Sustainable Energy Self-sufficiency

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Energy self-sufficiency means that we are capable of generating enough electrical energy on a micro-level to power all systems that require electricity to operate. Solar power can be used to generate electrical energy. Through these devices, we convert solar energy into electrical energy. If we cannot store the excess electricity produced, we feed it back into the electrical grid. Since solar power plants cannot provide continuous production, we either need to store excess electrical energy or obtain the missing energy from the electrical grid. For storage, we require energy storage systems, such as batteries. A battery pack from electric vehicles can also be used as an energy storage system. By managing these storage systems, we can regulate the daily demand for electrical energy on a micro-level. Through an energy marketplace, we can trade electricity and manage the generated electrical energy of the micro-location. Combining a solar power plant with a heat pump on a micro-level can create a fully self-sufficient energy system for the micro-location, capable of operating independently of the electrical grid.

Keywords:
energy self-sufficiency,
battery storage systems,
solar power plants,
smart grid,
energy management•

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1 Sustainable electricity management

1.1 Presentation of the environment

The need for electricity is growing. In Slovenia, final energy consumption is 82 kWh per capita per day, of which 33 kWh is used for transport, 28 kWh for heating households and industry, and 20 kWh for electricity for households and industry (GEN Group, 2025a). The largest share of energy in households and the public sector is used for heating. The largest energy consumers in the public sector are educational institutions and student dormitories, as well as health and social care institutions. Most of the energy in transport is used for driving, with more than 60% for driving in passenger cars (GEN Group, 2025b).

Electricity can be produced using fossil fuels, nuclear reactors or renewable energy sources. Fossil fuels are dominated by gas and coal, while renewable energy sources include wind, hydropower and the sun. Renewable energy sources are those sources that are obtained from natural processes and are renewed as a result of natural processes or human activity. They can then be used again to produce energy (Lucey, 2023; GEN Group, 2025d). In Slovenia, approximately the same share of electricity is produced in nuclear power plants, thermal power plants and hydroelectric power plants, while other renewable sources, mainly solar power plants, account for a smaller share (GEN Group, 2025c).

The electricity produced is traded on energy exchanges. The price of electricity is determined based on the most expensive energy source (currently gas), taking into account the principle of the order of economy. The cheapest electricity is sold first. This is electricity produced from renewable sources. If this electricity is not enough, electricity is sold from other, more expensive sources of electricity, such as gas-fired power plants or thermal power plants. However, electricity is not sold at a price according to the production source, but according to the price of the most expensive method of electricity production (Consilium, 2023). Therefore, distribution companies can generate significant profits by selling electricity generated from cheaper sources of electricity, especially from renewable sources. Energy self-sufficiency eliminates dependence on energy imports, which reduces the potential negative consequences of energy supply, especially price fluctuations in the market.

Energy self-sufficiency means the ability of an area to meet its energy needs on its own and thus not depend on energy imports from surrounding areas. A self-sufficient area has the capacity to produce and distribute energy to end users. It is important to highlight the rarity of areas that have all the types of energy we need. Energy sources are unevenly distributed, so there are differences between areas in the presence of different energy sources, which means that we have to obtain the necessary energy from elsewhere. Energy self-sufficiency partially eliminates losses that occur when transmitting energy through the distribution network (Lucey, 2023; Iberdrola, 2025).

1.2 Energy pyramid

Sustainable electricity management consists of several steps. Let's illustrate this with an energy pyramid. The first step is to use electricity more wisely. Reducing electricity consumption costs us nothing and the thoughtful use of electrical devices can bring us savings. The next step is energy efficiency. By replacing and installing more energy-efficient technological options, we achieve savings in electricity consumption. Here, the electricity savings are greater than when reducing electricity consumption. The top of the pyramid is the use of renewable sources to generate electricity, e.g. installing a solar power plant on a micro-location (see Figure 1) (comorinsolar.com, b. d.).

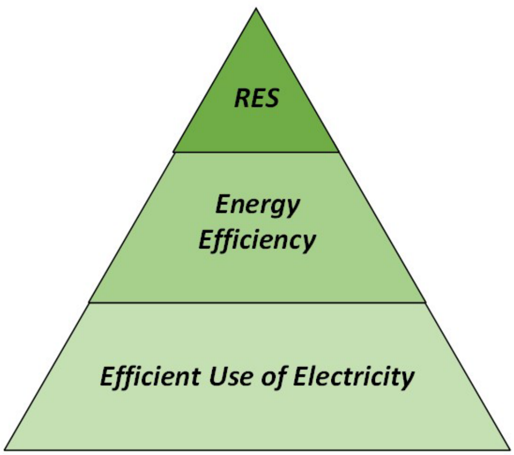

Figure 1: Energy pyramid diagram
Source: own

1.3 Energy management

Energy management allows us to manage electricity to reduce electricity costs by monitoring electricity consumption. Monitoring electricity consumption is enabled by built-in electricity meters. Electricity meters allow remote reading and thus monitoring consumption remotely, which can be used in energy management (Energy card, n. d.).

Since the production of electricity by solar power plants is influenced by the strength of the sun, the amount of energy produced cannot be adjusted to our daily needs. During the illuminated part of the day, there may be a surplus of electricity, but when the strength of the sun is lower or it is night, there is no electricity production by solar power plants. We obtain the missing electricity for our needs from the electricity grid. The excess amount of electricity is transferred to the ownership of the electricity company, and some suppliers also buy it (see Figure 2) (Pi-solarus, b. d.; termoshop.si, 2023).

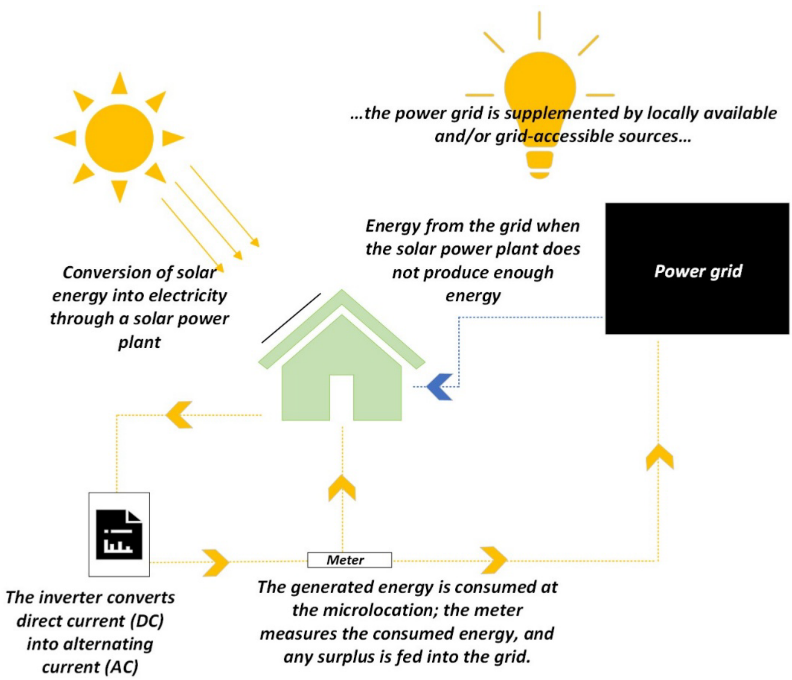

Figure 2: Management of generated electricity
Source: own

However, other options for managing excess electricity production are also used. Excess electricity produced by solar power plants can be transferred to another point of consumption in the network, or transferred to oneself for future use. Electricity can be transferred as kilowatt hours or as a percentage of the electricity produced (suncontract.org, 2023a). This allows several micro-locations to be combined into their own, self-sufficient system. For example, excess electricity generated in a holiday home in a solar-powered location can be used to charge a battery-powered electric vehicle at home. This way of managing excess electricity generation offers the potential to reduce electricity costs for consumers and increase revenue by selling electricity to producers without intermediaries (suncontract.org, 2023b).

Excess electricity management systems offer business customers the opportunity to buy or sell electricity at prices that change every hour, and users can also check electricity prices after auction trading for the day ahead (NGEN, b. d.a). They also offer users the opportunity to include electricity storage in the trading, which gives customers more options to buy electricity when it is cheap or to store generated electricity for later use (NGEN, b. d.b).

1.4 Smart grid

A smart grid is one that is able to balance production and demand on a daily basis. If we focus on electricity production during the day, we can see that more electricity is produced during the sunny part of the day, as shown in green in Figure 4. When solar radiation is optimal, we produce much more electricity from solar power plants than when it is cloudy. Given increased wind speed or higher river flows, we can produce more electricity through wind farms or hydroelectric power plants than we planned. Of course, the opposite is true when there is no wind or a drought. This leads to fluctuations in electricity production, which can contribute to a surplus or shortage of electricity at certain times of the day. In the event of a surplus, we need to store this energy, if possible. In case of shortage, outages can occur. Regarding consumption, which is shown in gray in Figure 4, we can highlight: household consumption is higher in the morning and evening than during the day when we are at work or school. Here we have the greatest shortage of electricity generated in the illuminated part of the day, as can be seen in Figure 4. The missing energy during the dark part of the day must be provided by the electricity grid from electricity storage or other continuously operating production sources, which is shown in red in Figure 3. The goal of the smart grid is that we will consume surplus electricity during the day, which has previously remained unused at a certain time, and thus eliminate excess demand when electricity production is less than current needs (see Figure 3 and Figure 4) (Let's Talk Science, 2019; Partlin, 2021; Ekart, 2023b).

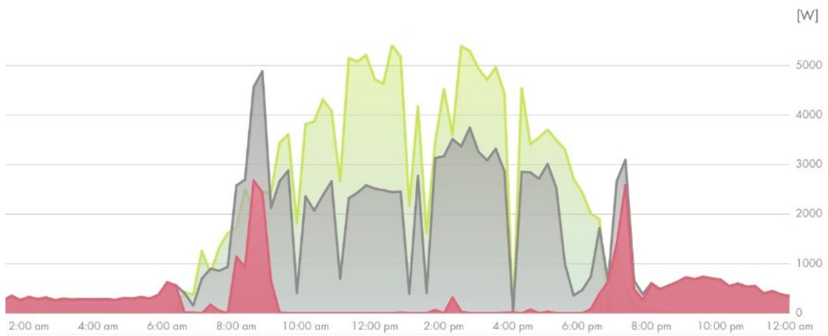

Figure 3: Display of fluctuations in electricity consumption over time
Source: Partlin, 2021.

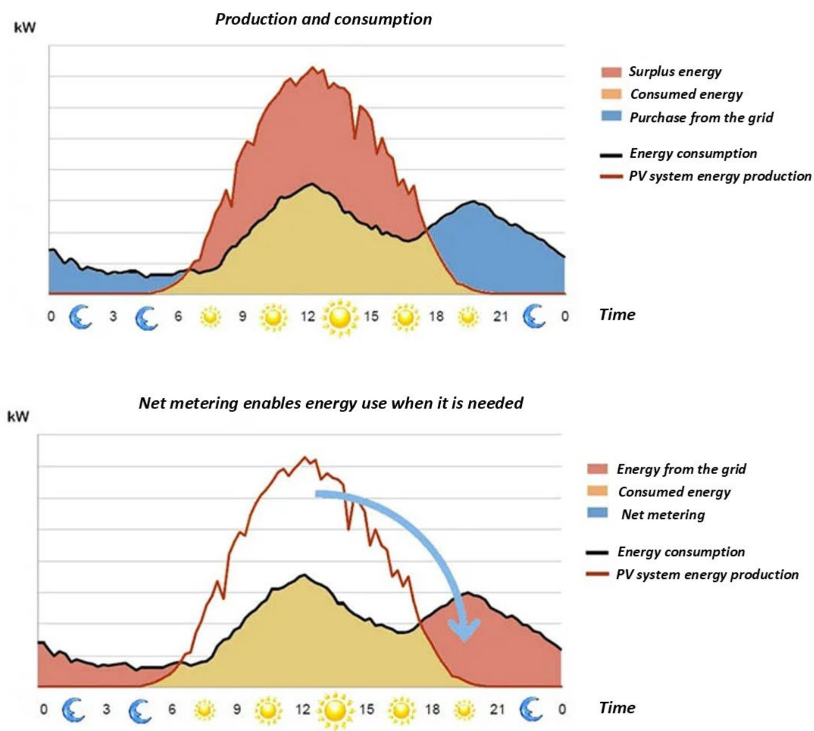

Figure 4: Demonstration of the concept of self-sufficiency in electricity
Source: Ekart, 2023b.

Self-sufficiency in electricity[1] is possible with a meter that can be rotated in both directions. At night, it measures the electricity used from the electricity grid, and during the day, it subtracts the electricity that is sent to the grid via the solar power plant. Self-sufficiency allows us to either send excess electricity to the grid or withdraw electricity from the grid (see Figure 4) (Ekart, 2023b).

1.5 Sustainable energy cycle

Renewable sources of electricity generation are not currently a reliable source of electricity production. Storing all electricity generated from renewable sources is not financially viable due to the high cost of large storage facilities. The sustainable energy cycle increases the possibility of using renewable energy sources in the electricity grid through electricity storage at micro-locations themselves. Each new battery electric vehicle or plug-in hybrid represents a new reservoir of electricity and provides us with a new location that can be used to store electricity and thus regulate electricity demand. In a sustainable energy cycle, this battery electric vehicle or plug-in hybrid becomes part of the electricity grid, capable of regulating both surpluses and deficits of electricity. Surplus energy can be stored in these electric vehicles or in a storage tank in the house, and when demand on the electricity grid increases, this stored electricity can be redirected from these micro-locations back to the grid to other consumers. The Metron Institute states that most of the battery capacity of these electric vehicles remains unused, as these vehicles are only used to cover short distances during the week. The use of "Vehicle-to-Grid" technology allows us to use the unused capacity of the battery pack in the vehicle to mitigate increased demand on the electricity grid and store surpluses. A larger number of micro-locations in the power system significantly increases the ability to store electricity generated from renewable energy sources. A group of micro-locations can also operate independently of the electricity distribution system as a stand-alone unit that can generate electricity from renewable sources and store it at micro-locations nearby until it is used (see Figure 5) (eauto.si, n. d.; Hanley, 2021).

[1]English Net Metering.

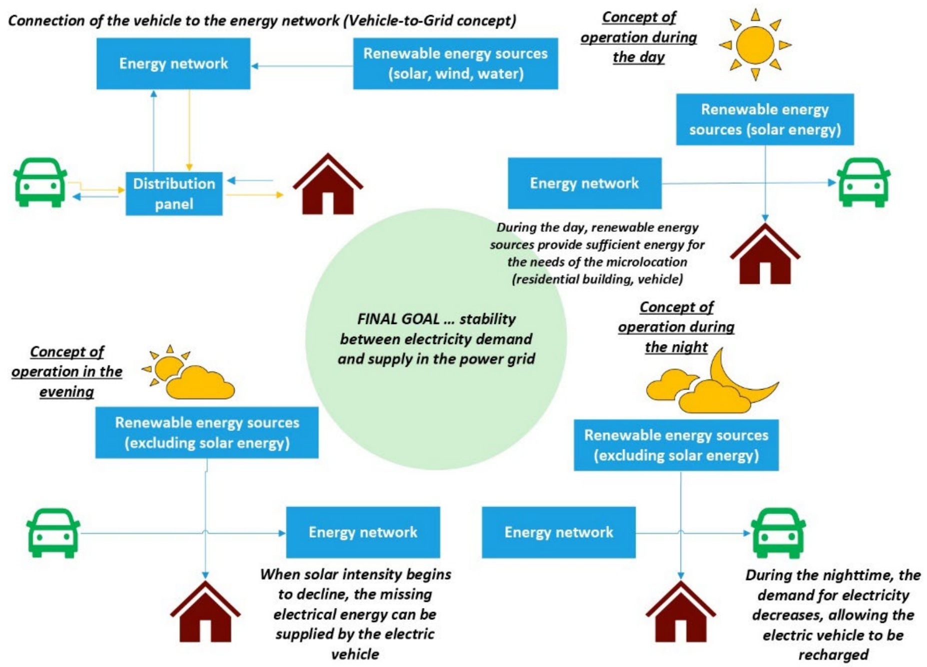

Figure 5: Vehicle-to-Grid (V2G, also P2X) concept
Source: own

2 Solar power plants

2.1 Definition of solar power plant

A solar power plant or photovoltaic system converts solar energy into electrical energy. We know photovoltaic solar power plants and thermal solar power plants. A photovoltaic solar power plant converts solar radiation into electrical energy. Through semiconductor materials, e.g. silicon, an electrical voltage is generated in the solar cell of the photovoltaic module, which drives the electric current. Such solar power plants have a low efficiency, somewhere between 10% and 20%. The most advanced systems achieve an efficiency of 25% (energija-solar.si, b. d.). The maximum efficiency of such a system is 60%. If we want to achieve the best possible performance of a solar power plant, the location must be taken into account during installation, i.e. where we intend to place the solar power plant. The chosen location should be as sunny as possible. Incorrect orientation and inclination of the solar power plant and possible shading in the surrounding area reduce the production of electricity. It is recommended that solar power plants be oriented towards the south, installed at an angle of 30° (trajnostnaenergija.si, p. d.). The photovoltaic module also works in cloudy weather, but the amount of electricity produced is lower (Fraile, Latour, El Gammail, Annett & Nemac, p. d., p. 3). In a thermal solar power plant, electricity is produced by concentrating solar energy into a substance, which then drives a turbine and produces electricity through the turbine. The operating principle of thermal solar power plants is the same as that of thermal power plants, except that instead of burning coal, solar energy is used to produce electricity (GEN Group, 2023).

2.2 Types of solar power plants

There are several types of solar power plants depending on the location of installation. Home solar power plants connected to the electricity grid generate electricity through modules installed on residential buildings (Valenčič, 2022). A direct connection to the grid allows for the sale of surpluses, and in the event of a shortage of electricity, it can be taken or purchased from the grid. Stand-alone solar power plants connected to the electricity grid produce larger amounts of electricity and are much larger than home solar power plants. They are installed on larger areas to make better use of space. Island systems for electrification of remote areas are intended for areas where there is no electricity grid. Such a system is supported by batteries for storing electricity and can supply electricity to a single facility or combine several locations into a smaller independent network. In hybrid systems, a solar power plant is combined with another energy source to provide an uninterrupted supply of electricity. Solar power plants on finished products are used on electrical appliances themselves and provide all or part of the energy needed to operate the electrical appliance. Island industrial plants are used to supply electricity to areas that are very far from the electricity grid. This eliminates the high costs of building a new electricity grid (Fraile, Latour, El Gammail, Annett & Nemac, b. d., pp. 10-11). Possible locations for the installation of individual types of solar power plants are listed in Table 1.

Table 1: Installation locations of individual types of solar power plants

Type of solar power plant	Installation locations
Home solar power plants	Roofs, exterior walls, facades and balconies of residential buildings, window blinds.
Standalone solar power plants	Roofs of larger industrial facilities or public buildings, in the area of airports or railway stations.
Island systems for electrification of remote areas	In all areas where there is no electricity network, mountain huts.
Hybrid systems	In wind turbines, next to generators.
Island power plants on finished products	Watches, pocket computers, toys, battery chargers, vehicles, traffic signs, lights, parking meters, telephone booths.
Island industrial facilities	Mobile communication poles, traffic signals, marine navigation, remote lighting, water treatment plants.

Source: Fraile, Latour, El Gammail, Annett & German, b. d., p. 10-11.

2.3 Advantages and disadvantages of using solar power plants

The advantages of using solar power plants are low operating costs, no noise pollution, and no emission of greenhouse gases during operation. They also enable distributed production, as collectors can be installed on individual devices that require electricity to operate, so there is no need for the consumer to be close to the power grid. While one of the advantages is low operating costs, a major disadvantage is high investment costs. The reliability of solar energy as an energy source should also be highlighted. The production of electricity with solar power plants depends on the amount of solar radiation, so there is a high probability that the production of electricity with solar power plants alone will not meet the demand for electricity (GEN Group, 2023). The use of solar energy is not limited to the production of electricity, as it can also be used for hot water preparation and space heating (trjanostnaenergija.si, b. d.). Due to their modular design, solar power plants can be upgraded to increase their capacity due to increased electricity demand, e.g. by installing a charging station for a battery electric vehicle or a heat pump (termoshop.si, 2023). Solar power plant modules can be recycled and reused in the production of photovoltaic modules. This closes the life cycle of photovoltaic modules (trajnostnaenergija.si, b. d.).

With every investment, we are interested in the payback period. This also applies to solar power plants. We have tools available to calculate the electricity savings and the time when the investment in a solar power plant will be paid back. For example, for a 100 m2 roof, the investment in a solar power plant with a power of 6.72 kW will be paid back in 6.5 years. If we currently pay an average of 70 EUR per month for electricity, in 30 years, the lifespan of a solar power plant, by installing it we save 7,669 EUR on the average monthly cost of electricity (vrhunskaemobilnost.si, b. d.).

2.4 Challenges in integrating solar power plants

The promotion of solar power plant installation by the state and solar power plant providers has encountered a major obstacle, specifically the capacity of the existing distribution network. As a result, distribution companies are rejecting applications for the installation of solar power plants. The introduction of the net metering system in 2016 has led to a tremendous increase in interest in the installation of solar power plants, as households have been able to significantly reduce their electricity costs by installing a solar power plant. Among other things, they were exempted from paying network fees, although solar power plant owners still use the distribution network both to send excess electricity produced and to receive electricity from the distribution network when production at the micro-location does not meet current demand (Zgonik, 2023).

Another problem is that solar power plants are oversized for household needs, which has actually led to an increase in household electricity consumption due to the desire to send as little surplus electricity as possible to the distribution network. As a result, households have started to combine a solar power plant with a heat pump or a charging station for electric vehicles in order to purchase such a vehicle. The problem with this way of thinking occurs during the period of the year when production is lower. Due to the installation of additional electricity consumers, households require even more electricity from the distribution network, which increases the need for electricity. Industry solves this problem by installing energy storage systems, and the advantage for industry is also the organization of the work process, which is adjusted to the part of the day when electricity production is highest. Greater self-sufficiency of industry also means less strain on the distribution network. The importance of incentives for the installation of solar power plants should also be emphasized. The net metering system has revived interest in the installation of solar power plants, which had completely died out after the abolition of state subsidies (Zgonik, 2023).

2.5 Projections for the implementation of solar power plants by 2050

As part of the LIFE Climate Path 2050 project, a study was conducted to determine the potential of rooftop solar power plants in Slovenia by 2050. To model the potential of solar power plants, data on insolation were used, broken down by the following factors: local units; an assessment of the share of available areas for the installation of solar power plants, which included existing buildings, parking lots and degraded environments suitable for the installation of solar power plants; an assessment of the impact of climate change due to rising average temperatures; an assessment of economic parameters and an assessment of other impacts on the operation of solar power plants, e.g. increasing the efficiency of solar panels due to technological advances. The research found that the technical potential of solar power plants in Slovenia for electricity production is 27 terawatt hours per year, which is almost double the amount of electricity produced in 2020, when Slovenia produced 16.5 terawatt hours of electricity. It was also found that the reference costs of solar power plants in 2050 will be between EUR 40 and EUR 105 per megawatt hour. For 2020, these costs were estimated to be between EUR 70 and 170 per megawatt hour, which means that these costs are expected to decrease significantly by 2050 (Kovač, Urbančič & Staničić, 2018, pp. 13-49).

3 Heat pumps

3.1 Definition of the term heat pumps

Heat pumps can be used for heating and cooling. A heat pump uses electricity to transfer heat from a heat source, such as air, water or soil, to a heating system. The heat pump gets all the energy it needs for heating from the environment. The heat pump uses renewable energy sources to operate and does not produce harmful greenhouse gas emissions. By combining a solar power plant and a heat pump, a microlocation can become completely self-sufficient (termoshop.si, 2023). Heat sources of heat pumps differ from each other. Earth and water offer a constant temperature throughout the year, while the temperature of air varies. With water, there may be a problem with the availability of the source due to fluctuating water levels and water quality, while with earth and air there are no such problems (Kronoterm, b. d.a).

We distinguish between heating heat pumps and sanitary heat pumps. Heating heat pumps are divided according to the heat source and the temperature range. Depending on the heat source, we distinguish between air/water heat pumps, water/water heat pumps, ground/water heat pumps and hybrid ground/air heat pumps. Depending on the temperature, we distinguish between heat pumps that operate in a high-temperature regime and heat pumps that operate in a low-temperature regime. Sanitary heat pumps operate using a single heat source, namely air (Kronoterm, b. d.a). The main characteristic of a heat pump is the heat index, which represents the ratio between the heat produced and the electrical energy input. It shows us how many kWh of thermal energy we get from 1 kWh of electrical energy input. For example, if we produce 3,000 kWh of electrical energy with a solar power plant and have a heat pump, we can use this electricity to obtain approximately 9,000 kWh of heat for heating buildings. The heating number in this case is 3. By integrating heat pumps and solar power plants, we can effectively achieve energy self-sufficiency, but only taking into account the net calculation over a longer period of time, e.g. on an annual basis. For self-sufficiency on a daily or weekly basis, it would be necessary to integrate an energy storage device in the form of a battery into such an energy circuit (Kronoterm, b. d.b).

Table 2: Comparison of savings with different energy sources, calculated as of September 6, 2023

Energy source	Price unit	Annual amount of energy required	Annual heating cost	Annual cost of water heating	CO_2 emissions	Saving CO_2 emissions with a heat pump
Heat pump	0,14 €	4.852,22 kWh	771,43 €	92,12 €	2.572 kg	
Natural gas	0,81 €	2.652,63 m³	1.832,09 €	316,54 €	5.090 kg	2.519 kg
LPG gas	0,97 €	3.625,90 m³	2.998,97 €	518,16 €	5.418 kg	2.846 kg
Pellets	222,00 €	5,14 m³	973,51 €	168,20 €	9.828 kg	7.256 kg
Firewood	55,00 €	25,20 m³	1.181,81 €	204,19 €	9.828 kg	7.256 kg
Fuel oil	1,08 €	2.500,00 l	2.302,23 €	397,77 €	6.678 kg	4.106 kg
Electricity	0,14 €	25.200,00 kWh	3.008,24 €	519,76 €	13.356 kg	10.784 kg

Source: Sagadin, b. d.

For example, let's take a 4-member family from Maribor, who lives in a residential building with 170 m2 of living space. They currently use an oil-fired stove for heating. They consume 2,500 liters of oil per year. They heat the rooms with radiators, and the amount of sanitary water used does not deviate from the average. By installing a heat pump, the family would save around EUR 2,000 annually, and

CO2 emissions would be reduced by around 4 tons (Sagadin, b. d.). A more detailed comparison of savings with different energy sources for our example is given in Table 2.

Savings can also be calculated for different types of heat pumps and for a longer period. For example, let's take a family of 4 living on 170 m2 of living space. They currently use an oil-fired stove for heating. They consume 2,500 liters of oil per year. The age of the oil-fired stove is 20 years (ceu.ijs.si, b. d.). A more detailed comparison of savings with different energy sources for a longer period is given in Table 3.

Table 3: Comparison of savings with different energy sources showing total costs over 20 years, calculated as of September 6, 2023

Heating type	Annual costs	Total costs over 20 years	Annual savings in energy costs	Annual CO_2 emissions
District heating	1.300 EUR	26.600 EUR	1.620 EUR	6.900 kg
Water/water heat pump	1.700 EUR	33.260 EUR	1.810 EUR	1.900 kg
Ground source heat pump with horizontal collectors	1.700 EUR	33.820 EUR	1.820 EUR	1.900 kg
Ground source heat pump with geoprobes	1.700 EUR	34.600 EUR	1.850 EUR	1.800 kg
Air/water heat pump	1.800 EUR	35.920 EUR	1.470 EUR	2.700 kg
Heating with pellets	1.900 EUR	37.900 EUR	1.510 EUR	
Heating with logs	2.000 EUR	40.820 EUR	1.340 EUR	
Heating with wood chips	2.200 EUR	44.800 EUR	1.630 EUR	

Source: ceu.ijs.si, b. d.

4 Electric vehicles

4.1 Battery electric vehicles

Battery electric vehicles are vehicles that use electrical energy stored in the vehicle's battery pack to operate. This provides energy to the electric motor that enables the vehicle to move. The vehicle's battery pack is mostly charged by charging it with electricity from the electrical grid at charging points. Battery electric vehicles offer quiet, emission-free driving and are cheaper to maintain and charge than combustion engine vehicles. Barriers to the use of battery electric vehicles include: short range, higher purchase price, and the existing charging infrastructure network, which is significantly less extensive than the network of stations for combustion engine vehicles (DriveClean, 2021a).

The return on investment in a battery electric vehicle varies depending on the car segment. In the city car segment, the investment in the purchase of a battery electric vehicle is repaid in eight years after driving 200,000 kilometers, or in six years assuming free charging. In the SUV segment, cost equalization is achieved in 4.7 years, or after driving 118,000 kilometers, compared to a vehicle with a diesel engine, and in 15.6 years, or after driving 391,000 kilometers, compared to a vehicle with a gasoline engine. In the premium vehicle class, the investment is repaid in less than a year, as there are no such price differences between the powertrains of more expensive vehicles, as there are, for example, in the city car segment (Božin, 2022).

4.2 Plug-in hybrids

Hybrid vehicles are vehicles that use a combination of an internal combustion engine and an electric motor to move, powered by a battery pack in the vehicle. The advantages of combining both modes in hybrids are reduced fuel consumption and lower exhaust emissions (DriveClean, 2021b). Plug-in hybrids combine the characteristics of battery electric vehicles and hybrid vehicles. In one vehicle, an electric motor with a battery pack that can be charged via electric charging stations and a classic internal combustion engine are combined. A plug-in hybrid allows electric driving at both lower and higher speeds, of course over shorter distances. The range of electric driving is even shorter than that of battery electric vehicles. When the battery pack is discharged, the vehicle switches to the internal combustion engine. In this way, the range of a battery electric vehicle is significantly extended. The plug-in hybrid is charged with electricity at electric vehicle charging stations, while the fuel tank is filled at a gas station. The goal is to make as many daily journeys as possible purely electric, using the internal combustion engine only when necessary. This mode of operation significantly extends the vehicle's range, reduces exhaust emissions while driving, and provides a more extensive network of charging stations than for battery electric vehicles (DriveClean, 2021c).

4.3 Fuel cell vehicles and electric vehicle comparison

Fuel cell vehicles use fuel cells to convert liquid hydrogen (fuel for fuel cells) into electricity, which powers an electric motor and thus the vehicle. Like a battery electric vehicle, a fuel cell vehicle produces no emissions during operation. Water is produced as a byproduct of the conversion of hydrogen into electricity. In terms of range, refueling and driving characteristics, fuel cell vehicles are comparable to vehicles with an internal combustion engine (DriveClean, 2021d). The differences between the individual types of electric vehicles are given in Table 4.

Table 4: Comparison of electric vehicle types

Vehicle type	Battery electric vehicle	Hybrid vehicle	Hybrid vehicle	Fuel cell vehicle
Energy source	Electricity	Fuel	Electricity, fuel	Liquid hydrogen
Vehicle charging	Charging point for electric vehicles	Gas station	Gas station, electric vehicle charging station	Liquid hydrogen gas station
Greenhouse gas emissions	Emissions-free	Yes, when the vehicle is powered by an internal combustion engine	Yes, when the vehicle is powered by an internal combustion engine	Emissions-free

Source: DriveClean, 2021a; DriveClean, 2021b; DriveClean, 2021c; DriveClean, 2021d.

If we compare battery electric vehicles and hybrid vehicles with petrol or diesel versions, we can conclude that battery electric vehicles and hybrid vehicles have been comparable in price to vehicles with an internal combustion engine for several years. A 2018 comparison test (Lukić) showed the comparability of these vehicles based on costs per kilometer. If a vehicle travels 50,000 km in 5 years, the cost per kilometer for a battery electric vehicle is EUR 0.41, for a hybrid vehicle EUR 0.40, for a vehicle with a petrol engine EUR 0.40 and for a vehicle with a diesel engine EUR 0.41. However, if a vehicle travels 125,000 km in 5 years, the cost per kilometer for a battery electric vehicle is EUR 0.18, for a hybrid vehicle EUR 0.16, for a vehicle with a petrol engine EUR 0.16 and for a vehicle with a diesel engine EUR 0.18.

5 Energy storage devices

5.1 Definition of energy storage system

Energy storage devices or batteries are devices that convert stored chemical energy into electrical energy. Batteries can be divided into primary and secondary. Primary batteries are those that cannot be recharged and are discarded after use, while secondary batteries are those that can be recharged. They are also called accumulators (Linden, 1995, pp. 20-22).

5.2 Required battery characteristics

The characteristics of the battery depend on the type of consumer. Batteries for battery electric vehicles must have a sufficiently high energy density for sufficient range of the vehicle, enough power to accelerate the vehicle, a long battery life with minimal maintenance, and a low price. Batteries for hybrid vehicles must have enough power to accelerate the vehicle, the ability to continuously charge through regenerative braking, a very long life, and a low price. Electronic devices require cheap and accessible batteries that have high power and energy density. Batteries for devices that are part of the energy grid must have low investment costs, be reliable, and have high power and energy density. For all batteries for all consumers, safe operation and minimal environmental impact during production, use, and disposal are mandatory (Symons & Butler, 1995, p. 1187). Batteries used for storing electricity allow the use of electricity even in the event of failures, repairs, or power outages in the electricity grid, which is key to the self-sufficiency of a microlocation (termoshop.si, 2023).

5.3 Reusing batteries from used electric vehicles

It has been found that batteries that are part of the battery pack in electric vehicles still retain 70% of their original capacity after the end of their intended useful life as part of the vehicle's powertrain and would be useful as electrical energy storage for at least another ten years (nrel.gov, b. d). Research by Wood, Alexander and Bradley (2011), which focused only on plug-in hybrids, found that the proportion of remaining battery pack capacity in these vehicles is as high as 80%. As the number of electric vehicles on the road increases, the number of scrapped electric vehicles will increase over time, and so will the number of batteries suitable for energy storage. However, in order to store electricity in such storage systems, the price of such systems would need to fall by 90% to 0.05 EUR/kWh (batterycouncil.org, 2022). Currently, such storage of electricity is not economically viable (Lamp & Samano, 2022). However, savings can be made on electricity prices. A consumer with 5,000 kWh of annual electricity consumption can save 680 EUR through a solar power plant and a storage tank with 80% self-sufficiency in electricity at current regulated prices, and even more with the expected increase in electricity prices after the end of the regulation period. If the price were to rise to the level of prices for German households, the annual savings would amount to as much as 1,800 EUR (Ekart, 2023a).

The increasing emphasis of companies covering various links in supply chains and operating in different geographically distant parts of the world and households on increasing their own energy production, increasing efficiency and reducing energy consumption indicate that the energy management sector is among the priority areas, as the cost of energy can also be the dominant cost of a selected energy-intensive company. The energy management sector is one of a number of priority areas, stemming from the growth in companies covering various links in supply chains and operating in geographically distant parts of the world as well as households increasing energy production and efficiency and reducing consumption. We should also note that the cost of energy can be the dominant cost in an energy-intensive company. Due to the relatively high energy prices in the EU, this is all the more visible in our country. Sustainable energy self-sufficiency makes us more resistant to supply disruptions and reduces our dependence on suppliers. It enables the use of our own resources and, in combination with advanced flexibility systems in the electricity system, brings reliability and greater added value, which is created in the local environment. Self-sufficiency will be much more effective if it is established and operates at the level of the entire EU and not just in micro-locations. The production of electricity from renewable sources, as well as energy use, is dispersed, time-dependent and variable, so it makes sense to interconnect larger systems, thereby achieving a more stable and robust system.

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