voltstorage

White Paper

How on-shore wind and solar parks can provide base load power with long duration batteries

Long duration storage as a key technology

The need of solar and wind farm operators for long duration energy storage will increase significantly in the coming years. Currently, there is a high negative correlation between wind and solar energy generated on a monthly basis – but in order to ensure the provision of the base load on a daily and weekly basis, long duration storage is a key technology.

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What is long duration energy storage

Long duration energy storage is the term for energy storage systems and technologies (such as batteries or mechanical energy storage), that charge or discharge over a duration of well more than 8 hours. This is not to be confused with how long this charge can be hold, which needs to be in the range of weeks to months.

This is in strong contrast to batteries used for electric vehicles, where the trend goes to shorter charge cycles (down to less than one hour). However, for certain applications, especially with renewable energies the focus lies on lower cost and longer durability rather than shorter charging times. That is especially the case in storage technologies for the electric grid, since renewable energies are available for a longer period of time (e.g. 8–16 hours of sunlight each day or constant wind for a full day).

Why long duration well above 12 hrs is required?

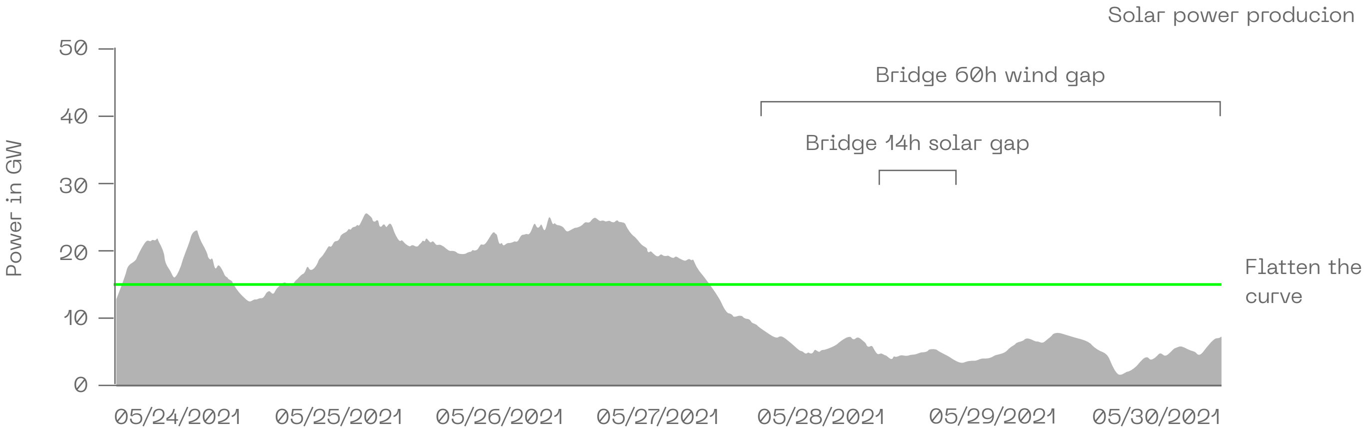
In order to gap the supply of intermittent renewables that are available almost everywhere (such as wind and solar power) longer discharge durations much longer than 12 hours are required. During multiple times per year, the lack of wind power for example is longer than 24 hrs. The same is true for solar power, where in the winter days the gaps between the end of a reasonable amount of solar production in the evening until it ramps up again in the morning is 14–16 hrs+. So right now, it is impossible to provide base load power by wind and solar alone and some sort of long duration energy storage is required.

The limiting factor so far has been the lack of an available technology to store electricity not only efficiently but at much lower cost than conventional batteries (i.e. Li-Ion or lead acid batteries). Moreover, a system that can be set up virtually everywhere (in comparison to pumped hydro which is bound to several geographical constraints) and covers 95% represent a typical service agreement of conventional power plants, representing a typical Availability Rate (planned maintenance is taken out of this rate) to provide base load power at a given power setting does not exist yet.

What is the iron salt battery?

The Iron Salt Battery is based on the redox flow technology that is a proven technology with years of experience and has decisive advantages regarding long duration energy storage compared with conventional storage technologies. Developed as a storage solution with cascadable storage capacities of up to 5 x 50 kWh in one standard 20ft ISO container and power output of up to 9.4 MW or 235 MWh per acre, the Iron Salt Battery is suitable for stationary applications with a power demand of 10–100 hours. The efficiency of the Iron Salt Battery is about 70% and therefore significantly higher compared to other long duration storage technologies: Iron Air (45%), Power-to-Gas-to-Power (P2G2P 35%), Thermal Energy Storage or Compressed Air Energy Storage (CAES 40–55%). With DC pack cost of 50 $/kWh and total AC system cost of <100 USD/kWh the iron salt technology is very cost-effective. In addition, the cost advantages of this storage technology increase significantly in correlation with the storage duration, which makes this storage technology particularly interesting for use as a long duration battery from an economic point of view (< 10 USD/kWh for additional capacity). The Iron Salt Battery not only generates significant cost advantages but is also impressive in terms of durability and versatility. It is a particularly temperature-resistant battery technology that can be used worldwide, even in climatically challenging regions up to 50°C. The Iron Salt Battery does not require any massive investments in the provision of a suitable infrastructure or any special geological conditions. Iron Chloride is a byproduct from the steel production and commonly used in the electronics industry (PCB production) and cleaning exhaust gases, therefore it is available on a large scale and at low costs. The other components are mostly common salts and water, and also available everywhere. As the iron-based electrolyte of the Iron Salt Battery consists exclusively of non-flammable components, mainly pure water and iron, it is furthermore to 100% non-flammable. With a lifetime of more than 20 years and with over 10,000 charging cycles, the Iron Salt Battery also promises a high degree of durability.

Net electricity generation in Germany in week 21 2021

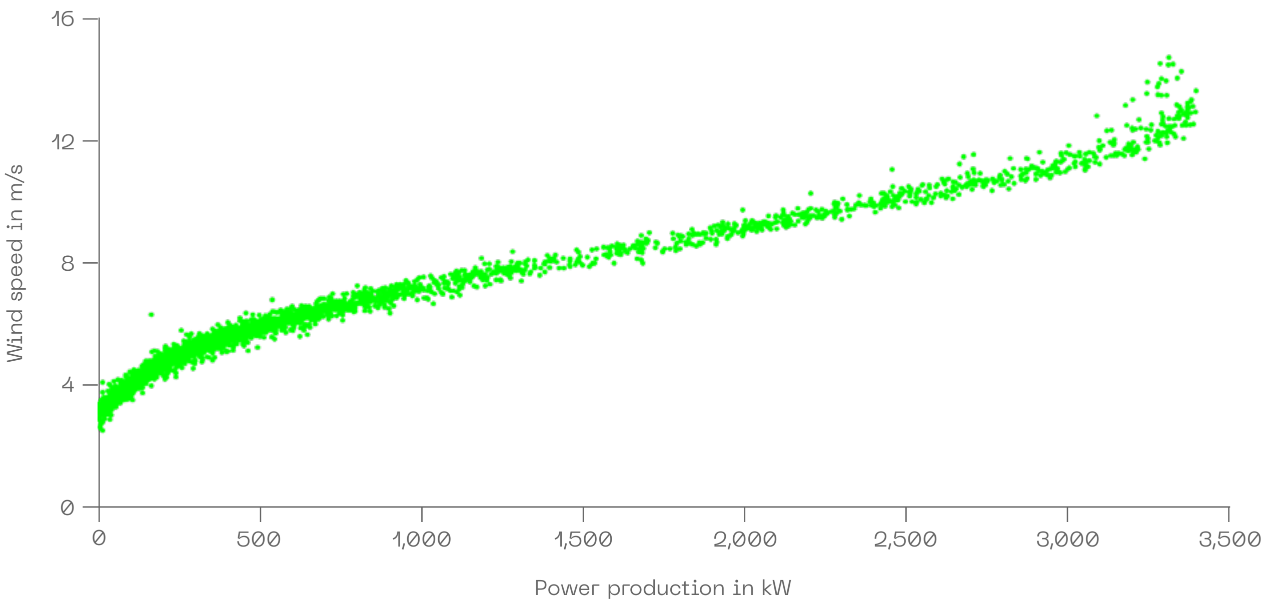


Source: Fraunhofer ISE , https://energy-charts.info

ONSHORE WIND POWER AND STORAGE AS BASE LOAD GENERATOR

In this use case, an onshore wind turbine of the type Senvion 3.4M-104, located in (central) Germany with an installed nominal power capacity of 3.37 MW produced a total of 6.49 GWh in 2020. This is an equivalent to 1,926 full load hours or a utilization factor of 21.98%, which is to be expected in most central European regions.

Dependency between wind speed and power production

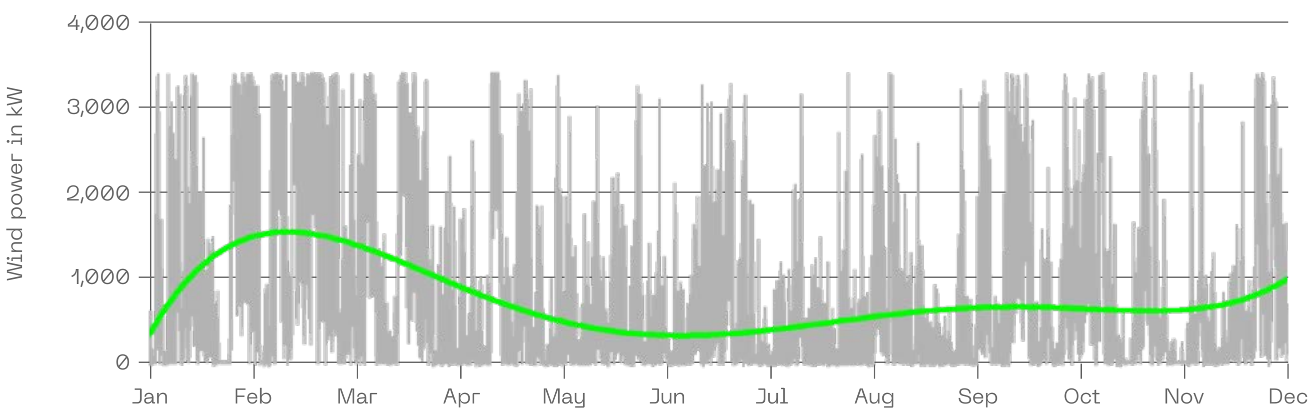


Source: VoltStorage

The theoretical average power supply over the entire year of that specific turbine is 741 kW, however, the power generation is dictated by the weather and thus quite fluctuating, as can be seen below:

Power production of wind turbine over a year (10 min interval basis) in kW

The red line indicates the trendline (moving average).



Source: VoltStorage

Also, it becomes clear that the wind production in the fall/winter months is much higher than the spring/summer months, with a majority of 59.5% of energy produced between Sept-Feb. Adding a long duration storage (12-48 hr duration) option to the wind turbine, it is possible to provide base load power to the grid for a certain amount of power (in order to fullfill the >95% availability criteria mentioned in *Why long duration well above 12 hrs is required?*).

The following graphic gives an overview of how reliable baseload power can be provided by the wind setup when added different amounts of storage capacity and power. To provide baseload power of i.e. 100kW, the storage system must be designed for an output power of the full 100kW to take over even in times without any production. The amount of storage time then defines the needed energy capacity. The vertical axis lists different baseload power outputs, the horizontal axis different storage duration configurations and therefore energy capacity setups. The result is a Matrix overview, giving the percentage of the time of the year, the combined configuration (wind+storage) is able to cover the respective baseload.

Baseload power requirements

Baseload Power provided / Storage in hours	No storage	4 h	8 h	12 h	24 h	48 h
100 kW	67.41 %	80.40 %	85.19 %	88.29 %	93.29 %	97.03 %
200 kW	59.58 %	74.45 %	79.26 %	82.34 %	88.10 %	94.04 %
300 kW	53.09 %	68.62 %	73.05 %	76.10 %	81.81 %	88.65 %
400 kW	47.60 %	63.14 %	67.17 %	69.81 %	75.30 %	82.05 %
500 kW	42.86 %	58.09 %	61.90 %	64.34 %	69.50 %	75.84 %
600 kW	38.77%	53.53 %	57.24 %	59.55 %	64.27 %	70.15 %
700 kW	35.31 %	49.47 %	52.85 %	55.02 %	59.52 %	64.99 %

In this use case the base load supply criteria would only be fulfilled for 100 kW of continuous supply over the whole year.

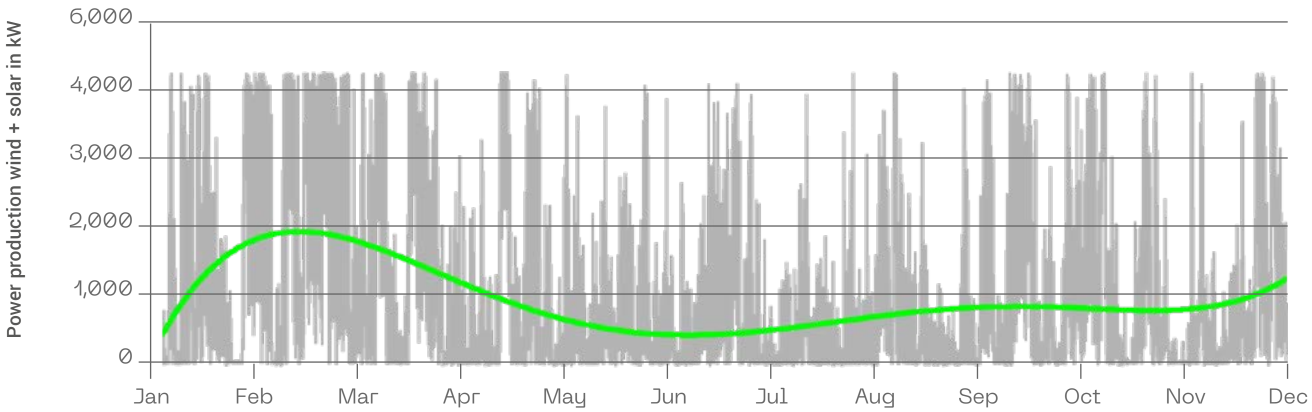
Source: VoltStorage

COMBINING WIND, SOLAR AND IRON SALT BATTERIES

When pairing that wind turbine with a 2.5 MW solar plant to fill in the gaps of low wind in the summer, the picture changes drastically. In combination, these two power plants have a total installed power capacity of 5.87 MW and produce 8.59 GWh over the same timeframe as above (2020), which equates to 1,463 full load hours and a theoretical average power supply throughout the year of 980 kW. The power production (due to solar power being more dominant in the spring/summer months) is much more levelled out over the year:

Power production of wind turbine in combination with a solar power installation over a year (10 min interval basis) in kW

The red line indicates the trendline (moving average).



Source: VoltStorage

Scale of 2.5 MW solar farm, 3.4 MW wind power and 24 MWh Iron Salt Battery

Compared to storage systems based on hydrogen or pumped-hydro power plants, the Iron Salt Battery does not require any massive investments in the provision of a suitable infrastructure. The storage system can be connected to existing infrastructures in a space-saving and decentralized manner.

In combination with the solar plant and a long duration storage option, the base load capabilities are enhanced significantly. With a 48h duration battery such as the VoltStorage Iron Salt Battery, the combined system can provide up to 500 kW of base load power when fulfilling the 95% availability criteria.

Enhancement of baseload power by using a long duration storage option

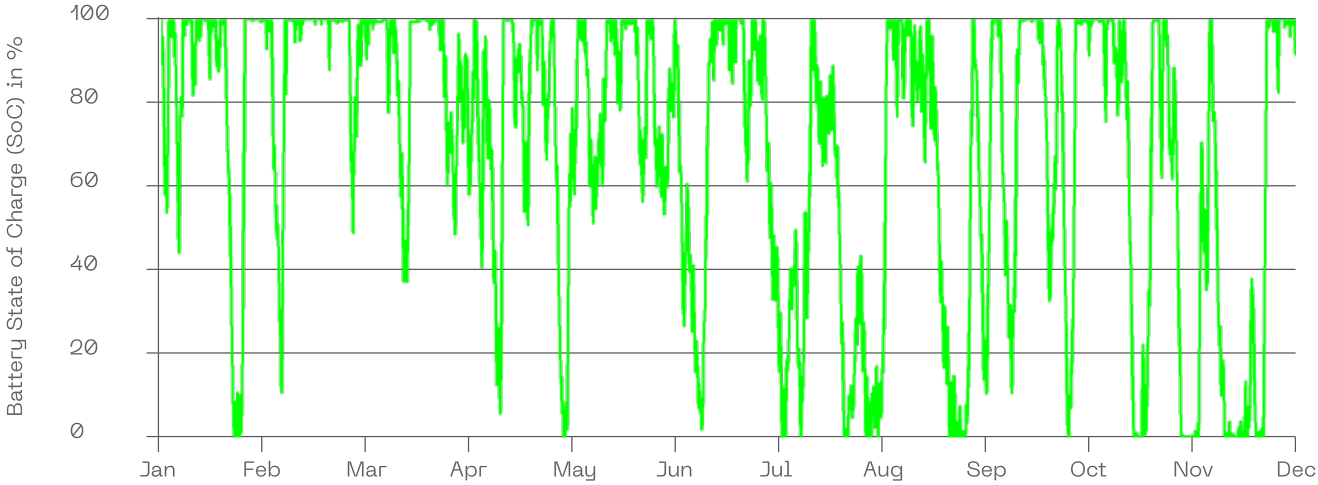
Base load power provided	No storage	4 h	8 h	12 h	24 h	48 h
100 kW	78.25%	93.17%	95.87%	98.52%	99.42%	99.98%
200 kW	71.19%	89.80%	94.33%	96.70%	98.33%	98.97%
300 kW	64.82%	86.41%	91.31%	95.11%	96.75%	98.41%
400 kW	59.31%	82.38%	87.59%	90.26%	94.08%	97.18%
500 kW	54.31%	77.82%	82.65%	85.27%	90.31%	95.01%
600 kW	49.91%	73.03%	77.03%	79.35%	83.95%	89.07%
700 kW	45.98%	67.78%	71.17%	73.30%	77.72%	82.60%
800 kW	42.34%	62.47%	65.42%	67.42%	71.54%	76.29%
900 kW	39.13%	57.46%	60.38%	62.29%	65.92%	70.35%

Storage in hours

Source: VoltStorage

The battery system is in this case cycled frequently and exhibits 50.6 full cycles per year and is well within its cycling lifetime after 20 years of usage (1,012 cycles).

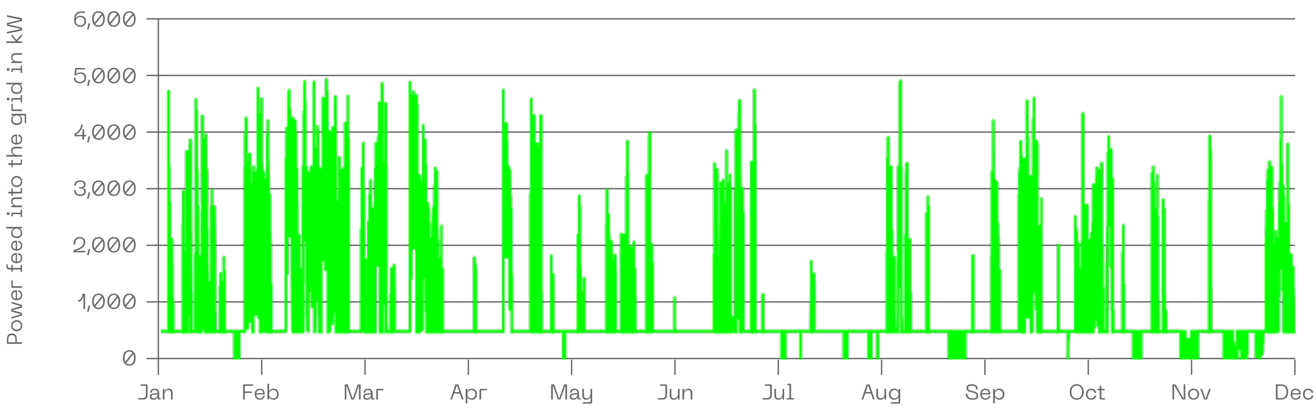
Battery State of Charge (SoC)



Source: VoltStorage

Emphazising, that half of the produced energy can be used as baseload, in this 500 kW continuous supply scenario, the energy provided as baseload totals sums up to 4.38 GWh annually of a total of 8.59 GWh produced (the excess energy is fed into the grid as well) and the power at the connection point to the grid looks like this:

Power at meter



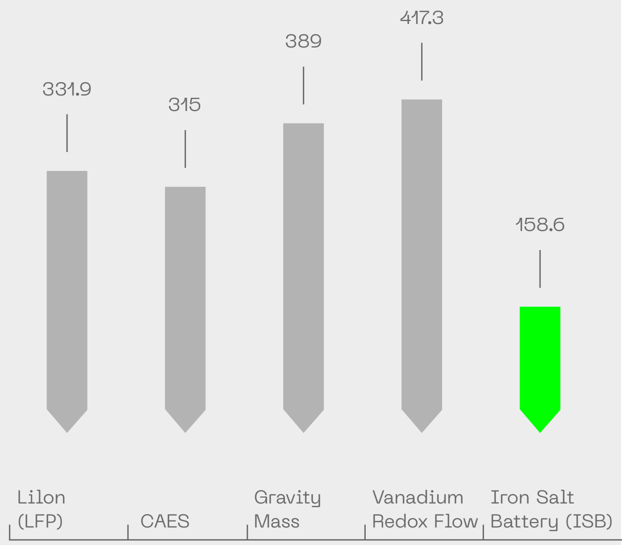
Source: VoltStorage

The battery system is designed to have a discharge power of 0.5 MW and a capacity of 24 MWh, fits into a 96 20ft-ISO-Container and set up on site. The total throughput of energy through the battery per year is 1.214 GWh.

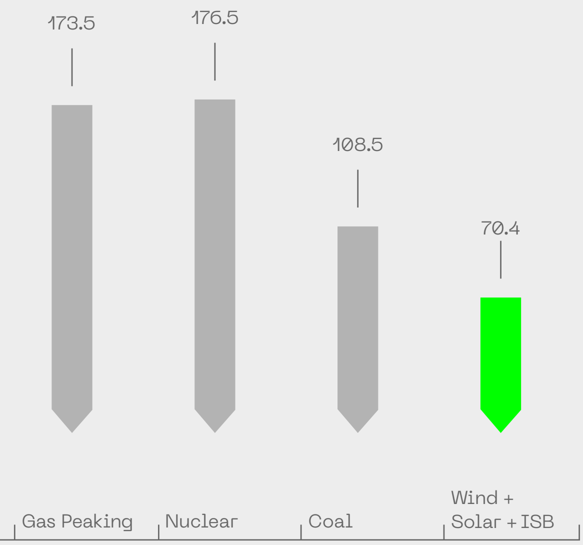
CAN THIS BE ECONOMICALY VIABLE?

Within a lifetime of 20 years, the system will run an equivalent of 1,012 full cycles. The Levelized Cost of Storage (LCOS) per MWh come out at 159 USD (factoring in a roundtrip efficiency of 70% and maintenance cost over the lifetime of 25% of initial purchase price). This is much less than any other battery technology on the market yet: Only a fraction (~25%) of the offered baseload power is provided by the storage system. Adding that to the LCOE of wind power in that location (36 USD/MWh) and solar (avg. 35.5 USD/MWh) respectively in the respective amount utilized, the base load power comes out to a total Levelized Cost of Electricity (LCOE) of 70.4 USD/MWh. Depending on the location of the wind turbine, the costs can be even lower in the range of 50-65 USD/MWh. This is lower than any direct fossil/nuclear fueled generation type today (2021):

LCOS per MWh in USD



LCOE per MWh in USD



All numbers are sourced from Lazard's unsubsidized LCOE overview as of October 2021: https://www.lazard.com/media/451905/lazards-levelized-cost-of-energy-version-150-vf.pdf

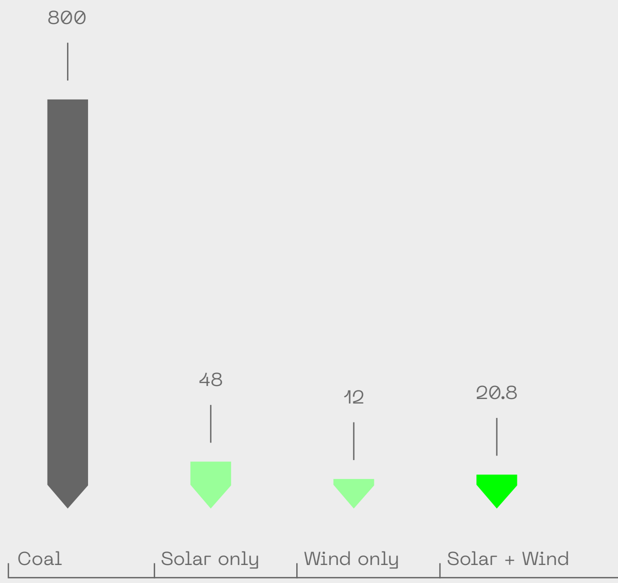
These numbers may also be higher in the years to come, since they are calculated with a CO_2 emission price in December 2021 (as low as 65 USD/t_{CO2}).

What impact on CO_2 emssions can this have?

Providing baseload from renewables is crucial to reduce emissions and the Global Warming Potential (GWP) of our electricity usage. The effective emissions of solar and wind power production are significantly lower than from coal, which is currently mainly used to provide the necessary baseload. The combined solar + wind production shown below has effective emissions (CO_2-eq) of about 20,8 g/kWh compared to coal-fired power plants with 800 g/kWh.

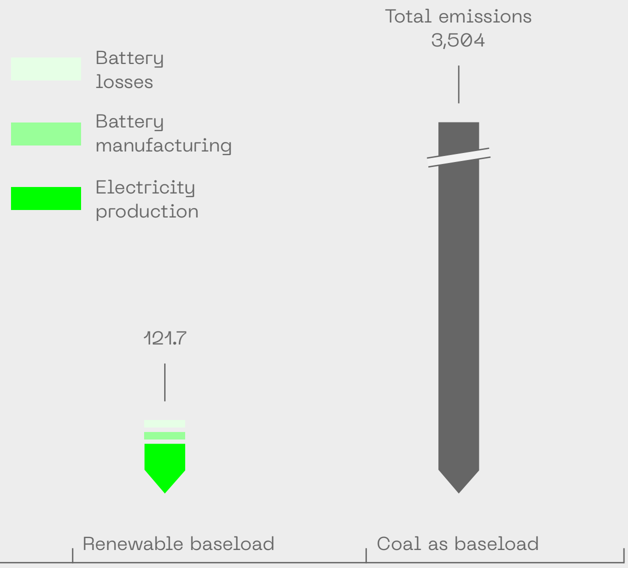
In the case described below, a 48h Iron Salt Battery system provides 0.5 MW baseload. Over one year, this baseload has an effective GWP of 121.7 t_{CO2-eq}. This number accounts fo the emissions for the renewable energy production, the self-consumption and losses in the battery system as well as for emissions during manufacturing and commissioning of the Iron Salt energy storage system. In comparison, coal as baseload has a 29x higher annual GWP of 3,504 t_{CO2-eq}. With a single 48h Iron Salt Battery system, annual CO_2 emission reductions of 2,282t_{CO2-eq} for our electricity usage is achieved.

CO_2-eq emissions in g/kWh per energy source



Source: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf#page=7

CO_2-eq emissions in metric t to provide 0.5 MW baseload for 1 year



Clean Energy Day & Night

VoltStorage: The future of energy storage

VoltStorage GmbH is the technological pioneer for stationary flow batteries. VoltStorage develops and produces energy storage systems based on ecological redox flow technology. With its sustainable storage solutions, VoltStorage strives to achieve the vision of making 100% renewable energy available 24/7. VoltStorage has an international research and development team as well as the largest operating flow battery fleet worldwide, and thus extensive expertise and experience in the development and production of sustainable storage technologies. With redox flow technology, VoltStorage is establishing a mass-market alternative to lithium-based storage technologies that does not require rare materials or conflict raw materials, is fully recyclable, and also has high operational reliability and durability. For a fairer and cleaner world for generations to come.

Contact

Do you have any questions, would you like more information or an individual consultation? We are here for you.

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