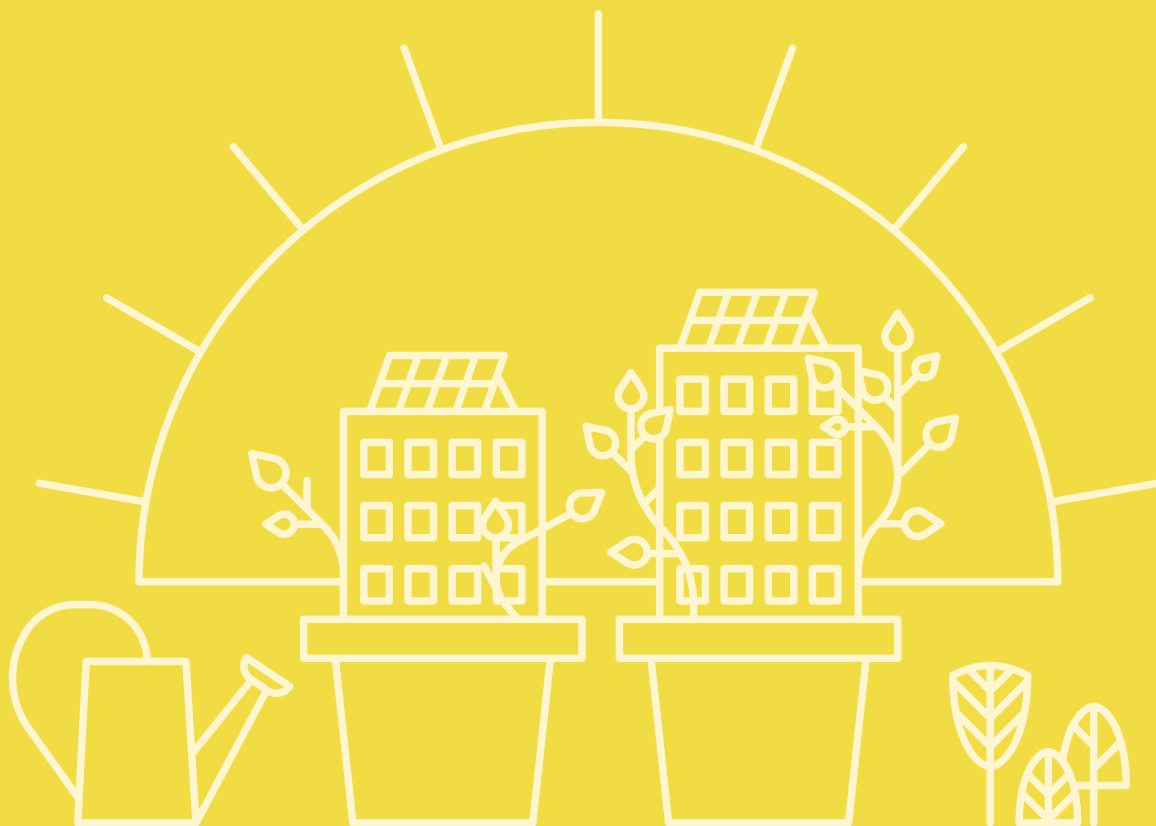


Solar Energy Handbook

Guidance on Combining Solar Technology
with Green Roofs & Vertical Greening Systems





Building-integrated PV
Transparent PV
Design feature
Coloured PV

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Shading element
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Foreword



The climate emergency is the greatest challenge of our times. Its consequences, such as rising temperatures, have long since made themselves felt in Vienna as elsewhere. Vienna City Council has responded by launching an ambitious local authority programme with the goal of making itself the first climate-neutral federal province by 2040. By 2040 we aim to be emitting less greenhouse gases than our plants can absorb. One crucial milestone on our path to net zero is the transition to clean energy. We have set ourselves the target of doubling renewable energy production in Vienna, compared to 2005 figures, by 2030.

In order to achieve this goal, we have launched the biggest solar photovoltaics campaign in history. We aim to increase solar electricity production fivefold by 2025, and by 2030 some 530,000 Viennese citizens will be supplied with solar power made in Vienna. The roofs and facades of buildings and other sealed surfaces are especially useful for solar photovoltaic installations. Thanks to the technological advances made over the past few years, there is no longer any question of whether or not a roof can be greened and/or used to generate solar energy. This Solar Energy Handbook summarises the technical possibilities and potentials for combining green roofs/vertical greening systems with solar energy and shows how the two can be implemented together.

To help us achieve our goals, it is also important to create the necessary incentives. On 1 June 2021 we thus introduced a subsidy scheme for private individuals to support the installation of solar PV systems on green roofs. Both the subsidy scheme and this guide are aimed at anyone interested in implementing solar PV & green roof/vertical greening projects to harness the benefits of these combined solutions.

I hope you'll find it interesting reading.

A handwritten signature in dark ink, appearing to read 'J. Czernohorszky', written in a cursive style.

Jürgen Czernohorszky

Executive City Councillor for Climate,
Environment, Democracy and Personnel

Introduction

Climate neutrality, or net zero, means a complete switch from fossil fuels to renewable energy sources. Over the next 50 years, solar energy will thus become one of the most important global sources of energy. Especially in cities, solar energy, alongside geothermal energy, will play a crucial role in the transition to renewables. For a city like Vienna, this chiefly means that in future, the roofs and facades of buildings and covered outdoor areas will be used for solar energy production. The City of Vienna's solar PV campaign will be instrumental here in making the city's energy supply fit for the future. Furthermore, for many years now, building-integrated solar thermal energy generation has been a key application with a view to meeting the city's climate action target.



Since Vienna, as an urban centre, is disproportionately affected by global warming, the city also has ambitious goals with regard to urban greening, with greening measures planned in public spaces as well as on the roofs and facades of buildings. Urban greenery can improve the microclimate, provide shade and enhance urban biodiversity, particularly in the summertime, while local people also benefit from the enhanced amenity value of green outdoor spaces. Vienna's ambitions in terms of climate action and climate adaptation thus come together on our city's roofs and facades, and it is precisely here that the new Solar Energy Handbook aims to position itself, highlighting ideas and solutions that tackle climate action and climate adaptation as combined goals rather than competing ones.

In the past few years there have been a multitude of innovations and advances in the field of solar technology and greened buildings. The handbook thus focuses on two specific areas – building-integrated photovoltaics (BIPV) and combined building greening/solar PV solutions.

This new Solar Energy Handbook is deliberately being published to coincide with the launch of Vienna's solar PV campaign. It is designed to provide state-of-the-art guidance, ensuring that smart concepts are employed to achieve the roll-out targets so that all the city's needs can be combined and met as effectively as possible.

The City of Vienna will lead by example here, installing as many photovoltaic systems as possible on the city's municipally owned buildings in the months and years ahead. But private property owners can likewise do their bit to support the shift to more renewables and contribute to safeguarding Vienna's high quality of life. Efficient use of land and maximising the potential of the urban infrastructure are essential considerations to this end.

As the programme leaders of the City of Vienna's solar PV campaign, our task is to create solutions for all usable surfaces, take steps to simplify the relevant procedures and, ultimately, to make Vienna a model city for solar PV in the urban context.

Programme leaders of the City of Vienna's solar PV campaign

Bernhard Jarolim
Director of Construction
and Technology, City of Vienna

Bernd Vogl
Head of Energy Planning,
City of Vienna

1

Using solar energy and building surfaces in the city – Now and in the Future



The last few decades have seen significant changes in the demands placed on urban built environments. At the same time, climate-related problems in new and existing buildings are being aggravated by more and more surface sealing, the urban heat island effect and less water evaporation from green spaces, including parks, roofs and building facades (Pfoser et al., p. 11, 2013). The number of very hot days in Vienna is expected to double over the next 100 years, causing the amount of energy needed for cooling to increase threefold over the next 50 years. Alongside the creation of green spaces, the surface areas of existing and newly built structures can be used to generate energy. Photovoltaic systems and solar thermal systems placed on walls and roofs can generate electricity and heat. As space and surfaces are limited resources, it is important to integrate different needs in designs for multi-purpose use.

- Urban space**
Microclimate, noise protection, CO₂ sequestration potential, design, appeal, well-being, air purification, particle dust fixation
- Surrounding area**
Rainwater drainage, water retention, evaporation, ecological benefits, biodiversity
- Building**
Cooling, noise protection/insulation, optimising the efficiency of active systems, CO₂ potentials, design, facade weather protection, financial effects

Figure 1: Potential effects of building greening on the building, its immediate surroundings and the wider urban space



Meeting future climate and energy challenges in urban environments requires solutions that combine and draw upon synergies from solar and photovoltaic technologies, "Green City" solutions and nature-based systems.

Under the headline theme "Using Solar Energy and Building Surfaces in the City – Now and in the Future", this handbook presents the technologies that are available to harness solar power as we look to the future. By describing in detail how electricity and heat generation technologies can be applied in combination with vegetation on buildings and which synergies can be expected from this design approach, the

¹ Presentation by Jürgen Preiss, PV and roof garden workshop, 04.11.2019

authors hope to provide a tool that will help building designers to optimise the use of solar energy. The combination of technology and nature enables us to use solar energy most effectively and to improve the urban climate, thus raising the quality of life in the city.

The roofs of existing buildings offer great potential for the installation of solar technology, and we should make use of it. Nearly two-thirds of the total roof surface area of the City of Vienna are at least theoretically suitable for retrofitting with solar technology. The surface area suitable for greening has been calculated at about 5,800 hectares of rooftops and 12,000 hectares of wall surfaces (net figures).¹

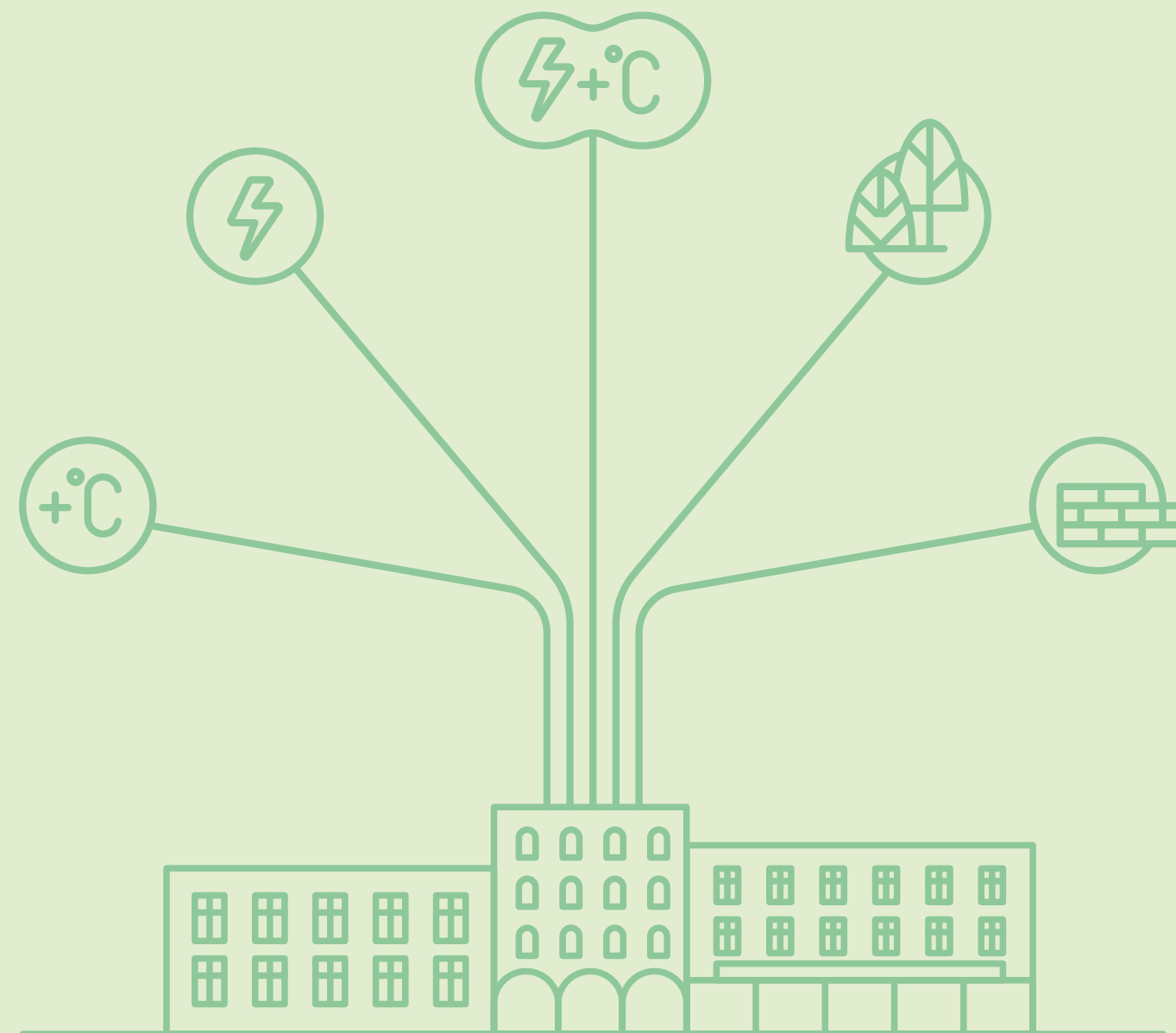
And the relevant technologies are evolving all the time. In photovoltaics, for example, solar cells are now available in different colours. They no longer have the typical look of a PV array and can be integrated as design features in building facades. Thanks to these advances, solar technology has become very versatile and can be integrated in urban settings with hardly any constraints on design. Likewise, coloured glass for solar heating systems has been on the market for several years now, enhancing the appearance of solar thermal collectors on building walls.

Vegetation on roofs and walls is a valuable asset in densely built-up areas, providing benefits in terms of microclimate, energy, economy and ecology as well as prolonging the useful life of buildings. Moreover, greening of buildings creates amenity value; providing a more pleasant environment for people, greenery contributes to human well-being and quality of life.

The combination of building greening and solar technology gives rise to synergy effects which help to increase the efficiency and performance of existing surface systems. Greening/cooling the rear of a PV facade has a positive effect on the performance of the PV modules. Combining PV and solar heating with a green roof creates shaded areas on the roof that function as new habitats for diverse plant and animal species.

2

Technologies



The following section presents the three technologies that can be used on building surfaces – photovoltaics, greening with vegetation and solar thermal systems –, and describes their design and how they function. Additionally, there are sections on community installations and the Renewable Energy Development Act.

2.1 Photovoltaics

How does a photovoltaic system work?

Photovoltaic (PV) technology uses solar cells to transform the energy from sunlight into electrical energy. PV installations can be mounted directly on a building (on the roof area) or integrated into the building facade. There are also free-standing PV systems mounted on the ground.

The components of a PV system are: the PV modules, wiring, safety devices and a current inverter. A power storage unit (battery pack) can be added to store energy and thus improve the PV system's effectiveness.

The sunlight that is intercepted by the PV modules is transformed into electricity, with both direct and indirect solar radiation being used. The PV modules produce direct current, which has to be converted to alternating current to be usable in the building. This is done by means of a current inverter. The solar-generated electricity is now ready for use, to run electrical appliances in the building, power vehicles and generate heat. PV systems are designed to use most of the electricity generated on site, reducing the

- A PV modules
- B Direct-current power storage battery
- C Current inverter
- D Alternating-current power storage battery
- E Power-consuming fixtures/appliances
- F Electricity meter
- G Power grid

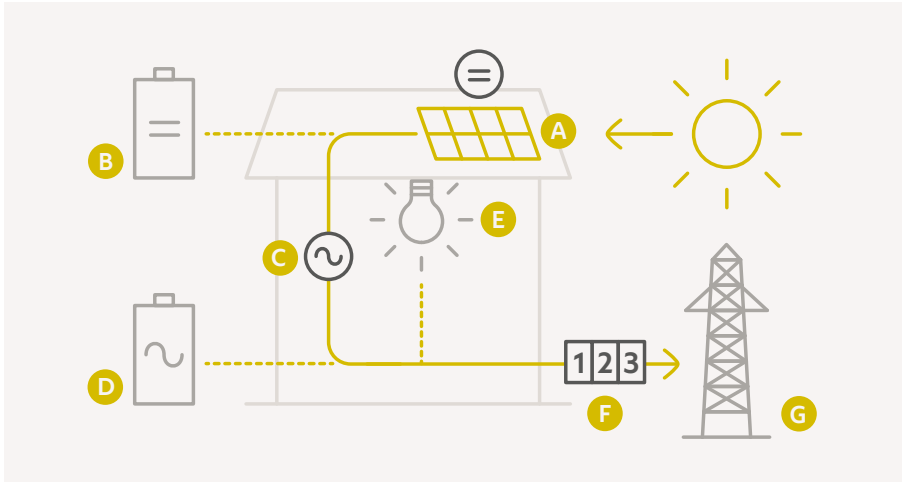


Figure 2: Design of a grid-connected PV system

need to buy electricity from the grid. When the PV system generates more power than is needed, the surplus may be either stored in a battery or fed into the grid, i.e. sold to a utility company.

Structure of a PV module

SOLAR CELLS

The smallest unit in a PV module is the solar cell, which converts sunlight to electrical energy. The module is made up of a number of interconnected solar cells. The most frequently used PV cells are made of crystalline silicon, either in monocrystalline or polycrystalline form.

POLYCRYSTALLINE SILICON SOLAR CELLS

This is the solar cell type which is most frequently installed. The characteristic crystal structure of the cells resembles frost patterns. Each flake in such a pattern is a small silicon crystal. The crystals grow naturally during the production process. This is why polycrystalline cells are easier to make than monocrystalline ones, which require additional processing. As a result, polycrystalline cells come at lower production costs than monocrystalline ones, but they are also slightly lower in performance. Because of the lower cost, polycrystalline solar cells are often used in PV systems on large surface areas.

MONOCRYSTALLINE SILICON SOLAR CELLS

As opposed to polycrystalline solar cells, monocrystalline cells are made from a single silicon crystal, which improves performance. They are regarded as highly efficient in harvesting direct solar irradiation, requiring less surface area than polycrystalline solar cells to generate the same amount of power. Monocrystalline-cell modules are the technology of choice for high outputs on a small (rooftop) area. The surface of monocrystalline cells has a homogenous appearance, with surface colours ranging from dark blue to black.

THIN-FILM SOLAR CELLS

Thin-film solar cells exist in different material compositions and structures. What they have in common is the manufacturing process and the thickness of the various layers (in the μm range), which are produced by vapour deposition of the material. Different materials are combined so that a broad range of radiation can be taken up and used for energy generation. The greatest advantages of thin-film modules are flexibility and low weight. But as a rule, their efficiency is lower than that of other solar cells, which means they require a larger surface area to produce the same amount of power. Surface colours typically range from orange-brown to black. Thin-film cells allow much greater freedom of design than crystalline cells.

SPECIAL SOLAR CELLS

In addition to standard cells, special designs are available, such as coloured cells (see Figure 4), cells with printed surfaces or designs with holes (to allow some sunlight to shine through the cell). Any modification of a cell affects performance, however. When coloured glass is used, energy output is reduced by 10–20%.



Figure 3: Holes in solar cells prevent total shading of the area under the PV array.

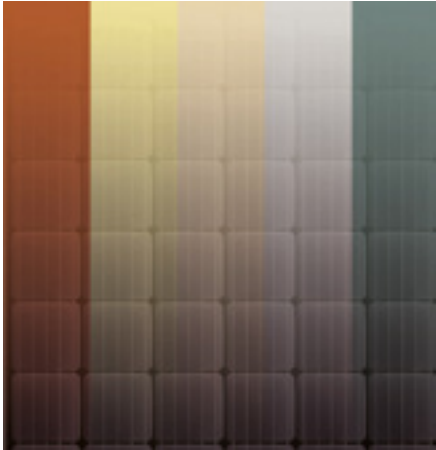


Figure 4: PV modules are available in nearly any colour

Types of PV modules

The power output of a PV system is measured in kilowatt-peak (kWp). “Watt peak” is defined as the power output produced by a module under standardised test conditions. A standard PV module today is made up of 60 solar cells, has a power output of up to 370 watt, a size of 1.7 m² and weighs about 18 kg. PV modules with 72 cells are also on the market, with top performers in the range of slightly over 400 watt. Their size is 2 m², and they weigh about 25 kg.

Half-cell modules are a new trend in the production of solar modules. The solar cells are cut in half for this application. The smaller cell size reduces the module’s internal resistance, thus enhancing its efficiency. Special designs are now available, in which colours are printed on the glass pane of a module which may then be used for installation on a building facade, for example. Such installations are often no longer recognisable as PV systems.

STANDARD PHOTOVOLTAIC MODULES

At the core of a PV module are the solar cells, which are connected to each other. To protect the solar cells against mechanical impact, weather and humidity, modules are made up of several layers. In standard modules, the outermost layer consists of glass. The solar cells are connected by solder tabbing wire. The rear side of a standard module consists of a synthetic back sheet and an aluminium frame.

GLASS-GLASS MODULES

In glass-glass PV modules, both the front and rear layers on the outside of the module are made of glass. With the stronger protective effect of the glass layers on either side, glass-glass modules are more robust and have a longer service life. Moreover, they are designed to let sunlight shine through the module, illuminating the area below. The drawbacks of glass-glass modules are slightly lower efficiency and slightly higher prices, and they are less easy to mount than standard modules. Some manufacturers offer customised module assemblies that allow shorter or longer distances between PV cells. With this option, the buyer can choose how much of the area below the module will be shaded, for example when installing the PV system as part of a conservatory roof.



Figure 5: Glass-glass module



Figure 6: Thanks to their pliability and low weight, flexible PV modules can be used for a wide range of applications.

FLEXIBLE PHOTOVOLTAIC MODULES

The special structure of flexible PV modules allows them to be bent, opening up a wide range of installation options, including mobile applications; examples are arched roofs (on caravans or boats) and roll-up shading elements. Combining very low weight and high performance, these modules are especially suitable for roofs that can only bear little additional weight load.

BI-FACIAL PHOTOVOLTAIC MODULES

Bi-facial modules generate electricity from direct radiation on the module front and from (indirect) light on the back of the module. The rear side of bi-facial modules is transparent – as opposed to standard modules, which have an opaque back. The solar cells are designed to process light from both sides. Light can thus be harvested from the front and rear side of the module, raising the energy output over that of standard (uni-facial) modules. Power output can thus be increased by up to 30%, depending on the reflective properties of the surface behind the module.

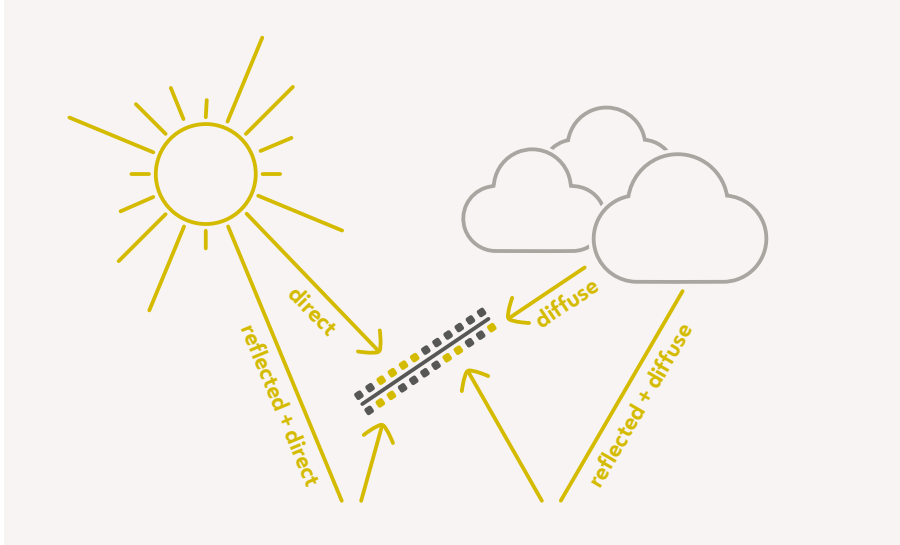


Figure 7: Structure of a bi-facial PV module

Bi-facial modules are best suited for reflective sub-surfaces, carports, noise protection barriers and for vertical installation, for example on fences, which makes them suitable for private as well as public use.

An advantage of vertically mounted bi-facial modules is that solar power generation is strong both in the morning and the afternoon. This helps to even out electricity generation and use over the day.

PLUG-IN MODULES

Plug-in modules are easy to install and may be used by any household without first obtaining approval for grid integration from a power utility. Their maximum rated output is 800 watt (*TOR Erzeuger* – Technical and organisational rules for power generators, Type A, version 1.1). For further information (in German), see www.pvaustria.at/normen.



Figure 8: A plug-in module on a residential building in Vienna

CURRENT INVERTER

A current inverter is required to transform the direct current generated by the PV modules into alternating current, which is used in households. Systems with a rated power of 3.68 kVA and more have to have three-phase feed-in to avoid substantial unbalanced loads. These and other technical requirements are specified in the *TOR Erzeuger* (*Technische und organisatorische Regeln für Erzeuger*, Technical and organisational rules for power generators). In most systems, the inverter is selected to be capable of dealing with slightly more than the rated power load. This is done because a system runs at highest efficiency in the upper output ranges. The inverter serves as an interface between the PV system and the public grid and ensures smooth operation. Important parameters of inverters are efficiency, service life, functionalities and ease of installation.

POWER OPTIMISER

Even with optimum planning, shading of some PV modules at certain times cannot always be completely avoided. Shading or soiling cause the power output of the affected module to drop, affecting the performance of other modules as well. Power optimisers, which are attached directly to individual modules, monitor and optimise performance of each single module. This prevents shaded modules from affecting the performance of other modules. Many manufacturers are already integrating power optimisers into their modules at the production stage. An online tool is used to monitor the individual PV modules and detect drops in power output in good time.

POWER STORAGE UNIT

By using a battery pack for temporary storage of PV-generated electricity, even more solar power can be utilised at the place of production, raising the on-site harvesting rate significantly. As a result, the owner of the battery pack is less dependent on the local energy utility, and potential price increases will have less of an effect.

Lithium-ion batteries are the state-of-the-art technology today. They are maintenance-free and highly efficient and offer large depths of discharge for up to 8,000 charge/discharge cycles. Moreover, they are small and light-weight. In addition to lithium batteries, there are also saltwater-based battery systems. These are a very safe and eco-friendly option. A power storage system should always be chosen based on the specific needs of a given project.

The average lifespan of a battery pack is 20 years. As batteries are charged only when surplus energy is produced, the system can be expected to go through 100 to 200 charge/discharge cycles per year. This translates to about 4,000 cycles for the full lifespan of a solar power battery used in a PV system.

Given the ongoing developments in the field of e-mobility, battery prices are expected to go down further in the future.

Options for installing a photovoltaic system

There are three basic options for the installation of PV modules:

1. Mounting the PV modules directly on the building roof
2. Integration of the PV modules into the building design, where they may replace parts of the roof and/or walls, serve as shading elements or fall barriers, etc.
3. PV systems on the ground may have a double function, for example as roofing for a carport or car park, or in the management of agricultural land

Rooftop photovoltaic systems

Depending on the pitch of the roof, PV modules are either installed parallel to the roof surface or mounted on racks at an angle to the surface. Parallel installation is usually the preferred option for roofs with a pitch of between 20 and 50 degrees. The solar power yield of PV systems on roofs that are flat or with very little pitch can be increased by mounting the PV modules at an angle of 15 to 35 degrees. In addition, rain will keep the modules clean, and snow will be able to slide down the module surface. PV systems on pitched roofs are mounted directly on the rooftop, anchored into the roof structure. Rooftop- and wall-mounted PV systems require sufficient rear ventilation to keep them cool. The distance between the module body and the roof surface should be 10 to 15 cm. A PV system with an east-west orientation on a flat roof produces power mainly in the morning and the afternoon, as shown in Figure 12.

The following pictures show various options for mounting PV systems on building roofs.



Figure 9: Rooftop PV system on a multi-unit apartment building



Figure 10: Rooftop PV plus solar thermal system on a single-family home



Figure 11: Rooftop PV system on an apartment building, used as a community PV plant, Lavaterstrasse, Vienna



Figure 12: East-west-orientated PV system on the roof of a multi-storey car park



Figure 13: PV system on the roof of Technology Centre 2, Seestadt Aspern

Figure 14: Flexible, lightweight PV modules supply power for the Ottakring station on underground line U3



Figure 15: PV array atop Vienna's aquarium ("Haus des Meeres")



Figure 16: PV roofing (seen from below) at the Vienna aquarium; bi-facial modules generate electricity and provide shade



An array of bi-facial PV modules provides power for Vienna's aquarium ("Haus des Meeres") and shade for the rooftop café, as shown in Figures 15 and 16. Special steel brackets and custom-made semi-transparent solar panels have been deployed to preserve the impressive view of the city from the building roof.

Building-integrated photovoltaic systems

Given the significant potential of building surface areas, integrating PV modules into a building's walls is a viable solar design option. In addition to generating electrical power, building-integrated photovoltaic (BIPV) systems also have a functional role in the building design. Made of customised glass-glass modules, BIPVs may be used instead of conventional facade or roofing elements or for shading. In this design approach, the BIPV system replaces and fulfils the functions of the roof or facade. Integrated designs may be more aesthetically pleasing, they do not require racking, and the conventional roof/facade surfaces will be smaller and thus cost less. On the other hand, BIPV modules which have to fulfil the functions of a roof (moisture and noise protection, thermal insulation) often come at a higher cost compared to conventional modules, and their installation is more complex.

The power output of facade-integrated modules that are mounted at right angles to the ground is 30% lower than that of arrays with an optimum tilt angle.

BIPV systems can be used freely in very diverse designs, as the following pictures show.

Figure 17: BIPV system takes on the functions of the roof



The BIPV system on the administrative building of TU Vienna is one of Austria's largest building-integrated PV systems. The modules are mounted on the building's facade, roof, staircase and terrace and also function as shading elements. The power generated by the system is used directly in the building, with surpluses being transmitted to neighbouring buildings on the University campus.

Figures 18 + 19: BIPV glass-glass modules are integrated into the facade of TU Vienna



The Solaris residential building in Zurich (see Figure 20) sets a standard for sensitive development in an urban setting. Here, state-of-the-art solar panels have been integrated into the building envelope, giving the apartment building a homogenous appearance. Creative solar panel solutions combine structured cast glass on the front and ceramic digital printing on the back; they are not immediately recognisable as PV modules and add to the building's appeal.

More examples from Switzerland and Germany of different BIPV system designs and ways of integrating them into buildings are shown in Figures 21–24.

Figure 20: Solaris residential building in Zurich; facade made of PV modules that generate electricity



Figure 21: Printed PV modules on the facade of the "Energiehaus" in Lucerne generate electricity



Figure 22: Apartment building with proactive energy design in Zurich. A project by the Stiftung Umwelt Arena Schweiz foundation in collaboration with René Schmid Architects



The envelope of the Pierre Arnaud Foundation building in the francophone region of Switzerland is an example of a near-perfect solution that combines several distinct functions. The solar cell facade generates electricity and protects the works of art within against harmful UV radiation, and it is also capable of producing LED projections that are reflected in the adjacent lake surface at night.



Figure 23: Headquarters of the Pierre Arnaud Foundation at Lac Louche, Lens, Switzerland by night

The single-pitch flying roof at the Fraunberg municipal offices (see Figure 24) is a good example of PV roofing in a public space. The overhead structure between the L-shaped building tracts provides a canopy that allows the space to be used as an assembly area.

Figure 24: PV canopy in front of the Fraunberg (GER) municipal offices



One of Austria's first commercially used energy-plus building complexes can be found at the Seestadt Aspern development in Vienna. Electricity for on-site use is generated by a PV system which has been integrated into the building facade (see Figure 25) and the roof structure, including eaves with projecting solar panels. The site comprises two building complexes, Technology Centres 1 and 2.



Figure 25: PV modules integrated into the facade of Technology Centre 2 at Seestadt Aspern

Figure 26: PV modules on the facade of Technology Centre 1 at Seestadt Aspern

Figure 27: PV modules mounted on projecting eaves form a canopy on the facade of Technology Centre 1 at Seestadt Aspern



Free-standing photovoltaic systems

PV systems need not always be installed on buildings; they can also be mounted on the ground, for example in car parks, on public land, in waiting areas, and many more sites besides. There are no limits to the designer's imagination. With no pre-defined building orientation to take into account, ground-mounted PV arrays can be more freely placed and aligned. They can also perform multiple functions, such as shading or cooling in combination with power generation.

PV systems can be used as canopies for public circulation and parking areas, such as traffic lanes, carports and bicycle parks, as shown in Figure 28. Carports with integrated PV modules provide shade and generate electricity at the same time.



Figure 28: Bicycle park with glass-glass module roof



Figure 29: Double-function PV system on agricultural land, Schafflerhofstrasse



Figure 30: PV system in combination with bee-keeping

Installing PV systems on agricultural land may create a variety of synergy effects.

Many different options for placement of PV arrays have become available, and land use can continue as before when panels are mounted vertically or at a height of several metres. The PV modules can be either fixed in place or mounted on trackers that follow the sun.

When the panels are placed in a single continuous line (as in Figure 31), agricultural use of the surrounding land can continue as before. The benefits are manifold: the solar panels shade the nearby ground, protecting the topsoil and crops against direct solar irradiation (harmful UV radiation). Less water is needed, and the soil is protected against drying out.

PV systems may also be used as fencing, both on agricultural land (enclosures for farm animals) and in private gardens.



Figure 31: PV system on agricultural land, Schafflerhofstrasse



Figure 32: PV modules used as fencing

Community PV systems

When several parties join forces to run a community PV system, they can move from being exclusively buyers of electricity to being so-called "prosumers", using the self-generated electricity to achieve a degree of self-sufficiency. Building owners and tenants in residential buildings as well as operators of office blocks and shopping centres stand to benefit from a communally run PV system, making full use of the roof area available in each case.

Participating in a community PV system

Every resident who wants to draw on the solar power generated by a community PV system has to buy a share in the system. At least two or more parties have to participate. Before building the system, the parties have to make a solar power distribution agreement (with fixed or dynamic allocation).

The community PV system is installed alongside the power supply from the public grid. As before, the parties can freely choose the utility from which they want to buy grid-supplied electricity. All parties in the building are free to share in the community solar power. The parties have to appoint a system manager who acts as liaison with the grid operator and power utilities.

There are several operating models for community PV systems. The list below presents the main options, which may be modified as required in practice.

Model 1: PV system as infrastructure and “free-of-charge power”

The property owner invests in a PV system and supplies the power to the residents (similar to a communal bicycle storage or laundry room).

Model 2: Installation and utilisation by a residents’ association

Residents/property co-owners invest in a PV system and agree on its operation and the allocation of the power output (e.g. through a residents’ association established for this purpose).

Model 3: An external company installs the PV system and leases usage rights to the residents

An external company makes the initial investment and operates the PV system; the residents lease the right to a share of the power output.

Model 4: An energy utility builds and operates a PV system as single power supplier

The PV system is built and run by an energy utility that supplies on- and off-grid power to the residents.

Models 3 and 4 are a type of facility contracting.

Further information on community PV systems and standard contract forms are available (in German) on the community PV systems platform www.pv-gemeinschaft.at.

Outlook: Energy communities

Taking community PV systems (multi-party power generation systems) a step further, the future will see the establishment of energy communities, specifically renewable energy communities and citizens’ energy communities. As the relevant EU directives (Renewable Energy Directive and Internal Market in Electricity Directive) are translated into member states’ national legislation, they will promote the establishment of energy communities that can act jointly across property boundaries and regionally, over a certain distance, to

- generate
 - use
 - store
 - consume and
 - trade electricity,
- and such energy communities may also own and operate grids of their own.

Energy communities will facilitate the local consumption of regionally generated power from renewable resources. Optimising each PV system for self-consumption will be less of a concern as soon as the electricity from a local system can be used in a community that includes more than one building. This will ensure that existing potentials are most efficiently harvested. With less power needed from the grid, the cost of grid tariffs will be reduced. The renewable power systems can thus be run economically while making the most efficient use of available surfaces.



Figure 33: Schematic diagram of an energy community

Costs of PV systems

The prices of photovoltaic systems have dropped significantly over the last few years. The cost of installing a new system has come down by 50% since 2011. Specific costs are lower for bigger systems than for smaller ones. The payback period of a PV system is shorter if more of the solar power generated is used on site, as this means that the PV system owner has to buy less grid power from a utility and will therefore pay less in tariffs and taxes. The cost of a ready-to-operate PV system is currently €1,880 /kilowatt-peak, or €1,520/kilowatt-peak for larger systems. Building-integrated PV systems, which are custom-designed for each project, entail higher costs. The costs of PV systems also vary depending on the products built into the system and the performance they offer.

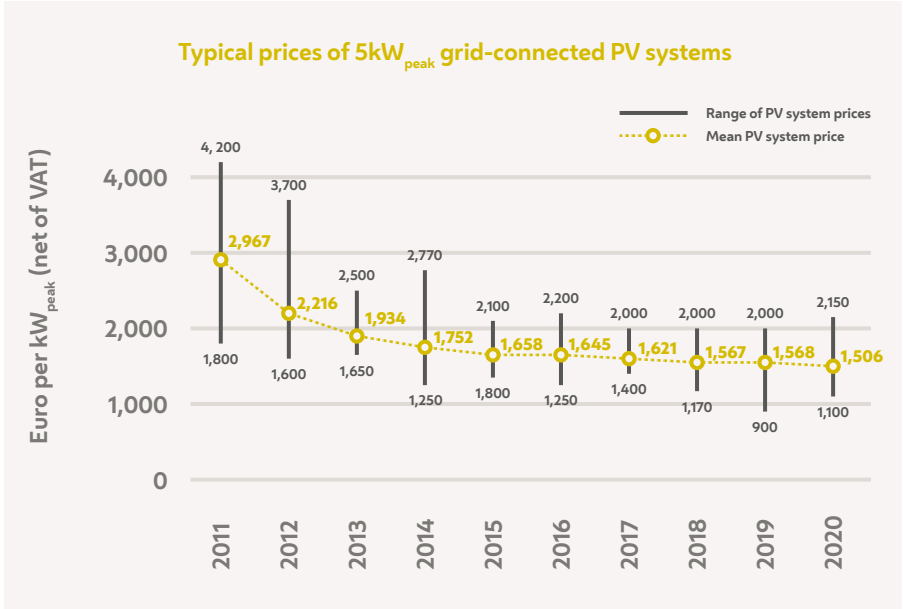


Figure 34: Prices of 5kW_{peak} grid-connected PV systems (2011–2020)

Potential of photovoltaics

The electricity produced by PV systems can be used for a variety of purposes. It can power electrical fixtures and appliances in the building, but may also be used for all types of e-mobility, as well as for hot water and heating systems. Any surpluses not needed at the moment can be stored in a battery pack.

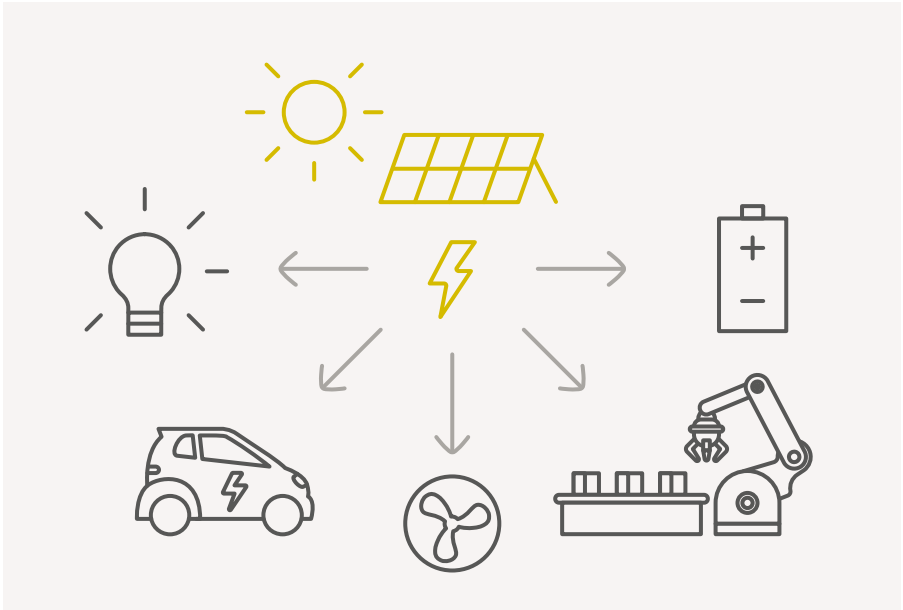


Figure 35: Self-produced electricity from a rooftop PV system can be used for a variety of purposes

If a photovoltaic system is connected to the public grid, any surplus electricity can be fed into the grid. The PV system operator receives payments for this power in the form of feed-in tariffs. As feed-in tariffs are usually lower than the price of electricity from the grid, it makes economic sense to use as much of your own solar power as possible. To be able to feed electricity into the grid, the PV system operator has to conclude a contract with an energy utility that will buy the solar power.

Stand-alone PV systems are not connected to the public grid and produce solar power exclusively for on-site use. They are not usually found in cities, but are deployed in remote locations, such as mountain shelters.

Output of PV systems

PV systems in Austria generate 900 to 1,100 kilowatt hours (kWh) per kilowatt-peak per year. A surface area of about 7 m² is required per kilowatt-peak.

The annual power consumption of an average four-person household is about 4,000 kWh. So a photovoltaic system with four kilowatt-peak output produces roughly the amount of solar power in a year which the household needs over the same period. The size of this PV system would be 28 m². About 30% of the solar power could be used directly in the building. The rest could be stored in a battery pack for later use or fed into the grid. As electricity is increasingly used for heating (heat pumps, heating rods, electric water heating), cooling and transport, overall power consumption is bound to rise despite more energy-efficient appliances. New buildings in particular are designed to require very little energy for heating. This can be covered by a heat pump and a heating rod for water heating. The power to operate the equipment can be generated by a PV system.

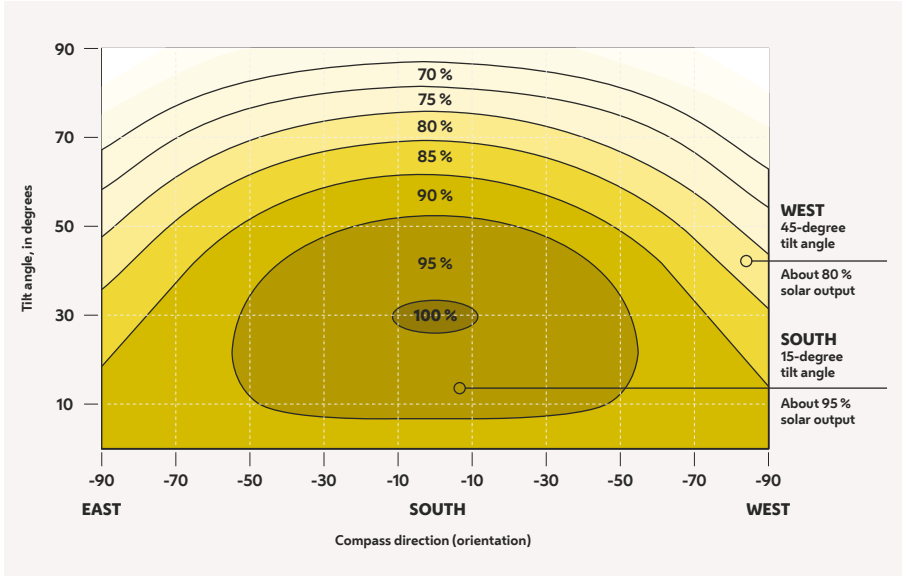


Figure 36: The influence of orientation and tilt angle on the annual solar power output

Orientation of a PV system

A PV system will produce its best performance when it is orientated towards the south, with a tilt angle of about 30–40 degrees. Deliberately choosing east or west instead of a southerly orientation may make sense in cases where the need for electricity is highest in the morning and afternoon. East- or west-orientated systems may still reach about 80–85% of the maximum possible output. To ensure optimum performance it is much more important to prevent any shading of the modules by other buildings or trees, or soiling of the surface of the array.

Energy payback period

The energy payback period is the time for which a PV system has to operate until its cumulative power output over time equals the energy expended in making and setting up the system. Typical energy payback periods in Vienna are 2 to 4 years for systems that use crystalline PV modules and 1 to 2 years for systems based on thin-film modules.

Service life

Photovoltaic systems have a service life of over 25 years. The only exception are inverters, which can be expected to function for about 10 to 15 years. The systems have to be properly designed, correctly mounted and serviced at regular intervals to achieve the best possible operating results.

2.2 Solar thermal systems

Solar thermal systems transform solar radiation into heat, which is then used to supply hot water or support room heating systems. The basic elements of a solar thermal system are the solar collectors, pump, heat exchanger, and buffer storage tank or boiler.

How do solar thermal systems work?

The energy contained in the sun's rays is collected and transformed into heat by the solar collectors. The central component of a solar collector is the solar absorber, which contains a heat transfer liquid. This liquid, usually a mix of water and an antifreeze fluid, absorbs the heat and transports it to the heat exchanger. In the heat exchanger, the heat energy is transferred to the buffer storage tank. The cooled-down liquid is then pumped back into the collector, where the heating cycle starts again.

Components of a solar thermal system

The components that are built into a solar collector vary according to collector type (see the section on "Types of solar collectors" below). The following paragraphs describe the components of the most widely used glazed flat-plate collector (97% of collectors installed in Austria were glazed flat-plate collectors in 2018), the heat storage unit and the heat exchanger.

Structure of a solar collector

ABSORBER

The central component of a solar collector is the absorber. This is a metal sheet which catches the solar energy. It is usually made of copper or aluminium, with a dark coating. The absorber transfers the heat to a transfer liquid in copper or aluminium pipes underneath the absorber, which are connected to the storage unit.

THERMAL INSULATION

To minimise solar energy losses, the collector is insulated with special solar glass on the front; the rear insulation typically consists of mineral wool. Collectors are usually contained in aluminium frameworks.

HEAT STORAGE UNIT AND HEAT EXCHANGER

A so-called buffer storage tank is used in most cases to store the water heated by the sun for days with no sunshine. Packed into at least 10 cm of insulating material, the tank can conserve the collected heat for a few days. Storing heat through the winter months requires a much larger seasonal storage tank with about 50 cm of insulation. The heat exchanger, which transfers heat from the sun-warmed water cycle to the building's hot water system, is built into or, more rarely, onto the heat storage unit.

Types of solar collectors

UNGLAZED FLAT-PLATE COLLECTORS

Unglazed flat-plate collectors are the most cost-efficient option in terms of production and installation. They generate about 300 kWh/m² energy per year and are suitable for use in low-temperature systems. Ideal applications include water heating for swimming pools and pre-heating of water in building supply systems. They consist of a bundle of plastic pipes or an absorber plate with a hydraulic system plus insulation underneath.

GLAZED FLAT-PLATE COLLECTORS

The price of glazed flat-plate collectors is about double that of unglazed flat-plate collectors. The annual energy yield is also higher, at about 400–600 kWh/m². Glazed flat-plate collectors are the most widely used type in the European Union. They are deployed mainly for water heating and as an auxiliary heating technology. Glazed flat-plate collectors consist of an absorber, a hydraulic system and insulation. The glass cover provides additional insulation between the absorber and the ambient air.

EVACUATED TUBE COLLECTORS

The price per square metre of evacuated tube collectors is about triple that of unglazed flat-plate collectors. The annual energy output is 450–650 kWh/m². Evacuated tube collectors are suitable for very high working temperatures, but they can also be used to heat water and as auxiliary room heating systems. The absorber and the hydraulic system are contained in evacuated glass tubes. The vacuum has a very strong insulating effect. Evacuated tube collectors may also be integrated into a building's architectural design. The benefit of such solutions is their additional functionality, for example as parapets or shading elements.

AIR COLLECTORS

Air collectors differ from the collector types described above in that the fluid that is heated as it passes through the system is not water, but air. As air does not heat up as readily as water, air collectors are not as well suited to running room heating or hot water supply systems. Their main application is drying of agricultural products. The warm air can be used to dry fruits, herbs, hay, wood chips and many other goods.

Options for installing a solar thermal system

The collectors for a solar thermal system are usually mounted on the building roof. If the roof is pitched, the collectors may be either mounted on top of it, with a gap of 5–15 cm, or they may be integrated into the roof, replacing part of the actual roofing. The latter, more complex option entails higher costs, but is more aesthetically pleasing in most cases. If the roof is flat, the collectors have to be mounted on racks. This allows optimised pitch and orientation of the collectors, though care must be taken to avoid mutual shading. The same applies to collectors mounted on the ground and used for district heating or industrial purposes.

When the system is mounted on a building, the collectors may also be integrated vertically into the facade, with or without rear ventilation.

Costs and benefits of a solar thermal system

Installing a solar thermal system for water and/or space heating requires expert analysis and planning. The energy yield of the system varies over the winter and summer seasons. The system has to be designed for optimised utilisation of solar energy on both winter and summer days. A good compromise has to be found between the capital investment needed to install the solar thermal system and the savings to be had in terms of conventional energy costs.

On average, the energy needed for water heating in a three-person household is about 3,400 kWh per year. An average solar thermal system with a size of 6 m² and 400 kWh/m² annual energy output produces 2,400 kWh per year. This will be enough to supply about 70% of the average amount of hot water needed per year by a family of three.

The total cost of a typical solar thermal system for water heating (6 m² collector surface, 300-litre storage tank) comprises about €3,800 for the system, €500 for additional materials needed and €1,500 for the installation. If the system is to be used for water and space heating (15 m² collector surface, 1,000-litre storage tank), the cost is about €8,100 for the system, €800 for additional material and €2,700 for the installation. The exact numbers vary from system to system.

Other applications

PROCESS HEAT

Large solar thermal systems are capable of producing a significant part of the heat needed in industrial processes. They are more or less universally deployable in the low- and medium-temperature range, and many companies are already using them to save money and reduce CO₂ emissions.

DISTRICT HEATING

Large solar thermal systems can make an important contribution to the heat supply of cities and smaller communities. With production costs of 4 to 6 eurocents per kWh, solar district heating is generally a more cost-effective option than oil or gas.

Output of solar thermal systems

The combined surface area of all solar thermal collectors operating in Austria at year-end 2019 was 5 million m², corresponding to a rated output of about 3.5 GWth. The useful heat output of the systems amounted to 2,081 GWh. This translates into a reduction of CO₂ emissions by 353,713 tonnes per year.

To harvest as much solar energy as possible, collectors are precisely orientated towards the south. However, deviations of up to 45 degrees towards south-east or south-west are possible without major heat losses. Orientation is also a determining factor for a system's output and the required collector size. The farther a collector faces away from due south, the bigger it has to be to yield an equal amount of heat.

Most solar thermal systems are mounted at an angle of 30 to 45 degrees. However, ideal pitch depends on the intended use and the place where the system is installed. Collectors that are used to heat swimming pools are mounted at 0 to 30 degrees, those for water heating at 25 to 55 degrees, for auxiliary room heating at 50 to 70 degrees (suitable for catching the winter sun), and facade-mounted collectors are mounted at an angle of 90 degrees to the ground. Design and installation by an experienced contractor is recommended to ensure maximum yields, with the goal of harvesting energy for direct use in periods of strong irradiation and storing surpluses for periods of less solar heat.

Energy payback period

Solar thermal systems have a very short energy payback period. It takes them about a year to produce an amount of energy equal to the energy input that went into the production of the system.

Service life

According to the Solar Heating and Cooling Programme (SHC) of the International Energy Agency (IEA), solar thermal systems have a statistical service life of 25 years. In practice, however, the systems tend to work for much longer.



Figure 37: Roof-integrated collectors on a single-family home



Figure 38: Rack-mounted rooftop collectors

2.3 Hybrid collectors

Hybrid collectors, or photovoltaic-thermal (PVT) collectors, combine solar thermal and photovoltaic technology to cogenerate both electricity and heat. A PVT collector is basically a PV module with piping fixed to its rear side, in which transfer fluid carries heat to a buffer storage tank. In purely PV systems, only a part of the solar radiation intercepted by the PV modules is transformed into electrical power. A large part becomes heat, which remains unused.

Hybrid (PVT) collectors harvest this heat and carry it to a buffer storage tank. As a result, the PV cells do not heat up so much, and output increases. PV modules work most efficiently at about 25 degrees Celsius; when temperatures rise above this level, efficiency drops at a rate of about 0.5% for each one-degree increment. In contrast, PVT collectors create a synergy effect that enhances efficiency per size unit by cogenerating electricity and heat from the same surface area. The diagram below shows the systems side by side for comparison. Given the similarity in design, the life expectancy of PVT collectors is about the same as for PV modules and solar collectors.

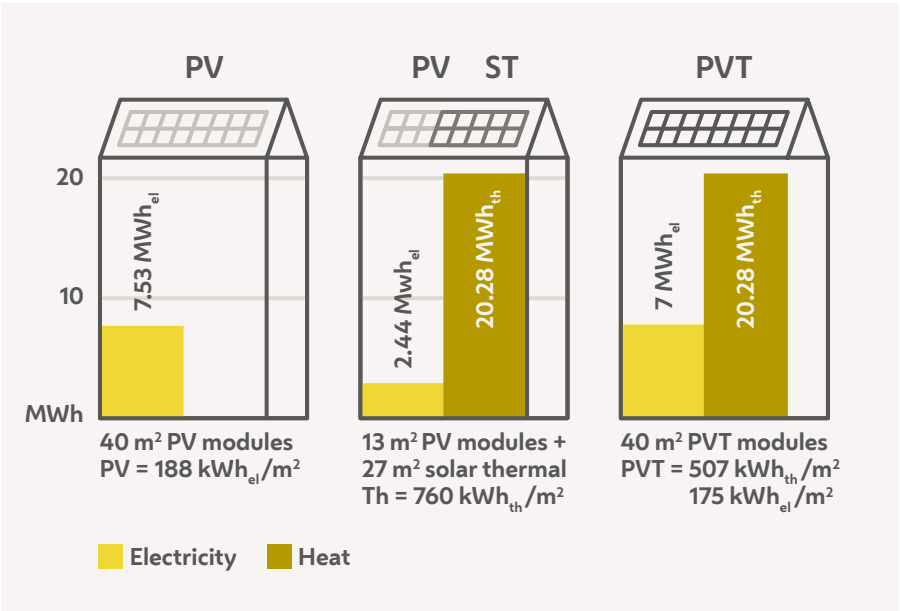


Figure 39: Annual energy output of PV, solar thermal and hybrid collectors

2.4 Greening of buildings, a contribution to green infrastructure

The deteriorating microclimate of our cities is something we are all experiencing first-hand. More and more frequent heatwaves in the last few years are causing increased mortality among vulnerable groups, especially elderly people with restricted mobility and children. Austria has reached a point where deaths caused by excessive heat are believed to outnumber traffic-related deaths. These developments have been caused, among other things, by the spread of sealed, heat-conserving surfaces in combination with insufficient air movement. The difference in temperature levels between urban areas with their growing proportion of sealed surfaces and the surrounding region has been described in the City of Vienna's Urban Heat Island Strategy. Strategic greening with vegetation has been recognised as an effective means of climate change adaptation. In densely built-up urban areas, vegetation on the exterior surfaces of buildings is an important contribution to the city's green infrastructure. It adds to the visual appeal of the cityscape and is an effective way of using hitherto unused surfaces. The following section discusses green roofs and vertical greening systems.

What is the impact of greening on the immediate environment?

The deployment of green infrastructure in the city has an important role to play in many aspects of proactive urban development policies, both with respect to new urban developments and the existing built environment.²

GREEN OUTDOOR AIR-CONDITIONING

In contrast to sealed surfaces – asphalt, concrete, glass and mineral surfaces, among others – vegetation-covered surfaces provide an active cooling infrastructure. While the temperature on sealed surfaces may climb to 70 degrees Celsius and even higher on summer days, the surfaces of plant leaves hardly heat up to more than ambient air temperature. Vegetation also produces shaded areas. Water evaporates from the plant leaves and planting medium, cooling the surrounding air. The cooler air sinks to the ground, where it heats up again. As the heated air rises, the cycle starts over again. The “latent” heat in this cycle is not perceptible, but is transformed to perceptible heat in the condensation process. The cooling effect of evaporation from plants continues through the night as well. This has the effect of keeping the ambient air around a building cooler.

RAINWATER RETENTION

Deployed for rainwater management purposes, even sparsely vegetated green roofs are capable of holding back up to 90% (annual mean) of the total amount of precipitation.

² Pfoser N. et al. (2013): *Gebäude, Begrünung und Energie: Potenziale und Wechselwirkung. Interdisziplinärer Leitfaden als Planungshilfe zur Nutzung energetischer, klimatischer und gestalterischer Potenziale sowie zu den Wechselwirkungen von Gebäude, Bauwerksbegrünung und Gebäudeumfeld.*

With special designs and intensive roof greening, even 100% rainwater retention is possible, including the efficient retention of stormwater after heavy rainfalls. The rainwater is taken up by the plants, and either stored or given off through evaporation. Because green roofs prevent immediate stormwater run-off and release the water over time, they are much more efficient than conventional roofs in reducing stormwater flow to the sewer system. Moreover, greywater may become usable thanks to innovative green roof and facade systems. Green roofs could, for example, function as water filters, and the filtered water could be used to flush toilets inside the building.

WELL-BEING AND BIODIVERSITY

Greening buildings improves thermal comfort, helps to purify ambient air and mitigates noise, thus promoting human well-being and contributing to a healthier environment and enhancing quality of life. This leads to greater productivity and contentment, increases the recreational value of the urban environment and even reduces time spent on sick leave.

Another major role of vegetation on the exterior surfaces of buildings is that it helps to preserve and improve biodiversity. Green roofs and facades are valuable stepping-stone biotopes at a safe distance from the pesticides and herbicides that are used in agriculture. When implemented as part of an urban ecological strategy, they can provide diverse habitats for endangered species such as wild bees, butterflies and birds.

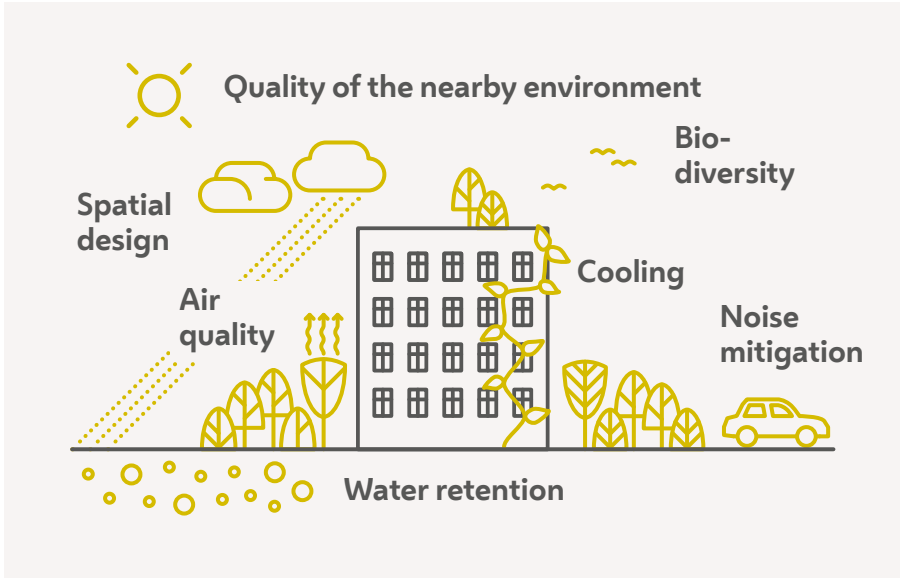
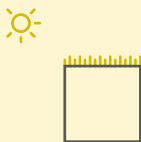


Figure 40: Benefits of greening buildings at the level of the city

Needs	 Temperature	 Light	 Venti-lation	
Action taken	 Adiabatic cooling	 Heat storage, buffer effect	 Outside shading	 Air preconditioning for natural/controlled ventilation
Effects of exterior building greening	+ Shading and evaporation by plants prevents building surfaces/interior spaces/absorbers from heating up	+ Reduction of building shell heat losses + Reduced wind pressure	+ Shading protects against glare + Functions of technical systems taken over by plants + Translucent, depending on selected plants	+ Air purification + Air humidification + Cooling of air inflow in summer
Savings Benefits	Cooling cost savings	Reduction of heat transfer	Reduced primary energy needs, savings on maintenance of technical systems	Auxiliary system for/ replacement of air-conditioning systems

Needs	 Electrical energy	 Water	 Materials lifecycle assessment
Action taken	 Green energy	 Greywater purification and use	 Carbon footprint
Effects of exterior building greening	+ Increase in efficiency of technical systems + Support for active and passive energy harvesting	+ Tap water savings + Cooling + Pollutant filter + Design feature	+ Carbon sequestration + O ₂ production + Reduction of energy needs + Particle filter + Protection of building components, prolongation of their service life
Savings Benefits	Efficiency increase of PV systems, savings on energy for cooling, harvesting of biomass	Savings depend on the system deployed	Savings on roofing/facade materials, longer service life

Figure 41: Benefits of greening at the level of the building

BENEFITS AT THE LEVEL OF THE BUILDING

The greening of buildings creates benefits not only for the city and society as a whole, but also at the level of the individual building: vegetation has a positive effect on temperatures on the building envelope and in the nearby environment. Synergies can be used in terms of natural ventilation, energy production, efficient water use, shading and the durability of materials. More specifically, a greened outer shell prolongs the life of the building because the vegetation acts as a temperature buffer, protecting materials physically and mitigating the effects of extreme weather conditions.

The plants protect the building against solar irradiation, hail and rain. At the same time, the vegetation enhances the value of the property. Plants store CO₂, produce oxygen, filter fine particle dust from the air and reduce the building's energy requirement, improving lifecycle assessments and carbon footprint.

Adiabatic cooling (shading and evaporation chill prevent the building from heating up) and high-quality insulation help to reduce the operating cost of heating and cooling systems. As regards heat insulation in winter, measurements on an ivy-covered wall have shown a temperature difference of 3°C between the outer leaves and the wall surface.³ Using plants effectively as a natural shading element will reduce the amount of primary energy needed by a building. Well-planned and properly tended vegetation also incurs lower maintenance costs than technical solutions for shading on the outside of a building. Deciduous plants shed their leaves in winter so that sunlight can pass through. Because the air around a greened building is preconditioned by the improved ambient microclimate, natural ventilation becomes possible again, minimising the need for air-conditioning.

Considering the growing amounts of energy required to operate buildings and the challenges ahead as a result of climate change, which will further drive up energy consumption, a number of measures will have to be taken, ranked by priority as follows. First of all, educational efforts are needed to bring about changes in user behaviour. At the same time, passive strategies – including thermal insulation and shading of buildings – have to be pursued to reduce energy consumption, and building environments have to be actively cooled by vegetation to allow natural ventilation. Additionally, active strategies have to be implemented as needed. These include the decentralised generation of energy from renewable resources, helped by greenery on and around buildings. Suitable combinations of photovoltaics and solar thermal energy will increase the overall efficiency of solar technology and contribute meaningfully to preserving and enhancing biodiversity through the creation of habitats.

³Bartfelder, F. and Köhler, M. *Experimentelle Untersuchungen zur Funktion von Fassadenbegrünungen*, Berlin: PhD thesis, Technische Universität Berlin, 1987

Green roofs

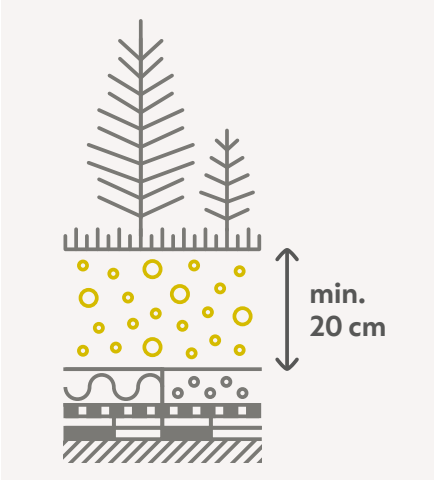
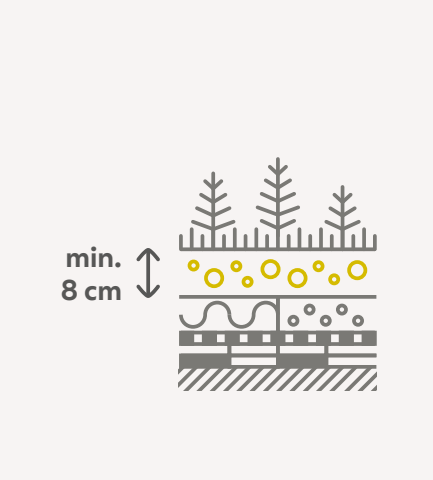
Which types of green roof systems are there?

The main difference in green roof types is between extensive and intensive (deep-soil) greening. Both types are described in detail in the City of Vienna's green roof guidance *Leitfaden für Dachbegrünung* (2020) and the relevant Austrian Standard ÖNORM L 1131 (2010) on green roofs. The documents specify regulatory requirements with respect to green roofs, including certification of the different layers and overall structure. Green roofs differ in thickness, weight, functionality and plant communities. They can be installed on flat or pitched roofs and may have a single- or multi-layer structure. Depending on the roof's intended functions, a green roof system may be installed on the whole or part of the roof surface and may also be designed as a hybrid system, i.e. a combination of different types in terms of thickness and habitat structure. A connection to the water supply system is required for an intensive green roof and recommended for an extensive system. In addition to primary horticultural work – planting and initial care until plants are established – a green roof also requires regular care and maintenance.

The minimum thickness of a lightweight, extensive green roof is 8 cm. Low-growing plant species, including succulents, mosses, herbs and grasses, dominate the picture. Extensive green roofs require little care. As this type of green roof is not usually used by humans, it provides a valuable habitat for plants and animals. Its weight is 80 to 150 kg/m². An extensive green roof can easily be combined with a solar installation (see Chapter 3).

Figure 42: Intensive green roof – structure

Figure 43: Extensive green roof – structure



Intensive green roofs are at least 20 cm thick and heavier in weight. Depending on the thickness of the substrate, a wide variety of plants can be grown, including trees, which need a planting substrate of at least 80 cm and have to be protected against strong winds. An intensive green roof may fulfil all the functions of a garden, or even a park, provided it receives sufficient care and is supplied with water as needed. It can serve as a recreational space or a communal gardening area; people may use it for sports or vegetable growing. The weight load of an intensive green roof is 300 to 1,000 kg/m². It may be combined with a solar energy system mounted on a pergola (see Chapter 3).



Figure 44: Extensive green roof on Dresdner Strasse



Figure 45: Intensive green roof on Favoritenstrasse

Components of a green roof

VEGETATION

Different plant communities, from ground-covering succulents to shrubs and trees, may exist on a green roof, depending on substrate depth, available root space and care of the green roof. Initial greening may be done with seeds, cuttings, potted or baled plants, or even pre-cultivated sod mats and turf.

PLANTING LAYER/MEDIUM

The planting medium provides space for the plant roots and stores water and nutrients. Planting mediums that meet the relevant standards consist of mineral open-pore aggregates, such as hard-fired clay, expanded clay or shale, or recycled brick chip-pings, which are mixed with organic materials (for example, quality-certified compost) in varying proportions. The share of organic material is low in extensive green roofs and high in intensive systems. Austrian Standard ÖNORM L 1131 contains a detailed description of the planting medium requirements (storage stability, pore air capacity, water retention capacity, drainage effect, proportion of fines, etc.).

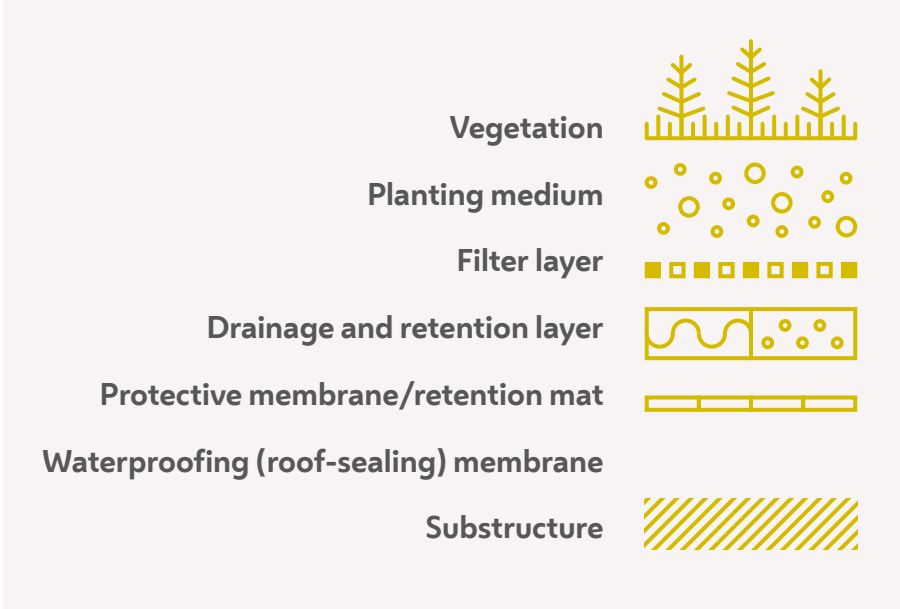


Figure 46: Typical green roof structure

FILTER LAYER

The filter layer separates the planting layer from the drainage and retention layer. This prevents the drainage layer from becoming clogged with fine particles which could otherwise be washed down from the planting layer. With the filter layer in place, the fine particles, which are also important for the plant roots, are retained in the planting medium. The filter layer is made of a geotextile that is water-permeable and can be penetrated by plant roots. It has to keep its permeability for decades.

DRAINAGE AND RETENTION LAYER

The drainage and retention layer is designed to control stormwater runoff after heavy rainfalls and acts as a reservoir for rainwater. It consists either of mineral (recycled) materials, prefabricated synthetic filling materials or material mixes with or without water storage characteristics.

PROTECTIVE MEMBRANE

The protective membrane is a geotextile as specified in Austrian Standard ÖNORM L 1131. It protects the waterproofing membrane from damage during construction and after completion of the project.

ROOT BARRIER

An additional root barrier is necessary if the waterproofing membrane itself does not protect against root penetration. Standard root barriers consist of mechanically arranged membrane layers.

WATERPROOFING MEMBRANE

The waterproofing (roof-sealing) membrane has to comply with the standard requirements and protect against root penetration. It is made of a bituminous membrane plus a root barrier or consists of several layers of sealing membranes. The City of Vienna's rules for subsidies granted for green roof construction specify that the waterproofing membrane has to be asbestos- and PVC-free. Waterproofing membranes containing substances that inhibit root growth or are biocides as defined in the EU Biocidal Products Regulation (No. 528/2012) are not allowed in green roof systems and materials. The root-barrier functionality of products has to be assessed pursuant to the relevant guideline of the *Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau* (FFL), a German industry and research association in the field. A list of roof-barrier membranes is published and annually updated by the Austrian industry association *Verband für Bauwerksbegrünung*.

Roof designs that are suitable for greening

The following roof types are suitable for greening (regardless of roof pitch):

Cold deck roof	ventilated double-skin design with load-bearing upper layer, single-skin design without thermal insulation
Warm deck roof	single-skin design with thermal insulation below the waterproofing layer
Inverted roof	single-skin design with insulation above waterproofing*
Plus roof	a warm deck roof with additional inverted insulation on top of the waterproofing membrane (to be treated in the same way as an inverted roof)

In principle, roofs are capable of being greened regardless of their pitch. Standard-compliant greening is possible on roofs with pitches of between 1.8% (1-degree pitch) and 58% (30-degree pitch). Roofs with a pitch of 9% or more require slippage or thrust protection to prevent the root barrier and waterproofing layer from slipping, those with 26% or more have to be protected against slippage of the entire construction (see Chapter 5.5, Planning aids and tools from the various specialist fields). Green roofs outside this pitch range are special engineering projects with highly stringent demands in terms of professional planning and construction.⁴

* Please note: Water storage and vapour permeability have to be taken into account in the build-up of an inverted roof, which needs to be adjusted accordingly. Inverted roofs are always constructed as multi-layer systems.

⁴ Austrian Standard ÖNORM L 1131, "Garden design and landscaping – green building roofs – design, installation and maintenance requirements"



Figure 47: Biodiversity roof, Sargfabrik residential development

⁵<https://www.wien.gv.at/recht/landesrecht-wien/rechtsvorschriften/html/b0200000.htm>

GREEN ROOF OPTIONS

FLAT ROOFS ON NEW BUILDINGS

Multi-storey residential buildings and major industrial complexes offer highly scalable options for green roofs. In principle, any flat roof surface can be used to establish a green roof, with a wide variety of potential uses and benefits. The land use and development plans of the City of Vienna can mandate greening of flat roofs. See relevant content of the development plans (*Bebauungspläne*) § 5 (4) k.⁵

FLAT ROOFS ON EXISTING BUILDINGS

When a flat roof is in need of renovation, the possibility of installing a green roof should always be considered. Existing gravel roofs in particular harbour great potential, as they are usually designed with sufficient load-bearing capacity for an extensive green roof. In some specific areas of Vienna, this is prescribed by regulatory mandate.

RETENTION ROOF – A SPECIAL TYPE OF FLAT ROOF

Retention roofs are capable of holding large quantities of stormwater runoff from heavy rainfall events, effectively reducing the workload of sewer systems. State-of-the-art retention roof technologies include regulator systems for controlled water accumulation. We expect the number of completely flat (zero-degree) roofs to grow in future as a result of the improvements made in stormwater management and because of the favourable microclimatic effects to be had.

PITCHED ROOFS

Extensive greening is possible on pitched roofs (standard-compliant solutions up to 30 degrees), with slippage/thrust protection required for slopes of 9 or more degrees.

BIODIVERSITY ROOFS

Extensive or semi-intensive green roofs may be designed specifically to create near-natural spaces. Dedicated to biodiversity in terms of habitats and species, these roof system variants contain a broad variety of structures (planting media, deadwood, rocks, nest boxes, temporary water surfaces, etc.). Existing green roofs can be modified to create a biodiversity roof.

Greening of facades

Facades that are suitable for greening

The requirements which facades have to meet depend on the desired outcome. Facade type is a constraint on vertical greening projects and determines the choice of greening system in both new-build and existing buildings.

Among facades suitable for greening, these are the three types most often found in Austria:

- 1. Composite thermal wall insulation systems
- 2. Solid brick or concrete walls
- 3. Rear-ventilated cladding

In existing structures, suitability for greening has to be determined by an expert on a case-by-case basis. In addition to load-bearing aspects, the surface characteristics have to be considered, as some surfaces (e.g. sandy/crumbling or highly reflective surfaces) are unsuitable or present major difficulties for greening.

Which types of vertical greening systems are there?

The different technical approaches to facade greening are regulated by guidance published by the City of Vienna, the *Leitfaden der Stadt Wien für Fassadenbegrünung* (2020), and Austrian Standard ÖNORM L 1136 (2021), including certification of vertical greening systems. Green facades differ in terms of system build-up, weight, functionality and plant communities. The main types are ground-bound systems with climbing plants, mixed systems based on containers, and wall-bound vertical greening systems. The vegetation consists either of climbing plants or, in the case of living walls, grasses, herbs and herbaceous perennials. In addition to primary horticultural work – planting and initial care until plants are established – a green facade also requires regular care and maintenance work.

Components of vertical greening systems

Different system components are needed, depending on the vertical greening system that has been selected based on suitability for a specific facade and greening objectives. They comprise plants, growing media, plant support systems, supply technologies, etc.

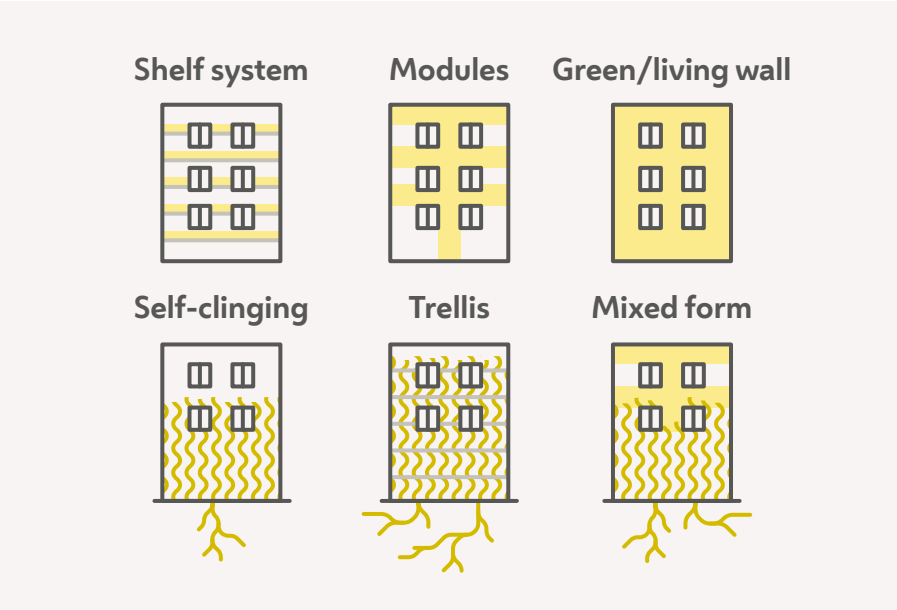


Figure 48: Different forms of vertical greening

Ground-bound vegetation

If the ground next to the wall offers enough space for plant roots, ground-bound vegetation is usually the most cost-effective facade greening solution. The ground should thus be examined and soil conditioning carried out where needed. The design should ensure that plants receive enough water, either by supplying rainwater to them or via an irrigation system. The root space size requirements are determined by the greening objective, the plant species and the envisaged height of the vegetation cover. A minimum depth of 60 cm and a minimum volume of 1 m³ per plant are advisable.

Climbers can either be self-clinging, such as Virginia creeper, or require a support structure.

Different support structures are in use, depending on the growth patterns of the plants and whether or not they have adhesive organs. There are more than 20 different species of climbers in Austria, some of which may grow to heights of up to 30 m.



Figure 49: Ground-bound facade greening, Kandlgasse

A range of different support structures are in use, such as cables, mesh or trellises. Important aspects to consider are how the system is fixed to the wall (minimising penetration), load-bearing characteristics, and that it has to match the growth pattern of the plants (twining, attaching by tendrils, etc.). This will ensure a pleasant appearance of the greened facade. Green vegetation curtains may also serve as external shading

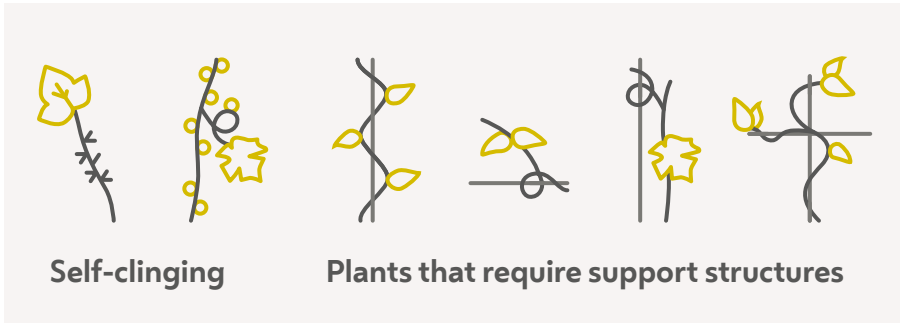


Figure 50: Different climbing strategies of climbing plants

elements. The load-bearing characteristics have to be specified taking into account the plant type (weight, climbing patterns), maintenance intervals and additional loads that have to be expected (e.g. wind, snow).

Plants in containers

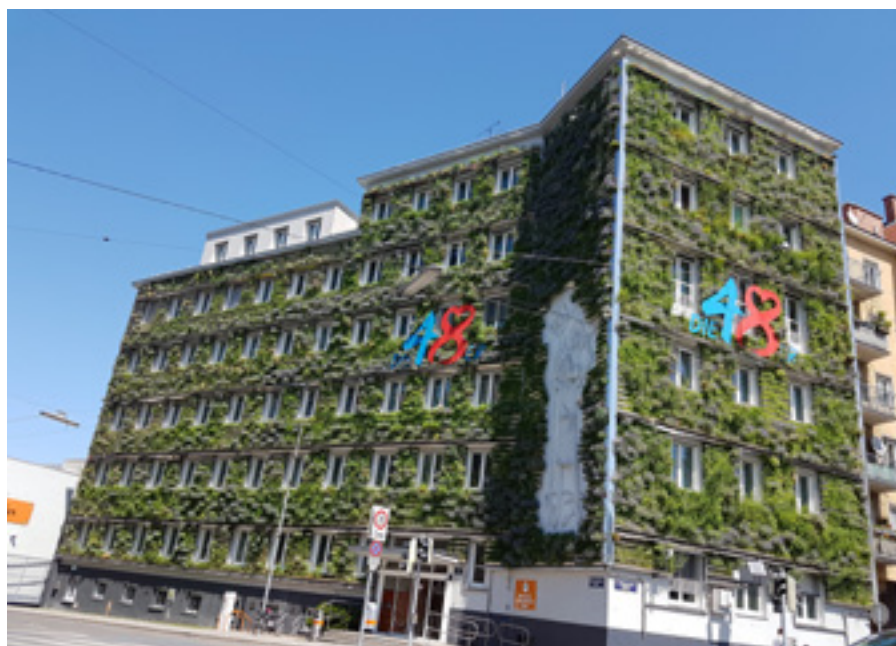
If ground root space is not available or if the selected plant species cannot be expected to grow to the desired height from the ground, root space has to be created in front of the facade. The containers used for this purpose must be made of materials suited to long-term use (e.g. fibre cement, mineral wool composite, high-strength concrete, metal, etc.) and capable of being recycled. Requirements in terms of material properties have to be taken into account. The technical specifications include frost, UV and fire resistance, stability against external mechanical forces and vandalism. Additionally, ecological criteria (such as regional production, short transport routes) should be applied.

When containers are used as planter boxes, the planting substrate has to be as durable and structurally stable as in a green roof. This is why it is typically built up in a layered structure. If water can accumulate in the container, this helps to supply water to the plants as needed and save on overall water consumption.



Figure 51: Facade greening with climbing plants in containers, Zedlitzhalle

Figure 52: Wall-bound vertical greening system, Municipal Department 48



Wall-bound vertical greening system

Structurally speaking, any wall-bound greening system, also called a green wall, living wall, or vertical garden, is a rear-ventilated mounted facade. Water-bearing levels are separated from the building. The plants receive water and nutrients as needed from automated irrigation and nutrient-supply systems. Suitable plantings range from intensive vertical gardens with flowering ornamental shrubs to flower meadows with a more extensive look. In most cases, this type of vertical greening also functions as insulation and protective cladding for the building. Its significant microclimatic effect is based on evaporation chill from the plants and the growth medium.

In systems of a certain size, the installation of sensors and self-learning control systems is recommended to ensure optimum water and nutrient supply as needed. Control systems must be housed in a frost-free utility room and accessible for maintenance work.

Where to use vertical greening

Large-scale vertical greening is potentially possible on nearly all facade types, both on new and existing buildings. An examination of relevant site conditions will reveal potential benefits, such as the replacement of technical external shading solutions or optimisation of energy efficiency, as well as constraints, e.g. fire safety requirements, in a timely manner.

If self-clinging plants are to be used on an existing facade, this first has to be examined to ensure that it is structurally intact. Separator bars can be used to prevent self-clinging plants from growing onto neighbouring buildings, roof structures or windows. Some producers of composite thermal wall insulation systems are already designing and offering systems specifically for vertical greening. Special considerations apply regarding climbers with shoots that turn away from the light (e.g. ivy). They may grow into the space behind ventilated walls or underneath windowsills, cracking open the structures. The same is true of twining plants with similar characteristics that are trained on structural supports. Particular care is necessary when existing facades have external technical shading installations which could be damaged by plants pushing underneath and eventually bursting the structure.

The orientation of the facade also plays a role in greening. Climate conditions on east- and west-facing facades are much more moderate than on north- and south-facing walls. On north-facing walls, plants have to make do with less natural sunlight. On the south side, they are exposed to hot and dry conditions and need much more water as a consequence. Suitable plant communities can be selected for all orientations and greening objectives (see Chapter 3). This has to be done in the context of professional project design. Likewise, planting and ongoing care also require professional expertise. The substructure and system components of a vertical greening project have to be adjusted to the type of greening to be implemented.

Costs of roof and facade greening

The factors determining implementation and maintenance costs are: project size, materials used, presence/absence of connections to electricity and water supply, as well as accessibility, which in turn determines the use of elevating work platforms and other equipment, industrial climbers, and integrated maintenance systems. Project planning costs are typically 5–15% of the total project realisation cost.

Table 1: Indicative price ranges for the realisation of building greening projects by professional contractors, compliant with Austrian ÖNORM standards, net of VAT (as of 2019)

PRICES OF GREEN ROOF SYSTEMS (ÖNORM L 1131 ASI 2010)

Cost of extensive roof greening (thickness 8 cm or more)	25 to 50 Euro/m²
Cost of intensive roof greening (12–30 cm or more)	50 to 100 Euro/m²
Cost of solar green roof/PV green roof system (green roof installation plus solar PV system racking, without modules)	from 65 Euro/m²
Professional care and maintenance of extensive and intensive green roofs	Depending on working conditions, 55 to 100 Euro/hour

The price ranges are indicative, based on 1,000 m² projects. Pitched green roofs require slippage protection, in line with the angle of pitch.

Care and maintenance work on extensive green roofs that is carried out according to the relevant standards is comparable to that on gravel roofs in terms of intervals and the extent of work needed. The standard differentiates between primary horticultural work – planting and initial care until plants are established – and ongoing care and maintenance. Design quality has an important influence on the extent of care required for intensive green roofs.

PRICES OF VERTICAL GREENING SYSTEMS (ÖNORM L 1131)

Cost of ground-bound facade greening* (climbers with or without support structures)	50 to 500 Euro/m²
Cost of facade greening with climbing plants in containers on the ground* (climbers with or without support structures)	250 to 800 Euro/m²
Cost of wall-bound vertical greening systems (green or living walls – herbs, grasses, herbaceous shrubs)	500 to 1,500 Euro/m²
Care and maintenance (at 2- to 5-year intervals) of ground- and wall-bound facade greening systems (depending on the selected plants, ease of access, technical equipment, e.g. sensors and control system)	10 to 50 Euro/m² per year

* Relevant cost factors in greening projects using climbing plants are: whether or not scaffolding is needed for the installation of the system; which type of system (with or without plant support structures) is used; and whether plumbing work is required/included in the contract. Design quality has an important influence on the extent of care required for vertical greenery.

Table 2: Indicative price ranges for the realisation of building greening projects by professional contractors, net of VAT (as of 2019)

2.5 Buildings and neighbourhoods for a sustainable future

Each building has to be considered in the wider context of its surrounding neighbourhood. Mutual shading, smart grid systems and microclimatic effects are factors that will influence future project plans and designs. Climate protection and adaptation to climate change are taking on ever greater importance. As we tap into local resources, we need to maximise active and passive harvesting of solar energy. This means that the placement of buildings relative to each other should be optimised to reduce the energy needed for heating in winter and cooling in summer; moreover, facades and roofs should be used to generate electrical energy (in photovoltaic systems) and heat (in solar thermal systems). As the surface area of a city is limited, available surfaces have to be utilised effectively to raise energy supply efficiency and contribute to decarbonisation while minimising the urban heat island effect.



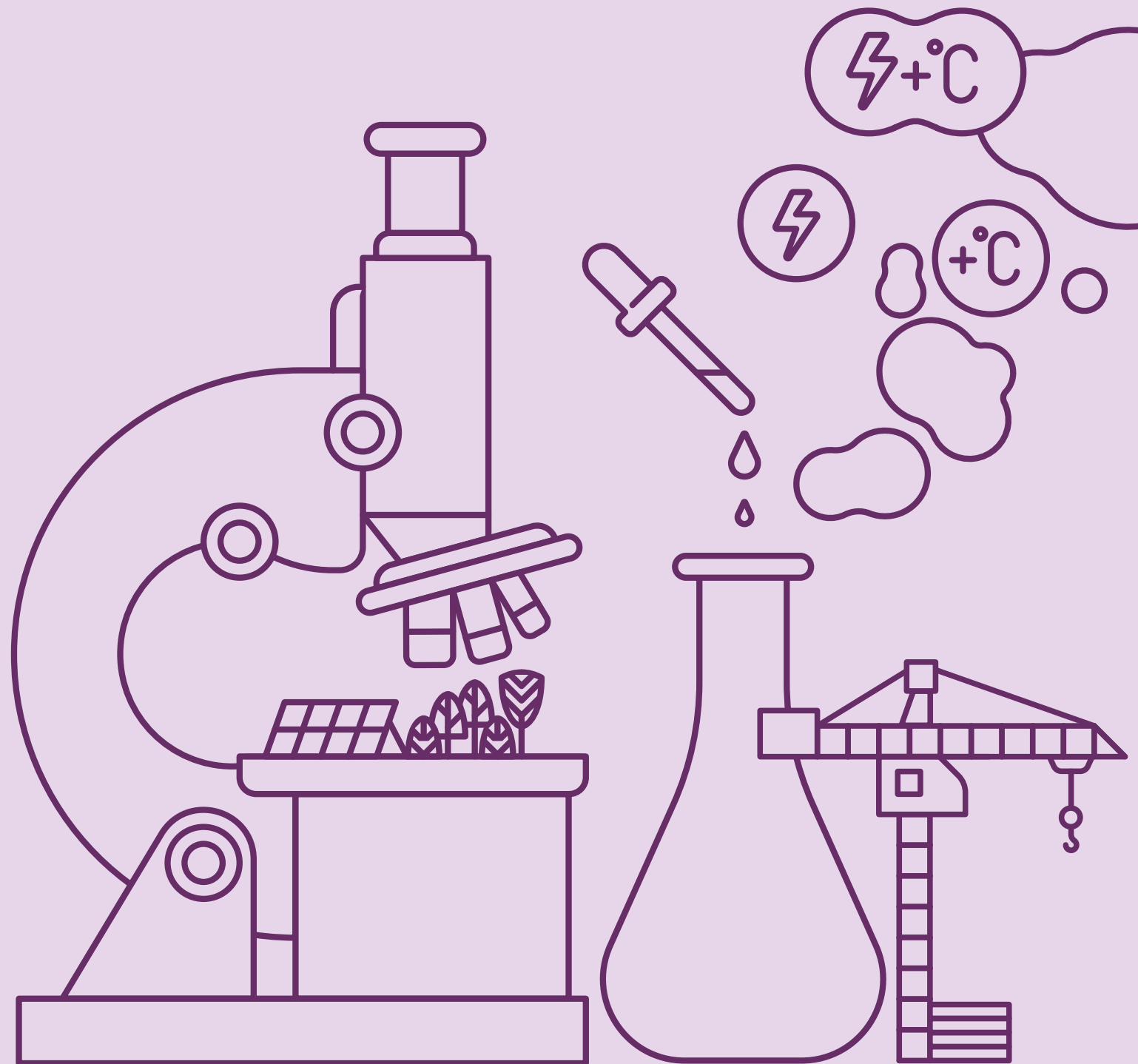
Figure 53: Research project GRÜNSTADTKLIMA

A future-proof building ...

- generates a part of the electricity and heat it needs and can supply them to other buildings as well;
- is capable of storing surplus energy and can cope with peak loads, running on locally stored energy for a certain time;
- can thus serve external energy networks (power grid or district heating networks), ensuring its own economically viable operation;
- uses multi-day market and weather forecasts for its control systems;
- is adjusted to summer/climate change conditions (temperature, greening, ventilation);
- is capable of storing or using locally generated heat and cold at the same time;
- is designed and engineered to meet realistic heating and cooling requirements (no cumulative addition of safety margins);
- reduces losses in hot water distribution;
- makes optimum use of local CO₂-free resources and waste heat;
- combines building greening and solar technology (to raise output, among other things);
- makes use of local and biodiverse seed mixes and habitat structures (to enhance biodiversity);
- incorporates new uses and operations (vegetable farming, biomass, water treatment, greywater, recirculating systems);
- deploys climbing plants for external shading, replacing technical shading systems, and/or for rear greening/cooling of PV facades; root spaces may also be housed in unused parts of the building (e.g. cellar);
- integrates building greening in the building's energy performance certificate and building information modelling (BIM);
- employs efficient control and supply systems that use sensor technology and cloud-based data storage;
- relies on robots and drones for monitoring and care of the system.
(The first robotic lawnmower for solar green roofs, which is also able to prune small shrubs, is currently being tested in Switzerland. Its integrated camera system recognises structural elements that support biodiversity, so that the robot can move around them. The robotic lawnmower is powered by renewable energy and is directly connected to the solar PV system. The first pilot project with trial runs of robots and drones in monitoring and care functions was conducted in Austria in 2019 under the *Stadt der Zukunft* (City of the Future) programme. The results indicate that further developments can be expected in this area.)

3

Combined options and usage synergies



3.1 Solar technology and green roofs/vertical greening systems

To make the shift away from fossil fuels, we need to place a greater focus on innovative solutions such as green roofs with integrated solar PV and/or solar thermal systems and facades with integrated solar energy systems, either with or without additional greenery. Expert planning, installation and maintenance are required to ensure smooth functioning of the synergy between building greening and solar technology (further information in Chapter 5). This chapter describes the various options for combining solar PV and/or solar thermal systems and green roofs/vertical greening systems that are state of the art as of 2020.

Options for combining solar technology and green roofs/vertical greening systems

These days there are multiple different approaches to combining solar technology and green roofs/vertical greening systems (see Figure 54). Besides the straightforward side-by-side arrangement, the green surfaces and solar PV modules can, of course, be installed one above the other. Here a distinction is made between configurations where the vegetation and solar modules are a short distance apart (min. 20 cm), and those where they are farther apart (over 2 m). In the latter case, the solar technology element (usually photovoltaic panels) is installed as a kind of pergola, thus providing protection against the weather and acting as a design feature in outdoor amenity spaces (e.g. roof gardens – see Figure 57). Solar modules can also be mounted vertically on the facades of buildings, or as a bi-facial vertical array on green roofs. The various combinations and factors to be considered in detail in each case are described in the following pages.

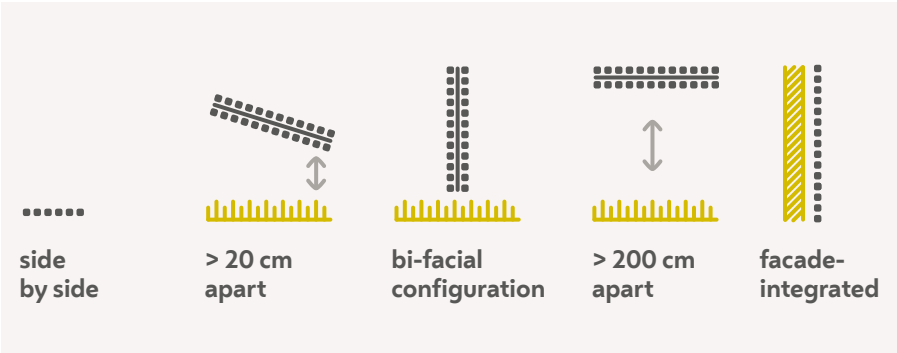


Figure 54: Options for combining solar technology and green roofs/vertical greening systems

3.2 Combined solutions and model projects

Side-by-side arrangement of solar modules and greening on roofs and facades

The simplest arrangement is to place the solar collectors and the green roof or vertical greening system on adjacent surfaces (see Figure 55). This provides unhindered access to both the plants and the solar panels. Provided there is a suitable distance between the surfaces, all types of vegetation can be used. However, it is necessary to ensure a clear structural divide between the surfaces to prevent the vegetation from encroaching upon the respective solar installation (e.g. climbing plants like ivy spreading behind solar panels); see Chapter 5 for detailed information. A synergy can be created by using the non-greened surfaces of the roof to collect rainwater for irrigation of the plants. However, this approach is not geared to multiple usage of every square metre of space and thus can only exploit the synergy potentials of the combination to a limited extent.



Figure 55: GrünAktivHaus

"Layered" combination with solar modules raised > 20 cm above a green roof

Pilot project: Studies show that the most commonly used method at present is to install the solar array over the green roof leaving a clearance of > 20 cm (see Figure 54), a combination that creates added value by enhancing plant and animal biodiversity.

Effects on plants, wildlife and solar technology

The installation of PV modules and/or solar thermal systems on green roofs creates additional partial shade, which results in longer water retention and thus has a proven positive impact on plant growth (Schindler et al., 2018). Since not all plant species can tolerate shade, special care must be taken to choose suitable plants. Furthermore, the study conducted by Köhler et al. (2007) affirms that the installation of PV modules on a green roof has a positive effect on plant biodiversity. Another positive effect is the improvement of conditions for local wildlife. The photovoltaic and/or solar thermal modules create new niches and hidden corners which serve as habitats for all kinds of different animal species. The use of suitable materials automatically creates structures that enhance biodiversity. Research published by Zurich University of Applied Sciences (ZHAW) (Brenneisen et al., 2015) shows that this kind of green roof creates an excellent habitat for insects and an excellent microhabitat for specialised plant species. In accordance with the Swiss specifications for green roofs with solar technology, biodiversity features are placed on parts of the roof that are not suitable for photovoltaic installations. In certain areas, for instance, the substrate is raised to a depth of 30 cm to form small hillocks. Deadwood and sand, temporary water features and varied substrates can also be added to meet the habitat requirements of a range of different species.



Figure 56: East-west orientation of PV modules

Plants evaporate water vapour through their leaves, a process for which they absorb energy from their environment. This effect is known as evapotranspiration, and it results in so-called evaporation chill. This means that given an adequate water supply, the rooftop temperature of green roofs barely rises above the ambient air temperature. A lower ambient temperature improves the performance of the photovoltaic modules on green roofs, so the evaporation chill produced by plants and their substrates can increase the output of PV systems by up to 4% (Brach et al., 2015). If the solar panels are placed too close to the vegetation, however, air circulation and thus the evaporation chill effect will be limited. The minimum clearance between solar modules and greenery must be maintained anyway to ensure rear ventilation of the PV array.

The PV modules cause fluctuations in the air flow, creating small areas of turbulence in some parts of the roof and calm areas in others. These different air currents affect the evaporation of water from plants and/or the soil and hence also the ambient temperature. This gives rise to multiple different microclimates that meet the needs of a biodiverse range of flora. The right choice of plants is essential.

Technology and maintenance

A further advantage of installing PV systems and solar technology on green roofs is that the weight of the substrate and the vegetation layer anchors down the photovoltaic modules. The PV modules do not need to be attached to the roof structure, thus avoiding penetration of the roof membrane and preventing any insulation or moisture leaks and formation of thermal bridges. Ballasted mounting of the PV panels in the drainage/retention layer of the green roof also provides protection from wind uplift. Extensive vegetation is the only type that should be installed beneath the solar PV array. High-growing vegetation is undesirable here, and the nutrient content of the substrate needs to be reduced accordingly.

To ensure that the plants receive adequate sunlight, the photovoltaic modules are mounted on special racking to leave a minimum clearance of 20 cm between the module and the upper surface of the substrate, the actual distance depending on the system used, the tilt angle of the PV panels and the wind load. Special attention must be paid to the wind load if the above requires the modules to be positioned farther apart and/or at a steeper tilt.

A pebble strip is laid in front of the PV array to prevent unwanted shading of the panels by vegetation growth and provide maintenance access. Rainwater falling onto the PV modules runs off into the pebble strip. The water is then channelled underneath the modules via either a gradient or a capillary mat to allow plants to thrive in these areas.

The pebble strip requires regular maintenance and must be kept free of unwanted vegetation. The latest findings show that an east-west layout with rainwater run-off in the middle and maintenance access to the rear of the panels is the best option. Placing the modules in this "butterfly" configuration allows the distance between the modules to be kept to just 0.5 cm, so no plants can grow up between the panels but rainwater can still run off through the narrow gap.

Layered combination with photovoltaic system placed > 200 cm above greenery in roof garden or other outdoor space

This variant with the photovoltaic panels mounted > 200 cm above the rooftop (see Figure 58) allows a threefold use of the space combining solar technology, green roof and amenity space for people. The pergola structure incorporating semi-transparent PV modules is ballasted by the weight of the (non-penetrating) intensive green roof system. Rainwater is used to irrigate the plants and the space in the shade of the PV pergola can be used by people throughout the season. As well as being an amenity space, the roof garden also serves as a productive space. The PV pergola provides valuable shade, while the semi-transparent panels create optimum conditions for plant growth. This solution can be retrofitted in existing buildings as well as integrated into new-build projects.



Figure 57: PV roof garden

Figures 58 + 59: PV roof garden on the new TÜWI Building at the University of Natural Resources and Life Sciences, Vienna (BOKU)



MODEL PROJECT: THE PV ROOFTOP GARDEN OF THE FUTURE – FROM RESEARCH TO PRACTICE

At the start of this research project, a prototype was constructed on an unused roof terrace at the University of Natural Resources and Life Sciences, Vienna (BOKU) with input from a multidisciplinary team of experts from academia and the business community. The photovoltaic pergola with integrated semi-transparent glass-glass PV modules provides shade while simultaneously producing solar electricity and offering a spacious amenity area with a relaxed atmosphere for outdoor work and/or recreation. The PV system delivers an annual power output of around 5,800 kWh, with all the generated electricity being used directly on site. This kind of multiple-use solution creates synergies between uses that would usually compete for the same surface area. In this case, for instance, the beds under the PV pergola are used to grow vegetables and herbs for the institute's canteen.

Thanks to the positive experiences gathered during the research project, a further PV roof garden has meanwhile been installed on another building at the University of Natural Resources and Life Sciences. Similar solutions are under development for use outside the university in residential environments.

Combination of bi-facial PV modules and green roof

This approach to combining greening of buildings with power generation is based on the latest research from Switzerland. The Solarspar Association and the Zurich University of Applied Sciences (ZHAW) are working on a pilot project to optimise combined solar PV/green roof solutions. The ongoing research focuses on double-sided solar panels, placed upright on a green roof, which can produce electricity from both morning and evening sunlight (see Chapter 2). The PV modules are mounted in the drainage/reservoir layer of the green roof, ballasted and anchored in place by the

substrate and vegetation. The east-west orientation of the panels means that energy production is spread out over the entire day.

To maximise reflection of the solar irradiation, the roof has been planted with an extensive system of silver-leaved plant species such as thyme and white rock rose, interspersed with white ornamental gravel, which has increased the albedo effect and boosted output by 16%.

The upright vertical configuration of the panels produces a higher wind load, which can be counterbalanced by increasing the depth of the substrate layer. With this arrangement there is no risk of loss of output due to shading by plants, except in exceptional cases. At the same time, it ensures that 80% of the annual rainfall is retained, thus optimising the climate mitigation effect of the green roof. Rainwater runs off in the centre, with a capillary mat to facilitate distribution of the water throughout the substrate.

Combined solar thermal system and green roof

The advantage of solar heating panels is that, unlike with photovoltaic modules, any shading caused by plants has hardly any effect on energy output. Otherwise the same basic prerequisites apply as for other combined systems.



Figure 60: Vertical arrangement of bi-facial PV modules

Figure 61: Solar PV with vertical greening system

Figure 62: Solar PV with vertical greening system and green roof



Combination of photovoltaic system and vertical greening on the same facade

To mitigate heating of the PV modules and counteract any associated reduction in power output, various types of vertical greening system can be installed behind the modules. The evaporation chill produced by the greenery cools down the heated PV modules, meaning that their performance can be increased by 4–5% on very hot days (Pfoser, p.114 ff., 2018). The efficiency of the system depends on the right choice of climbing plants and/or herbaceous perennials behind the solar modules, and on ensuring sufficient light exposure for the plants. To avoid any damage to the PV array, careful attention must also be paid to the growth characteristics of the climbing plants (increase in girth through secondary growth, shoots that turn away from the light). For these reasons, the number of suitable plant species is very limited.

Consideration must also be given to essential care and maintenance activities such as removal of fallen leaves and pruning back of shoots, and maintenance access must be ensured.

Figure 62 shows a combination of multifunctional vertical greening and green roof systems. The TU Vienna research project was installed on a pre-war building in an urban neighbourhood, currently used by a school. Semi-transparent photovoltaic modules were integrated into the green roof as well as the vertical greening system. The research findings from this project indicate that the thicker the growing medium/substrate layer, the more resilient the system, because it is then better able to compensate for fluctuations in temperature. Wall-bound vertical greening systems reduce the thermal transmittance of a non-insulated facade, the degree to which they do this being dependent on the rear ventilation openings and the surface area of the greenery. On non-insulated buildings the U-value can be improved by as much as 20%.⁶

⁶<https://nachhaltigwirtschaften.at/de/sdz/projekte/gruenplusschuleballungszentrum-hoecheffizientefassaden-und-dachbegruenung-mit-photovoltaik-kombination-optimale-loesung-fuer-die-energieeffizienz-in-gesamtoekologischer-betrachtung.php> (in German)

Combination of solar thermal and vertical greening system

Direct solar irradiation and ambient temperature are the decisive factors affecting the performance of solar thermal systems. The smaller the difference in temperature between the absorber and the surrounding air, the more effectively the absorber works. The collectors of facade-mounted solar thermal systems cover most of the facade surface, so a greening system does not have such a pronounced effect as it does on a roof.

Other synergetic solutions

THE BUS SHELTER OF THE FUTURE – STEGERSBACH

STATION BY FONATSCH is an energy self-sufficient bus shelter incorporating an extensive green roof. The synergy of economic and ecological plus points makes for a sustainable concept with potential for upscaling. The PV installation powers the shelter lighting as well as the integrated USB charging ports, WiFi point and e-bike charging station. Recycled materials and succulents have been used for the extensive green roof, though near-natural vegetation would also be an option.⁷

⁷ <https://www.green4cities.com/?p=1900&lang=de> (in German)



Figure 63: Bus shelter in Stegersbach with PV system and green roof

MODEL PROJECT: SOLAR-POWERED GREENED PETROL STATION, HUNGARY

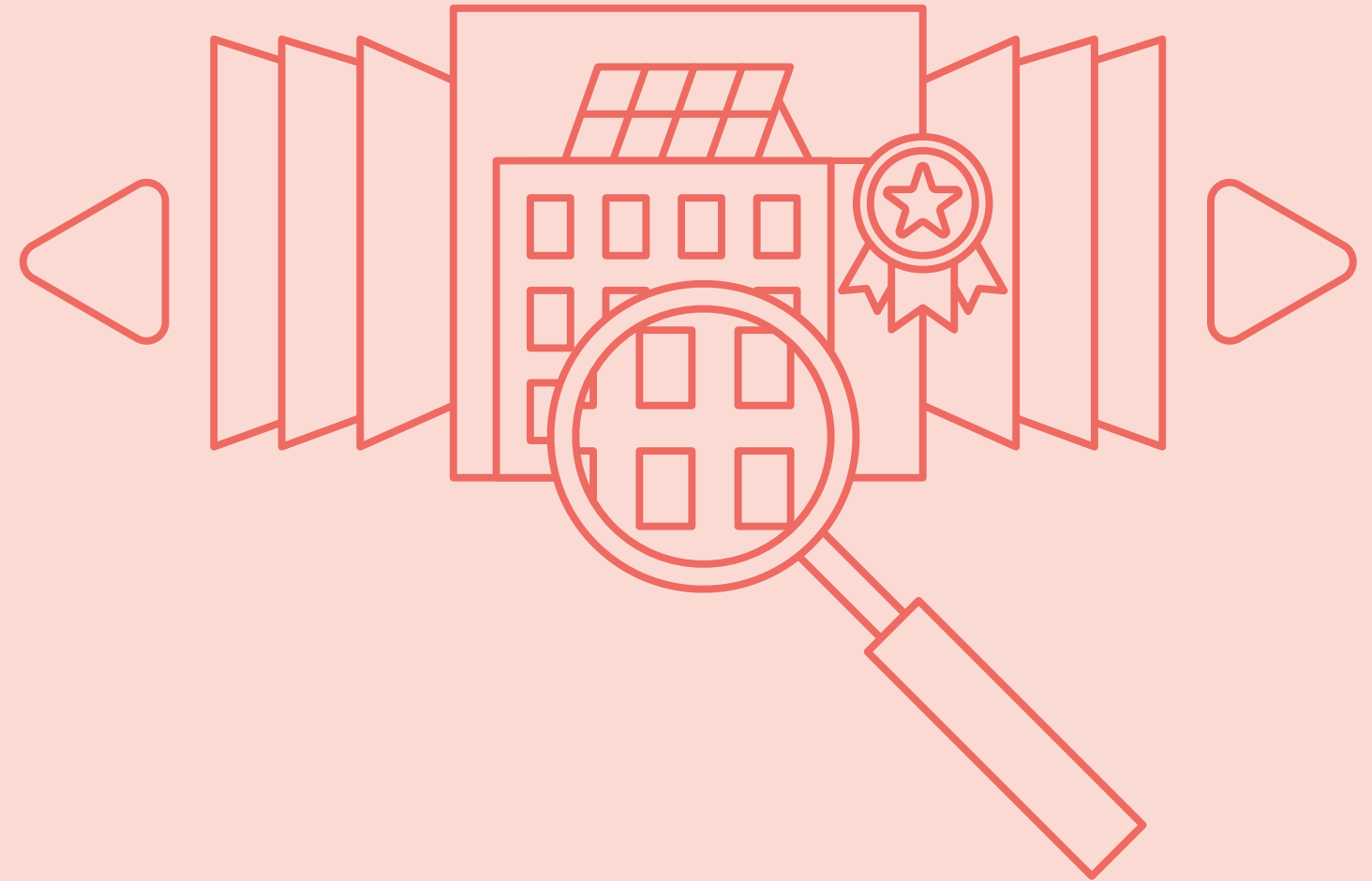
This petrol station in Budapest, Hungary, shows how sustainable technologies can be combined, incorporating a green wall, an extensive green roof and PV technology in the form of innovative "solar trees". The branches of the trees have integrated PV modules with a total surface area of 250 m², producing almost 31,000 kWh of electricity per annum. The green roof and wall are irrigated with the help of rainwater harvested in cisterns. Originally greened with succulents, the roof and wall have now been planted with a mix of herbs and grasses to replicate a natural wildflower meadow.



Figure 64: Greened petrol station in Hungary powered by solar PV trees

4

Model projects



4.1 Solar photovoltaics



Figure 65: Schönbrunn Giraffe Park

Schönbrunn Zoo – Giraffe Park

Project type	Restoration
Location	Schönbrunn Zoo, 1130 Vienna
Project/planning launch date	January 2015
Year completed	April 2017
Construction costs	€7,000,000 net
Building use	Giraffe park
Technology(ies) deployed	Building-integrated photovoltaic panels (glass-glass modules with thin-film monocrystalline PV cells; 16.02 kWp and roof-mounted monocrystalline PV modules; 4.05 kWp) & solar thermal system on the flat roof above the visitors' area (14 m², 10 kW)
Total photovoltaic capacity	Total of 20 kWp producing 18,000–20,000 kWh of electricity per year
Surface area of solar panels	Approx. 237 m² building-integrated PV panels, approx. 24.4 m² PV array on flat roof
Project partners/Teams	Burghauptmannschaft Österreich (authority responsible for historic buildings owned by the Republic of Austria), Arch. Dipl.-Ing. Peter Hartmann

The integration of photovoltaic modules in laminated safety glass makes this project a unique multifunctional symbiosis of energy-saving technologies. In close collaboration with the Federal Monuments Authority, the historic giraffe house was restored to its original form and combined with a new winter garden extension to provide the giraffes with a generously proportioned indoor space. The winter garden roof is supported by a steel structure that branches upwards like a tree, while the roof itself is a delicate lattice of glass panes with integrated PV cells.

The PV modules have been embedded in the glass in an irregular pattern to produce a "leaf canopy" effect of dappled light and shade. A broad facade of glazed panels, some of which can be opened, creates a light and airy indoor enclosure for the giraffes. The integrated photovoltaic and solar thermal systems do a lot to help balance the zoo's energy budget, with the PV installations covering the entire power requirement of the Giraffe Park.



Figure 66: PV wave roof, Rauris

PV wave roof, Rauris

Location	Rauris/Wörth, Austria
Year completed	March 2014
Construction costs	€155,000 net + 20% VAT
Ownership	Province of Salzburg
Building use	Information point and interactive visitor centre of the Province of Salzburg Hohe Tauern National Park Authority
Technology(ies) deployed	Photovoltaic modules: Ertex Solartechnik, laminated safety glass; Inverter: SMA Tripower 7000TL; Electrical installations: HUBER+SUHNER
Total photovoltaic capacity	Total of 7.1 kWp producing 5.5 kWh of electricity per year
Type	Glazed overhead structure with linear supports on 4 sides (to counter wind uplift, the modules have linear supports plus point fixing on 2 sides); laminated safety glass series
Surface area of solar panels	78.1 m²
Architect	Büro Dialer Architects

The "King of the Skies" visitor centre in Rauris, an information point and interactive exhibition space run by the Province of Salzburg Hohe Tauern National Park Authority, is surrounded by high Alpine scenery. The building was completed in 2008 and meets low-energy standards. 2010 saw the launch of the planning phase for the glazed roof over the porch and assembly area, with an integrated solar PV system to make the building energy self-sufficient. The wavelike porch roof of the "King of the Skies" centre is covered with laminated safety glass photovoltaic modules.

The project planning for the Rauris PV wave roof pursued an integrated approach, combining an innovative structure with efficient solar technology. The PV modules have a surface area of approx. 78 m² with a generating capacity of approx. 7 kWp.



Figure 67: Stadthalle Boutique Hotel

Stadthalle Boutique Hotel

Project type	Renovation & new build
Address	1150 Vienna
Year completed	2009
Ownership	Private
Building use	Private/hotel
Type of vegetation/Plants used	Various herbaceous perennials
Technology(ies) deployed	Living wall, soil moisture sensors/photovoltaic modules, solar thermal system
Irrigation system	Storey-by-storey drip irrigation system with reservoir mat and sealing layer
Surface area of greenery	120 m²
Project partners/Teams (contact for enquiries)	Dachgrün GmbH/Boutiquehotel Stadthalle

The vertical garden on the street facade is a plus for hotel guests, who can pick fresh strawberries straight from the windowsill, and also provides amenity value for local residents. For fire safety purposes, the vertical garden is interrupted by a horizontal metal band (fire stop) between the individual storeys. The storey-by-storey drip irrigation system is controlled by 10 ground sensors measuring soil moisture, plus a separate temperature sensor. In technical terms the vertical garden is a facade-bound green wall system (rear-ventilated and insulated)

consisting of 10 cm aluminium plant troughs in a cascade arrangement with mineral substrate, reservoir mat and sealing layer. It is classified as a multi-layered mounted facade in accordance with Austrian Standard ÖNORM L 1131. The planting medium is a crushed clay aggregate with an organic component and other added nutrients. The plants used are selected herbaceous perennials such as cranesbill geranium (*Geranium sp.*), heuchera (*Heuchera sp.*), lavender (*Lavandula sp.*) and wild strawberry (*Fragaria vesca*).



Figure 68: Erich Kästner School

Erich Kästner School

Project type	Renovation
Address	40764 Langenfeld, Germany
Year completed	2010
Ownership	Public
Building use	Public
Type of vegetation/Plants used	Extensive/sedum
Technology(ies) deployed	Photovoltaic modules
Irrigation system	None
Surface area of greenery	600 m²
Project partners/Teams (contact for enquiries)	Optigrün international AG

A beneficial combination of green roof and photovoltaic system has been installed on the roof of the Erich Kästner School in Langenfeld, Germany. The PV array is a ballasted, non-penetrating system, with the photovoltaic modules installed on mounts at a height that prevents shading and also allows plant growth underneath the solar panels. The plants for the green roof were chosen to ensure easy maintenance, and the system was tested in a wind tunnel to guarantee its structural safety.



Figures 69 + 70 + 71: Zurich Opera House

Zurich Opera House

Project type	Refurbishment
Address	Zurich – Oerlikon
Project/planning launch date	2016
Year completed	2019
Construction costs	17 million Swiss francs
Ownership	Public
Building use	Public
Orientation/Shading	East-west
Type of vegetation/Plants used	Extensive/native wildflowers + sedum
Technology(ies) deployed	Photovoltaics
Irrigation system	None
Surface area of greenery	7,700 m²
Surface area of solar panels	2,660 solar modules
Total capacity:	825 kWp (310 Wp per module)
Project partners/Teams (contact for enquiries)	Solarspar

This project was designed to create habitats for as many plant and animal species as possible. In order to achieve maximum biodiversity, special green islands were constructed alongside the solar modules and the extensive green roof system. Biodiversity features such as piles of deadwood and mounds of unwashed sand can be used as a nesting place by wild bees, digger wasps and other beneficial insects. An innovative element of the project is the deployment of a specially developed prototype robotic lawnmower, a pilot project aimed at reducing the

longer-term maintenance costs of green roof systems. The mount for the solar panels was modified slightly to allow the robotic mower to pass easily underneath. Solarspar mounted the solar modules in a V-shaped ("butterfly") configuration in line with the latest research findings on solar green roofs. Most of the rainwater collects at the lowest point of the panel array, where it is diffused into the substrate via a capillary mat to encourage plant growth beneath the PV panels.



Figure 72: Rooftop experimental facility

Experimental solar PV system on the roof the Eichgut retirement home

Project type	Research facility
Address	8400 Winterthur, Switzerland
Project/planning launch date	2012
Year completed	2017
Care & maintenance	1–3 x per year
Ownership	Public
Building use	Residential home for the elderly
Orientation/Shading	East-west
Type of vegetation/Plants used	Extensive/silver-leaved plants (white rock rose, thyme)/white gravel
Technology(ies) deployed	Bi-facial solar cells (special modules)
System capacity	10.8 kWp
Project partners/Teams (contact for enquiries)	Zurich University of Applied Sciences (ZHAW) and Solarspar

This research project aims to establish optimum conditions for biodiversity, rainwater retention and solar power generation. Special modules were developed for this purpose, consisting of bi-facial solar cells that can produce electricity from solar irradiation on both the front and rear sides. The modules can therefore be mounted vertically on upright supports, leaving most of the roof surface available for an extensive green roof system of silver-leaved plants interspersed with white ornamental gravel. This in turn reflects the solar irradiation, thus intensifying the albedo effect and increasing the output of

the solar modules by 16%. The vertical bi-facial arrangement combined with an east-west orientation generates maximum output during the early morning and late afternoon demand peaks, so no temporary battery storage is required. It also significantly reduces the problem of output loss caused by plant shading. The higher wind load requirements have been met by increasing the depth of the vegetation substrate layer to 15 cm. This simultaneously allows 80% of the annual rainfall to be retained, thus optimising the climate mitigation effect of the green roof.

4.2 Solar thermal systems



Figures 73 + 74: The hybrid array



Hybrid system

Project type	Renovation
Address	1150 Vienna
Project/planning launch date	2015
Year completed	2015
Care & maintenance	1 x per year
Ownership	Private
Building use	Private
Type of vegetation/Plants used	Extensive/sedum
Technology(ies) deployed	Hybrid collectors (solar thermal and photovoltaic)
Capacity	2.12 kWp electrical, 10 kW thermal
Surface area of solar panels	13.6 m ²
Project team (contact for enquiries)	3F SOLAR (Alexander Friedrich)

This project combines an extensive green roof system with solar collectors on a flat roof. To meet the wind load and wind uplift criteria, the panel mounting structures are ballasted by concrete slabs/strips (with additional underlay mats to protect the bitumen sheeting). To avoid later shading of the panels by the vegetation, the lower edge of the solar modules must be positioned high enough to accommodate the full depth of the substrate layer plus the height of the grown plants (red arrow). The pre-insulated (thermal) pipes and cables are covered by the

substrate. Once the solar collectors are in place, the green roof can be planted, using either sedum sprouts, low-growing herbaceous perennial plug plants or sedum mats. Shade-loving and drought-tolerant species can be planted in the area underneath the collectors. The householder carries out annual care and maintenance to control the plant growth and cleans the surfaces of the solar collectors. Note/relevant experience: Close coordination among the specialist contractors during installation is especially important.



Figure 75: Hallwang Primary School

Hallwang Primary School

Project type	New build
Location	Hallwang, Salzburg
Year completed	2017
Ownership	Municipality of Hallwang
Building use	Primary school and youth centre
Technology(ies) deployed	Solar thermal collectors, monovalent heat pump (brine/water), adsorption refrigeration system, concrete core temperature control, 20.5 kWp capacity PV system
Total capacity	200 kW solar thermal
Surface area of solar collectors	280 m ²

The local state primary school in Hallwang (Province of Salzburg) is the first in Austria to be entirely carbon free, powered by solar thermal and PV systems and a heat pump. The classrooms are heated via a concrete core temperature control system. Solar collectors are mounted on the facade to make maximum use of the winter sun, and the 280 m² solar

thermal system covers 80% of the school's heating requirements. The building saves an annual total of 120,000 kWh of electricity and 30 tonnes of CO₂. In 2019 the school was awarded with the Austrian State Prize for Architecture and Sustainability.



Figure 76: Wohnmanufaktur Kröll.Winkel

Wohnmanufaktur Kröll.Winkel

Project type	New build
Location	Taxenbach, Salzburg
Year completed	2016
Ownership	Wohnmanufaktur Kröll.Winkel
Building use	Offices, workshop, showroom
Technology(ies) deployed	Solar thermal collectors, concrete core temperature control, heat pump, 50 kWp capacity PV system, geothermal collector
Total solar thermal capacity	74 kW
Surface area of solar collectors	105 m²

The bespoke carpentry and interior design firm in Taxenbach (Province of Salzburg) produces wooden furniture and interiors from wood, stone, glass, steel and textiles. The offices and production facility are 80% solar heated using a concrete core temperature control system, while a varnishing chamber is also supplied with solar thermal energy via a heater battery. The 105 m² of collectors are integrated into the facade to make maximum use of the winter sun. The remaining energy requirement is

covered by a 24 kW brine/water heat pump, the geothermal collector for which is used for passive cooling of the upper and lower storeys of the building in the summer months. The building saves an annual total of 55,000 kWh of electricity and 15 tonnes of CO₂.



Figure 77: Apartment building, Mariahilfer Straße 182

Apartment building, Mariahilfer Straße 182

Project type	Refurbishment
Location	Vienna
Year completed	2018
Building use	Housing
Technology(ies) deployed	Solar thermal collectors, gas central heating
Surface area of solar collectors	88 m²

The apartment building at 182 Mariahilfer Straße in Vienna was left in ruins following a gas explosion in 2014 and had to be completely refurbished. Under the direction of the architectural firm Trimmel Wall, the core of the building was remodelled and the facade restored to its original design. An additional rooftop storey was also added, built to passive energy standard. The building has a net living space of 2,360 m² and incorporates 20 refurbished pre-war flats und nine new penthouses. The heating system

was converted from separate gas boilers to gas central heating controlled from a boiler in the basement, and can be converted to district heating at any time. The 150 kW gas boiler supplies the underfloor heating system (70 kW) and the ventilation system (10 kW). Two 922-litre buffer tanks supplement the central heating and solar thermal systems. A solar thermal system with a surface area of 88 m² is mounted on the shallow pitched roof facing the rear courtyard and supplies energy for the hot water system.



Figure 78: HABAU Concrete Works

HABAU Hoch- und Tiefbau GmbH Concrete Works

Project type	New build
Location	Perg, Upper Austria
Year completed	2014
Ownership	HABAU GmbH
Building use	Manufacture of pre-cast concrete elements
Technology(ies) deployed	Solar thermal collectors, concrete core temperature control
Total solar thermal capacity	980 kW
Surface area of solar collectors	1,400 m²

The concrete works in Perg (OÖ) manufactures pre-cast concrete elements in four production halls. The 1,400 m² solar thermal installation supplies all the heating for the 7,700 m² of production space all year round via a concrete core temperature control system built into the foundations. A disused 80,000-litre gas tank has been repurposed as the buffer tank. From April to October the solar energy generated is also used

to heat the moulds for hollow-core slab ceiling production and for the curing kilns in the new circular production plant. This ensures optimum year-round utilisation of the solar thermal capacity. The solar thermal system saves the company 50,000 m³ of natural gas per annum and saves 190 tonnes of CO₂ emissions.



Figure 79: Fernwärme Wien

Fernwärme Wien

Project type	New build
Location	Vienna
Year completed	2018
Ownership	Wien Energie GmbH
Building use	Pre-heating of the feed water plant for Vienna's district heating network
Technology(ies) deployed	Solar thermal collectors
Total solar thermal capacity	459 kW
Surface area of solar collectors	656 m²

The solar thermal installation operated by Wien Energie GmbH is used to pre-heat the feed water for Vienna's district heating network. The solar thermal array was installed 70 metres up on the rooftop of a boiler house at the power station in Vienna's Simmering district. With a surface area of 656 m², the solar thermal facility supplies over 700 kWh/m², a possibly record-breaking output, and saves 70,000 m³ of natural gas per annum.

Rigorous interdisciplinary planning is required to ensure the long-term efficient operation of solar technology and combined solar & green roof/vertical greening systems. The following guidance is designed to provide a simple introduction to the subject and pave the way for a joined-up approach to planning in new-build and retrofitting projects alike. Coordinated project management by the planning, installation and maintenance contractors from the two sectors (solar energy and greening) is critical to the success of projects of this kind. A collaborative approach is thus urgently recommended.

Prerequisites for the installation of photovoltaic and solar thermal systems

The installation of visible new photovoltaic and solar thermal systems, or significant modification of existing ones, changes the overall aesthetic of a building. Nevertheless, a uniformity of design should be preserved on facades and roofscapes. The following urban design objectives should therefore be complied with:

- Photovoltaic and solar thermal installations should preferably be mounted on facades and rooftops that face onto rear courtyards or the householder's own garden.
- Rooftop photovoltaic and solar thermal installations should be mounted parallel to the roof pitch wherever possible.
- Visible cables and pipework must be avoided.
- One or several rectangular arrays should be aimed for (i.e. L-, T-, U- or C-shaped arrays are to be avoided where possible).
- There should be a gap of at least 50 cm between the edge of the array and the edge of the roof and/or any other rooftop installations, or alternatively the array should cover the entire rectangular roof surface with no gap at the edge (apart from guttering and flashing).
- Any protrusion beyond the edge of the roof must be avoided.
- With tilted modules on flat roofs, the distance from the edge of the roof should ideally be double the height of the modules (measured vertically).
- A basic requirement in all cases is that the proportions and scale of the photovoltaic and solar thermal installations should harmonise with the existing architectural features of the building; with facade-mounted systems this is usually unavoidable anyway.

5.1 Guidance on combining solar technology with green roofs/vertical greening systems

In new-build projects, combined solar and green roof/vertical greening solutions are apt to yield efficient results, in that the two systems are planned and executed hand in hand from the outset. However, refurbishment projects can also incorporate modifications (e.g. rooftop insulation) that allow a solar green roof to be installed at a later date. The right structural parameters are obviously an essential prerequisite here. Caution is advised when retrofitting solar technologies on existing green roofs/vertical greening systems, or when retrofitting green roof/vertical greening systems with existing solar installations. In this case the greening and solar technology experts must collaborate closely to synchronise the requirements of the two systems. With green roofs the key considerations are usually a reasonable clearance between vegetation and solar panels and appropriate layering of the various components to ensure unhindered drainage and even irrigation. When installing green roof systems, the necessary substructures can be built in to allow for subsequent retrofitting of solar technologies.

How to avoid mistakes when combining solar technology with green roofs/vertical greening systems⁸

- Maintain a sufficient clearance between greenery and sensitive structures, cable runs and feeder & distribution manifolds, ensuring compliance with the guidelines on non-vegetated strips set out in Austrian Standard ÖNORM L1131.
- Avoid shading at all costs (impaired performance); less critical with solar thermal systems.
- Avoid prolonged soiling of the solar modules, e.g. by falling leaves.
- Ensure professional care and maintenance of the greenery.
- Choose the right green roof/vertical greening system for the setting (extensive sedum, extensive biodiverse, semi-intensive, intensive).

The substrate layer of an extensive system must not be too deep, otherwise plants can grow above the solar modules and cause shading. More substrate means higher-growing plants and a different mix of plant species. Extensive greening is therefore recommended for layered arrangements where the plants are a short distance from the solar panels. The substrate must be properly structured for the desired vegetation (see Austrian Standard ÖNORM L 1131 for Green areas on roofs of buildings). Once the initial follow-up maintenance period has elapsed, ongoing care and maintenance of the plants under the solar modules is limited to once or twice per year.

⁸ Source: Pfoser N. (2018): *Vertikale Begrünung* ["Vertical Greening Systems"]. Fachbibliothek Grün. Eugen Ulmer KG. Stuttgart.

It is advisable to choose plants that produce little biomass and do not require much fertiliser and pruning. The exception to this is the combination of intensive greenery with solar modules mounted a larger distance away, e.g. on a pergola-type structure; in this case there is enough space for a wide variety of plant species, including e.g. vegetable beds or trees and shrubs. Intensive green roofs require a similar amount of care and maintenance as a garden.

With combined solutions in both new builds and refurbishments, professional planning and execution are important to ensure an optimum spatial configuration of the solar technology and greening elements. It often occurs that both a green roof and solar technology are desired and taken into consideration in the initial plans, but not implemented until a later date for reasons of cost. If the greenery is installed first this is not a problem, though it does require the green roof structure to be prepared accordingly for the installation of the solar technology. Synergy effects, suitable combinations and possible configurations of solar technology and green roof/vertical greening systems are explained in detail in Chapter 3.

In principle, existing solar PV/thermal systems or green roofs/vertical greening systems can usually be retrofitted with the respective other technology. This step-by-step mode of installation requires some precautionary measures, however, as described on the following pages.

Factors to consider when retrofitting solar technology on existing green roofs

"A stitch in time saves nine", as the saying goes, and the substructure for the solar array can already be built into the underlying layers of the green roof system. Ballasted supports with integrated mounting brackets for PV panels are suitable for this purpose, as they allow PV modules to be installed at a later date. The ballasted substructure with integrated mounting brackets should be pre-installed by anchoring it into the drainage/reservoir layer of the green roof system (see Chapter 3). This helps avoid subsequent damage to the existing vegetation, and possibly to other layers of the green roof.

The later installation of a solar thermal and/or PV system must be taken into account when selecting plant species for the green roof. By choosing the right type and depth of substrate we can influence the resulting plant community and hence the height of plant growth. The problem of shading by plants sometimes occurs because the original substrate was too deep, having been designed for a different plant community. Problems can also arise when the rainwater management system of the green roof is disrupted through installation of a solar array without leaving sufficient clearance and/or without prior modification of the green roof substructure.

Figure 80: Negative effects of plant growth on retrofitted solar technology



This leads to waterlogging in the run-off area of the solar modules, which changes the composition of the plant community. The vegetation underneath the solar array, on the other hand, is cut off from the water supply, so withers and dries up. In any event, a pre-existing green roof should be assessed for its suitability to integrate solar technology and structurally modified where necessary. In this case, the substructure of the green roof system should be adapted to suit the planned solar array and ensure even distribution of water run-off. This may entail e.g. installing capillary matting and/or water reservoirs.

In cases where tall plant growth is already causing problems with output and maintenance because there is no longer a sufficient gap between greenery and solar panels and the rainwater management system has been disrupted, perforated metal sheeting and other permeable metal fine-mesh elements can provide an emergency remedy. Although this limits the height of vegetation growth, the plants continue to receive water and sunlight. However, this is an emergency solution for established green roofs where proper restructuring of the entire green roof system would not be economic.

In cases where an existing green roof system has not been pre-prepared for solar technology and thus has an unsuitable substructure, the solar installation must always be planned with great care and with the involvement of experts from both fields.

If the solar array can only be installed with a gap of less than 20 cm from the surface of the growing medium, or even flush with the roof, then the green roof system needs to be partially or fully removed. However, this frequently goes against the stipulations of the municipal authority, because in most cases the green roof will have been officially mandated and must be preserved accordingly. Partial or complete remodelling of the green roof to install an appropriate substructure, plus configuration of the solar array to leave a clearance of > 20 cm between panels and green roof substrate is the most sensible, preferred alternative, because it preserves the function of the green roof system. Ballasted mounting brackets anchored into the drainage/retention layer of the green roof system should be used for this purpose.

Retrofitting of green roof/vertical greening systems on buildings with existing solar installations

If the solar thermal or PV system is being installed without greening for the time being, care must be taken to ensure that there is sufficient clearance between the modules and the substructure, otherwise any greenery retrofitted in future may cause unwanted shading. The vegetation must be given a certain amount of space in which to thrive. When a green roof/vertical greening system is combined with existing solar technology, a minimum clearance of 20 cm should therefore be left between the surface of the growing medium and the solar panels. Ideally the solar array should have an east-west orientation allowing easy access beneath the modules for maintenance purposes.



Figure 81: A negative example: ivy next to a PV array with no separator

The correct choice of plants is crucial

When planning a roof/facade greening project, care should be taken when choosing the intended plant communities (mix of species), because different plant species require different conditions for growth. Self-clinging climbing plants will not do well with trellises, for example, whereas suitable support structures are essential for twiners, bines, stem tendril climbers and ramblers (see Chapter 2). The growing bed or planter needs to have the right substrate and be of sufficient volume to supply the plants with everything they need for growth. Earth is not classified as a substrate and does not provide enough nutrients over the long term.

When retrofitting greenery with existing solar technology, a complex set of pre-requisites needs to be borne in mind. For example, caution needs to be exercised if shade-loving climbers are to be combined with solar technology on a facade. These plants put out shoots that grow into shady areas, where they can then increase in girth through secondary growth until they burst the confines of the space. Significant damage can be expected in such cases. If a combination of shade-loving climbers and solar technology is chosen, it is crucial that separators are installed to prevent uncontrolled spread of the plants.

Planning guidance for installing green roof systems with solar technology

In order to optimise both cooling of the solar modules and plant growth, it is essential to ensure that a certain clearance is maintained between the vegetation layer and the solar array. 20 to 60 cm is the minimum, depending on the respective system, tilt angle and wind load. Special attention must be paid to the wind load if the above requires the modules to be positioned with a larger clearance and/or at a steeper tilt.

If the modules are mounted with an east-west orientation, the distance between them can be as small as 0.5 cm to ensure that no plants can grow up there and cause shading. Rainwater, however, can still run off through the narrow gap.

Structural adequacy and calculation of roof loads

For installations on pitched roofs, the additional dead load of the solar technology usually poses no problem. On flat roofs, however, the existing roof structure is often inadequate to support the extra load, so the opinion of a structural engineer should always be sought in case of doubt. The effect of snow load, wind uplift and wind pressure on the solar installation needs to be calculated with reference to the

designated climatic, wind load and snow load zones (for further information, see the relevant maps). The contractor is responsible for verifying and providing written confirmation that the solar modules, mounting system and fixings are appropriate and sufficiently dimensioned for the local conditions.

Since both the solar panels and the greening system place an additional structural load on the roof, solar technology should only be installed in direct combination with the lighter extensive type of greening (roof gardens are an exception). An extensive greening system simultaneously ensures that the panels are not shaded by high-growing vegetation, because the greater the depth of the substrate, the greater the diversity of species and the likelier taller plants are to thrive. The required weight of the green roof elements for ballasting purposes can be pre-calculated and the substrate layers adjusted as necessary (lower substrate depth with heavier weight by using coarser-grained substrate with a higher specific weight; higher substrate depth with lighter weight by incorporating lighter components with finer granulation). The additional dead load of a solar green roof is at least 120 kg/m² (see Chapter 2).

Rooftop safety installations

The necessary rooftop safety installations need to be in place before construction work starts, but also for the later maintenance of the building. The range of rooftop safety equipment is wide and varied, from guard rails to single point anchors and rigid rail safety line systems. The installations need to be geared to the respective work to be carried out and incorporate fall protection systems and equipment for safe ascent and descent. The fall protection systems must be installed in compliance with ÖNORM L 1131 and conform to the requirements of ÖNORM B 3417 and OIB Guideline 4. Personal protective equipment (e.g. safety line with body harness) must be worn when installing and removing rooftop safety installations. The Austrian occupational health & safety organisation AUVA publishes a German-language safety manual for rooftop work ("Arbeiten auf Dächern") giving details of safety precautions, equipment and qualifications that may be required for maintenance of rooftop installations. Damaged components in solar installations can produce dangerous electrical voltages. For this reason, a professional electrician should ideally be tasked with the repairs and the green roof contractor given timely warning about the potential hazard.

After planting and the initial phase of care until the plants are established, extensive green roof systems require ongoing care and maintenance once a year. This includes removal of unwanted growth (woody plants), inspection of the water run-off and drainage systems and application of nutrients.

Indirect solar glare

In individual cases, unfavourable conditions can cause indirect glare (reflection of sunlight) from a solar module. It is important to carry out an assessment of solar glare at the planning stage. ÖVE Guideline R 11-3 sets out minimum requirements for the assessment of solar glare and its potential impact on the neighbouring area and/or on road users and other modes of transport. It thus serves as a decision-making aid when planning or evaluating solar installations for this purpose.

The following measures can be taken to mitigate/prevent glare:

- Screening of the line of sight between the relevant solar modules and the place of immission at the times when glare occurs.
- Optimisation of module positioning (e.g. height, tilt angle, orientation).

According to the Austrian Aviation Act (§ 94), installations which may cause disability glare may only go ahead with prior approval from the relevant authority. At any rate, a separate assessment should evaluate whether or not any glare is a potential safety hazard for air traffic.

Commissioning and maintenance

Care must be taken to ensure regular inspection, especially with combined solar PV and green roof/vertical greening systems. The first step is a visual inspection. In the event of reduced performance or other problems, inspection of the solar modules using infrared thermography or electroluminescence can help identify the cause.

Regular cleaning, snow clearance, and in some circumstances pruning of the vegetation all help keep power output at a maximum.

Damage and insurance

Insurance cover for damage caused by hail, snow, etc. must be discussed with the respective insurance company. It is important to clarify in advance what types of damage the insurance provider will cover.

5.2 Building type, usage and ownership – factors to consider in connection with greening of buildings

The building type is a decisive factor in determining the options available for greening of the available surfaces. It is important to consider the objective(s) behind the greening project: What spectrum of uses is the greened surface expected to cover, and who are the users? Is multiple use of the same surface a possibility, and what added value would that provide?

The type of building, e.g. detached, contiguous or semi-detached, determines the number of available surfaces and the basic energy modalities. It is a good idea to define a detailed set of usage and output objectives for the available surface area and use this to design an efficient and harmonious multiple-use solution that creates added value. Various design options and approaches for the outer shell of the building can be found in the previous Chapter 5.1.

The use of the building's ground-floor zone is especially relevant here. In buildings with a high visitor frequency, such as in the retail sector, for instance, precautions should be taken to prevent damage from vandalism or as a result of direct mechanical contact. With ground-level greening, for example, guards can be installed to protect the plant stem(s). Care should also be taken to ensure that vertical greening systems cannot be used as climbing aids. It is recommended that such systems are mounted a safe height from the ground.

The ownership details are another major factor. The approach suitable for a single-family house, for instance, is very different to that for a multi-storey block of flats. The ownership of solar technology and greening systems needs to be clarified at the planning stage. Tasks and responsibilities pertaining to care and maintenance of green roofs/vertical greening systems and solar technology must likewise be clearly defined and assigned. It is recommended that the cost-sharing arrangements and the modalities for care and maintenance work be determined before the systems are installed. For example, does responsibility lie exclusively with the direct beneficiary, or are the occupants collectively liable?

Greening measures and solar installations are associated with increased costs, so they are classified as an extraordinary matter in terms of property management law. The approval of the other co-owners must therefore be sought and obtained. In a commonhold property, at least 51% of the commonholders' association must give their consent. In cases of simple co-ownership, 100% of the co-owners must give their consent, although consent can be established by court decision instead. A written resolution

is required in all cases. The advice of a legal expert can be sought to clarify the legal situation in individual cases.

5.3 Example of a combined solar green roof system

For approximately ten years now, international manufacturers have been marketing operationally tried and tested solutions combining solar technologies and greening systems. The differences between the various racking systems, support brackets, tilt angles and clearances lie in the detail. A wider range of certified system configurations and combination options is likely to become available going forward. The suggestions, case studies and trends outlined in this handbook provide a look ahead and are designed to inspire a positive approach to creative planning.

The following schematic diagram provides an overview of common features and basic functioning:

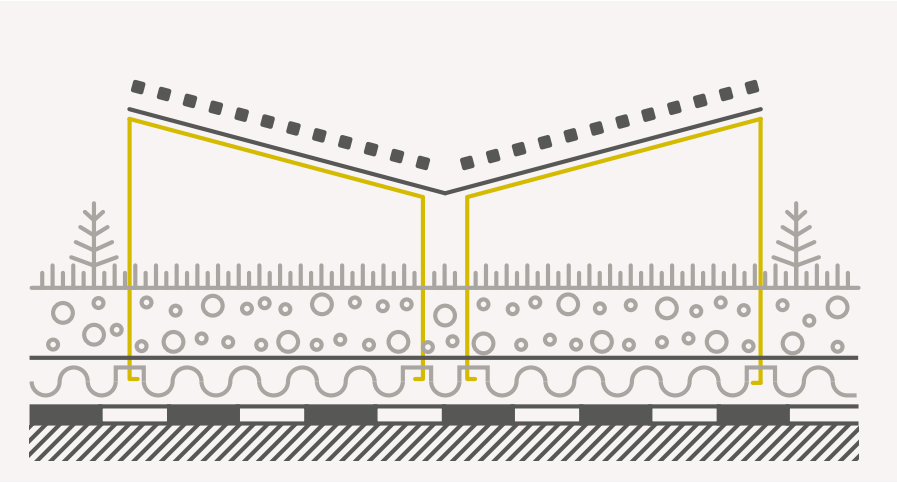


Figure 82: Solar green roof system with east-west orientation

The solar array is basically ballasted in place by the weight of the extensive greening system, so no penetration of the roof membrane is required. The mounts for the solar modules are anchored into the drainage/retention layer of a classic green roof substructure. All that remains is for the respective solar modules to be fixed to the mounts. The wind uplift must be calculated in advance and, if necessary, can be compensated by a deeper substrate layer.

5.4 Fire safety

Fire safety precautions need to be taken into consideration for solar technology installations as well as for green roof/vertical greening systems. The respective fire safety specifications for photovoltaic installations, solar thermal systems and green roofs/vertical greening systems are set out on the following pages.

Fire safety measures for photovoltaic installations

PV systems that are not carefully planned and meticulously installed, connected, wired and fused can increase the risk of fire. By the same token, however, this means that there is usually no need to fear a fire hazard if the system is properly installed and regularly maintained and serviced. Unprotected cabling should be avoided at all costs, for instance, because it poses a fire risk.

The fire safety regulations should be carefully examined before installing a photovoltaic system. The nationwide ÖVE Guideline R 11-1: 2013-03-01 (PV systems – Additional safety requirements; Part 1: Requirements for the protection of firefighters) sets out the safety requirements for planning and installation of PV systems and must be complied with. The above stipulations can be applied *mutatis mutandis* to free-standing PV systems in outdoor spaces. The following requirements are prescribed as standard:

- Diagrams of the PV system showing cable runs and indicating the location of any manual isolation switches at switching points must be available and readily accessible to firefighters at all times.
- The exact position of the photovoltaic modules and their distance from maintenance walkways, roof hatches, skylights and other installations must be documented and the information kept in a readily accessible place. The location of the PV inverter must be clearly indicated.
- If a building with a PV system is on fire, the firefighters have to switch off the electricity before starting the firefighting operations.
- When installing building-integrated photovoltaics, care should be taken to ensure that the system complies with the fire safety classification set out in EN 13501-1.
- The fire safety objective can be met by means of technical and/or structural measures, backed up by appropriate organisational procedures:

Technical measures:

- Cut-off and bypass switches in the vicinity of the PV modules

Structural measures:

- Easily visible and accessible DC cable runs
- Fire resistance rating of 30 minutes (roof)
- Cables to be routed away from fire risk areas
- Safe access to PV modules for firefighters (e.g. walkways, etc.)

The actual measures that need to be implemented are decided by the respective fire safety inspector (in the case of notifiable installations that are subject to approval).

Structural fire safety measures are normally regulated in the Building Codes of the individual federal provinces. A fact sheet containing all the fire safety requirements for the installation of photovoltaic systems on buildings in Vienna is available for download at <https://www.wien.gv.at/wohnen/baupolizei/> (in German).

The fire safety requirements for the installation of vertical greening systems in Vienna are listed in the City of Vienna Guide to Vertical Greening Systems, which is available for download at <https://www.wien.gv.at/umweltschutz/raum/pdf/fassadenbegruenung-leitfaden.pdf> (in German).

Fire safety measures for solar thermal systems

As a matter of principle, fires can only be caused by solar thermal collectors with timber frames. All known fire incidents to date were associated with manufacturing faults in in-roof collectors, where the surface of the collector is inset into the roof. In this case the solar collectors are not mounted on top of the roof cladding, but actually replace it. Up until 2017, only around two dozen solar collector fires were known of in Germany, half of which were caused by faulty collectors produced by a certain manufacturer (which has since gone bankrupt).

A solar thermal system cannot usually cause spontaneous combustion of wood, because the stagnation temperature of flat-plate solar collectors at the hottest point (centre of absorber plate) is around 200 degrees Celsius, whereas wood only ignites at a temperature of approx. 280 degrees Celsius. However, if wood is repeatedly heated to temperatures of between 120 and 280 degrees Celsius for prolonged periods, the ignition temperature gradually decreases and can fall to below 120 degrees Celsius ("thermal degradation" causes a reduction in the weight of the wood). Fire damage incidents to date were not due to periodic stagnation of the system during the summer, but were all the result of an unusually prolonged period of stagnation caused by a functional defect (leak, pressure loss, etc.) or an installation that was oversized for the setting, causing the wood to be in direct contact with very hot system components.

If, due to faulty manufacturing or installation, the wood is directly exposed to such defective and/or oversized and hence permanently overheated systems, the result can be thermal degradation and, in extreme cases, spontaneous combustion.

The trade association Austria Solar has incorporated measures to minimise the fire risk of solar collectors in the guidelines for its Austria Solar quality seal. In future, the mounting instructions for collectors must contain guidance on how to avoid damage caused by overheating. When laying the pipework in the rooftop area, care must be taken to ensure that non-insulated sections of the solar pipework are not touching any wooden materials. With in-roof collectors, rear ventilation must be ensured in compliance with ÖNORM B 4119.

Fire safety measures for vertical greening systems

The structural properties of contemporary vertical greening systems were tested by the City of Vienna Testing, Inspection and Certification Body in a series of practical fire safety experiments on systems featuring climbing plants with and without support structures. The findings indicated practically no lateral fire spread, not even close to the flames immediately adjacent to the fire compartment. There is no secondary fire risk from burning debris falling from the facade. Likewise, no vertical fire spread via woody roots was observed. However, vertical fire spread may be caused by a sudden short burst (a few seconds) of "flash fire".

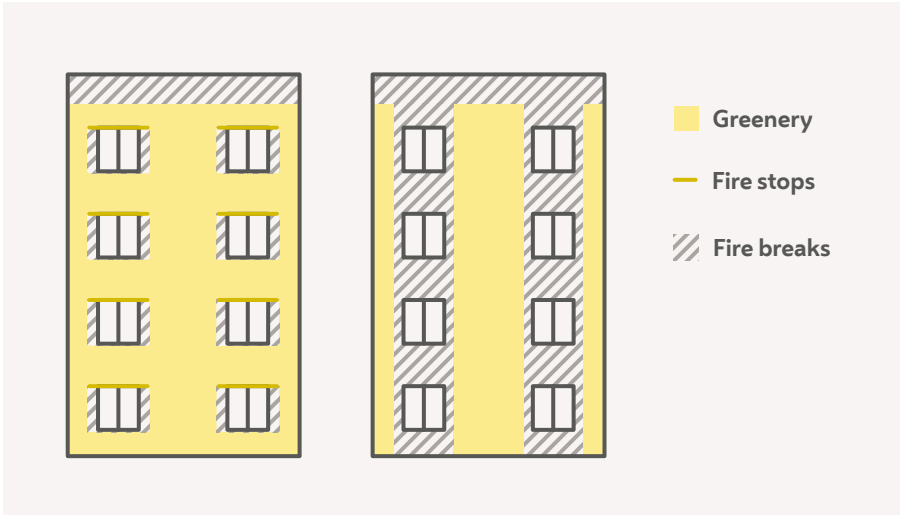
Based on the above, no special fire protection measures are required for buildings up to building class 3. Consequently, vertical greening systems up to a maximum of three storeys high do not require a separate fire risk assessment. Buildings of class 4 and above require additional measures to prevent spread of fire and stop burning debris falling to the ground. Inspections will check for compliance with ÖNORM B 3800-5.

The following basic planning guidance thus applies:

- There must be a minimum vertical gap of 1 m between the greenery and the combustible roof structure.
- Non-vegetated fire breaks must be left around openings (windows); 1 m vertically and 0.2 m horizontally.
- Access must be ensured for fire-fighting vehicles.

As a further measure, sheet metal fire stops may be installed on each storey, as shown in the following diagram:

Figure 83: Fire safety regulations for buildings with vertical greening systems



These fire stops can be integrated into living walls, for example, or installed along the upper edge of windows.

Fire safety measures for green roofs

According to the German FLL Guideline 2018, ÖNORM L 1131 and international norms and practice, all types of standard-compliant intensive and extensive green roof systems with sedum-moss-herbaceous plants, provided they are professionally and properly planned, installed and maintained, are designated as a "hard roof". They are deemed to be resistant to flying sparks and radiant heat and are classified as BROOF(t1) in the most commonly used testing and certification procedures. As a matter of principle, ÖNORM L 1131 for Green areas on roofs of buildings specifies that the requirements set out in ÖNORM EN 13501-1 and ÖNORM EN 13501-5 and/or the relevant local regulations must already be taken into account during the planning phase.

The following rules apply for extensive green roof systems:

- Mineral-based growing medium with a maximum of 20% organic matter (by mass)
- Depth of substrate ≥ 3 cm

The green roof should incorporate non-vegetated strips about 30–50 cm wide around perimeters and penetrations (depending on surface area and layout of greening). On intensive green roofs with trees and shrubs, these strips can additionally perform a preventive function as fire breaks.

The strips can be laid out using pebbles, but also with other suitable building materials (e.g. paving slabs, grating, etc.).

In addition, general fire safety precautions must be observed during the construction phase and in normal operation, e.g.:

- Careful handling of open flames and other heat sources during the construction phase as well as in ongoing operation.
- Changes of use that no longer meet the criteria for a "hard roof" classification must be compensated by appropriate fire protection measures.
- Appropriate care and maintenance measures to ensure continued compliance with the "hard roof" designation criteria.
- Torches and burners must not be used to eliminate undesired plant growth.

Providing the above are complied with, there are no obstacles to combining green roofs with solar technology from the fire safety point of view, because the green roof system is classified as a "hard roof".

5.5 Planning aids and tools from the various specialist fields

The tools, guidance and standards set out below are designed to ensure proper, professional design and installation and help avoid mistakes.

Regulations and guidelines for green roofs/vertical greening systems

Austrian Standard ÖNORM L 1131, "Green areas on roofs and ceilings of buildings – Directives for planning, building and maintenance", describes permissible, approved categories of green roof, including suitable building materials and vegetation types and their proper care and maintenance.

Further sets of regulations and guidelines:

- ÖNORM B 2241 – Garden design and landscaping
- ÖNORM L 1040 – Plants – Vegetation engineering works
- ÖNORM L 1041 – Care and maintenance
- ÖNORM L 1110 – Plants – Quality requirements, growing forms and provisions for sorting

- ÖNORM L 1131 Supplement on solar green roofs by the *Verband für Bauwerksbegrünung* (Greening Buildings Association) FA 2 (2019)
- LBH LG58 (Sample terms of reference for green roof installations)
- City of Vienna Guide to Green Roofs (scheduled for publication in 2021)
- ÖNORM B 3417 – Design and construction of safety equipment on roofs
- City of Vienna Guide to Vertical Greening Systems (2020)
- OIB Guideline 2: Fire safety (2019)
- ÖNORM B 3806 – Fire behaviour requirements for building products and materials
- FLL Guidelines for the planning, construction and maintenance of vertical greening systems (2018) DE
- FLL Guidelines for the planning, construction and maintenance of green roofs (2018) DE
- Sia SN 564 312 Green roofs (2013) CH
- ÖNORM L 1136 – Outdoor vertical greening systems (contains directives for planning, building, maintenance and control as well as requirements for different types of vertical greening)

Vertical greening systems can be implemented in a number of different ways. The requirements and regulations for the various types, up to and including certification, are set out in the City of Vienna Guide to Vertical Greening Systems (2020) and in ÖNORM L 1136 (2021).

Regulations and guidelines specifically for photovoltaic systems:

- ÖNORM EN 62446 – Grid-connected PV systems - Minimum requirements for system documentation, commissioning tests and inspection
- ÖNORM E 8101, in particular Part 7–712 (Solar photovoltaic power supply systems: Requirements for special installations or locations)
- ÖNORM M 7778 Assembly planning and assembly of thermal solar collectors and photovoltaic modules
- ÖNORM EN 1991-1-3 Actions on structures – Snow loads – National specifications, comments and supplements
- ÖNORM EN 1991-1-4 Actions on structures – Wind actions – National specifications, comments and supplements
- ÖNORM EN 62305 Protection against lightning
- ÖVE Guideline R 6-2-1 Photovoltaic power supply systems – Lightning and over-voltage protection
- ÖVE Guideline R 6-2-2 Photovoltaic power supply systems – Selection and application principles of surge protection devices
- ÖVE Guideline R 11-1PV systems – Additional safety requirements
Part 1: Requirements for the protection of firefighters

- ÖVE Guideline R 11-3 Glare from photovoltaic systems
- ÖVE Guideline R 20 Safety requirements for stationary electrical energy storage systems intended for fixed connection to the low-voltage grid
- *TOR Erzeuger* (Technical and organisational requirements for producers of PV systems in Austria)
- TAEV (Technical requirements for connection to public supply grids with operating voltages up to 1000 volts)

Recommended tools and contact points:

- With its "Greening Check" service, GRÜNSTATTGRAU, a competence centre for greening of buildings, offers a free technical feasibility study for potential greening projects in existing buildings as well as new builds.
- GRÜNSTATTGRAU also maintains an open public database containing details of model projects, certified products and experts in the field.
- The *Verband für Bauwerksbegrünung Österreich* (Austrian Greening Buildings Association) and the competence centre GRÜNSTATTGRAU are available to answer specific queries about technical feasibility, as well as providing quality-assured, government-subsidised initial consultations and ongoing advice and support through to technical sign-off and certification.

Map of roof spaces in Vienna with potential for solar technologies/ green roof systems

Vienna's urban area extends over a total of 415 km². This currently includes 53 km² of roof surface, 34 km² of which alone are well or very well suited for installation of solar technologies. The City of Vienna's solar potential map provides an initial estimate of the potential for solar energy installations in the urban area. The map shows whether the roof of a particular building is suitable for solar power generation. A similar map assessing green roof potential indicates which roof spaces might be suitable for greening. Link to the City of Vienna's solar potential map:

<https://www.wien.gv.at/stadtentwicklung/stadtvermessung/geodaten/solar/>

Pre-plan your own photovoltaic system with the Sonnenklar online planning tool

The Sonnenklar online planning tool is a free software program that allows interested members of the public to find out the ideal photovoltaic system for their needs by inputting a few basic parameters. The tool shows how the system can be designed to optimise the self-consumption rate, i.e. the share of the generated solar electricity that is used

directly on the premises. However, please note that the Sonnenklar tool is for information only and not a substitute for proper professional planning by a specialist contractor.

Link to the Sonnenklar online planning tool (in German):

www.pvaustria.at/sonnenklar_rechner

A summary of key norms and standards in the PV sector is available at

www.pvaustria.at/normen

Photovoltaic simulation software

Several systems are available on the market for professional design of PV installations. Programs frequently used in practice include, among others:

- PV*SOL
- PVSites
- PVsyst

Use of these software programs is usually subject to a fee, but many of them allow school pupils and students to install them free of charge.

SHW – Simulation software for solar thermal systems

The University of Innsbruck has developed a simulation tool for the planning and design of solar thermal systems that is available to students for teaching and research purposes but also to solar energy specialists and interested laypeople. The software is free of charge and can be downloaded from the university website. Potential users are asked to complete a simple online form and are then sent a link for download. However, please note that the simulation software is for information only and is not a substitute for proper professional planning of a solar thermal system. Follow this link to access the simulation software:

<https://www.uibk.ac.at/bauphysik/forschung/shw.html.de>

Selling solar electricity

Self-produced solar power that is not used directly on the premises can be sold to an energy supplier. E-Control, the Austrian state regulator, offers an independent tool to help you find the most suitable buyer for your surplus power. You can find this by following the link below (in German):

www.e-control.at/konsumenten/service-und-beratung/toolbox/tarifikalkulator

5.6 Guidance on care and maintenance of solar technology and green roofs/vertical greening systems

Proper care and maintenance are crucial to ensure the smooth functioning of greening systems and solar technology throughout their intended lifespan and beyond. From the economic point of view, it makes sense to have both systems (solar technology and green roof/vertical greening) serviced at the same time. This approach saves time, money and emissions and also minimises the disturbance to flora and fauna.

Care and maintenance of green roofs/vertical greening systems

Care and maintenance during the planting and establishment phase are an integral part of the installation contract, and ongoing care and maintenance should also be entrusted to a professional. If the greening installation is well cared for over the first few growing seasons and handed over in a fully functional state, it will require far less ongoing routine maintenance to keep it in good condition.

Care and maintenance of green roofs/vertical greening systems is subdivided into three phases, which are defined in detail in Austrian Standard ÖNORM L 1131:

- Installation and planting phase (up to acceptance sign-off)
- Establishment phase (up to final quality control)
- Ongoing routine care and maintenance

The aim in the installation, planting and establishment phase is to establish an ecological balance and achieve the specified vegetation coverage. This phase usually lasts for two seasons and can comprise various different steps depending on the building and type of greening installed. The following list serves as an example:

- Application of fertiliser
- Removal of unwanted plant growth
- Plugging of any gaps
- Pruning
- Replacement planting/reseeding
- Inspection of drainage outlets and non-vegetated areas and removal of any encroaching vegetation

Once the planting and establishment phase is over, an extensive green roof only requires one routine maintenance inspection per year. With intensive green roofs, the maintenance interval depends on how the roof is used and the plant communities installed. In addition, intensive green roofs usually have an irrigation system that also requires servicing.

Additional measures for solar green roofs

- The necessary wiring must be designed so as to facilitate the use of electric garden tools (trimmers, hedge clippers, robotic lawnmowers, etc.) for care and maintenance purposes.
- As a general rule, over 80% coverage by the desired plant species must be achieved during the planting and establishment phase, and 100% coverage should be aimed for.
- With a view to fire safety, the intended mix of vegetation should be maintained and unwanted plant growth avoided.

The Austrian Standard does not allow the use of chemical substances (biocides, herbicides, fungicides, etc.) or of peat in the care and maintenance of the greenery component of solar green roofs. Invasive plant species must be removed immediately in accordance with the valid regulations.

Care and maintenance of vertical greening systems

Care and maintenance of vertical greening systems follows the same three phases as described above for green roofs: installation and planting phase, establishment phase and ongoing routine care and maintenance. The maintenance intervals for living walls and vertical greening systems based on climbing plants can vary considerably, depending on the system in question, its location and accessibility. If the system uses trellises or other support structures, these need to be inspected regularly. The care and maintenance of vertical greening systems likewise calls for a high degree of specialist skill and expertise. Care and maintenance activities comprise the following steps:

- Assessment of plant vitality
- Pruning
- Training of plants where necessary
- Removal of unwanted plant growth
- Application of slow-release fertiliser
- Removal and replacement of dead plants
- Inspection of irrigation system (incl. automatic nutrient supply system and/or sensors where applicable)
- Visual inspection for structural damage

Additional measures for combined solar technology/vertical greening systems

The breadth and height of the plant growth must be adjusted to prevent shading of the solar modules. Any plants growing too close to a solar module need to be either pruned back or replanted elsewhere. With self-clinging climbing plants, separator bars can also be installed to ensure a clear division between the surfaces.

Maintenance, monitoring and cleaning of solar thermal and PV installations

Solar thermal and PV installations require very little maintenance. Nonetheless, a professional inspection must be performed each spring at the start of the sunny season, as this allows minor faults to be discovered and swiftly remedied. Strong winds, snow and ice can cause damage or soiling to the system during the winter months, and this is easily spotted during a physical inspection.

Regular maintenance inspections also help ensure that the system yields the maximum possible output. Maintenance must be carried out by a specialist contractor, as only the latter possess the necessary professional expertise and the right equipment to guarantee the safety of the system.

Good ongoing monitoring of the system is likewise recommended. Many manufacturers of solar thermal systems now offer solar control units and/or systems with an integrated heat meter, which allows precise monitoring of the energy output. Automatic monitoring systems are also available for PV systems. Because these systems are subject to wear and tear from external factors, a maintenance interval of no longer than three years is recommended. The manufacturer's documentation and/or system testing and inspection certificates may specify further requirements regarding servicing and maintenance intervals. In accordance with ÖNORM B 1300 (2012) "Object safety tests for dwelling buildings", the owners of residential buildings are responsible for people's health and safety in those buildings. They are therefore required to ensure that their property does not pose a safety hazard to the residents of the building or their belongings.

Regular cleaning is especially important with PV installations, because soiling caused by e.g. pollen, leaves, bird excrement, soot deposits, sand dust, moss and lichens can become worn in, and the resulting opaque spots on the panel surface can lead to reduced performance. The required frequency of cleaning varies enormously, however, ranging from several times a year to once every few years. Soiling very quickly leads to loss of output, especially with PV installations. At any rate, the cleaning of the PV array should always be entrusted to professionals who are familiar with the safety regulations. This is because incompetent cleaning of the solar panels can cause damage and thus increase the risk of injury.

Care must be taken to ensure that PV modules are not overshadowed in any way whatsoever. Any high-growing plants should therefore be pruned back at regular intervals (see Chapter 5.1).

5.7 Step-by-step implementation guides for solar technology and green roof/vertical greening systems

10 steps to a green roof/vertical greening system

0. If a combined solution with solar technology is being considered, this needs to be planned as the first step, even if it is not installed until a later date.
1. Feasibility study for the envisaged new build or retrofit greening project, taking into account project parameters such as type of facade or roof construction, objective of greening project, budget, ownership, etc.
See the City of Vienna Guide to Vertical Greening Systems (in German):
<https://www.wien.gv.at/umweltschutz/raum/pdf/fassadenbegruenung-leitfaden.pdf>
2. Initial on-site consultation with a qualified building greening consultant. The on-site consultation also includes a basic assessment of any potential constraints such as pavement width, listed historic building status, organisational factors, indicative costs, declarations of consent in the case of commonhold or co-owned properties, and structural considerations. (Note: This service is subsidised by the City of Vienna, and qualified consultants are certified and procured by GRÜNSTATTGRAU.)
3. Before you start, obtain information about official permits & approvals required (e.g. visual compatibility MA 19, Federal Monuments Authority, fire safety MA 37, structural installations MA 28, among others) and clarify the situation regarding funding and possible government grants.
4. Engage a qualified planner to plan the project; draw up cost estimates, care & maintenance plan and project schedule. (Note: Details of planners and their reference projects can be found in the GRÜNSTATTGRAU database.)
5. Obtain offers from specialist contractors for installation and maintenance of the system. (Note: Details of specialist contractors, system manufacturers and certified products can be found in the GRÜNSTATTGRAU database.)
6. Identify potential interfaces for the incorporation of solar technologies (see the following step-by-step guides).
7. Obtain the necessary planning permission, including any expert appraisals required (structural load calculations, structural adequacy of existing building).
8. Commission contractors to install the green roof/vertical greening system; installation phase.
9. Acceptance sign-off and transition to post-installation establishment phase; receive contractor's invoice and claim grants applied for.
10. Final quality control and sign-off; arrange for ongoing care and maintenance based on care & maintenance plan.

10 steps to a solar thermal system

0. If a combined solution with a green roof/vertical greening system is being considered, this needs to be planned as the first step, even if it is not installed until a later date.
1. Initial basic assessment: Is sufficient space available on the roof or facade? Does the roof have a suitable orientation and pitch? Is there enough space for a thermal storage tank? Can the solar pipework be laid properly?
2. Gather information: Find local solar thermal contractors and planners (further information at www.solarwaerme.at), contact them to arrange a consultation and quote, option to seek additional energy planning advice if required. Clarify details of system size and function (hot water only or room heating as well?).
3. Clarify the funding situation and find out about possible government grants (see also Chapter 6 – Government funding).
4. Submit notification of building works or apply for planning permission if necessary.
5. Draw up an installation plan with the selected specialist contractor.
6. Installation of the entire solar thermal system (collectors, storage tank, plumbing and pipework, control unit, etc.).
7. Final inspection and handover: including a detailed explanation of how the system works to ensure decades of problem-free use.
8. Adjust the system control settings to suit the individual usage patterns.
9. Day-to-day monitoring of the solar thermal system: a heat meter is recommended to allow regular monitoring of system performance and optimisation as and when necessary.
10. Regular servicing: have the system inspected and serviced by a professional every three years.

10 steps to a photovoltaic system

0. If a combined solution with a green roof/vertical greening system is being considered, this needs to be planned as the first step, even if it is not installed until a later date.
1. Clarification of basic questions such as available surface area, system capacity, tilt angle, orientation, roof or facade installation, placement of inverter, cable runs.
2. Contact potential PV system suppliers and planners and obtain a number of quotes for comparison.
The trade association Photovoltaic Austria provides a useful search tool for this purpose (in German): <https://www.pvaustria.at/pv-profi>
3. Organise funding; find out if notification of building/electrical installation works and/or relevant permit required.

4. Find out about possible grants and subsidies: when applying for a grant or subsidy, make sure you meet the specified deadlines and conditions (for detailed information on government grants and subsidies, see Chapter 6).
5. Apply to grid operator for assignment of a meter point (with assistance from PV contractor).
6. Agree the time schedule with the selected contractor (factoring in a certain amount of leeway!) and sign the contract for installation of the PV system.
7. Installation of PV system and issue of a test certificate by a certified firm of electrical engineers, who will notify the grid operator that the system has been commissioned.
8. Choose the energy supplier you wish to export your electricity to and conclude the feed-in contract. The grid operator will exchange the existing meter for a new one.
9. Invoicing of the project and final submission to the funding body.
10. Regular maintenance and cleaning of the PV system.

6

Government funding



Government grants and subsidies are available to help fund the installation of solar technology and green roofs/vertical greening systems. The following chapter provides an overview of the relevant funding schemes. Grants are available from the Province of Vienna, and alternatively also from the federal government. The cost of retrofitting photovoltaic and solar thermal systems is also tax deductible ("Expenditure on housing refurbishment" under "Special expenditure" on the annual personal income tax assessment form).

6.1 Funding from the Province of Vienna

Grants for green roofs/vertical greening systems

In Vienna, building greening measures are embedded in the urban development plan STEP 2025, the Thematic Concept for Green and Open Spaces and the Urban Heat Islands Strategic Plan for Vienna, UHI-STRAT. Municipal Department MA 22 (Environmental Protection) provides grants to private entities for building greening projects, alone or in combination with solar technology, with the objective of enhancing quality of life, improving biodiversity and fostering a healthy urban microclimate.

- Planning permission or a structural survey must be available for the project submitted for funding. The project may not receive any other subsidies. Both new-build and refurbishment projects are eligible. Refurbishment projects must involve conversion from a conventional roof to a green roof. If greening is prescribed in the land use and development plan, funding is only available for green roof systems with a substrate depth exceeding the prescribed depth. Funding is only awarded for quality-assured installations in compliance with ÖNORM L 1131 and up to a maximum grant value of €20,000. However, separate grants are also available for greening consultancy services. The roof membrane must be asbestos-free and PVC-free.
- A maximum grant of €5,000 is available for greening of street-facing facades, and a maximum of €3,000 for courtyard-facing facades. Signed declarations of consent must have been collected from the (co-)owners of the property. The building must be part of a contiguous group of buildings. Applicants may not have received any funding for vertical greening systems within the past five years. The vertical greening system must remain in place for at least 15 years. The use of peat and PVC is prohibited.

Under the *Firmengrün* strand of its *OekoBusinessPlan* environmental service package for businesses, the City of Vienna provides grants to companies (including property management firms) for quality-assured independent consultancy services in connection with building greening projects.

Follow this link for an overview of grants and subsidies currently available for building greening projects in Austria:

<https://gruenstattgrau.at/foerderungen-fuer-gebaeudebegruenung-im-ueberblick/>

Grants for photovoltaic installations in Vienna

Fostering innovative technologies is an essential part of the fight against climate change. Vienna's subsidy schemes for photovoltaic systems also incorporate funding for electric storage batteries and financial support for the installation of PV arrays on green roofs. The aim of these local authority grants is to increase solar power output and boost consumption of self-produced solar electricity.

Vienna provides funding for commercially and privately owned photovoltaic systems installed on buildings, other built structures or business premises (with the exception of green spaces). Suitable documentation indicating the type of installation must be enclosed with the grant application. At present, funding is only available for PV systems with capacity exceeding 50 kWp. A federal grant for the first 50 kWp installed can be applied for under the subsidy scheme of the Austrian Climate and Energy Fund.

1. Grants for photovoltaic installations

PV systems with a capacity of up to 100 kWp are subsidised to the amount of €250 per kWp. Larger PV systems (i.e. 101 kWp plus) up to a maximum capacity of 500 kWp are subsidised to the amount of €200 pro kWp. The grant is limited to a maximum of 30% of the eligible costs.

2. Grants for photovoltaic installations on green roofs

This funding scheme specifically supports installation of PV systems on green roofs and/or installation of PV systems as a pergola-type shading element in multifunctional roof gardens incorporating green roof elements as well as providing amenity value. The attractive incentive is designed to expand the use of renewables in the urban context and utilise the synergy effects resulting from the combined installation of green roofs and photovoltaic systems. Grants are awarded for photovoltaic systems on green roofs up to a maximum amount of €400 per kWp.

3. Grants for electric storage batteries

Grants are available for newly installed stationary electric storage batteries based on lithium technology, as well as for brine storage batteries in combination with a photovoltaic system. There is separate funding of up to €300 for installation of a load management system. Electric storage batteries have multiple advantages. They store the electricity produced by your own PV system for use when the sun is not shining. This increases consumption of self-produced solar power, which means that less energy has to be taken from the public grid. For grid operators, sunny days

when large amounts of solar power are generated pose a major challenge in terms of energy storage. Use of electric storage batteries can reduce the burden on the public grid at peak times.

Detailed, up-to-date information about the funding scheme (in German) is available at <https://www.wien.gv.at/stadtentwicklung/energie/foerderungen/strom.html>

Grants for solar thermal systems in Vienna

Funding is available in Vienna for solar thermal systems installed in privately financed new residential buildings. There are two funding strands for solar thermal systems (the current subsidy guideline expires as of 31 December 2021). The general eligibility requirement is that the quality and performance of solar collectors must comply with European Standard EN 12975.

RETROFITTED SOLAR THERMAL INSTALLATIONS

The City of Vienna subsidises retrofitting of solar thermal installations for the supply of hot water in private housing to a maximum of 25% of the eligible investment costs. As a maximum, the funding consists of a basic grant of €1,000 plus a lump sum of €70/m² of absorber surface area. To be eligible for funding, the solar thermal system must have an absorber surface area of at least 5 m² and a storage volume of at least 300 litres.

If the solar thermal system is also used to supplement the heating system and/or for cooling purposes, the maximum grant available increases to 35% of the eligible investment costs. As a maximum, the funding consists of a basic grant of €1,000 plus a lump sum of €100/m² of absorber surface area. To be eligible for funding, the system must have an absorber surface area of at least 10 m² and a storage volume of at least 800 litres. For the cooling components of the solar cooling system the grant amounts to 35% of the eligible investment costs.

There is a separate calculation scheme for buildings comprising more than two dwelling units:

- 3–5 dwelling units €750/dwelling unit
- 6–10 dwelling units €600/dwelling unit
- 11–15 dwelling units €550/dwelling unit
- 16–20 dwelling units €500/dwelling unit
- 21+ dwelling units €450/dwelling unit

SOLAR THERMAL SYSTEMS WITH HIGH SOLAR COVERAGE

The grants available for solar thermal systems that fall into this category are significantly higher. In this case subsidies are also available for solar thermal systems in new-build projects. The grant amounts to max. 25% of the eligible investment costs, limited to a maximum of €2,200 for single-family and €3,100 for two-family homes. For projects comprising three or more dwelling units, the maximum subsidy is €650/dwelling unit.

However, a bonus is available if the solar thermal system covers at least one-third of the building's annual heat energy requirement: in this case the maximum grant rises to €3,100 for single-family, €4,400 for two-family and €800/dwelling unit for multi-unit residential buildings.

Solar thermal systems subsidised under this strand must meet the following requirements:

- Integration into the room heating system is mandatory.
- The system must cover at least 20% of the building's annual heat energy requirement (room heating and hot water).
- The heat transfer must be effected via a low-temperature heating system, and a heat meter must be installed.

The current calls for funding applications (in German) are always listed at <https://www.solarwaerme.at/foerderuebersicht-privat/> for private buildings and <https://www.solarwaerme.at/foerderuebersicht-betrieblich/> for commercial buildings.

6.2 Federal grants & subsidies

OEMAG FEED-IN TARIFFS SCHEME 2021

- Subsidies are available for PV installations on buildings (regardless of the legal form of ownership).
- The scheme is open to PV systems with a capacity of 5 kWp up to max. 200 kWp.
- The electricity exported to the power grid is subsidised by means of a feed-in tariff.
- An additional one-off grant is available towards investment costs.
- The funding body is OeMAG (Austria's renewable energy authority).
- Available funding amounts to €8m per year.

The level of the feed-in tariffs and the one-off investment grant is set on a yearly basis via the Ordinance to the Renewable Electricity Act. Once contracted, the tariff is guaranteed for the next 13 years.

For 2020 the feed-in tariff is 7.06 eurocents/kWh; the investment grant is €250/kWp or max. 30% of the investment costs.

See the following link for details of the scheme and how to apply (in German):
<https://www.oem-ag.at/de/foerderung/photovoltaik/tarifforderung/>

INVESTMENT GRANT FOR PV SYSTEMS (UP TO 500 KWP) AND ELECTRIC STORAGE BATTERIES (UP TO 50 KWH) – LAUNCHING IN 2021

- One-off investment grant for installation of a PV system.
- The PV electricity produced and exported to the grid is not subsidised (unlike under the feed-in tariffs scheme).
- The funding body is OeMAG (Austria's renewable energy authority).
- €36m per year are available (€24m for PV systems and €12m for electric storage batteries).

Subsidy rates for PV systems:

- Capacity up to 100 kWp: €250 per kWp
- Capacity over 100 kWp to 500 kWp: €200 per kWp (limited to max. 30% of the investment costs)

Subsidy rates for electric storage batteries:

- Electric storage batteries (new and expansions) with capacity up to 50 kWh; the storage capacity may be larger, but funding is limited to max. 50 kWh
- Minimum capacity of the storage battery: 0.5 kWh per kWp installed bottleneck capacity
- €200/kWh or max. 30% of the direct capital investment costs

See the following link for details of the subsidy scheme and how to apply (in German):
<https://www.oem-ag.at/de/foerderung/photovoltaik/investitionsfoerderung/>

AUSTRIAN CLIMATE FUND INVESTMENT SUBSIDY FOR PV SYSTEMS (UP TO 50 KWP) 2020–2022

Preliminary note: the current call for funding applications runs until 31 December 2022 (or as long as funds are available).

This subsidy scheme was topped up and expanded in December 2020, with a further €20 million added to the original funding budget. Grants are available for both free-standing and rooftop PV installations, with a bonus for building-integrated systems. The investment grant is available for the first 50 kWp installed, though the overall capacity of the PV system itself can be greater.

Grants for photovoltaic installations:

- €250/kWp for 0 to 10 kWp capacity
- €200/kWp for each further kWp of capacity from > 10 to 20 kWp
- €150/kWp for each further kWp of capacity from > 20 to 50 kWp
- €100/kWp bonus for building-integrated PV systems

For details of the subsidy scheme and how to apply (in German), visit
www.klimafonds.gv.at

STAND-ALONE OFF-GRID SYSTEMS

This scheme subsidises stand-alone installations to produce power for self-consumption in isolated sites with no access to the power grid (e.g. photovoltaic systems, small hydropower or wind power plants or electric storage batteries to supply mountain lodges and shelters). The funding programme is open to companies of all kinds, other commercially active organisations, associations and religious institutions.

See the following link for details of the scheme and how to apply (in German):

<https://www.umweltfoerderung.at/betriebe/stromerzeugung-in-insellage-auf-basis-erneuerbarer-energietaeeger.html>

An up-to-date summary with details of all current funding programmes (in German) can be found at <https://www.pvaustralia.at/forderungen/>

Grants for green roofs/vertical greening systems

Greened buildings and the associated implementation measures are an integral part of the following specialised initiatives: Bioeconomy Strategy 2020+, klimaaktiv, Climate Change Adaptation Strategy, #mission2030, Renewable Energy 2018 and the environmental audit scheme. Greened buildings are also included in the Biodiversity Strategie 2020+ launched by Environment Agency Austria. Local grants, usually at municipal authority level, are also available throughout Austria to help cover the costs of expert consultation and installation.

For up-to-date information on subsidy schemes for greened buildings, see:
<https://gruenstattgrau.at/urban-greening/foerderungen/>

Subsidy scheme for green roofs/vertical greening systems as an energy-saving refurbishment measure (KPC):

GREENED BUILDINGS

As part of the Austria-wide climate action funding programmes of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), grants are available for the installation of green roofs/vertical greening systems on business or local authority premises. Kommunalkredit Public Consulting GmbH (KPC) administers these grants and awards various subsidies for green roofs/vertical greening systems in new-build and refurbishment projects if combined with energy-efficient building design or retrofitting of thermal insulation.

- Grants for new business or local authority premises built to energy-efficient standards (Federal Ministry for Sustainability & Tourism, BMNT) – (incl. extensive green roof or vertical greening systems: up to €150/m²).
- Grants for retrofitting of thermal insulation in business or local authority premises (Federal Ministry for Sustainability & Tourism, BMNT) – (incl. extensive green roof or vertical greening systems: up to €150/m²).

Grants for solar thermal systems

PRIVATE USE

The Austrian Climate and Energy Fund runs a nationwide subsidy programme for solar thermal systems in private buildings, with a new round of funding each year. The current grant amount is €700 per system in the form of a one-off payment towards investment costs. Visit the Climate and Energy Fund website for details (in German). The Climate and Energy Fund's "Solar House Programme" provides grants for solar thermal systems that cover at least 70% of the total heat energy requirement of a single-family or two-family residential building. New builds, retrofit and refurbishment projects are all eligible and there is a new round of funding each year. Details of the scheme are available on the Climate and Energy Fund website (in German).

The current calls for funding applications (in German) are always listed at <https://www.solarwaerme.at/foerderuebersicht-privat/>

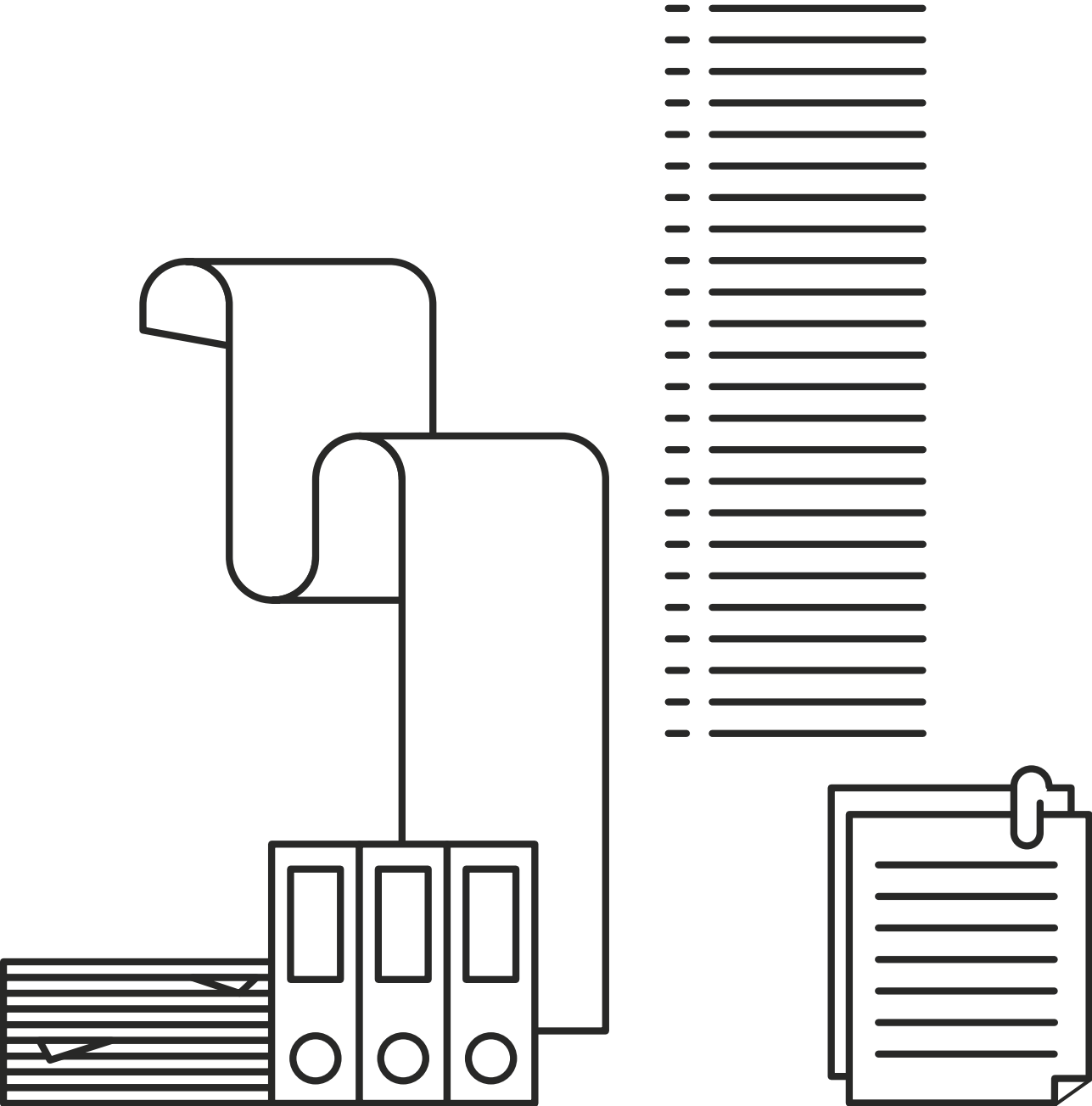
COMMERCIAL USE

Under the eco-friendly funding programme UFI, commercially used solar thermal systems with a collector surface area of up to 100 m² supplying hot water, room heating and heat for manufacturing processes are subsidised at a rate of €150 per m² for standard collectors and €195 per m² for vacuum collectors. The grant is limited to a maximum of 30% of the eligible costs. For installations with a collector surface area of

more than 100 m², the subsidy amount depends on the volume of carbon emissions saved. Here the grant is limited to a maximum of 25% of the eligible costs, and the minimum investment is €10,000. The Climate and Energy Fund's subsidy programme for large-scale solar thermal systems covers 30–50% of the investment costs for installations with a collector surface area greater than 100 m² (50 m² in exceptional cases). Integrated energy systems, new technologies and extra-large installations (> 5,000 m²) are incentivised under six thematic priorities. Grants of up to 100% are also awarded towards the cost of feasibility studies for projects with a collector surface area greater than 5,000 m².

The current calls for funding applications (in German) are always listed at <https://www.solarwaerme.at/foerderuebersicht-betrieblich/>

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