MOOC Zero-Energy Design

Course Reader Module 5

TU Delft

This reader provides additional information for the Massive Open Online Course (MOOC) Zero Energy Design.

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Electricity

1. Electricity

EU policy is to ensure that by the year 2020, 20% of total energy use in Europe is supplied by renewable sources and there is a CO_2 reduction of 30% compared to 1990. The generation of renewable electricity will play an important role in this. Photovoltaic (PV) solar energy is expected to provide positive opportunities within the built environment. On top of that, it is also important for there to be a continued effort to save electricity.

This includes:

- the use of efficient heating and ventilation
- optimised use of daylight so that there is less need for artificial lighting
- encouraging residents to use less, and more efficient, household appliances. Possible measures include developing a designated space to dry the laundry and a install a hot-fill device.

Electricity savings and sustainable energy are both discussed in this chapter. In terms of the latter, PV is paid particular attention. The use of wind energy and biomass are beyond the scope of this report because opportunities for these sources lie mainly outside the built environment.

1.1 Reducing electricity consumption

In the Netherlands, the average electricity consumption per household has risen steadily in the past. In 2009, the consumption per household stabilized and is currently on average 3.500kWh per household per year.

The increase in these years was mainly due to the higher use of electrical appliances for heating and ventilation, in addition to an increase in the number of appliances per household. Most of these appliances are more energy efficient than they would have been a few years ago. However, this is not enough to compensate for the number of appliances there are in each household. There is a similar trend in lighting; light bulbs became more efficient, while the amount of light bulbs per dwelling significantly increased.

Household appliances that are kept in standby mode tell a similar story in terms of energy consumption. The total for the Netherlands is around 400 kWh/year, which is equivalent to one large coal power plant. Not all these devices need their active standby function; at least half can be totally switched off.

It is possible to limit electricity use through measures in housing design and heating, hot water, ventilation and elevator installations, as well as encouraging residents to use less, more efficient, household appliances.

1.1.1 Savings by building design

It is possible to reduce the use of electricity through:

- the extensive use of daylight: This reduces the need for artificial lighting. The amount of daylight can be increased by large windows, ponds that reflect daylight, solatubes and so on.
- the use of summer night- or groundwater cooling so that air conditioning systems are not purchased.
- Appoint a laundry drying area, in this way the tumble dryer can be used less.

1.1.2 Savings in building installations

The two main ways to reduce the electricity use by household is with more efficient appliances and lighting. Beside that electricity use can largely be reduced by changes in the behavior of the consumers. Adequate information should be provided for residents and landlords on issues, such as energy-efficient lighting. Sensors and measurements can also help to optimize the time electricity is used (demotics).

Energy efficient appliances

Using more efficient household appliances results in less electricity use. The efficiency of the appliances is often indicated with an energy label in which A(+/++/+++) is given to the most efficient appliances.

Examples:

- creating hot water connections for a hot-fill washing machine and dishwasher. In the Netherlands, for example, both dishwashers and washing machines are almost always filled with just cold water and the device heats it electrically. It is generally beneficial , from an environmental point of view, to fill these appliances with hot water, particularly when the heat comes partly from a solar boiler.
- increasing gas cooking as electric cooking increases energy consumption: Two to four times as much primary energy is used compared to when cooking with gas. Gas networks are rarely used in local authority developments.
- the use of energy-efficient elevators: Always asks for consumption data and compare it with alternatives, do not use hydraulic lifts because they are inefficient.

LED-lighting

LED light bulbs use much less energy than traditional light bulbs, since they are 6-7 times more efficient. At the same time they have a lifespan of about 25 times longer. In this way they can reduce the energy bill for lighting with 75%.

When replacing fluorescent light bulbs by LED 10-15% of electricity can be saved. When replacing conventional light bulbs with LED even more electricity is saved: 75%.

Demotics

Demotics include all equipment and infrastructure in and around homes that use electronic information to measure, control and program functions for residents and providers of services at home. Thereby the time ventilation, heating, cooling and lighting is activated can be optimized. This is done by sensors that continuously measure presence of people, air quality, light intensity and temperature. With these sensors the energy demands for heating, cooling, ventilation and lighting can be reduced with ten to thirty percent.

Demotics can also provide information about the energy use of the house, increasing the awareness and thereby stimulation energy savings by the resident.

1.2 Generation

1.2.1 Photovoltaic (PV) systems

A photovoltaic (PV) system converts solar energy into electricity. The term derives from the combination of light (photo) being required to generate electricity (voltaic). Solar power is achieved by a physical process in a PV cell which provides a direct current (DC). The cells are linked together in series within a PV panel. These panels, and other required components such as inverters, cabling and installation requirements, are referred to as a PV system.

Most dwellings with PV are connected to the grid and no batteries are required to run the systems. In autonomous facilities, like parking meters, boats and buoys for navigation, batteries are needed to store power. Energy for grid connected systems tends to be used in a house or residential building as much as possible. Only the surplus is supplied to the grid.

Details on solar architecture can be found on www.iea-pvps.org (International Energy Agency, IEA), or www.pvdatabase.com where there is a great deal of information about solar power projects and products across the world.

PV cells, the technique

A PV cell consists of a semiconductor material that produces electricity when light shines on it. Silicon is the most common material and three types of PV cells are made of this:

- Multi-crystalline or polycrystalline silicon (p-Si): This is the most common type of silicon used for PV cells. The cell's colour is usually rich shades of blue and sizes range from 10 x 10cm to 15 x 15cm. The efficiency of these PV cells exceeds 16%.
- Monocrystalline silicon (m-Si): The colour of the PV cells is uniformly grey or dark blue. They come in sizes that range from 10 x 10cm to 15 x 15cm. The efficiency of these PV cells exceeds 17%.
- Amorphous silicon (a-Si): The colour of these PV cells is brown to black and they are applied in a very thin layer on the support material. The efficiency of these cells is around 6%. In a model with three layers (triple), this could increase to approximately 10%.

Besides silicon, other semiconductor materials are used in PV:

- CIS or copper-indium-diselenide: approximately 9% efficiency
- CdTe or cadmium telluride: around 8% efficiency

PV cells are coated to reduce the reflection of sunlight. This colour determines the extent of the reflection reduction; a dark blue or black coating gives the least reflection. There are other colours options, such yellow, green, brown, grey and purple, but their efficiency decreases by 10% to 30% compared to dark cells. PV cells based on polymers (plastics) and organic materials are currently being developed.

PV panels

PV cells are connected in series and housed in a panel called a PV panel or PV module. There are no standard sizes for photovoltaic panels. Panels are available with or without a frame, and frameless panels (laminates) can be treated as ordinary glass windows. The thickness of a panel without a frame is 5 to 8mm. A panel including frame is approximately 70mm thick.

There are various options available with regards to PV panels:

- Multicrystalline- and monocrystalline PV should always be placed behind glass..
- Other options can be also be placed behind glass or on a flexible surface, such as a plastic film. A special type of PV panel comes in the form of glass tubes that have amorphous PV evaporated inside. The tubes are attached to metal racks and can be laid on flat roofs. Little or no ballast is needed because they are fairly impervious to wind due to the open space around the pipes.
- Laminates can be produced in virtually any form, but extraordinary shapes will incur additional costs.
- Translucent or semi-transparent PV panels can be implemented in varying degrees of transparency, so they can be used as permanent blinds.
- Roof and façade integrated PV panels (except for amorphous PV) must have sufficient cooling. The higher the temperature of the PV systems, the lower the return will be. Cooling can be achieved by applying a cavity between the PV panels and the rear wall or roof construction, which is generously connected to the open air. A pitched roof with a cavity of 50mm will be sufficient for cooling through natural ventilation (wind).

Inverter

An important part of a PV system is the inverter. This converts the by the PV panel produced direct current (DC) into the grid's alternating current (AC). Grid-connected inverters ensure that the generated electricity is as powerful as that from the public grid. Security and control equipment will ensure that no unwanted currents and voltages enter the circuit. Grid connected inverters only work when they are connected to the grid.

There are a number of available options in terms of inverters:

- The inverter can be installed on each PV panel (mini-inverter): The inverter is connected to the back of each PV panel. Once the inverters (AC modules) have been fitted, a maximum of 4 to 6 panels per electricity unit (up to 600 Wp) can be connected directly to the household power supply.
- A home inverter (or central inverter, string inverter) can, for example, be placed by the meter or in the loft. In stacked housing constructions these can be fitted in a separate cupboard in the stairwell so that the inverter can be accessed by third parties, such as a manager or technician, without having to enter the house. The room or cabinet in which the inverter is placed must be well ventilated.
- PV systems for homes or a residential building can be connected to an inverter in a special area (central inverter). This should be well ventilated as inverters should not become warmer than 45 ° C.

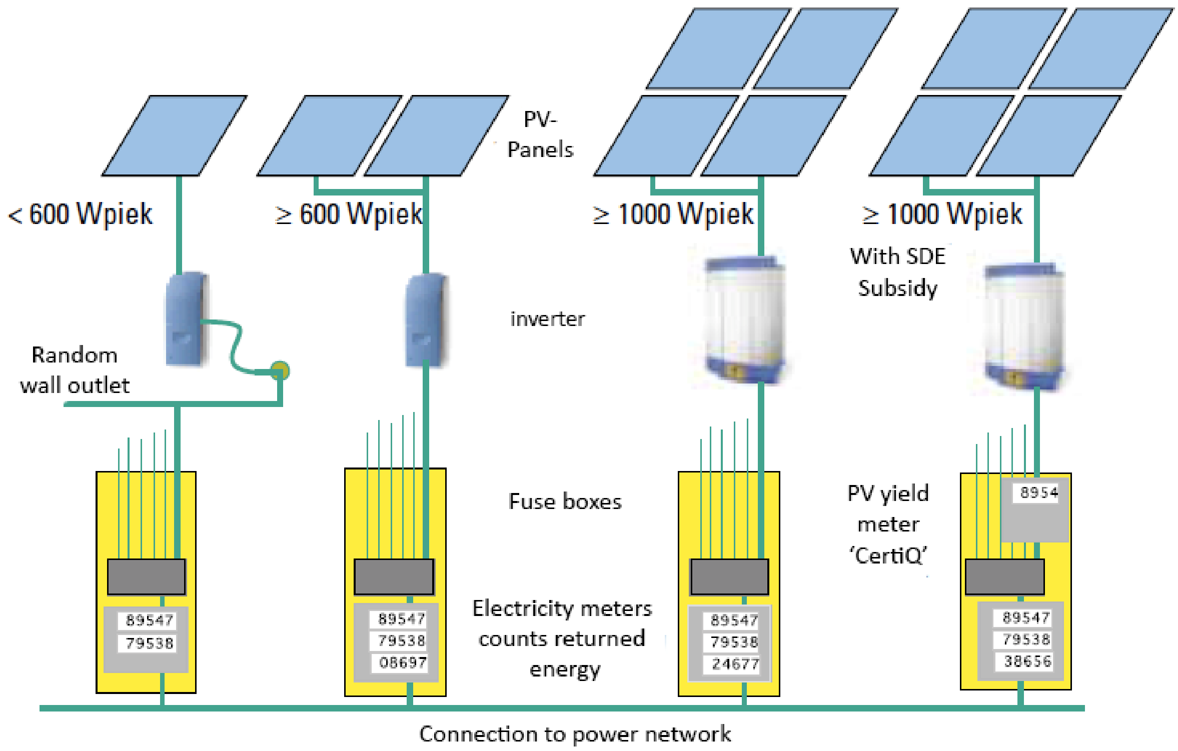

Figure 1.1. Ways to connect PV panels to the grid. Panel 1: Use any outlet in the house. This will bring power to the meter. Panel 2: Use a house inverter. Panel 3: Use more than one inverter. Panel 4: Use inverters + a meter so that the amount of electricity supplied to the grid can be measured

The conversion of direct current to alternating current by the inverter results in 2-8% electricity losses. At the same time some equipment like batteries, LED light and USB-ports work with direct current, resulting in double conversion losses. Energy can be saved by using a part of the generated electricity directly with the these appliances, resulting in a lower amount of energy that needs to be converted to the alternating current of the electricity grid.

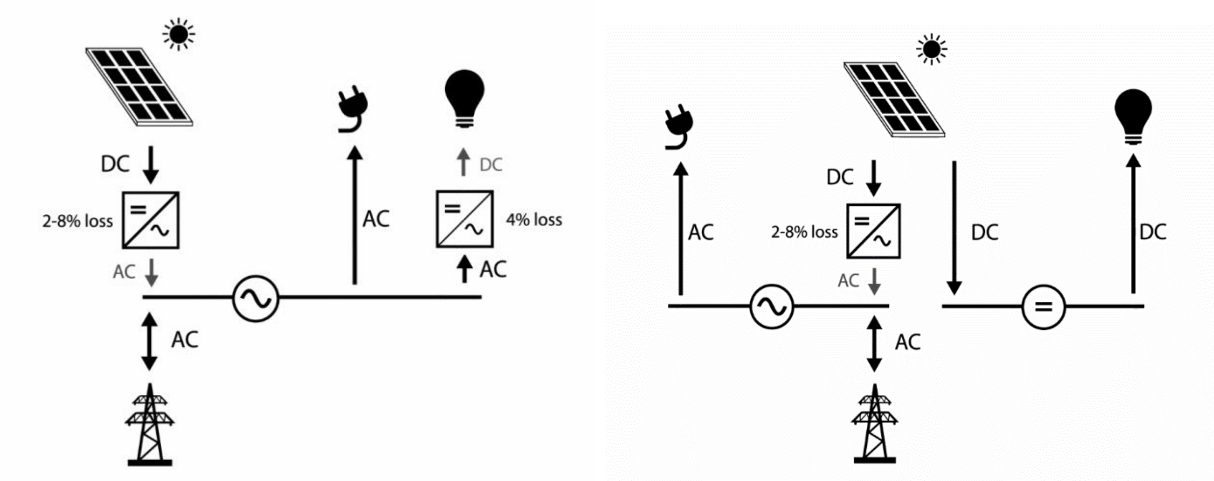

Figure 1.2 Left: traditional situation in which the electricity of the PV panel used by the LED light bulb is converted twice. Right: optimized situation, the LED light bulbs uses the produced DC-current, resulting in less energy that needs to be converted.

Yield

The yield of a PV system depends on the:

- efficiency of the system
- size of the system (power)
- amount of sunshine that shines on the panel.

Return

The amount of sun that shines on a horizontal roof area in mid-Europe is roughly 1000 kWh per m^2 of solar energy per year. The efficiency of a PV system with crystalline PV cells (16%) has a maximum annual yield of 160 kWh of electricity per m^2 of PV panel. With amorphous PV cells (6%), the maximum is around 60 kWh. In both cases, this is using the most beneficial orientation and inclination.

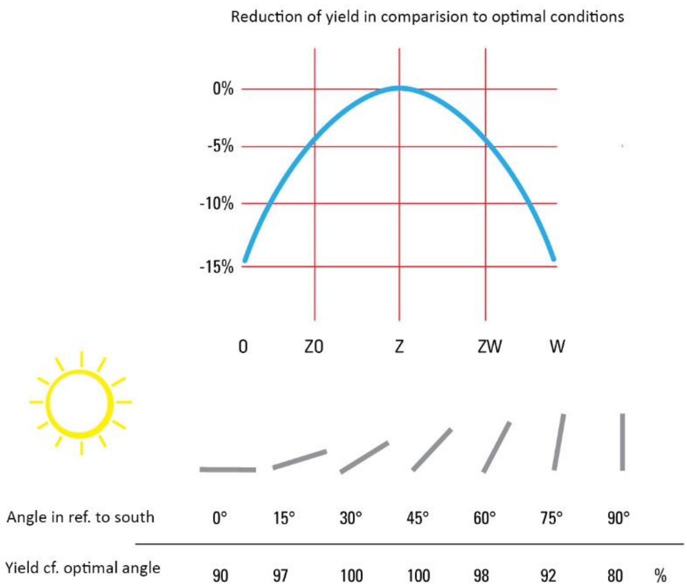

Figure 1.3: Yield of a PV panel in relation to its orientation and angle

Sunshine

The maximum yield of a PV panel is achieved by:

- a south orientation (optimum 5° from the south turned west)
- a roof angle of 36°.

A reasonable variation in the angle and orientation is possible without there being too much of an effect on the yield (fig. 179).

Yield indication

It appears that, in mid-Europe, an average year has approximately 850 full load hours of sunshine when using the most beneficial orientation and slope. Within the 850 hours, the average yield losses are taken into account. An important indicator for each type of PV system is the 'specific yield' of the unit in kWh / kWp per year. This ratio reflects what one installed kilowatt peak (kWp) of solar capacity per year of electrical energy (kWh) yields.

Shading

The yield of a PV panel drops dramatically when the panel is partially shaded. This is because the PV cells are connected in series and usually in a number of these per panel. When a cell is shaded, the entire series will fail to provide any power. Panels are also installed in series, so the same effect can occur with full panels.

Ensure that no shading occurs through the roof structure, installation, ventilation units or any trees or solar panels.

The relationship between radiation and shading loss is indicated in fig. 180. For example, if a south-facing PV panel is placed at the optimum 36° angle and less than 5% radiation loss, then an angle barrier of a maximum of approximately 12° should be held on the bottom of the PV panel.

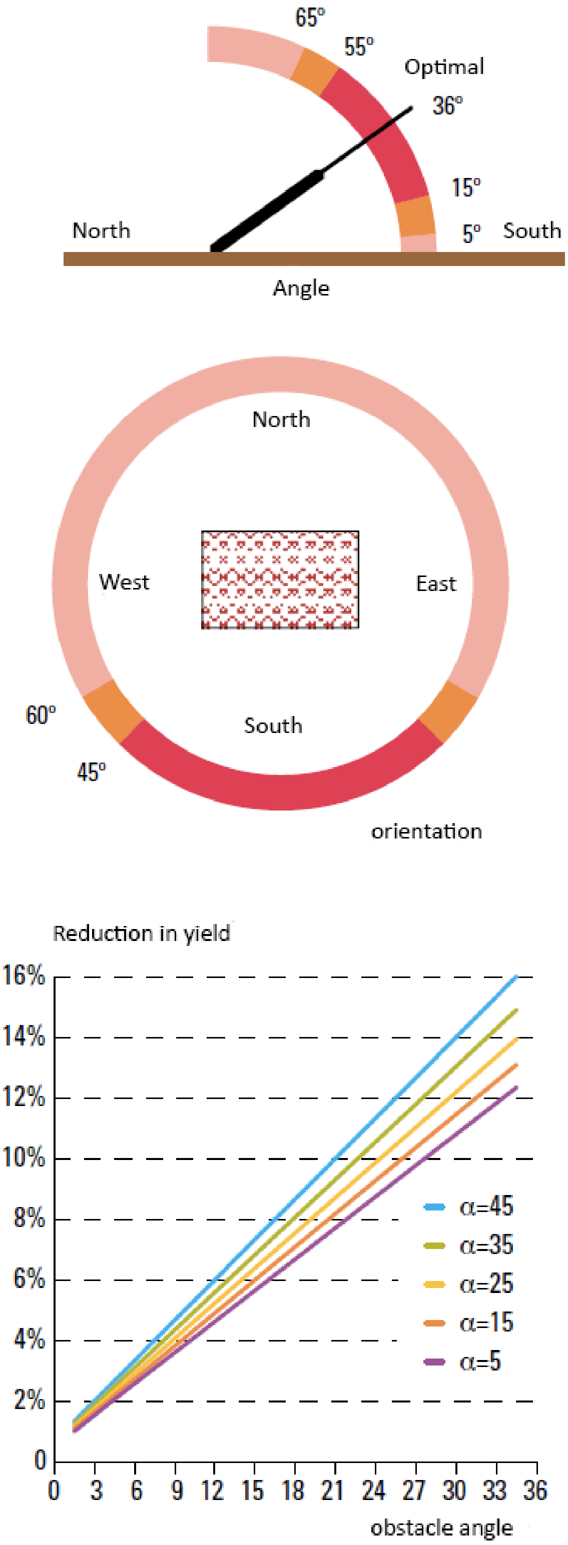

Figure 1.4. The relationship between the angle of the PV panel and the reduction in yield

Integrating PV systems into the building

PV panels can be integrated into:

- roofs
- façades
- conservatories and atriums.
- Photovoltaic panels also serve as blinds.

Roofs

In residential applications the use of PV on, or near, the top of the house is most common as it is least likely to be shaded by buildings and vegetation. Furthermore, it is usually the largest available continuous surface (fig. 181).

There are a number of options:

- Standard PV panels fixed in the roof profile: On pitched roofs there is usually a water protective film under the panels.
- PV panels on a standard (metal) support structure located on top of the roof: This is for flat and pitched roofs.
- Roof tiles with integrated PV cells.
- PV cells integrated into glass roofs (see below).
- PV foil pasted on metal roofs.
- PV integrated into plastic sheet roofing.
- PV deposited on an inner glass tube.

Benefit

Panels on flat roofs can be positioned towards the sun independently of the configuration of the house.

Figure 1.5 An example of integrated PV panels in a roof. This is the 'Stad van de zon' (city of sun) demonstration project. Each roof has 3600Wp installed. The yield is around 3400 kWh/yr. This type of PV was awarded the 'Dakaward' (roofaward) 2004. Design BBHD architects, Development VBM (vos Alkmaar) Projectleader Willem Koppen, contractor Heddes Bouw, PV producer BP-Solar, built in: 2003

Façades

PV can be attached to a façade (fig. 1.5). It may be the form of 'loose' PV panels or PV integrated into windows and/or glazing.

Disadvantage

In a vertical arrangement, only 70% of the maximum amount of sunlight is received and the risk of shading is great. To combat this, display panels (glazing with partly covered with PV cells) should offer some architectural options because they temper daylight and sun.

Fig. 1.6: In the sustainable skyscraper redevelopment Bieslandsekade by Woonbron Delft, a total of 260 m² PV panels were installed during the refurbishment. The PV panels are integrated into the façade, roof and balconies. The PV panels on the roof also serve as sunshades and those on the balconies at the same time ensure privacy. The solar electricity generated provides nearly all public facilities in the ten-story building such as lifts, lighting and mechanical ventilation. Client: Woonbron, Architect: Van Schagen architects, engineering and installation PV: BST, Elektron, advice: W / E consultants. Built in: 2003

Greenhouses, conservatories and atriums

'See through' panels in atriums offer all kinds of options to ensure that roofs and façades bring in sufficient light, as well as blocking out some of the heat that could lead to overheating.

Blinds

PV panels can serve as blinds, fixed and movable (e.g. plate-blind). Again, 'see through' PV can be applied.

Recommendations

- Orientation: Choose an orientation between south east and south west, south-optimal (and 5º west).
- Inclination: Choose an angle of at least 5° to prevent dirt from sticking to the panel. Ensure that the bottom of the panel does not have a raised edge so that water does not collect on the panel itself.
- Ventilation: A high temperature reduces the yield of PV modules (this does not apply to amorphous PV). Ensure the panels stay cool. For example, through an air cavity behind the top and bottom of the panel that is in contact with the outdoors.
- Shading: since PV cells are connected in series their efficiency drops dramatically when the panel is partially shaded. Keep this in mind for the design and for future building plans (also in the surroundings).
- Accessibility: It is important, for maintenance purposes, for panels to be accessible. However, they should not be so accessible that they become an easy target for thieves.

1.2.2 PV-thermal panels

Integration of solar thermal collector and PV panels into one system, which results in the generation of both thermal heat and electricity. The thermal collector is integrated in the back of the panel. A fluid runs through the solar collector panel to absorb the solar heat.

With this combination the efficiency of the electricity generation compare to the conventional PV-panel increases because the fluid of the solar collector will cool down the panel (the higher the temperature of a PV-panel, the lower the output). The heat generated with the PVT-panel will have a lower temperature (about 35ºC) than the output of a solar thermal collector but can still provide low temperature heating of the building. If this generated heat will be used for domestic hot water an electric boiler or a heat pump booster needs to be added to the installation system of the building.

The PVT panels are more expensive then standalone PV or solar collectors and they are a relatively new technology and thereby not commonly applied yet.

1.2.3 Small wind turbines

The wind spins the blades and this movement drives a turbine, which converts this energy into electricity. Windmills come in all shapes and sizes. Generally, at a height of less than 30m, urban wind systems are used. These systems are mountable on roofs and their axis is sometimes not horizontal, but vertical, whereby the rotational movement is less noticeable. Generally, the small windmills are less (cost) effective, because the length of the blades and the wind strength have a crucial role in the generation of electricity.

Wind turbines are generally less suitable for in, or near, the built environment. This is mainly due to a relatively low, non-stable wind supply, however, noise and visual obstruction may play a role as well. In special cases, building-related small turbines are worth considering. In these optimal conditions a small wind turbine can achieve an efficiency of 35%. However often the efficiency is between 15-25%.

Wind power generated by large turbines is relevant if they are situated on the borders of building areas that are adjacent to open- areas or water.