

----- RENEWABLE ENERGY TECHNOLOGIES -----

STORAGE SYSTEMS IN SOLAR PLANTS

**Preparation of Training Documents for Installation, Repair and
Storage Systems of Solar Energy Systems Supported by Artificial
Intelligence and Increasing Energy Efficiency**

2023 -2-TR01-KA210-VET-00017445





Co-funded by the
Erasmus+ Programme
of the European Union



This individual learning material was written within the scope of the Erasmus+ Project titled 'Preparation of Training Documents for the Installation, Maintenance and Storage Systems of Artificial Intelligence Supported Solar Energy Systems and Increasing Energy Efficiency'.

2022-1-TR01-KA220-VET000085806.

It is intended to guide vocational education trainers. It is free for users, cannot be sold. It cannot be duplicated. It will be published as an e-book on the Project Website (<https://ai-solarpower.com/>)

It is funded by the Erasmus+ Program of the European Union. However, the European Commission and the Turkish National Agency cannot be held responsible for any use of the information contained herein



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EXPLANATIONS

AREA	Energetics
BRANCH/PROFESSION	
THE NAME OF THE MODULE	STORAGE SYSTEMS IN SOLAR PLANTS
DESCRIPTION OF THE MODULE	The module provides general information about Storage systems in Solar plants and explains the different technologies and properties of these systems.
DURATION	40/32
PRECONDITION	This module does not have any prerequisites, but an elementary knowledge of electricity and/or physics is recommended.
COMPETENCY	Introduces the basic concepts and facts related to the subject.
PURPOSE OF THE MODULE	<p>General Purpose</p> <p>This module on Storage systems in Solar plants aims to provide participants with knowledge and skills in innovative energy solutions.</p> <p>Objectives</p> <p>STORAGE SYSTEMS IN SOLAR PLANTS</p> <ul style="list-style-type: none"> • Can solar energy be stored? • Two is better than one • When the sun isn't shining • What Is Energy Storage? • Advantages of Combining Storage and Solar • Types of Energy Storage • How long can solar energy be stored?



	<ul style="list-style-type: none"> • Methods for storing solar energy • Storage Batteries • Benefits and Limitations of Energy Storage Systems • How to Choose the Best Energy Storage System
<p>EDUCATIONAL ENVIRONMENTS AND EQUIPMENT</p>	<p>Environment: Renewable energy technologies area, renewable energy systems workshop</p> <p>Equipment: Basic electrical knowledge, basic electronic knowledge</p>
<p>MEASUREMENT AND EVALUATION</p>	<p>At the end of the module, the teacher will evaluate the knowledge and skills acquired in the module applications by using an assessment tool (multiple choice test, true/false test, gap filling, matching etc.).</p>



Dear Students

With the grid-connected energy storage market maturing and commercial projects starting up, companies in different sectors are increasingly interested in the potential of energy storage for their business. But insight into technical, market and financial aspects is essential to realizing that potential.

This module will help you to increase your overall understanding of the technical, market and financial aspects as well as the risks associated with combined solar and energy storage projects.

Moreover, the module is intended for students wishing to acquire a comprehensive overview of grid-connected energy storage and energy storage systems, and to have the latest technology, market conditions and issues clearly explained.



LEARNING ACTIVITY _7

PURPOSE

This module on solar energy storage systems will provide participants with a full knowledge and skills in the subject.

RESEARCH

- Solar energy storage systems fundamentals
- Technologies for solar energy storage
- Global market and trends. In solar energy storage systems
- Benefits and limits of the different technologies

7 STORAGE SYSTEMS IN SOLAR PLANTS

7.1 Introduction

As the world moves toward large-scale renewable energy adoption and the elimination of fossil fuels, numerous options are being explored. A key factor in this transition to low-carbon energy is the adoption of renewable energy sources, and solar energy deserves special attention.

According to the French energy company EDF, the volume of solar energy that reaches the Earth's surface in one hour is equivalent to the total annual energy needs of Planet Earth. The problem, however, now is to harness this energy and use it effectively.

Renewable energies are inevitably subject to changes in availability. Wind and sun, for example, are by their nature unpredictable and, consequently, not programmable. To harness the force of the winds, the Greek god Aeolus decided



to enclose them in an amphora. Helios, on the other hand, marked the alternation of light and dark by pulling the sun with his winged chariot.

Today, thanks to technological advances it is possible to transform into reality what in the ancient world was only possible to the gods: to accumulate wind and solar energy and make it available 24 hours a day. All thanks to energy storage systems.

7.2 Can solar energy be stored?

Solar energy must be used as soon as it is generated, otherwise it is lost. However, if it is stored, it can be used when no energy is being produced. In the case of solar energy, when the sun is not shining. Not only do solar energy storage systems allow users, both residential and commercial, to get the most out of their solar panels, otherwise known as photovoltaic (PV) panels, but they can also reduce costs, improve the efficiency of power grids, and reduce harmful carbon emissions and greenhouse gases (GHGs).



Figure 1: <https://etimg.etb2bimg.com/photo/109747691.cms>

7.3 Two is better than one

Coupling solar energy and storage technologies is one such case. The reason: Solar energy is not always produced at the time energy is needed most. Peak power usage often occurs on summer afternoons and evenings, when solar energy generation is falling. Temperatures can be hottest during these times, and



people who work daytime hours get home and begin using electricity to cool their homes, cook, and run appliances.

Solar energy offers a sustainable way of supplying electricity to homes, offices and factories for the future, but without solar energy storage systems, the full benefits of solar energy cannot be realized. As we know, there are many times during the day when solar production is at a low level, but the energy demand is high. For example, on dark evenings when power is needed for lights or to power construction or event work. In short, lithium-ion energy storage systems allow you to access powerful solar energy when you need it instead of when it's being generated.

7.4 When the sun isn't shining

Storage helps solar contribute to the electricity supply even when the sun isn't shining. It can also help smooth out variations in how solar energy flows on the grid. These variations are attributable to changes in the amount of sunlight that shines onto photovoltaic (PV) panels or concentrating solar-thermal power (CSP) systems. Solar energy production can be affected by season, time of day, clouds, dust, haze, or obstructions like shadows, rain, snow, and dirt. Sometimes energy storage is co-located with, or placed next to, a solar energy system, and sometimes the storage system stands alone, but in either configuration, it can help more effectively integrate solar into the energy landscape.



Figure 2: Energy storage in a solar farm



7.5 What Is Energy Storage?

“Storage” refers to technologies that can capture electricity, store it as another form of energy (chemical, thermal, mechanical), and then release it for use when it is needed. Lithium-ion batteries are one such technology. Although using energy storage is never 100% efficient—some energy is always lost in converting energy and retrieving it—storage allows the flexible use of energy at different times from when it was generated. So, storage can increase system efficiency and resilience, and it can improve power quality by matching supply and demand.



Figure 3: Solar Battery Storage (<https://e-greenelectrical.com.au/solar-battery-storage/>)

Storage facilities differ in both energy capacity, which is the total amount of energy that can be stored (usually in kilowatt-hours or megawatt-hours), and power capacity, which is the amount of energy that can be released at a given time (usually in kilowatts or megawatts). Different energy and power capacities of storage can be used to manage different tasks. Short-term storage that lasts just a few minutes will ensure a solar plant operates smoothly during output fluctuations due to passing clouds, while longer-term storage can help provide

supply over days or weeks when solar energy production is low or during a major weather event, for example.

7.6 Advantages of Combining Storage and Solar

Balancing electricity loads – Without storage, electricity must be generated and consumed at the same time, which may mean that grid operators take some generation offline, or “curtail” it, to avoid over-generation and grid reliability issues. Conversely, there may be other times, after sunset or on cloudy days, when there is little solar production but plenty of demand for power. Enter storage, which can be filled or charged when generation is high and power consumption is low, then dispensed when the load or demand is high. When some of the electricity produced by the sun is put into storage, that electricity can be used whenever grid operators need it, including after the sun has set. In this way, storage acts as an insurance policy for sunshine.

“Firming” solar generation – Short-term storage can ensure that quick changes in generation don’t greatly affect the output of a solar power plant. For example, a small battery can be used to ride through a brief generation disruption from a passing cloud, helping the grid maintain a “firm” electrical supply that is reliable and consistent.

Providing resilience – Solar and storage can provide backup power during an electrical disruption. They can keep critical facilities operating to ensure continuous essential services, like communications. Solar and storage can also be used for microgrids and smaller-scale applications, like mobile or portable power units.

Solar energy storage not only means that excess energy can be stored for use in the future when generation decreases and demand increases, but also that this energy can be used to mitigate any short-term disruptions to energy supplies, such as outages, problems with generators, or routine maintenance. A reliable



solar energy storage system will allow users to keep their electrical systems running, no matter what happens.

7.7 Types of Energy Storage

The most common type of energy storage in the power grid is pumped hydropower. But the storage technologies most frequently coupled with solar power plants are electrochemical storage (batteries) with PV plants and thermal storage (fluids) with CSP plants. Other types of storage, such as compressed air storage and flywheels, may have different characteristics, such as very fast discharge or very large capacity, that make them attractive to grid operators. More information on other types of storage is below.

Ultimately, residential and commercial solar customers, and utilities and large-scale solar operators alike, can benefit from solar-plus-storage systems. As research continues and the costs of solar energy and storage come down, solar and storage solutions will become more accessible to all

7.7.1 Pumped-Storage Hydropower

Pumped-storage hydropower is an energy storage technology based on water. Electrical energy is used to pump water uphill into a reservoir when energy demand is low. Later, the water can be allowed to flow back downhill and turn a turbine to generate electricity when demand is high. Pumped hydro is a well-tested and mature storage technology that has been used in the United States since 1929. However, it requires suitable landscapes and reservoirs, which may be natural lakes or man-made by constructing dams, requiring lengthy regulatory permits, long implementation times, and large initial capital. Other than energy arbitrage, pumped hydro's value of services to integrate variable renewables are not fully realized, which can make the financial payback period long. These are some of the reasons pumped hydro has not been built recently, even though interest is evident from requests to the Federal Energy Regulatory Commission for preliminary permits and licenses.



7.7.2 Electrochemical Storage

Many of us are familiar with electrochemical batteries, like those found in laptops and mobile phones. When electricity is fed into a battery, it causes a chemical reaction, and energy is stored. When a battery is discharged, that chemical reaction is reversed, which creates voltage between two electrical contacts, causing current to flow out of the battery. The most common chemistry for battery cells is lithium-ion, but other common options include lead-acid, sodium, and nickel-based batteries.

7.7.3 Thermal Energy Storage

Thermal energy storage is a family of technologies in which a fluid, such as water or molten salt, or other material is used to store heat. This thermal storage material is then stored in an insulated tank until the energy is needed. The energy may be used directly for heating and cooling, or it can be used to generate electricity. In thermal energy storage systems intended for electricity, the heat is used to boil water. The resulting steam drives a turbine and produces electrical power using the same equipment that is used in conventional electricity generating stations. Thermal energy storage is useful in CSP plants, which focus sunlight onto a receiver to heat a working fluid. Supercritical carbon dioxide is being explored as a working fluid that could take advantage of higher temperatures and reduce the size of generating plants.

7.7.4 Flywheel Storage

A flywheel is a heavy wheel attached to a rotating shaft. Expending energy can make the wheel turn faster. This energy can be extracted by attaching the wheel to an electrical generator, which uses electromagnetism to slow the wheel down and produce electricity. Although flywheels can quickly provide power, they can't store a lot of energy.



7.7.5 Compressed Air Storage

Compressed air storage systems consist of large vessels, like tanks, or natural formations, like caves. A compressor system pumps the vessels full of pressurized air. Then the air can be released and used to drive a turbine that produces electricity. Existing compressed air energy storage systems often use the released air as part of a natural gas power cycle to produce electricity.

7.7.6 Solar Fuels

Solar power can be used to create new fuels that can be combusted (burned) or consumed to provide energy, effectively storing the solar energy in the chemical bonds. Among the possible fuels researchers are examining are hydrogen, produced by separating it from the oxygen in water, and methane, produced by combining hydrogen and carbon dioxide. Methane is the main component of natural gas, which is commonly used to produce electricity or heat homes.

7.7.7 Virtual Storage

Energy can also be stored by changing how we use the devices we already have. For example, by heating or cooling a building before an anticipated peak of electrical demand, the building can “store” that thermal energy so it doesn’t need to consume electricity later in the day. The building itself is acting as a thermos by storing cool or warm air. A similar process can be applied to water heaters to spread demand out over the day.

7.8 How long can solar energy be stored?

This depends on the type of solar energy storage system used. Mechanical systems and batteries often "lose" energy when it is stored and released, so it is difficult to perform an accurate calculation. However, solar-powered batteries can hold a charge for up to five days.



rotated by excess electricity and generates electricity for later use. Another mechanical method is pumped hydropower, which pumps water upwards into a reservoir. The water then flows through the turbines to produce electricity. A third mechanical energy storage option is to pump compressed air into large containers and release that air to generate electricity.

Thermal energy storage systems can reduce CO₂ emissions and reduce costs, but energy cannot be stored or released at a constant temperature, and a lot of energy can be used to convert solids into liquids. As for mechanical energy storage systems, flywheels can provide power quickly, but they can only store small amounts of energy, while pumped hydropower requires access to large reservoirs that can involve the construction of large dams and can be very expensive to set up and operate.

c. Batteries

By far the best methods of storing solar energy are those that use batteries.

BESS (Battery Energy Storage Systems), whether lithium-ion, lead-acid, nickel-cadmium, or nickel-metal hydride batteries, can store energy that has been captured by solar panels. We all know how our mobile phone batteries are charged and how they release power throughout the day, and we are becoming more familiar with how EVs connect to a battery charging station work (EV batteries can handle up to 100kWh).

7.10 Storage Batteries

Lead-acid batteries have been widely used for years and have found many applications in solar energy storage systems. The attraction is that they are the cheapest option for storing solar energy, but they have a short service life. In addition, only a relatively low percentage of the energy stored in a lead-acid battery can be used, regular maintenance is required, and external venting is mandatory, which limits installation options.



In contrast, compared to lead-acid, lithium-ion (Li-ion) batteries are recognized as the best option for solar-powered batteries. These high-density, lightweight, low-maintenance batteries with a small footprint are those in our mobile phones and other portable equipment. They are reliable and offer better performance and extended lifespans throughout their lifespan. Lithium-ion batteries are now a cost-effective means of storing solar energy, not least because they offer a longer life cycle life and greater depth of discharge (DoD).

In a BESS, the fundamental components are the blocks formed by the batteries, but there are also other elements: an inverter, which converts the direct current of the batteries into the alternating current of the electricity grid (and vice versa); a transformer, to adapt the voltage of the system to that of the grid; finally, auxiliary systems (in particular cooling and firefighting).

As in all storage systems, in BESS the electricity produced by a power plant, or by any other generation plant – even a single photovoltaic panel – is stored and then released at the desired times and times. The specificity of BESS lies in the technique used for storage: since electric current is a flow of electric charges, a battery is charged by accumulating charges of particular materials (called electrolytes) in one of the two poles, from which they then flow towards the other pole in the discharge phase.

Battery storage systems work as well as the miniature accumulators in our everyday devices: they are able to convert a chemical reaction into electrical energy, storing energy that can then be released as needed. Like a power-bank when our smartphone goes into reserve.

When the frequency of the power grid decreases due to high demand, the storage system is able to start delivering the stored energy within seconds; In the event of an increase in frequency due to a drop in demand, the battery is charged with excess energy. A fundamental dual function for the stabilization of electricity grids.



Lithium-ion batteries are the most widespread, efficient and increasingly cost-effective technology today; typically these use lithium in combination with other materials, such as iron and phosphate used in LFP batteries.

The most advanced research also focuses on lithium-sulfur batteries.

The drop in prices over the past decade has allowed a wide diffusion of lithium batteries in storage systems. Most storage systems currently operating in the world use lithium batteries. The universe of lithium batteries is based on a varied group of technologies, in which the common thread for storing energy is the use of lithium ions, particles with a free positive charge that can easily react with other elements.

Operation and features

The charging and discharging operation of lithium batteries, whose structure is composed of a positive electrode (lithium cathode) and a negative electrode (consisting of a carbon anode), is carried out through chemical reactions that allow energy to be stored and returned. Lithium batteries have very interesting technological characteristics for energy applications, including modularity, high energy density and high charge and discharge efficiency, which can exceed 90% at the level of a single module.

The future of lithium

The difficulty in finding some materials, primarily cobalt, is pushing researchers to test innovative solutions, in which the percentage of cobalt is increasingly lower or in which lithium can work in combination with other elements that are easier to find such as silicon or even oxygen.

In addition, there is an increasing attention to end-of-life management through the study of processes that allow the production cycle to be "closed" by enhancing the recycling of the most critical materials. According to data from the Global Battery Alliance, by 2030, 11 million tons of lithium-ion batteries



will reach the end of their life. Several possibilities are being studied to reuse lithium batteries (e.g. those of electric vehicles) for possible integration into the storage systems of renewable plants or to provide services to the electricity grid, thus creating a virtuous process of circular economy.

Among the alternatives to lithium, lead-acid and sodium-sulfur batteries are already in use, while others are being studied, such as aluminum-sulfur batteries.

An emerging technology is that of flow batteries, in which the internal dynamics change: unlike conventional batteries, the electrolytes are stored in separate tanks, and then flow into a central cell where they are put to react in the charging and discharging phase. The most common are vanadium models, but research also focuses on zinc-bromine and zinc-iron models. It is a promising solution especially for its longer service life.

Flow Battery Storage Systems

An emerging technology is that of flow batteries, in which the internal dynamics change: unlike conventional batteries, the electrolytes are stored in separate tanks, and then flow into a central cell where they are put to react in the charging and discharging phase. The most common are vanadium models, but research also focuses on zinc-bromine and zinc-iron models. It is a promising solution especially for its longer service life.

Unlike conventional batteries, in flow batteries the liquid electrolytes are stored in separate tanks, and then flow (hence the name) into the central cell, where they are put to react in the charging and discharging phase.

Flow batteries have several advantages, starting with the duration of the energy stored: an aspect of particular importance for applications to electricity grids in which the contribution of renewable plants is strong as it allows, for example, to cover periods of even many hours (such as the night) without the production of electricity from solar sources.



Common raw materials are also used, or in any case without particular supply difficulties: for example, the most mature technology, and currently the most widespread at an industrial level, uses vanadium, of which there are important mineral reserves already known in Norway and Finland.

7.11 Benefits and Limitations of Energy Storage Systems

PV panels can be expensive to purchase and install (actual costs depend on the size of the installation), so it's essential to tap into maximum energy by connecting them to a solar energy storage system based on the latest technology. In this way, any PV installation works as efficiently and cost-effectively as possible.

Benefits

• Battery Backup

One of the highlighted benefits of energy storage systems is their unparalleled energy security. By storing excess green energy produced during the day, these systems ensure that energy needs are met even during the night or on cloudy days when solar power is not directly available. This backup is particularly beneficial in maintaining an uninterrupted power supply, highlighting a pivotal shift toward energy self-sufficiency.

• Impact on the Environment

One of the most significant benefits of energy storage systems, especially those powered by renewable sources like solar or wind, is their minimal environmental impact. By reducing dependence on fossil fuels, these battery energy storage systems contribute significantly to lowering carbon footprints and combating climate change, making them a key player in the push toward sustainable energy solutions.



- **Grid Independence**

Energy storage systems empower homeowners with the possibility of going off-grid, liberating them from the variability of the power grid and energy prices. This independence is not only financially advantageous but also ensures that households have a reliable energy source in times of grid failures or if they are positioned in remote locations.

- **Compact Size**

Modern energy storage systems are designed to be compact, offering flexibility in placement within residential spaces. This evolution from the bulky batteries of the past to sleek, space-efficient designs means that energy storage can be integrated into homes without significant spatial accommodations.

- **Monitoring**

Technological advancements have introduced sophisticated monitoring capabilities into energy storage systems. Homeowners can now track energy production and usage in real-time, optimizing consumption and enhancing the efficiency of their energy use. The ability to remotely control these systems further elevates the user experience by offering convenience and customization.

Limitations

- **Cost**

A major impediment to the widespread adoption of energy storage systems is their cost. The high initial investment costs not only for the storage units but also for compatible photovoltaic systems can be a barrier. However, considering the long-term savings on energy costs and the potential for subsidies or incentives, the financial impact may be mitigated over time.

- **Maintenance**



Maintenance requirements constitute a drawback, depending on the type of battery system chosen. While traditional batteries may necessitate rigorous maintenance protocols, including the use of distilled water for cleaning, modern lithium-ion batteries offer a reprieve with their comparatively minimal maintenance needs. Nevertheless, the responsibility of maintaining these systems to ensure their longevity and efficiency remains a consideration for potential users.

7.12 How to Choose the Best Energy Storage System

Choosing the best energy storage system is crucial for efficient energy management and sustainability. Below are key factors to consider:

1. *Capacity and Scalability*: The capacity of an energy storage system determines how much energy it can store, while scalability refers to its ability to expand. Select an energy storage system that not only meets your current energy requirements but can also be scaled up to accommodate future growth or increased demand. This ensures that your investment remains viable even as your energy needs evolve.
2. *Type of Technology*: Various technologies are available, including lithium-ion batteries, flow batteries, and flywheel energy storage. Each comes with its unique advantages in terms of energy density, lifespan, and efficiency. For instance, lithium-ion batteries offer high energy density and are well-suited for portable applications, whereas flow batteries are better for long-duration storage. Consider the very specific needs of your application to choose the most appropriate technology.
3. *Efficiency and Lifecycle*: The efficiency of an energy storage system determines how much of the stored energy power can be used, while its lifecycle indicates how long it will last. Higher efficiency and a longer lifecycle result in lower operational costs over time. Assess the round-trip efficiency and expected lifespan of the system to ensure it provides good value for the investment.



4. *Cost and ROI*: Evaluate the upfront costs against the long-term savings and potential ROI. While some systems may have higher initial costs, their efficiency, durability, and lower maintenance costs can offer better ROI. Make sure installation, maintenance, and potential subsidies or incentives are included in your cost analysis.

5. *Safety and Environmental Impact*: Safety is paramount, especially in residential or densely populated settings. Choose systems with a solid safety record and minimal risk of thermal runaway or hazardous emissions. Additionally, consider the environmental impact, including the recyclability of the system components and its carbon footprint during production and operation.

Choosing the best solar energy storage system should be a straightforward process, with actionable insights available on the functionality, strengths, and possible limitations of these systems. Empowered with such knowledge, individuals can make informed, strategic, and sustainable decisions, leading to a brighter, better, and more sustainable future.

7.13 Conclusion

Storage systems are critical to the future of renewable energy. Their role is to store electricity and make it available when it is needed most, acting as a balance between supply and demand and helping to stabilize the grid. Batteries - connected in sequence - are now among the most popular storage systems (with the obvious exception of pumped hydroelectric systems) and are going through a real technological revolution: year after year, new materials and cutting-edge technological solutions are introduced, thus ensuring greater efficiency, lower costs and a design-to-recycle approach, aimed at obtaining an increasingly sustainable product.



The use of raw materials is further reduced due to easy recyclability and becomes a negligible issue in the case of emerging technologies based on iron, zinc or organic electrolytes.

Finally, flow batteries can be allocated in a compact and modular way, guarantee high safety thanks to the zero risk of fire and have a useful life of at least 20 years undergoing minimal degradation.

Storage systems, i.e. electricity storage, are necessary to make up for the natural intermittency of renewable sources.

This is why it is a rapidly expanding sector: according to European Union estimates, it will grow by 20% per year in the near future, to reach at least 45 GWh by 2030 from the current 12 GWh.

An increasing slice of this market is that of long-lasting storage systems (8-10 hours or more) essential for managing electricity demand, reducing peaks and stabilizing networks: it is in this area that flow batteries prove to be very promising.

7.14 FAQ

Here are some commonly asked questions about the best solar energy storage system.

How Long Can Solar Power Be Stored?

Solar power can typically be stored in battery systems for 1-5 days. The exact duration depends on the capacity of the storage system, the efficiency of the battery, and the energy consumption needs of the household or facility. Modern lithium-ion batteries can often retain power efficiently for several days, ensuring that solar energy captured during sunny periods can be utilized during the night or on cloudy days. However, over extended periods without sunlight, the stored energy might deplete, as all batteries have some degree of self-discharge.

What Is the Cheapest Way to Store Solar Energy?



The cheapest way to store solar energy as of now is through lead-acid batteries, which have been used for decades in various applications, including off-grid solar systems. Although they have a shorter lifespan and lower efficiency compared to newer technologies such as lithium-ion batteries, their lower upfront cost makes them an attractive option for cost-sensitive projects. However, it's important to calculate long-term costs and savings as other technologies may be more cost-effective over the lifespan of the storage system.

What Is the Best Energy Storage System for Solar Panels?

The best energy storage system for solar panels lies in lithium-ion batteries. These batteries excel due to their higher efficiency, longer lifespans, better depth of discharge (DoD), and greater energy density compared to other types of batteries, such as lead-acid for example. While lithium-ion batteries carry more expensive upfront costs, they often provide a better ROI due to their longevity and improved performance.



MEASUREMENT AND EVALUATION

Read the questions carefully and choose the correct answer.

1. The following is not one of the categories of solar energy storage systems.

- A) BESS
- B) Pumped-Storage Hydropower
- C) Steinbeck junctions
- D) Solar Fuels

2. The growth of solar energy storage systems in Europe

- A) Will grow by 120% per year in the near future
- B) Will reach at least 45 GWh by 2030
- C) Will concern mostly short-lasting storage systems
- D) Will not concern flow batteries as they are an obsolete technology

3. Which of the following is not one of the technologies used in solar energy storage systems?

- A) Dual-bridge converters
- B) Lead-acid batteries
- C) Flywheel Storage
- D) Electrochemical Storage

4. Can energy storage and solar be combined in the same system?

- A) No, never
- B) Yes
- C) Depends on the time of the day
- D) Only in Countries where the sun is shining frequently



5. How do we call the total amount of energy that can be stored in an energy storage system?

- A) Energy concentration
- B) Energy availability
- C) Thermal energy
- D) Energy capacity

MODULE EVALUATION

Write the appropriate words in the xxxxxx spaces in the sentences below.

1. Without an energy storage system, xxxxxx must be used as soon as it is generated, otherwise it is lost.
2. Most storage systems currently operating in the world use xxxxxx batteries.
3. BESS means xxxxxx.
4. Thermal energy storage systems can reduce xxxxxx emissions.
5. By 2030, 11 million tons of xxxxxx batteries will reach the end of their life.
6. The volume of solar energy that reaches the Earth's surface in xxxxxx is equivalent to the total annual energy needs of Planet Earth.
7. Xxxxxx is an energy storage technology based on water.



Write the letters ‘T’ if true and ‘F’ if false opposite the information given below.

- 1.() A flywheel is a heavy wheel attached to a rotating shaft.
- 2.() The power capacity of a storage facility is the amount of energy that can be released at a given time.
- 3.() Batteries - connected in sequence - are obsolete storage systems
- 4.() Flow batteries can be allocated in a compact and modular way.
- 5.() The goal of a mechanical energy storage system is to convert excess electrical energy into electrochemical energy and turn it into electricity when needed.

1. Several possibilities are being studied to reuse lithium batteries. Can you mention some of them?

.....
.....
.....
.....

2. How long can solar energy be stored?

.....
.....
.....
.....

EVALUATION

Please compare your answers with the answer key. If you have incorrect answers, you need to revise the Learning Activity. If you answer all the questions correctly, please contact your teacher and move on to the next learning activity.



ANSWER KEYS

MEASUREMENT AND EVALUATION:

1	C
2	B
3	A
4	B
5	D

MODULE EVALUATION:

Gap Filling:

1	SOLAR ENERGY
2	LITHIUM
3	BATTERY ENERGY STORAGE SYSTEMS
4	CO2
5	LITHIUM-ION
6	ONE HOUR
7	PUMPED-STORAGE HYDROPOWER

True(T) - False(F)

1	T
2	T
3	F
4	T
5	F



1. Several possibilities are being studied to reuse lithium batteries. Can you mention some of them?

Several possibilities are being studied to reuse lithium batteries (e.g. those of electric vehicles) for possible integration into the storage systems of renewable plants or to provide services to the electricity grid, thus creating a virtuous process of circular economy.

Among the alternatives to lithium, lead-acid and sodium-sulfur batteries are already in use, while others are being studied, such as aluminum-sulfur batteries.

2. How long can solar energy be stored?

This depends on the type of solar energy storage system used. Mechanical systems and batteries often "lose" energy when it is stored and released, so it is difficult to perform an accurate calculation. However, solar-powered batteries can hold a charge for up to five days.



REFERENCES AND SOURCES

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These references provide information on different solar energy storage technologies, systems and markets.

