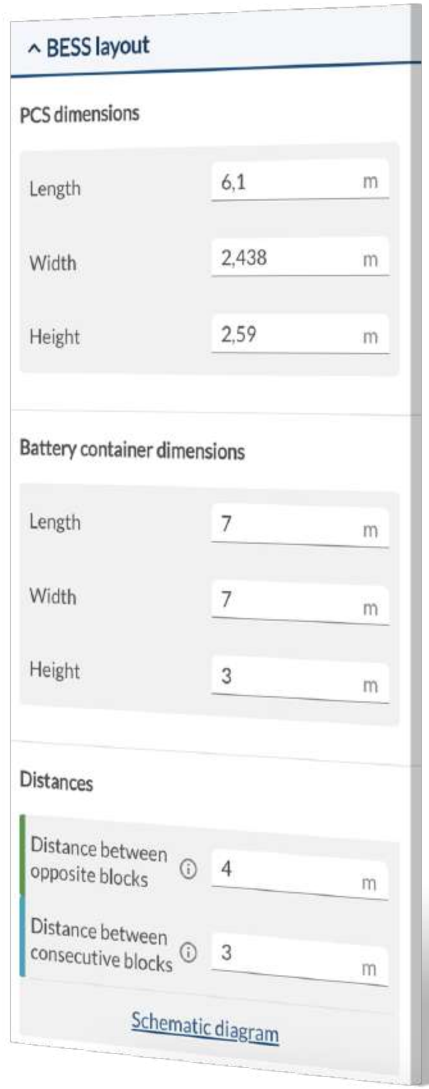
4. BESS dimensions

In the BESS layout section, **you can define the dimensions of both PCS and containers** to maximize the use of the space. You can also determine the distance between adjacent and opposing blocks, taking into account the safe distances between the containers and the PCS.

With these simple settings, pvDesign makes it easy to design the size and layout of a utility-scale BESS. **The results screen shows the system's installed capacity, power and supply duration** and the software allows you to generate the BESS layout and a system design report as documentation, with references in the PV plant documentation.



pvDesign

Rated Power's cloud-based software is designed to optimize the study, analysis, design and engineering of your utility-scale solar PV project by using digital technologies and heuristic calculations.

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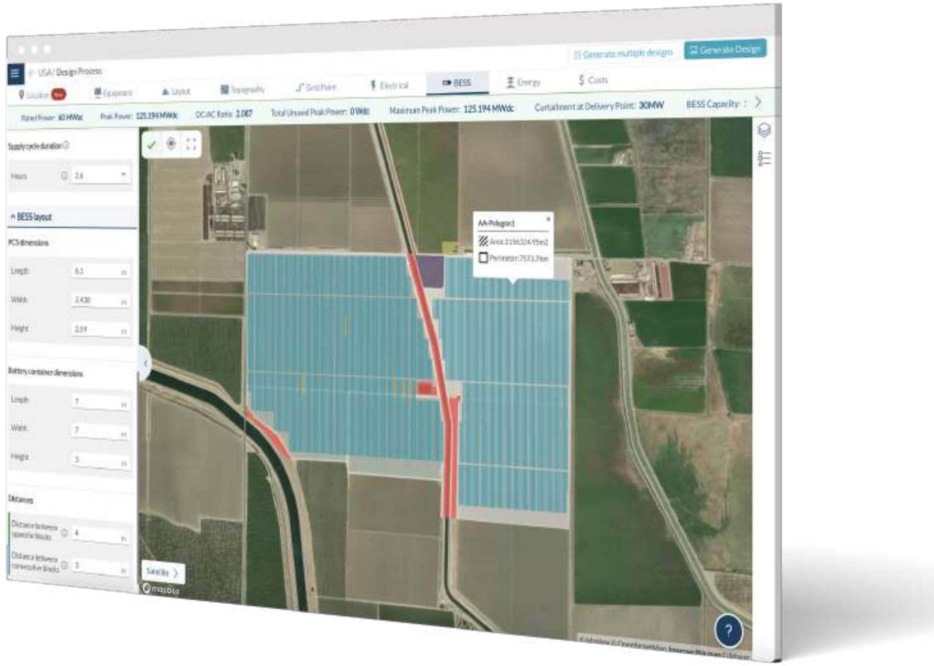
How pvDesign works

You can speed up the design and engineering process to increase efficiency, improve accuracy, and cut construction costs to maximize a project's profitability.

If you are planning to incorporate energy storage into your PV plant, the software automates the process of designing the layout of the BESS. It takes into account the battery's hours of operation, calculates the length of the cables, calculates the earthworks required, and sizes the interconnection facility. The software then generates the basic engineering documentation.



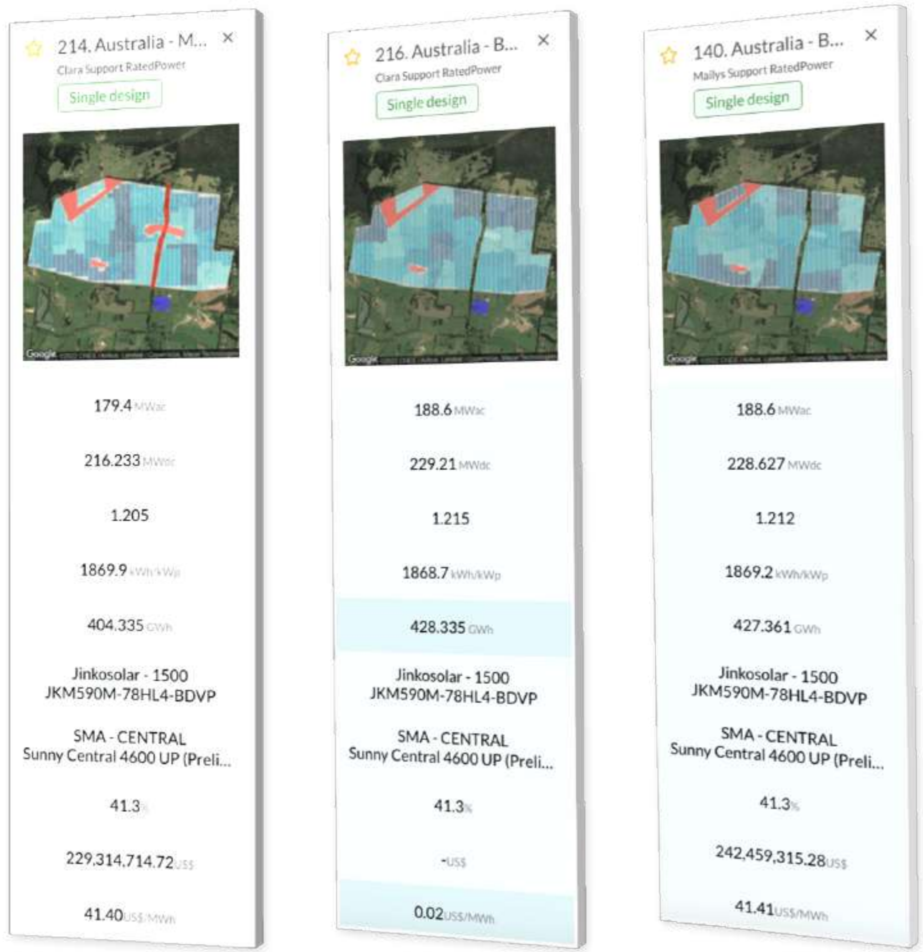
Some of the **key features of pvDesign's AC-coupled BESS** module include:

- **Automatic layout generation** taking into account battery supply duration and container dimensions.
- Options to **maximize the capacity** in an installation or **define specific capacity requirements.**
- **Automatic bill of material** generation simplifies capital expenditure (CAPEX) calculations.
- **Calculations of the available solar powe**r that could be used to charge the battery.
- **Automatic documentation generation** – BESS design report, layout, and bill of material – saving time.
- **Integration functionality** automatically takes the BESS system into account when designing the interconnection facility.

pvDesign rapidly generates the best layout for your hybrid project by scanning millions of iterations.

Compare different options from the results and adjust your configuration to attain the optimal design for any site.

In the following section, we look at a case study of how pvDesign's BESS module optimizes a hybrid solar storage project.



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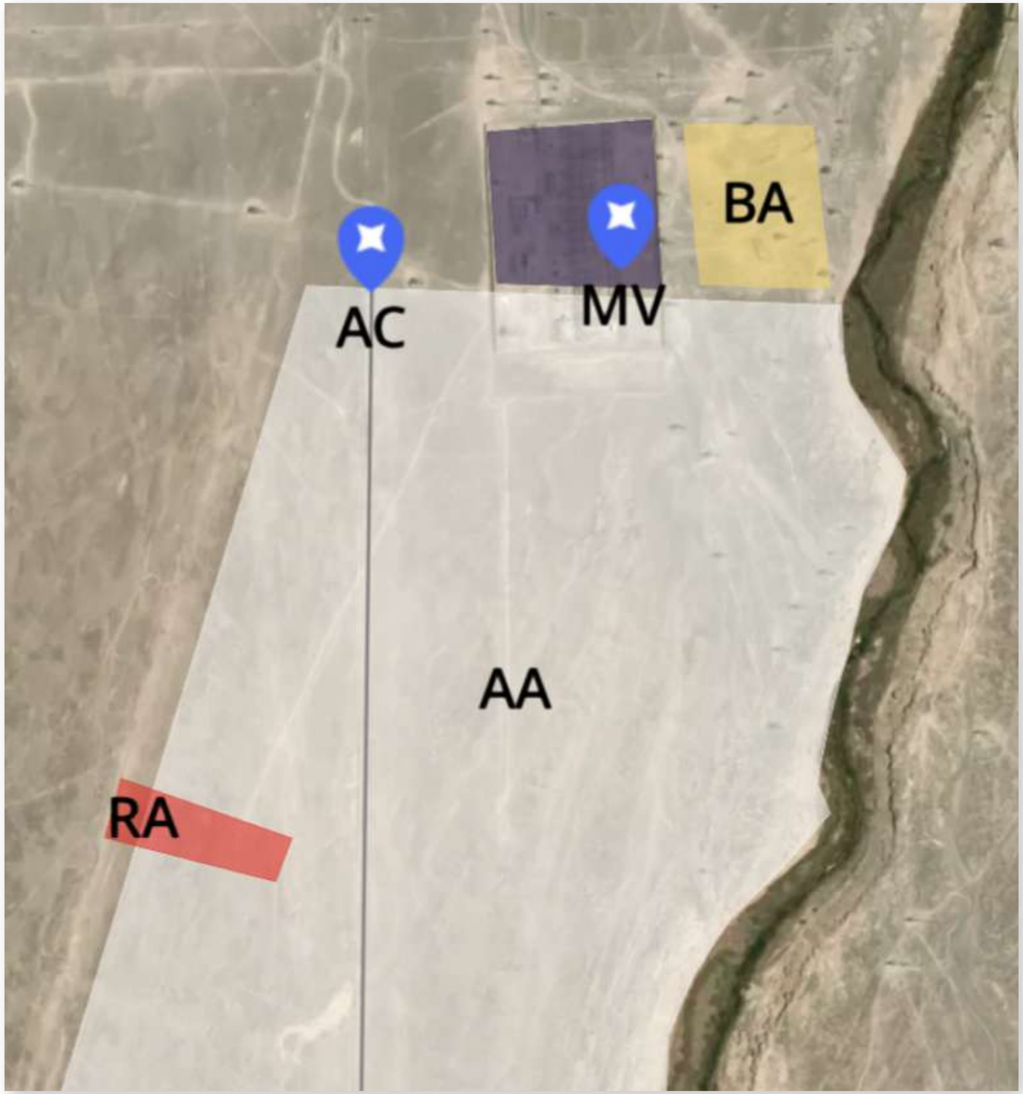
pvDesign case study

In our case study, an AC-coupled battery energy storage system will be included in a **142.60 MWac plant** in Atacama desert (Chile), with a maximum **DC installed capacity of 168.06 MW**. The battery system size will be defined based on an estimation on the load demand.

As no specific load demand information is available, the size of the system will be **20% of the AC capacity of the PV plant**, trying to cover the peaks of demand that usually occur on the grid.



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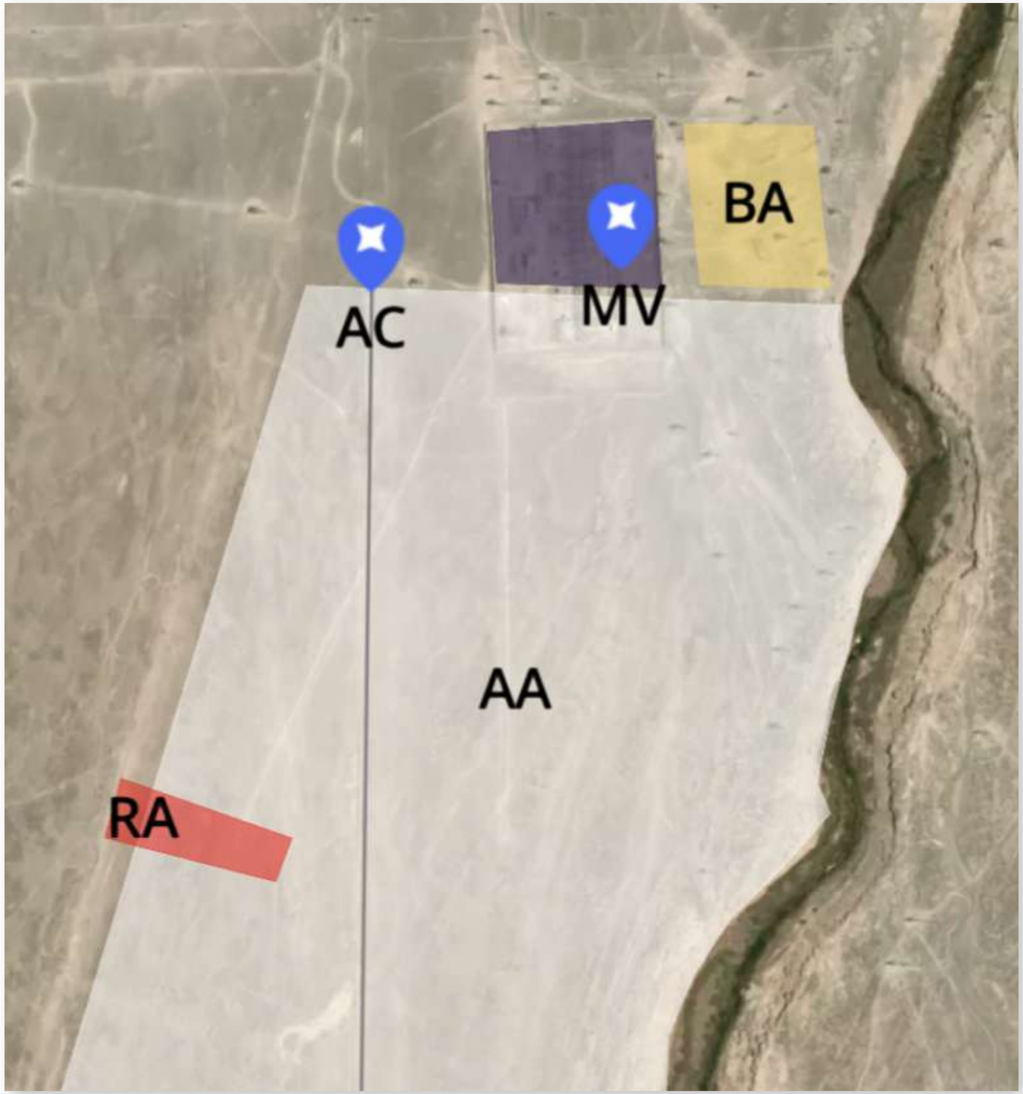
This 20% estimation is based on battery energy storage systems requirements in the U.S. market.

To implement the hybrid system in pvDesign, **the first step the user has to follow is to define a battery polygon (BA) and an MV placemark** within that polygon in the site.

The size of the user-defined area will determine the space available to install the storage system. The MV point will be the interconnection point between the battery area and the substation.



Once the battery area is defined for the storage system, **the "BESS" tab will be enabled in the design process**. This is where we will design the system.

First, within this tab, the electrical parameters of the minimum unit are defined. **The minimum unit or block of the BESS is the set of a PCS and the containers connected to it.**

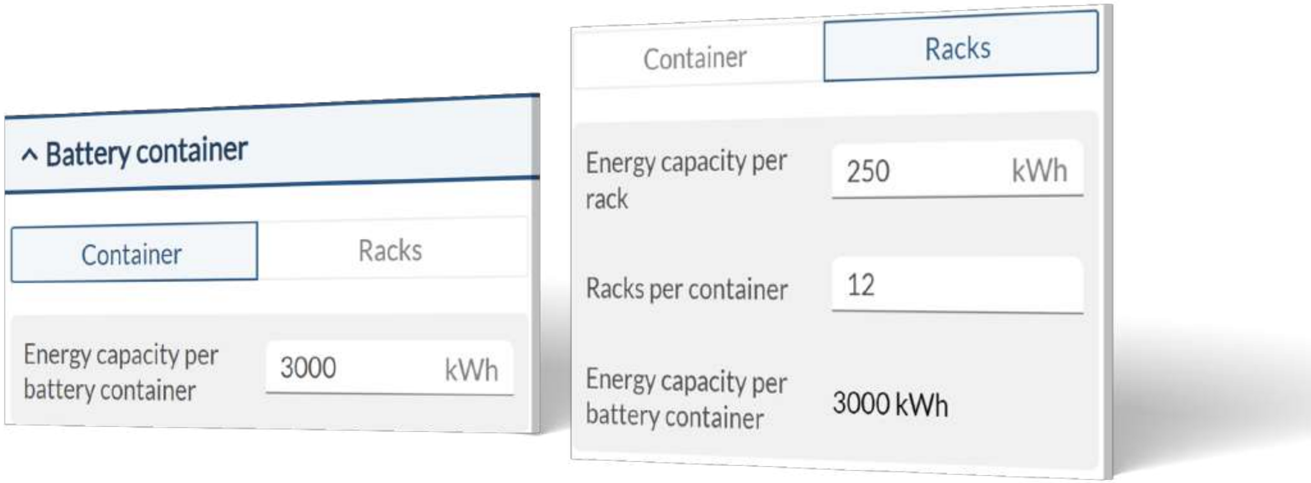
For this case study, a **battery energy storage system of 28.5 MW** will be designed, considering about the **20% of the AC capacity of the PV plan (142.60 MW).**

Next step is to establish the power of the Power Conversion System (PCS) by selecting a bidirectional inverter and a number of inverters per PCS. From the inverter's public database, **the inverter selected is the SG1500HV Sungrow, a bidirectional inverter** with a Pmax value of 1.5 MW.

As a result, **one inverter per PCS is defined**, meaning that the total number of PCS will be 19 to reach the 28.5 MW BESS power).

Once the PCS is defined, the capacity of the battery containers is established. To be able to work with a 4 hours of supply duration system, and two containers per PCS, **a container capacity of 3000 MWh is defined**.

If the racks option was selected, by defining the number of racks per container and the capacity of one rack, the maximum capacity of each container can be determined.



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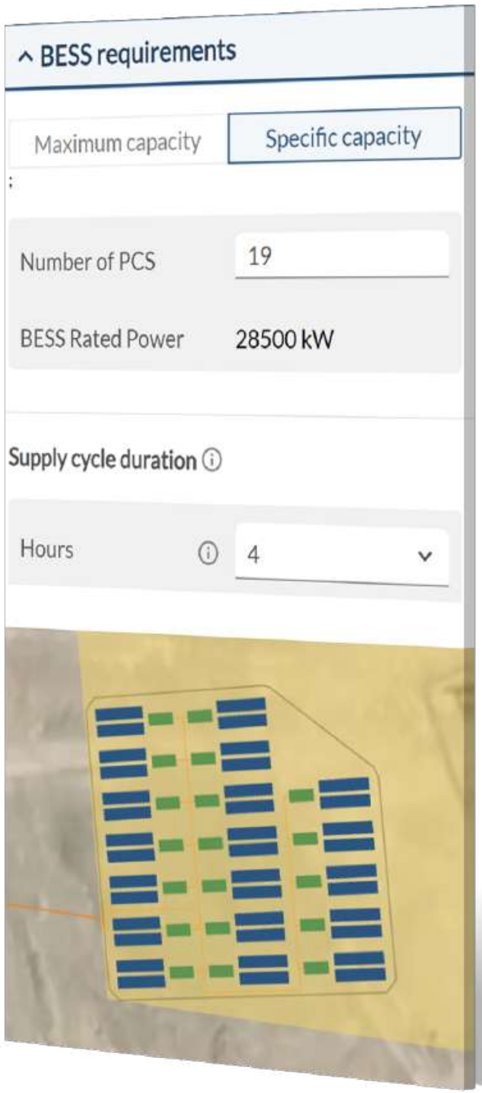
By displaying the BESS requirements menu, it is possible to define both the desired specific power for the battery bank and the number of hours of supply.

19 PCS are necessary to reach the specific power mentioned above, **28.5 MW**. Regarding the hours of supply cycle duration (charge and discharge), **by defining 4, two containers will be placed per PCS, and the capacity of the battery system will be 114 MWh.**



In the top bar, the rated power, **capacity and hours of supply duration of the battery energy storage system will be represented** during the design process.

BESS Capacity: **114 MWh** BESS Rated Power: **28.5 MWac** Supply duration: **4 hours**

A BESS layout and a system design report are generated as documentation when the design is generated.. The rest of the PV plant documents (SLDs, reports) will include references to the BESS system.

Download document

Start accelerating your PV plant design and engineering today

Our team of specialists is happy to answer your questions and show you our utility-scale solar software first-hand.

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