City of Munich
Department of Public Health and Environment

Handbook

Change the Power - (Em)Power to Change
Thematic Meeting "Renewable Energies"

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This handbook ist part of the project "Change the Power, (em)Power to Change" and was supported by the European Union. It was commissioned by the City of Munich's Department of Health and Environment and written by the company IB Sing. The content must not be percieved in any way as representing the position of the European Union.
More information: www.overdeveloped.eu

Dear readers,

for the third time the Department of Health and Environment has participated in a three-year EU-project on the 2030 Agenda and you are holding a concrete result of this project in your hand: a handbook that summarizes the content of a two day conference on renewable energies.
In order to raise awareness for the role of municipalities in energy supply as well as in energy consumption, in 2018 the Climate Alliance launched the joint educational project Change the Power - (Em) Power to Change - cities and municipalities for the SDGs and climate justice together with 20 partners from 11 countries.

An innovation in this project particularly was the exchange of experience and know-how inbetween the project partners. For this purpose in each project year one or two regional topical conferences were held. The City of Munich hosted the second of these conferences on July 25th and 26th 2019. The 25 participants learned about the advantages and disadvantages and the functionality of wind-, water- and solar-energy from experts. The topics of citizen participation and citizen energy were discussed as well. Besides theoretical inputs, excursions to an Isar hydropower plant of the Munich Municipal Utilities Company and to wind- and solar-systems in the municipality of Fuchstal near Landsberg am Lech were also part of the program. The citizens of this small Bavarian community are now using their private energy wind turbines and solar systems to produce electricity beyond their own needs and are looking forward to good returns on their investments. On the evening of the internal regional conference, all interested persons furthermore could find out in a public event about the possibilities how electricity can be generated by themselves. This event in cooperation with the NGO Women for a Common Future (WECF) was part of the 29 ++ climate week of the district office in Munich.

Two delegates from the indigenous Asháninka people from Munich's climate partnership with the Rio Negro region in the Peruvian Amazon rainforest also attended the entire conference and contributes their visions to the interchange.

More information about the EU project can be found at
http://overdeveloped.eu/en/overdevelopedeu.html

Enjoy reading this handbook

S. Jacobs

Head of the Department of Health and Environment
City of Munich

HANDBOOK

Change the Power - (Em)Power to Change
Thematic Meeting "Renewable Energies"

Munich

07/25/2019 – 07/26/2019

INGENIEURBÜRO SING GMBH
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OUTLINE

PREFACE

This Handbook provides background information about the talks given by *Ingenieurbüro Sing GmbH* during the thematic meeting "Renewable Energies" in Munich (25th to 26th of July 2019).

The Structure of this Handbook follows the five talks of the thematic meeting. These are:

- Introduction–Renewable Energies–German Energy Transition
- Hydro Power
- Photovoltaics
- Wind Power
- Public Participation in Renewable Energy Projects

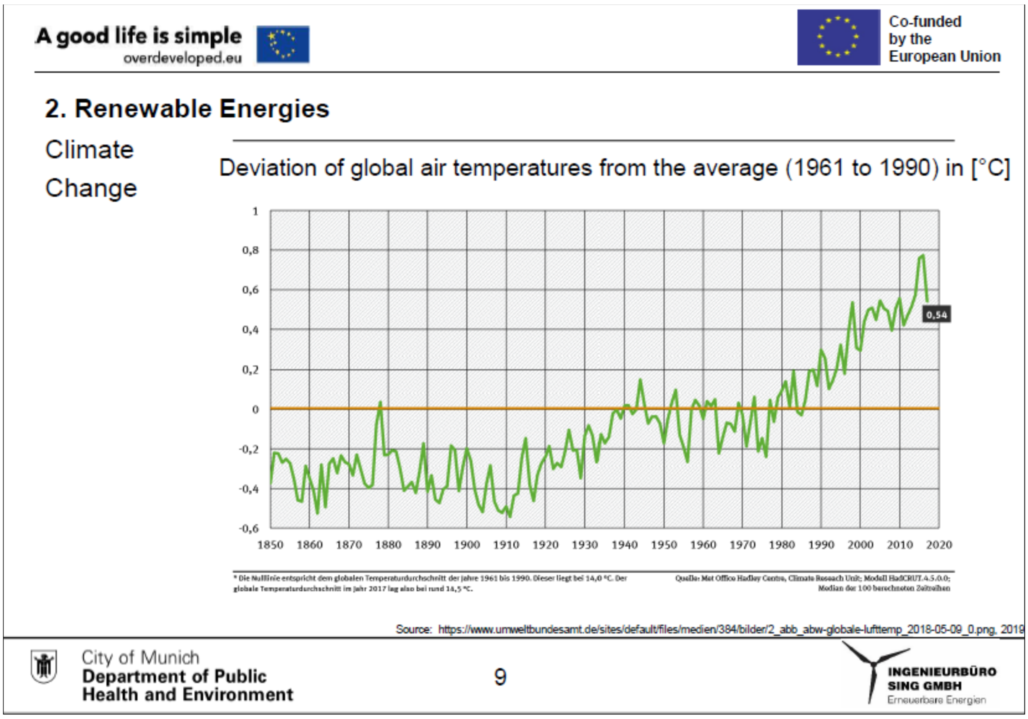
Therefore, the information is given using the slides, which were shown during the talks.

1 INTRODUCTION – RENEWABLE ENERGIES – GERMAN ENERGY TRANSITION

1.1 Renewable Energies

When discussing renewable energies the most important question is: “Why do we need renewable energies and why is it necessary to change our ways of producing energy in such a significant way?”

Climate change and the environmental impact of our current, conventional way of providing energy and its consequences are important arguments for us to change our ways of energy production. The following slide shows the significant rising of air temperatures since 1850.

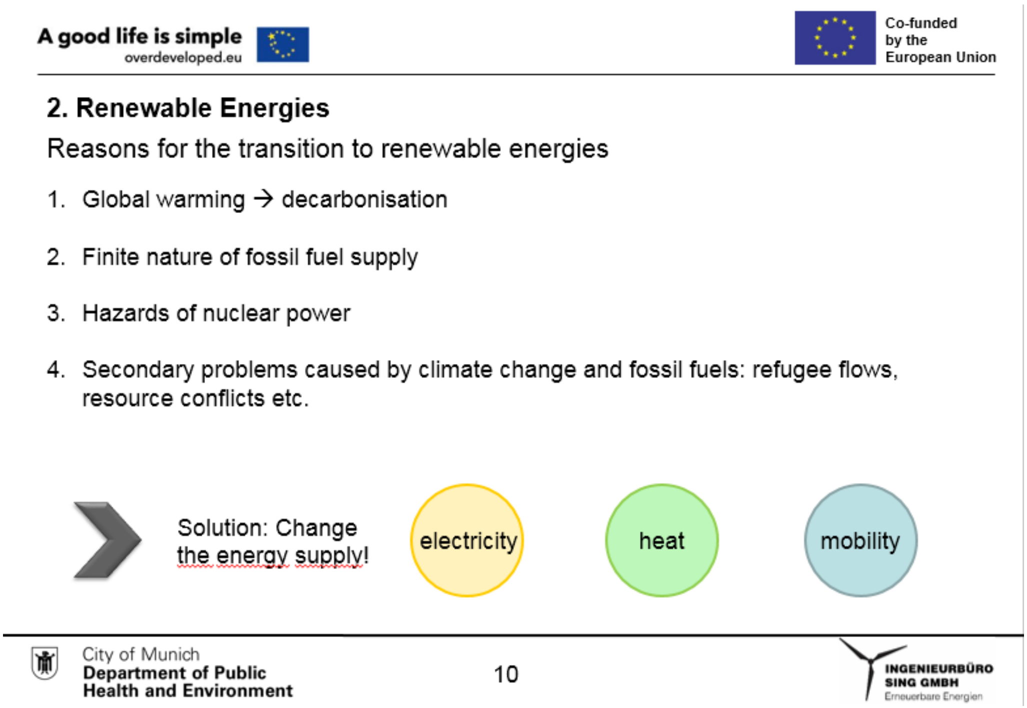


In this chart, the red line shows the average global air temperature of 14°C from 1961 to 1990. The deviation from this average over the last 150 years is shown in the green line. For the last 40 years, the average yearly temperature was higher than the red level, meaning that the temperatures have risen constantly.

This results in a loss of sea ice, acceleration of sea level rise and change of water temperature and water salinity resulting in a change of the weather systems. This has already led to longer periods of drought in some regions, wildfires that are more frequent and an increase in the number, duration and intensity of storms. This development is expected to continue and to get even worse.

All of this is a direct result of the emission of greenhouse gases. These emissions result mainly from agriculture, mobility and land use change as well as energy supply.

Besides the impacts of climate change and global warming there are also some other reasons for the usage of renewable energies as shown on slide 10.



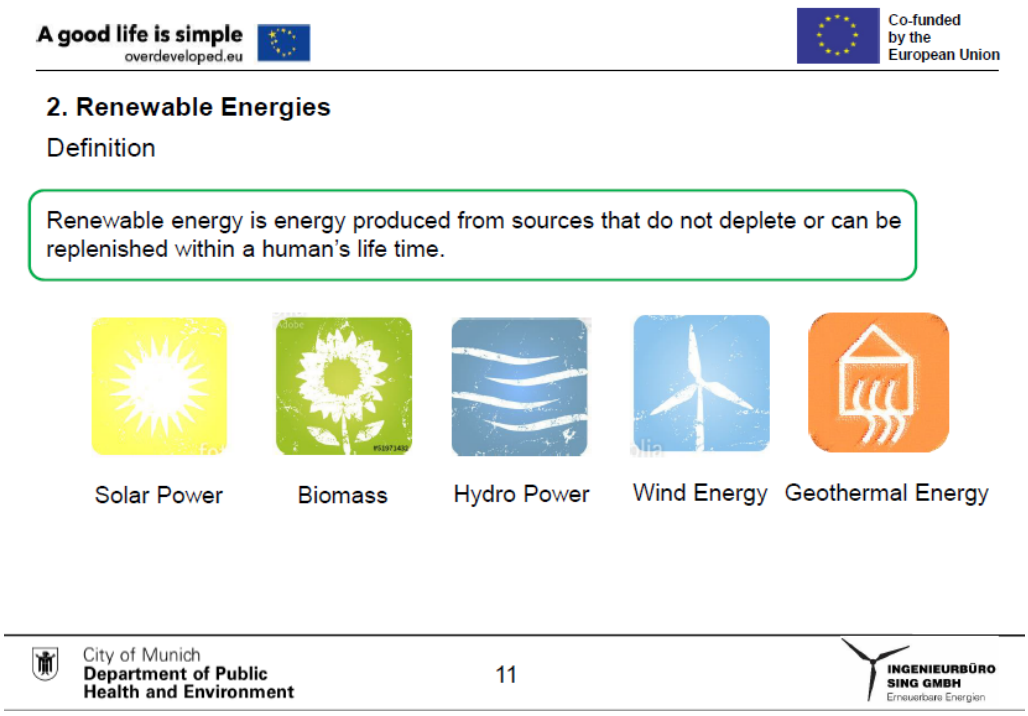
Other reasons include the resource availability of fossil fuels and the hazards of nuclear power, due to waste and due to accidents. The radioactive wastes of nuclear power plants will continue to harm human, animal and plant life for thousands of years.

Furthermore, there are secondary problems, which include not only refugees, but also intensified conflicts for resources.

To avoid these problems, we have to change the way we deal with energy in the sector of electricity, but also in heat and mobility.

A part of the solution to all of the problems mentioned above is an increased utilisation of renewable energies.

The following slide gives a definition of the term “Renewable Energies” and shows the most commonly used sources of renewable energies.



- Solar Power: ....
  Solar energy can be used directly. One part of using solar power is usage of photovoltaics, the direct transformation of solar into electrical power. But solar energy is more than that, it can also be used to produce heat, either for heating purposes or to transform the heat into electricity.The sun is the foundation of all other renewable energies – plants will not grow without sunlight, wind will not blow without irregularities in the radiation balance, rain will not fall without warmth and evaporation.

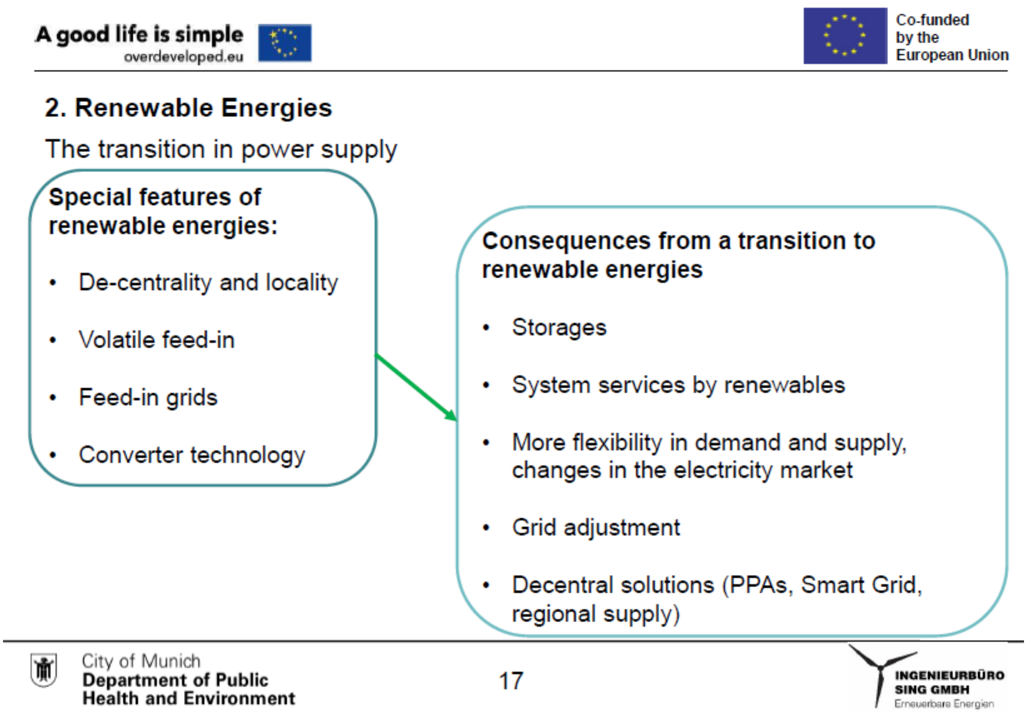
- Biomass:
  Many different kinds of biomass can be used for many different sorts of energies. One of the huge advantages of biomass is its storability. Bioenergy can be used for all energy sectors: Electricity, Mobility and Heat. However, there are disadvantages too. Examples are the impact on food production and land use conflicts, the effort in planting and harvesting, the costs and the necessity of big machinery, which in turn run on diesel and emit CO_2.

- Hydro Power: Hydro power has been used for hundreds of years to power mills. Today, hydro power plants are mostly used to generate electricity. Energy from water is also not (very) dependent on the weather and therefore deemed stable, but, as its usage is spatially limited to rivers and the sea, the potentials vary with the landscape. However, conflicts of hydro power utilisation and fish migration and nature protection are very common and need to be addressed.

- Wind Energy: Wind energy is still sometimes considered a "new" renewable energy – probably because the technology has changed so much over the last decades. Wind energy generates electricity – a lot of it, compared to the little space it uses. However, wind energy is probably the most controversial among the renewable energy types.

- Geothermal Energy.Geothermal energy rivals wind energy in terms of space consumption. It is the most invisible of the renewable energies, because it generates energy under the surface of the earth. Geothermal electricity is not yet competitive because of its high costs. Maybe one day it is worth it, but it is not currently. There are some main hindrances for Geothermal Energy. Instabilities resulting in earthquakes are feared to appear alongside geothermal power plants. In addition, long-term consequences of a cooling of deeper layers of the earth are still to be determined.

Changing our ways of electricity production and creating a system with more and more renewables has many consequences due to the special features of renewable energies. The special features and consequences of a renewable-energy-based system are shown in slide 17.



The energy transition is one from “energies for space” to “energies from space” and to de-centrality, one from steady to volatile feed-ins. Feed-in grids have to be changed, because the place where energy is generated and fed into the grid changes. In addition, technologies, like convertors have to be changed due to changed generation technology.

Varying times of feed-in result in a necessity of storage systems. Conventional power plants took care of system services. In order of keeping a steady grid frequency and voltage, system services like frequency control or supply of controlling power have to be provided by renewables. The electricity market has to deal with demand and supply in a more flexible way, and the grid has to be adjusted to these changes as well. Overall, decentral solutions of dealing with demand and supply in a more regional way may become inevitable.

1.2 German Energy Transition

The following chapter gives an overview over the status quo in Germany in terms of energy production. A special focus is being put on the sector of electricity.

The definition and goals of the German energy transition are written down in the German “Renewable-Energy-Act” as shown on the following slide.

3. German energy transition

The German Power-transition and its goals

Definition: Transition from using fossil fuels and nuclear power to a sustainable power supply by renewable energies

The current goals of the German energy transition in the electricity sector can be found in the “Renewable-Energy-Act” (Erneuerbare-Energien-Gesetz)

„The aim of this Act is to increase the proportion of electricity generated from renewable energy sources as a percentage of gross electricity consumption to

1. *40 to 45 percent by 2025,*
2. *55 to 60 percent by 2035 and*
3. *at least 80 percent by 2050.“*

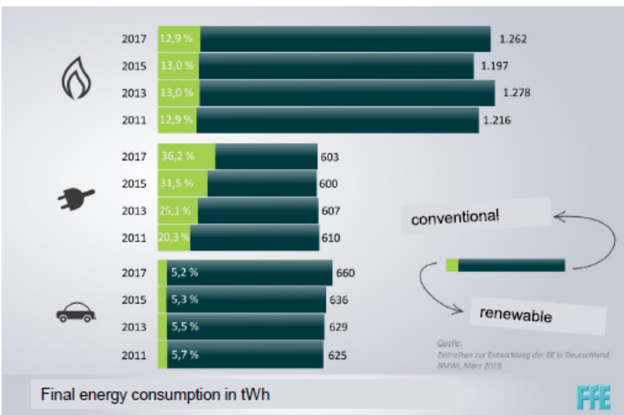
Source: https://www.beck-shop.de/salje-eeg-2017/product/16993575, 2019

The graph on slide 20 shows the energy consumption of all three sectors – and the part that is already provided renewably. Germany has made progress in the electricity sector, with the consumption going down (slightly) and the share of renewable energy rising from 20 to 36%.

Heat and mobility still have low shares of renewables. And the demand is rising – at least in the mobility sector.

3. German energy transition

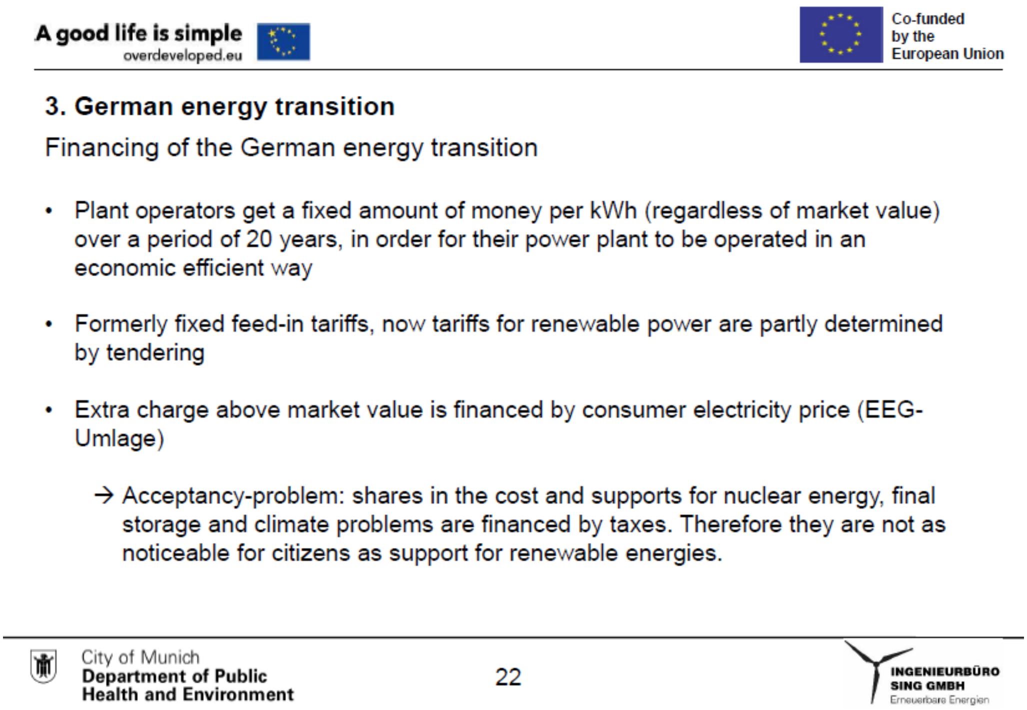
Previous achievements in the sectors of electricity, heat and mobility



Source: FfE 2019 (https://www.energie-innovativ.de/fileadmin/user_upload/energie_innovativ/Dokumente/Energiegipfel/AG_1/Vortraege/Impulsvortrag_Prof._Mauch_FfE_AG_1_Sitzung_2.pdf)

An important part of succeeding in changing the generation of electricity is the encouragement on the financial side. Slide 22 therefore shows the details of the financing of the German energy transition.

Realization of renewable energy projects is encouraged by financial benefits. However, opponents of the energy transition often use this as counter argument.

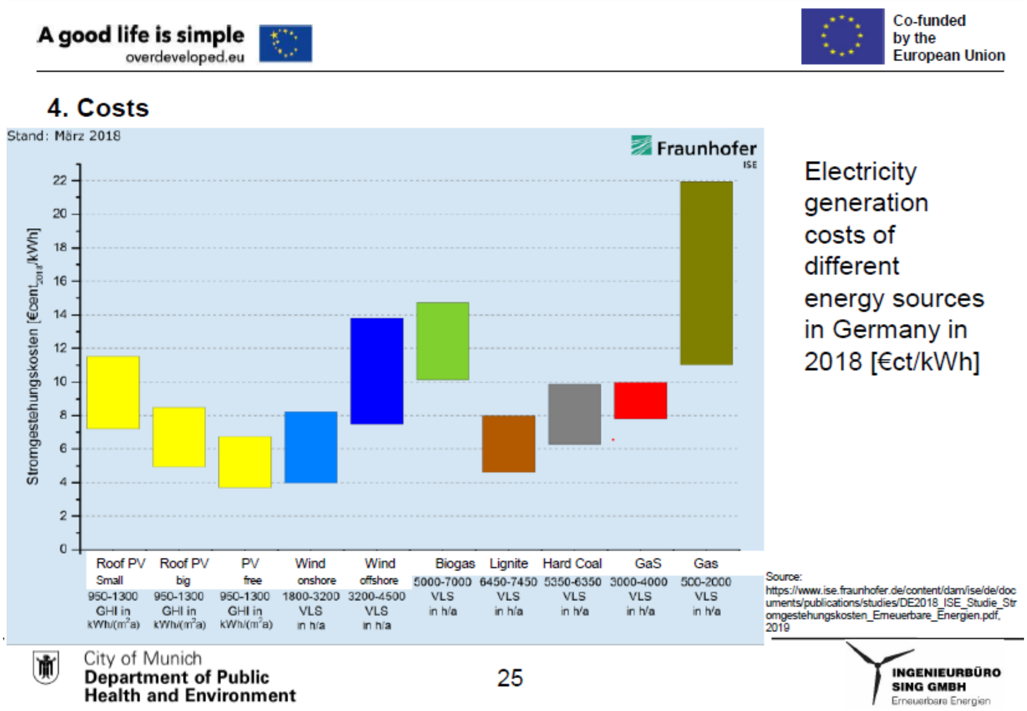


1.3 Costs

When talking about costs of renewable energies, levelized costs of electricity (LCOE) are used to compare different technologies. The unit for these LCOE is money per electricity generated (for example €/kWh). LCOE show how much money a technology needs to generate one defined unit of electricity.

Levelized Cost of Electricity: Costs for energy transition from another form of energy to electricity

The following slide shows the electricity generation costs (LCOE) for different energies.



Electricity production from coal is rather cheap – both hard coal and lignite. Gas is the most expensive one.

Among the renewables, PV (free = open space) and wind energy onshore have the lowest cost, ranging from 4 ct/kWh to 8 ct/kWh. Wind offshore is more expensive due to the higher installation costs. Biogas is significantly more expensive than coal and the other renewables, but still necessary to the energy transition as it is storable.

This diagram shows, that renewables are already competitive. Wind and PV already are the cheapest sources. The costs are predicted to decrease even more, as shown in slide 26.

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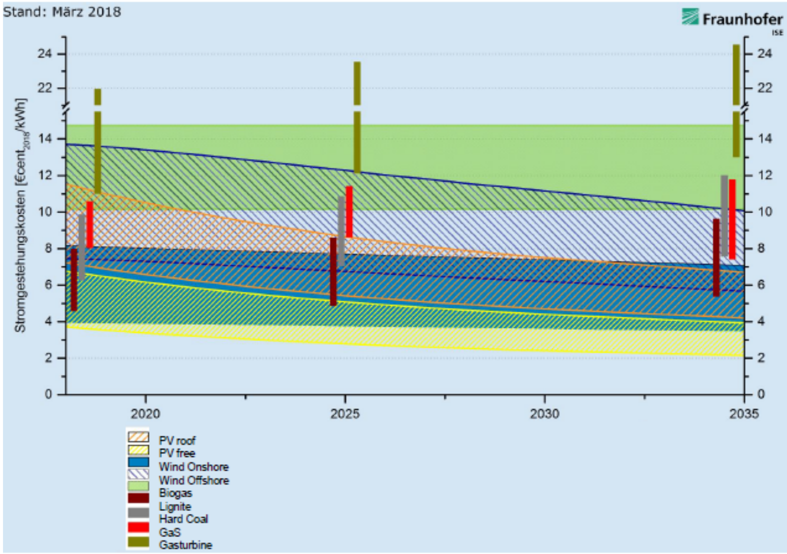
4. Costs



Electricity generation costs forecast to 2035 [€ct/kWh]

Source: based on: https://www.ise.fraunhofer.de/de/presse-und-medien/presseinformationen/2018/studie-zu-stromgestehungskosten-photovoltaik-und-onshore-wind-sind-guenstigste-technologien-in-deutschland.html, 2019, Legende angepasst

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1.4 Summary

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Summary

- Climate change, the finite nature of fossil fuels and the hazards of nuclear power necessitate us to rethink in the field of energy generation.
- Energy transition needs to happen in three sectors: Power, mobility and heat.
- Renewable Energy can be generated using wind power, hydro power, solar power, biomass and geothermal energy.
- The transition to renewable energies necessitates changes both demand-sided and supply-sided.
- The cheapest way to produce renewable power is the utilisation of wind energy (onshore) and photovoltaics.
- Costs for power production using renewable energies are predicted to decrease even further.

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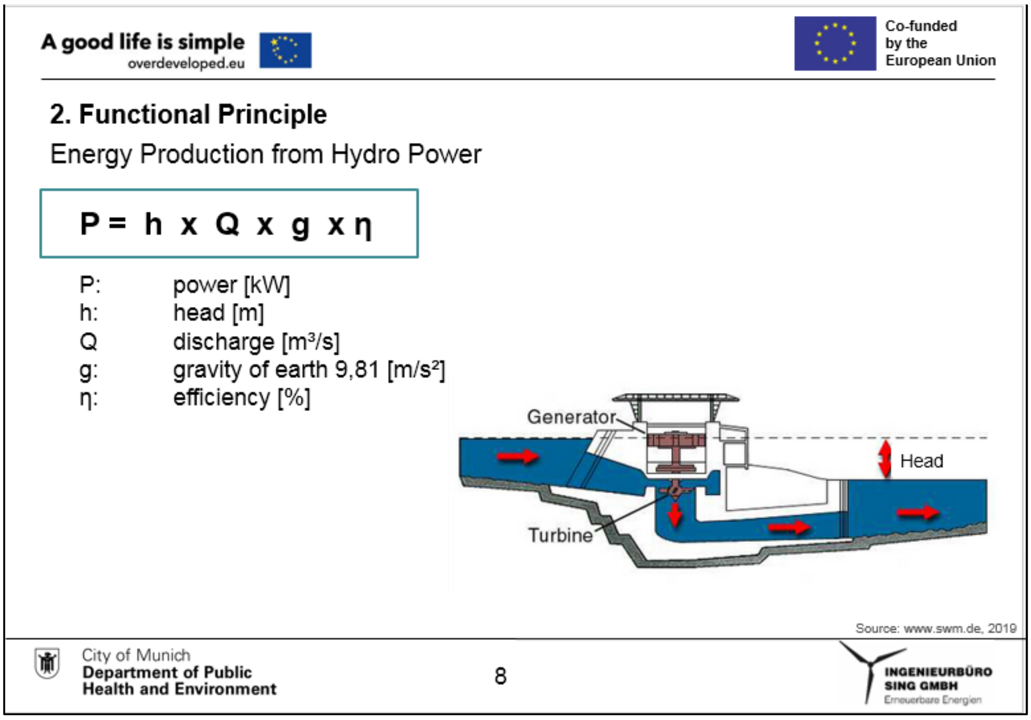
2 HYDRO POWER

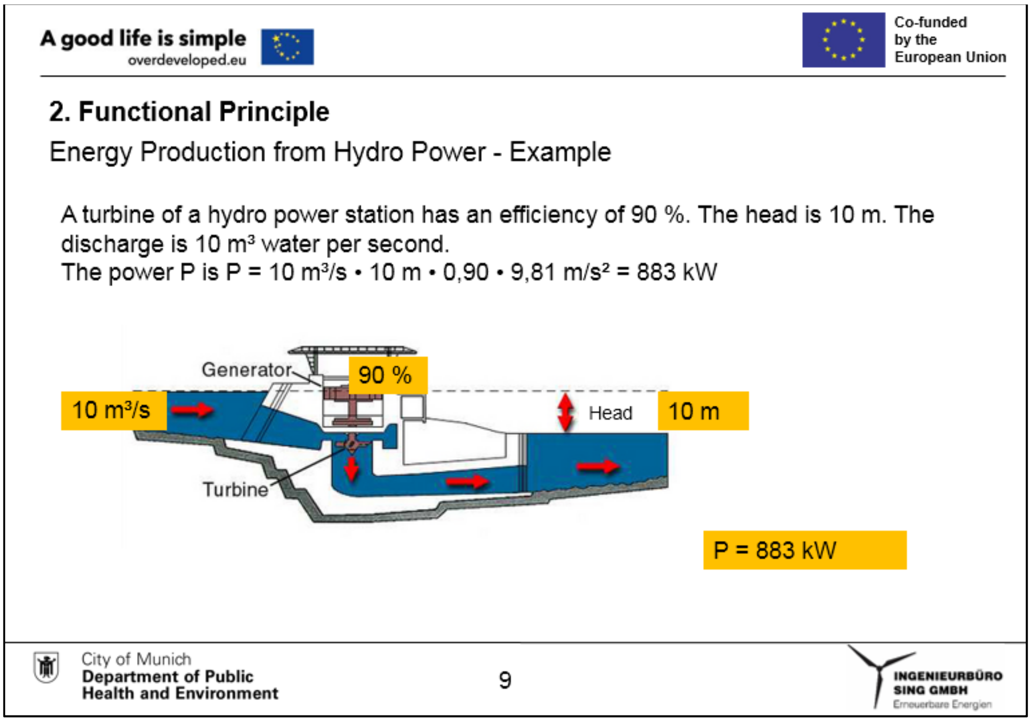
2.1.1 Functional Principle

Hydro power stations use the kinetic and potential energy of water to create electric energy.

2.1.2 Calculation of Power

The theoretic energy production of a hydro power plant is calculated using the formula shown in the following slides. The decisive criteria for power output are the difference of water levels of upstream and downstream water (head), the amount of water running through the turbine (discharge) and gravity of earth as well as efficiency of the power plant (generator, wiring etc.). Slide 9 gives an example of the calculation of the power P of a hydro power plant.

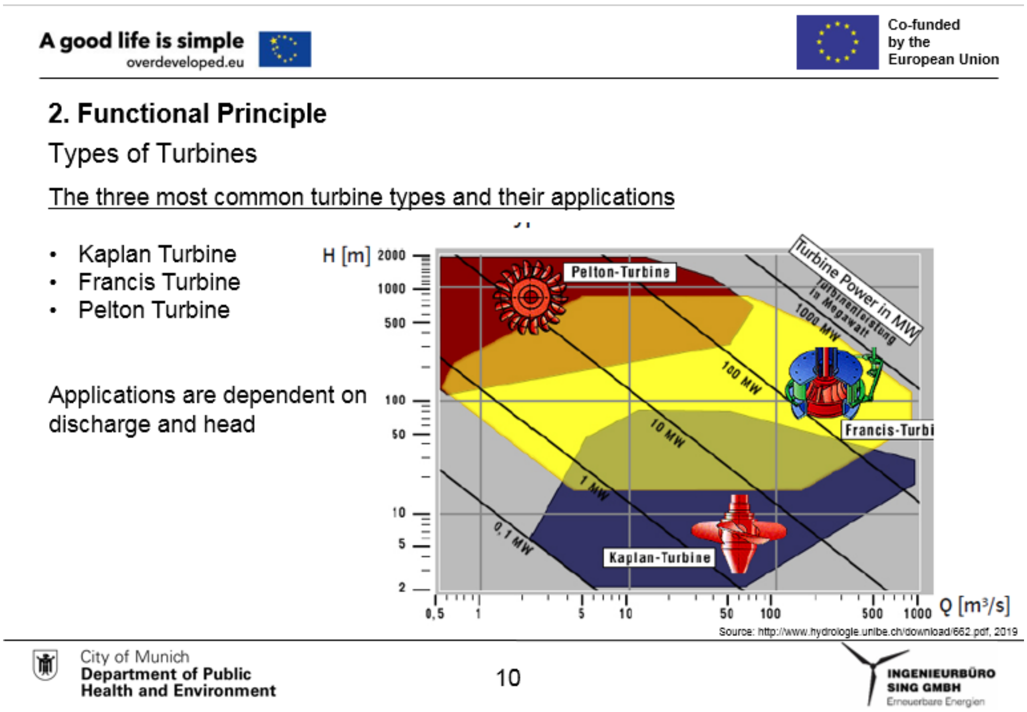




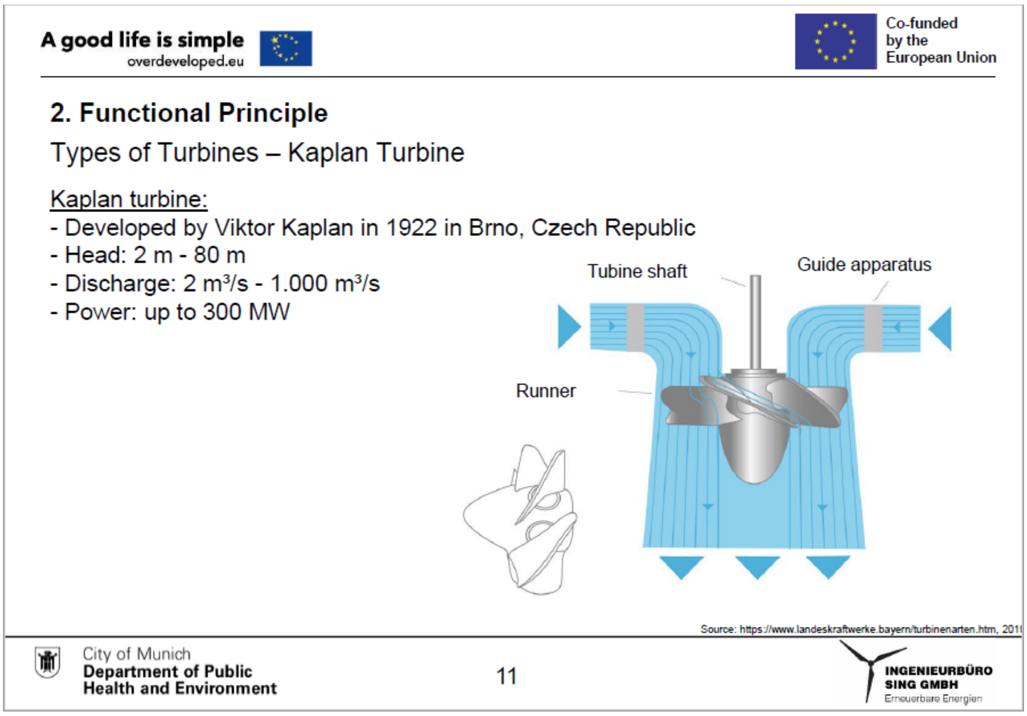
2.1.3 Types of turbines

There are three main types of turbines used in large-scale hydro power plants:

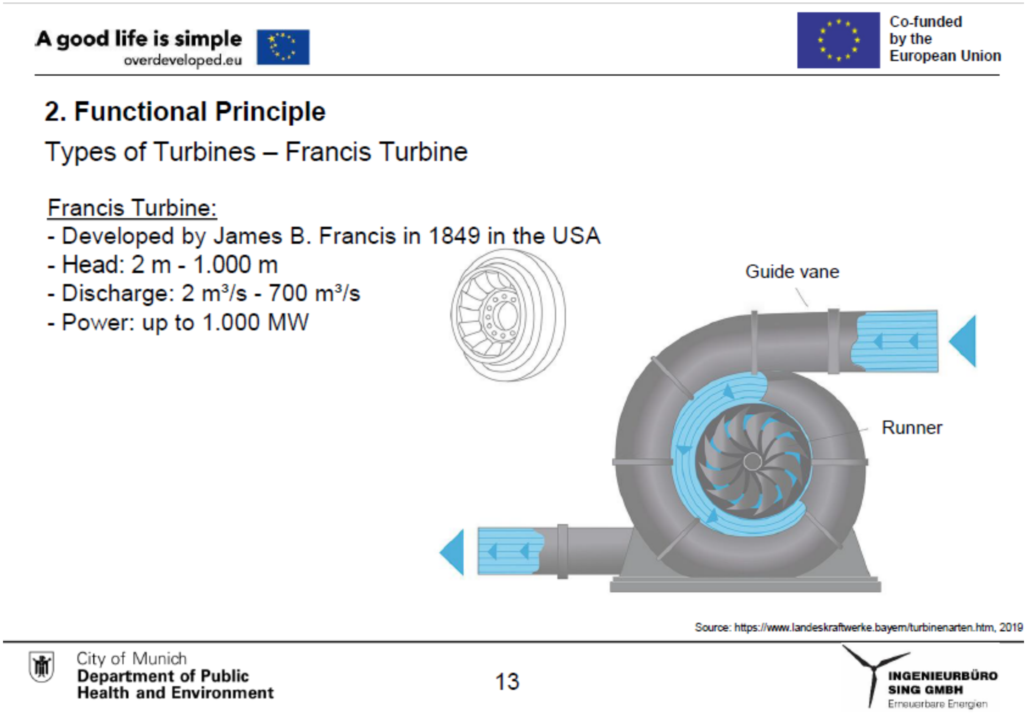
Kaplan Turbines, Francis Turbines and Pelton Turbines. Their application depends on head (H[m]) and discharge (Q[m³/s]) of the hydro power plant, each has an ideal range of ratio of discharge and head. This is shown in the diagram on the following slide.



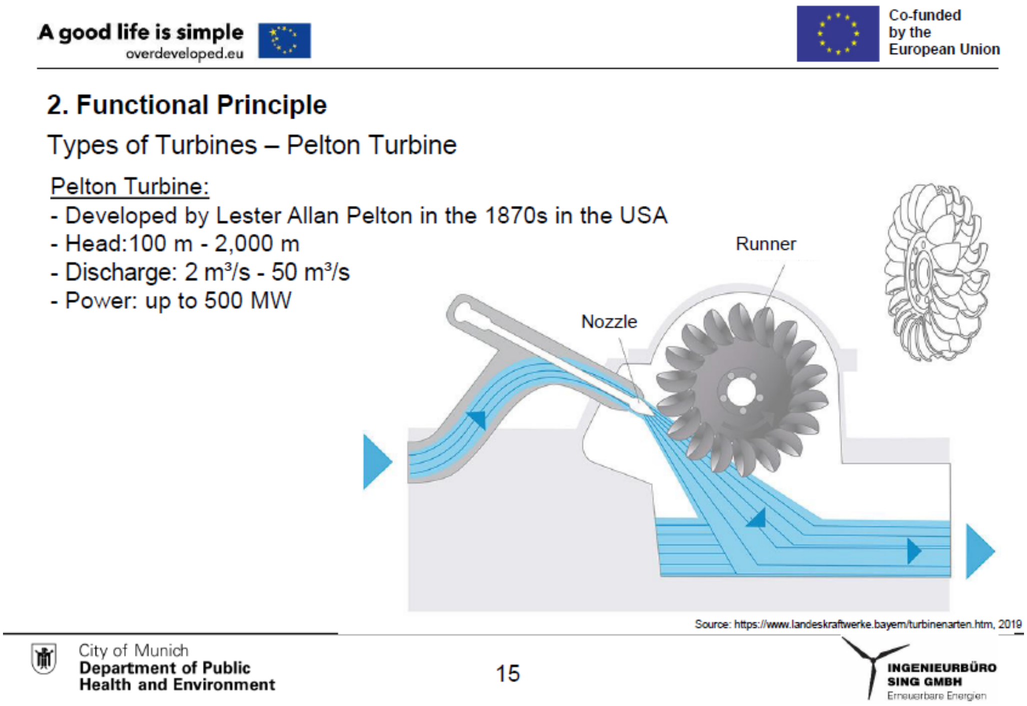
Kaplan Turbines are mostly used for lower heads and medium to high discharges. Water runs through the blades of the turbine and creates a lift force that causes the rotation of the runner and blades.



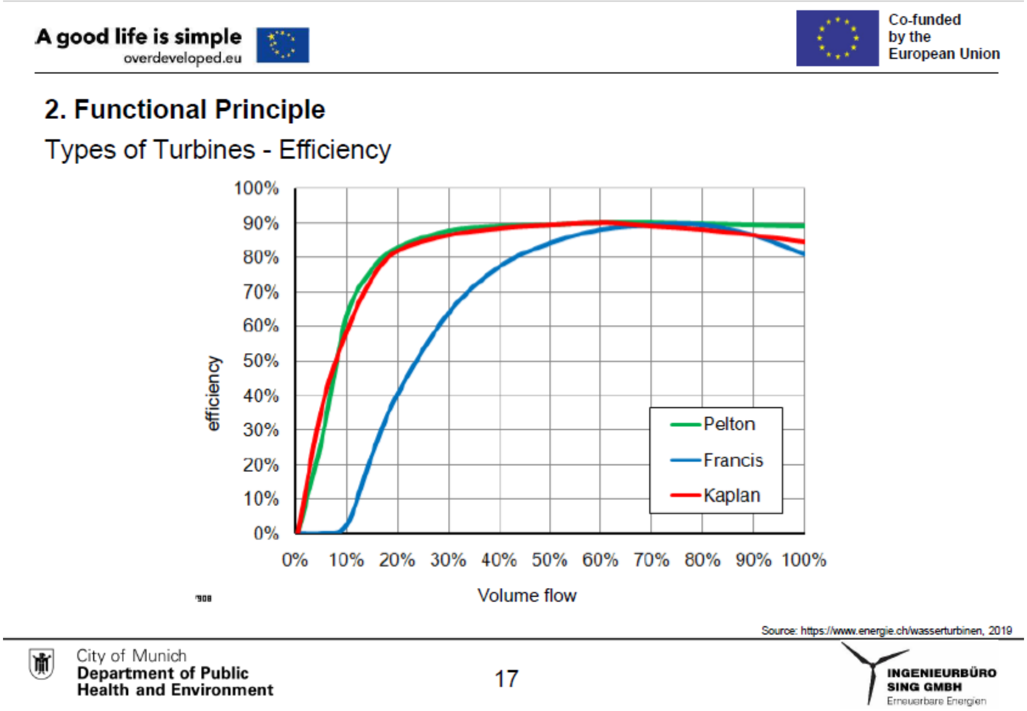
Francis turbines are eligible for all kinds of discharges and are mostly used for higher heads. Water enters the turbine through a guide vane and moves the runner by a combination of reaction and impulse force. With Francis turbines, very high power outputs are possible.



Pelton turbines are used for very high head power plants with comparably smaller discharges. Water runs through a nozzle that creates a high-speed water jet. This jet meets the buckets of the Pelton turbine thus creating a rotating force.



Efficiencies of hydro turbines are very high in general but dependent on the degree of capacity utilization. With ideal setups efficiencies of higher than 90 % are reached.



Kaplan, Francis and Pelton turbines are the most commonly used turbines in large-scale hydro power plants. However, for smaller power plants there are many other types of turbines.

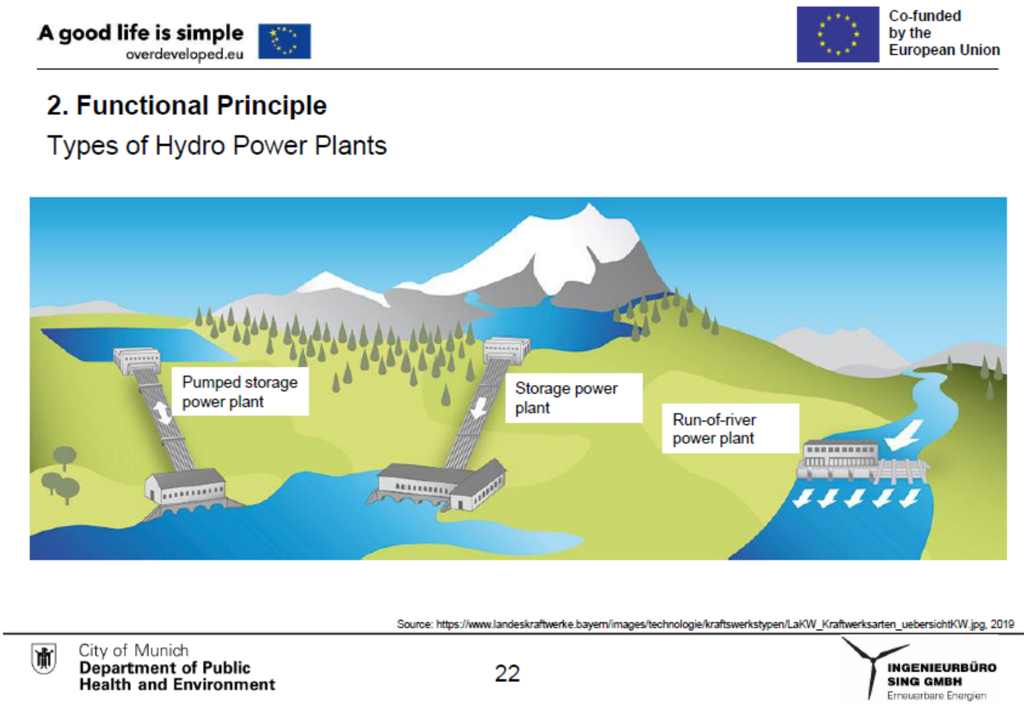
- **Water wheels** have the longest tradition in hydropower usage. Depending on the way the water meets the wheel there is a distinction between overshot, undershot and breast wheel.

- Passing Water creates the rotation of the **Hydrodynamic screw**. The rotation of the drive shaft is then transformed into electrical energy in a generator. Hydrodynamic screws are very fish friendly.
- **VLH (Very Low Head) turbines** is suitable for sites with very low head (about 1,5 m to 3 m). The turbines have big diameters creating a slow rotation of the turbine. This, along with the low pressure changes is one reason for its fish friendliness.
- A part of the water passes a shaft and then powers a turbine in the **Shaft Power Plant**. Therefore, this power plant is also eco-friendly as fishes can pass. Additionally, bed load of the river is not affected.

2.1.4 Types of hydro power plants

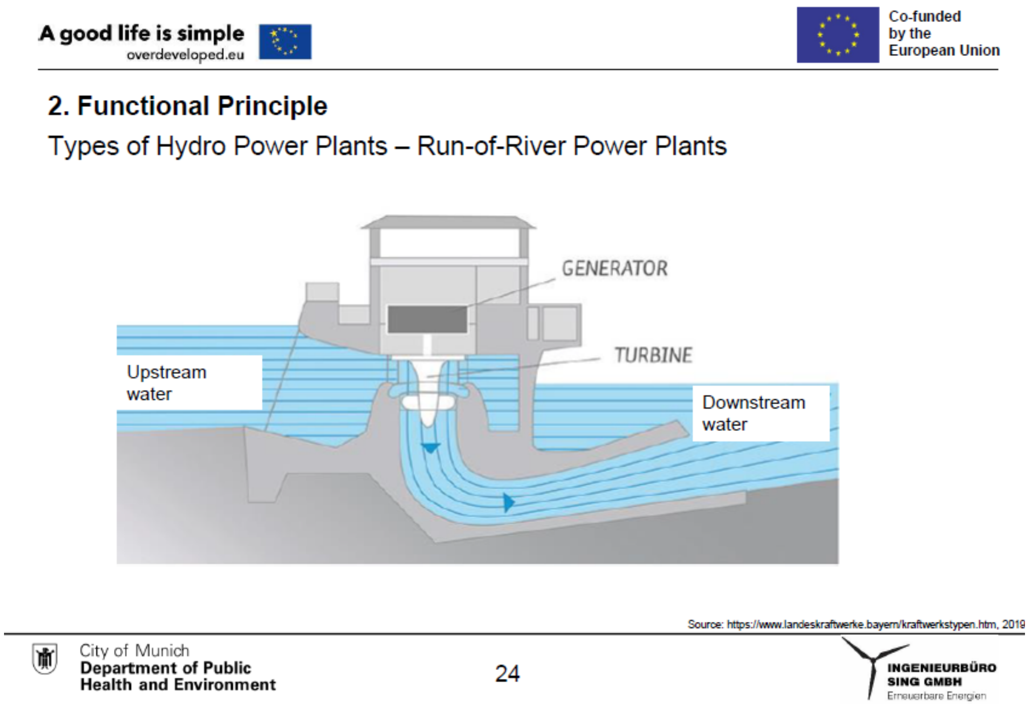
There are three main types of hydro power plants:

Pumped storage power plants, storage power plants and run-of-river power plants.

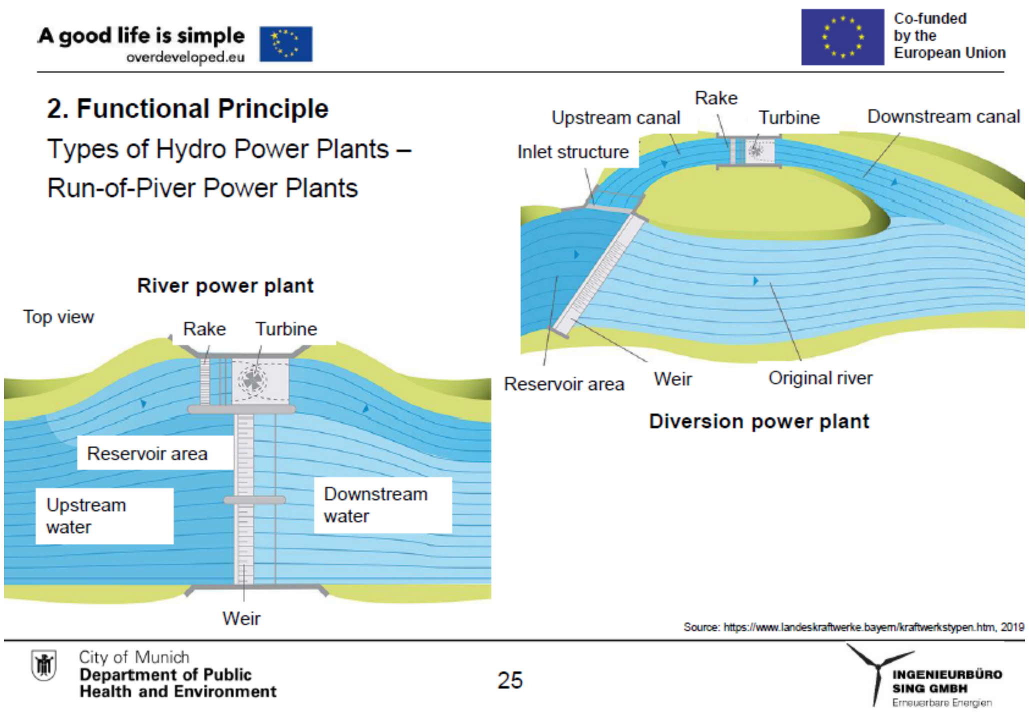


Slide 24 shows an exemplary run-of-river power plant. **Run-of-river power plants** use the flow of the river. Therefore, electrical power is produced all the time.

In a run-of-river plant upstream water passes through the turbine driving the generator.



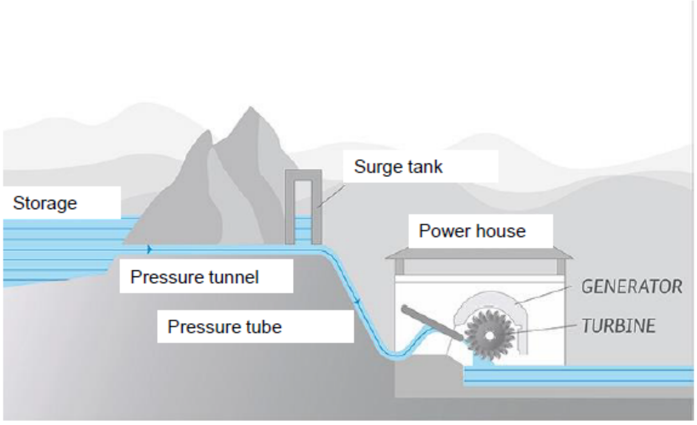
Run-river-plants are placed within the river (river power plants) or in a branch of the river (diversion power plants).



High-headed **storage power plants** (slide 26) need a reservoir and can produce electrical power on demand. The water is released from the upper storage reservoir into tubes or tunnels and runs a turbine in the power house at the end of the pipe.

2. Functional Principle

Types of Hydro Power Plants – Storage Power Plant

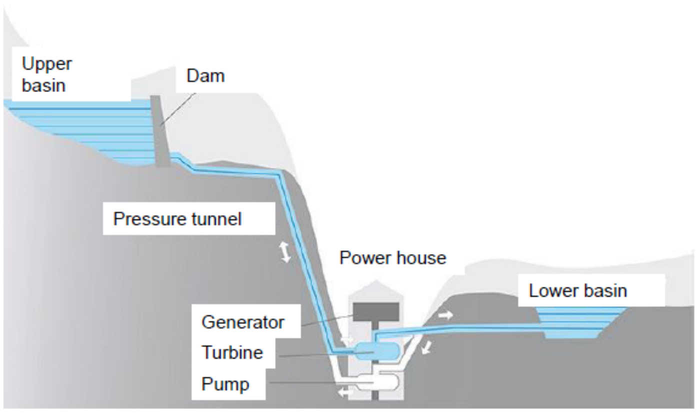


Source: https://www.landeskraftwerke.bayern/kraftwerkstypen.htm, 2019

Pumped storage power plants can produce and store electrical power because they can pump water into the upper basin on demand. The powerhouse not only includes a generator but also a pump. Electricity can be produced and stored according to demand; therefore, this type of power plant is grid stabilizing. However, suitable sites are hard to find.

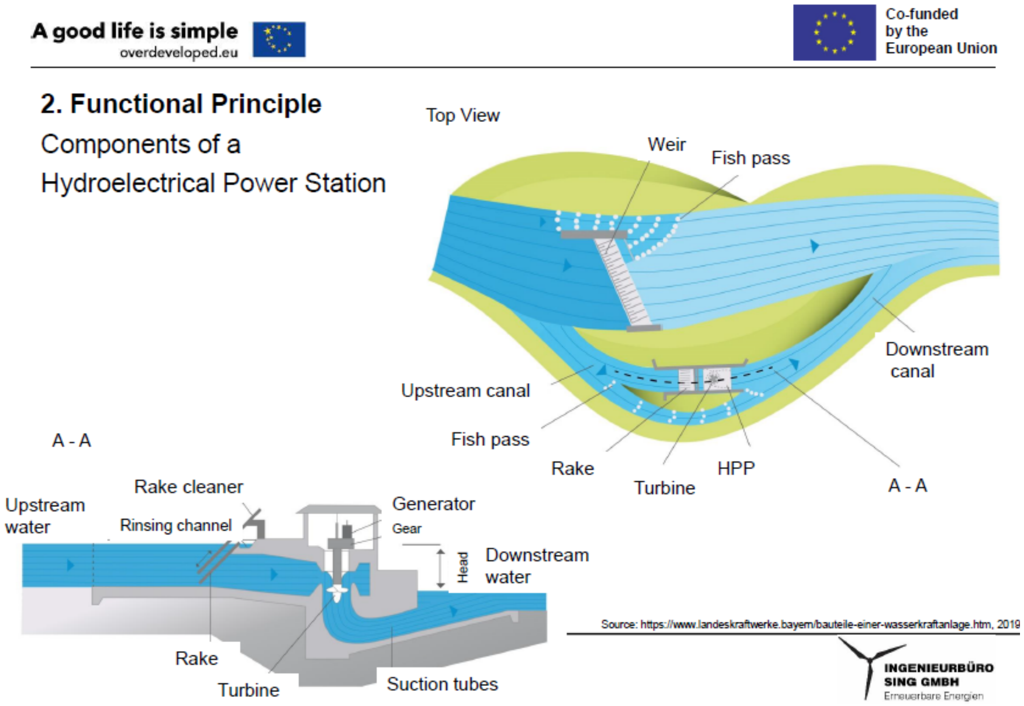
2. Functional Principle

Types of Hydro Power Plants – Pumped Storage Power Plant



Source: https://www.landeskraftwerke.bayern/kraftwerkstypen.htm, 2019

2.1.5 Components of hydro power plants



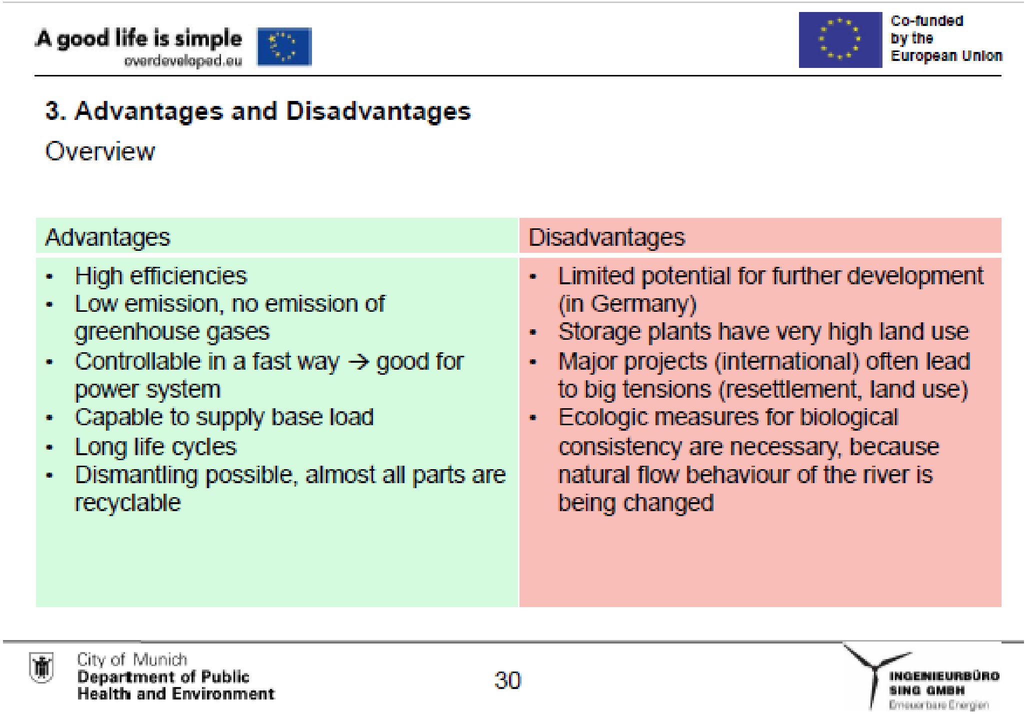
The main components of a hydro power plant are of course its rotating **turbine** and a **generator** that turns the rotational force into electrical power. Sometimes a **gearbox** is utilised. A pumped storage plant also has a **pump**. Depending on the type of power plant, different other components are necessary.

Weirs and Dams hold back the water, create a reservoir and increase head of the power plant.

Rakes protect the turbines from damages because they hold back debris. Sometimes automatic **rake cleaners** are utilised. The debris is cleaned of in the **rinsing channel**.

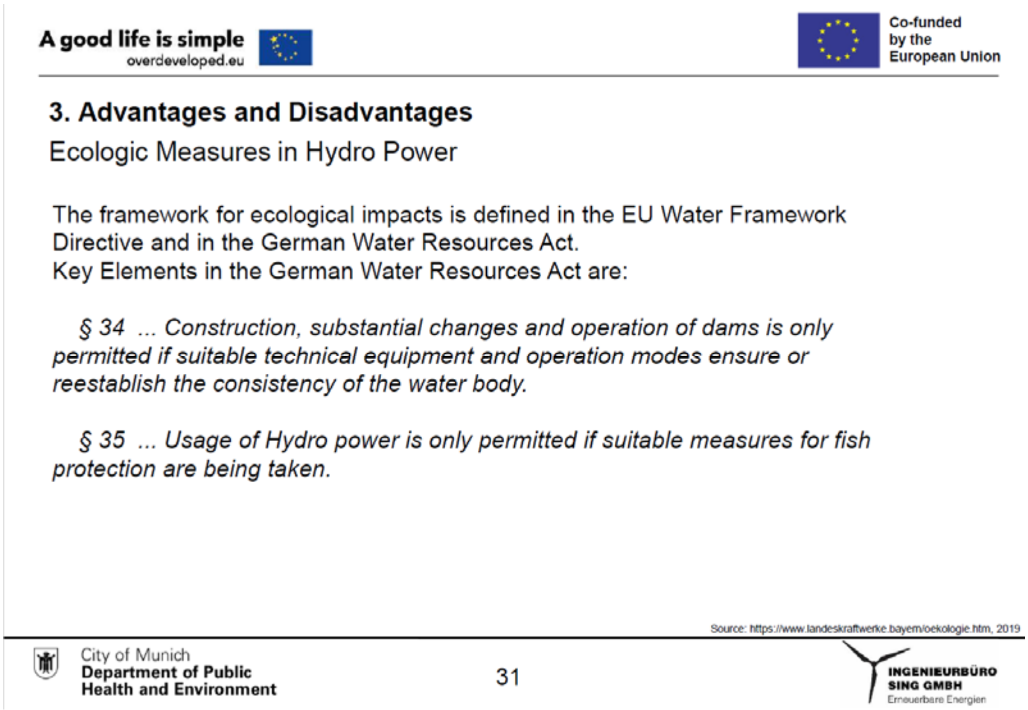
Fish passes make sure that fishes can pass the power station upstream and downstream.

2.2 Advantages and Disadvantages

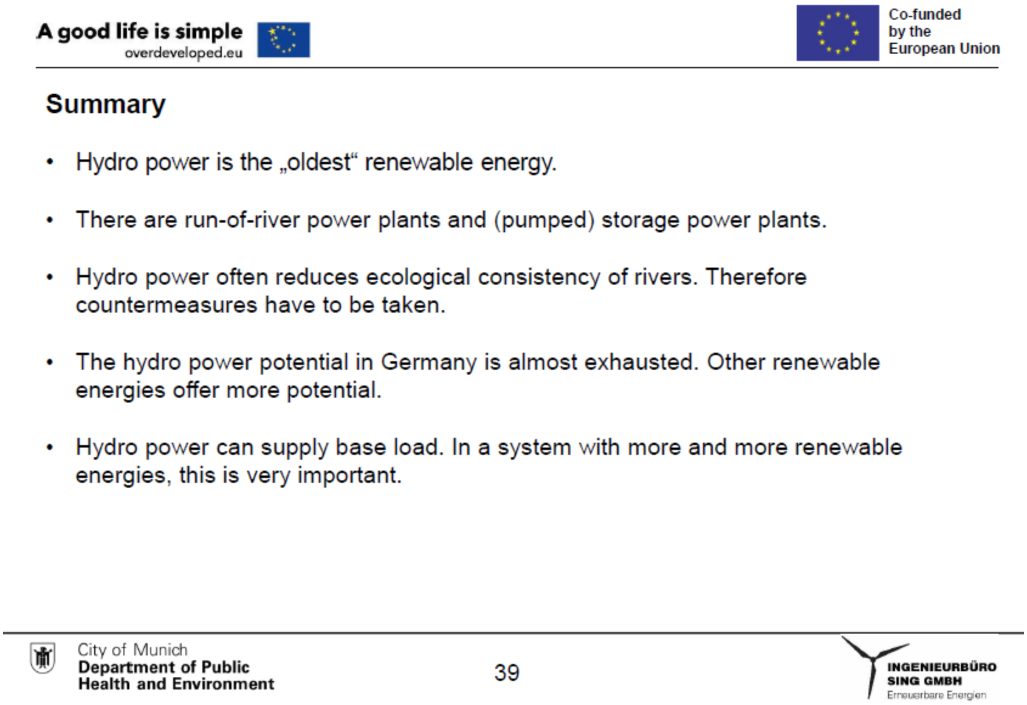


Hydro power plants have a lot of advantages, especially their high efficiencies and their capability to supply base load. However, as shown on slide 30 ecological aspects of hydro power are always discussed in a controversial way.

In order to minimize ecological impacts of hydro power some European and German laws are of importance. This is shown on the following slide.



2.3 Summary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Summary
• Hydro power is the „oldest“ renewable energy.
• There are run-of-river power plants and (pumped) storage power plants.
• Hydro power often reduces ecological consistency of rivers. Therefore countermeasures have to be taken.
• The hydro power potential in Germany is almost exhausted. Other renewable energies offer more potential.
• Hydro power can supply base load. In a system with more and more renewable energies, this is very important.
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3 PHOTOVOLTAICS

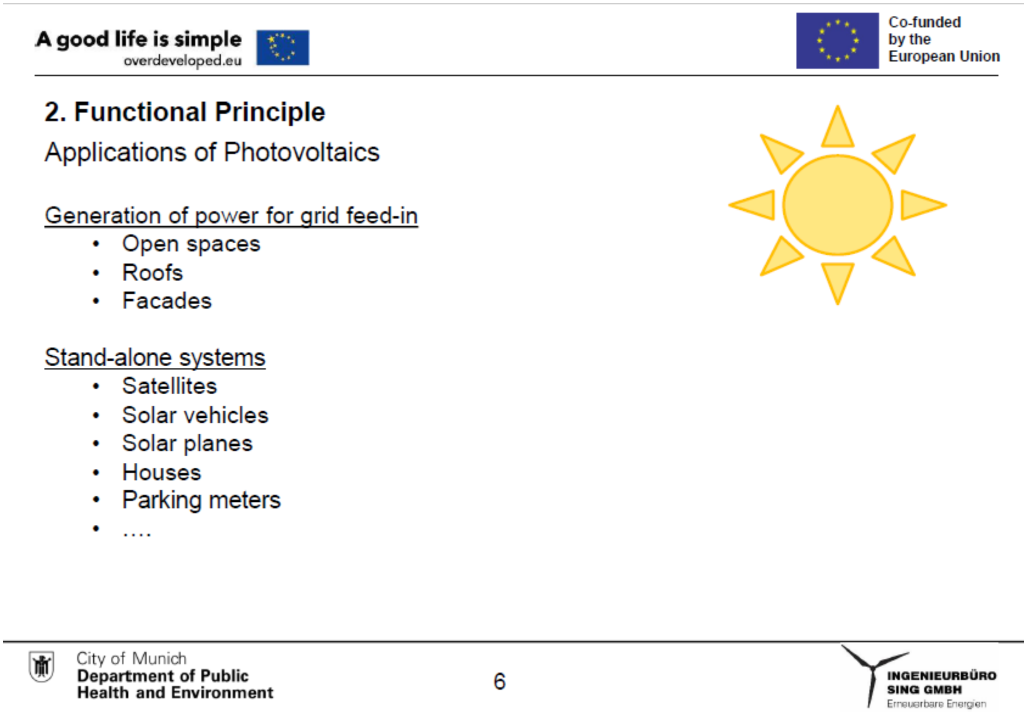
3.1 Functional Principle

3.1.1 Application

Photovoltaic power systems are either used for generation of power for grid feed-in or in stand-alone systems. Most of the times open space systems and roof and facade systems are used for power feed-in into existing grids.

Photovoltaic systems, sometimes in combination with other power systems and storage systems, also have a broad usage in stand-alone systems. Photovoltaics can power satellites, solar vehicles, solar planes, houses, parking meters, trash compactors, solar pumps, traffic signs etc.

Photovoltaic stand-alone systems have particular significance in remote areas with no existing power grid.

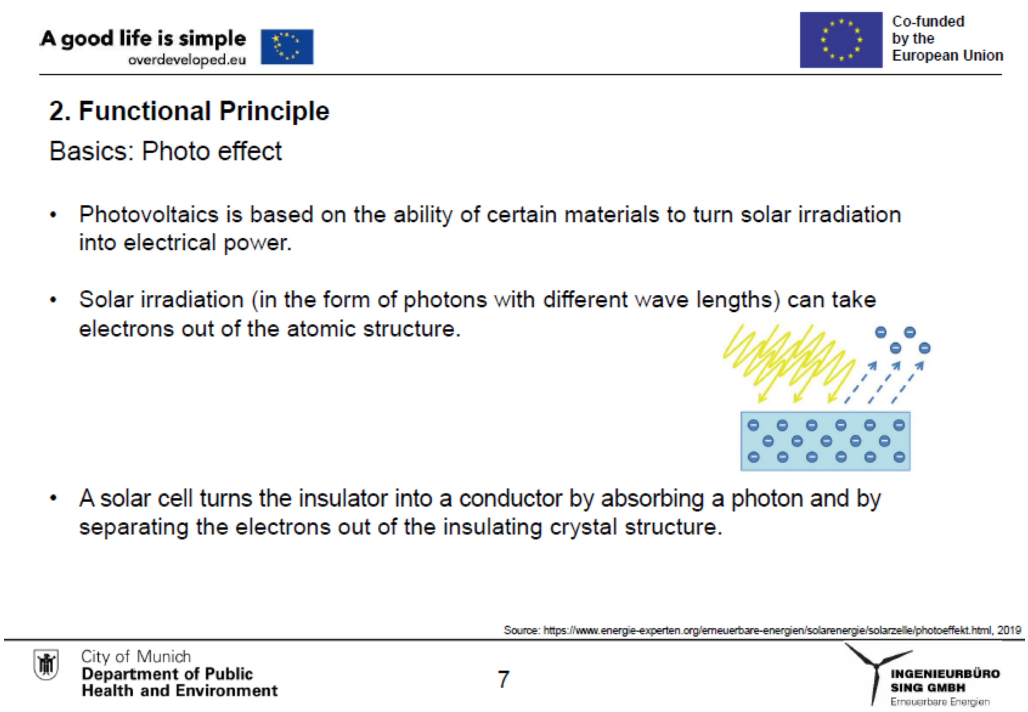


3.1.2 Functional Principle: power generation with photo effect

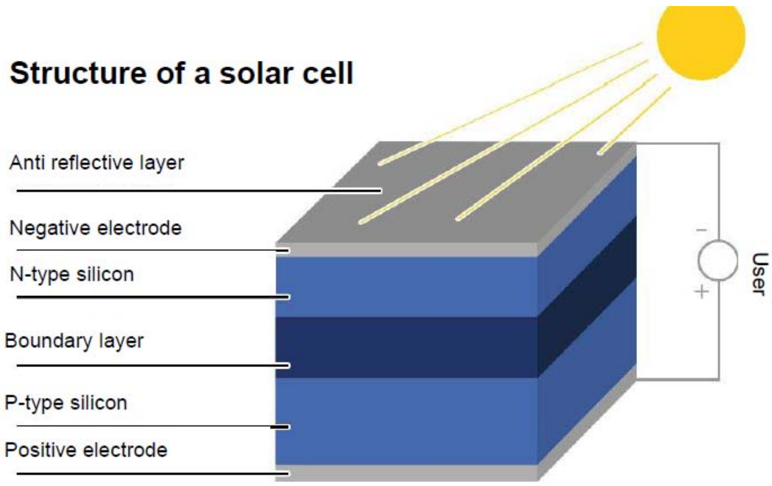
In his “quantum theory of light” Albert Einstein found out, that light can appear in the form of photons. If these photons hit a material, electrons are emitted and are therefore free to move around. This is called the photoelectric effect.

Power generation with a photovoltaic cell is based on this photoelectric effect, as electricity is the flow of electrons through conductors.

In a solar cell an insulating (non-conductive) material is turned into a conductor by absorbing photons and by separating the electrons out of the insulating crystal structure.



The following picture, extracted from slide 8, shows the structure of a solar cell.



The cell has two different kinds of silicon layers. Silicon in itself is a perfect insulator when it is not impurified. In order to create a solar cell, silicon needs to be impurified. Impurified silicon is then called a semiconductor.

As shown in the structure of the solar cell, there are two layers of silicon semiconductors. Both layers are intentionally impurified:

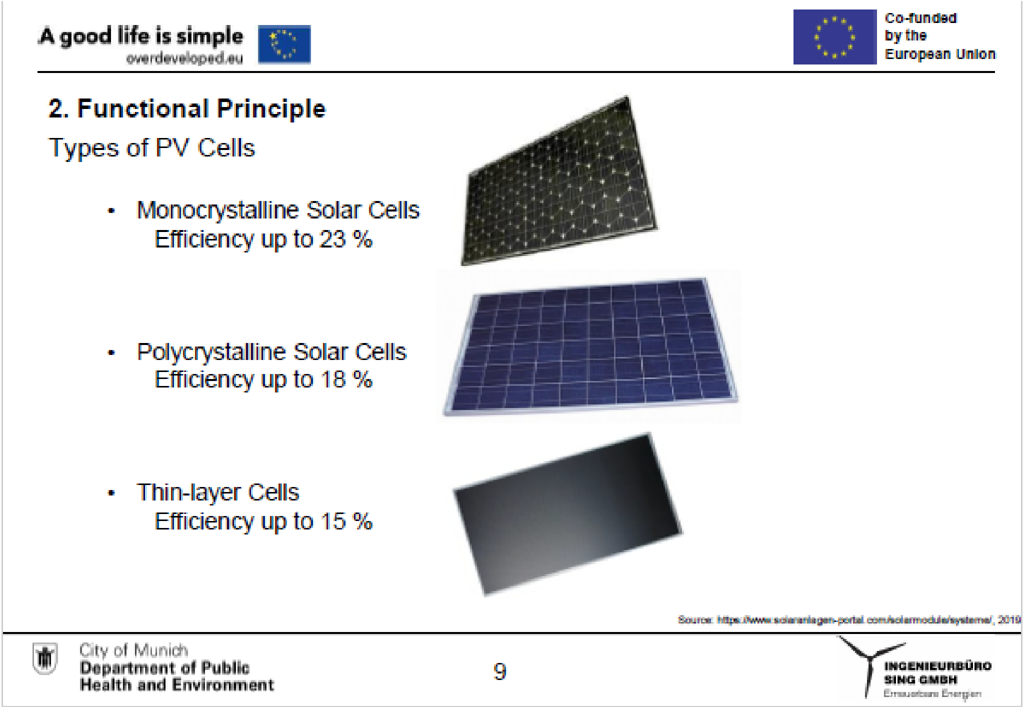
One has an abundance of protons and is therefore positively doped (so called p-type). One gets an atom with surplus electron and has an abundance of electrons; it is therefore negatively doped (so called n-type).

When sunlight hits, the electron in the n-type silicon gets free and can move around.

When those semiconductors are placed next to each other, an electrical current is created by the different charge of the two semiconductors.

3.1.3 Types of solar cells

Most solar cells are still made of silicon. However, there are different kinds of solar cells.



The three most common types, as shown on slide 9, are:

- Monocrystalline cells
- Polycrystalline cells
- Thin layer cells

Monocrystalline solar cells have an external even colouring and uniform look, indicating high-purity silicon. Monocrystalline solar cells are made out of silicon ingots (in cylindrical shape). Four sides are cut out of the cylindrical ingots to create silicon wafers, which is what gives monocrystalline solar panels their characteristic look They have a couple of advantages. Monocrystalline silicon solar panels are very space-efficient. They are the most durable of all solar cell types. Monocrystalline solar panels have the highest efficiency rates since they are made out of the highest-grade silicon. However, they are the most expensive.

Polycrystalline solar cells are blueish. For them, raw silicon is melted and poured into a square mold. Then it is cooled and cut into square wafers. The process used to make polycrystalline silicon is a lot simpler and costs less than the production of monocrystalline solar cells. However efficiencies and therefore space efficiency is lower.

Thin layer cells are made by depositing one or several thin layers of suitable photovoltaic material onto a substrate. Different types of thin-film solar cells can be categorized by which photovoltaic material is deposited onto the substrate: They can be made flexible, which opens up many new potential applications. However, they require a lot of space and tend to degrade faster than mono- and polycrystalline solar panels.

3.1.4 Performance of PV cells

Performance of photovoltaic systems is dependent on two things: Irradiation and temperature.

As shown on slide 10, efficiencies decrease the higher temperatures get. This is an issue especially in summer or for systems in countries with high temperatures. In order to prevent modules from getting to hot, good rear ventilation is advisable.

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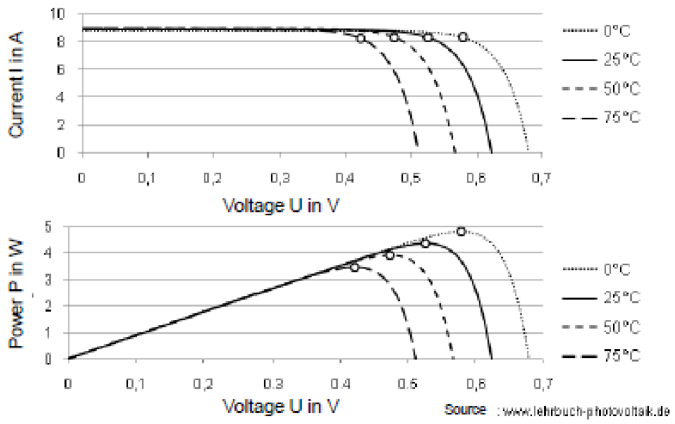
2. Functional Principle

Temperature Dependency of Efficiencies



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As slide 11 shows and describes, opacity is another thing that needs to be avoided, as performance decrease significantly.

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2. Functional Principle

Opacity

- Solar cells and modules are connected in series in order to increase voltage.
- If a single cell is in the shade, the power of the whole module decreases.
- Power of the whole series decreases.

Causes for opacity:
- Buildings
- Vegetation
- Topographic circumstances
- Self-opacity of modules
- Dirt
- Snow

→ Usage of bypass-diodes to avoid modules that are defective or in the shade
→ Avoid opacity!

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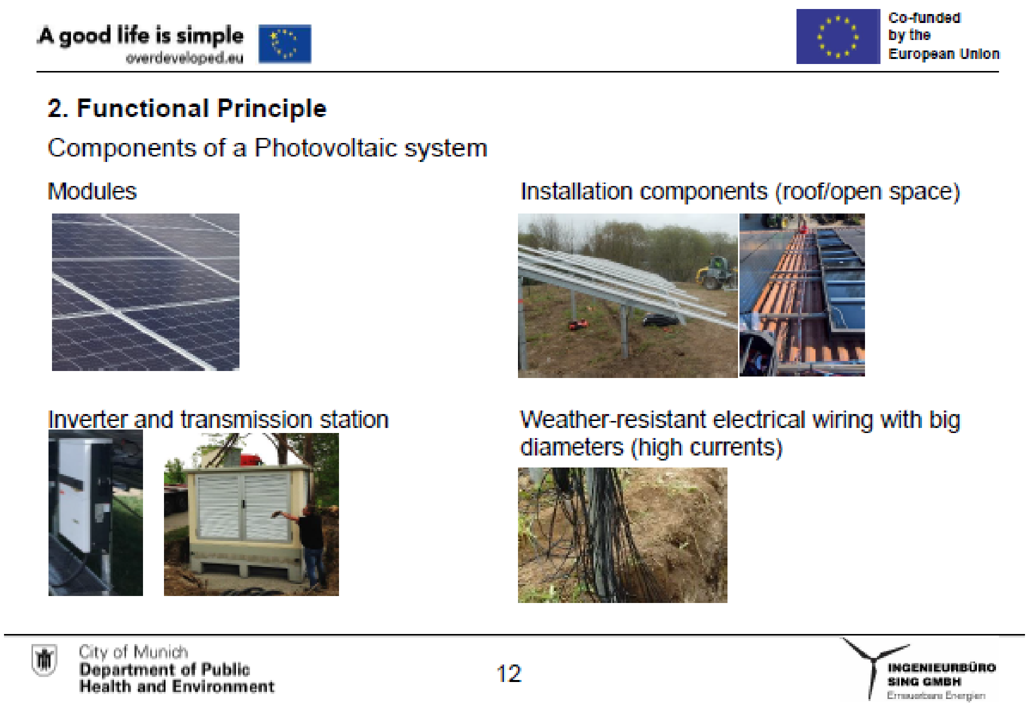
3.1.5 Components

As shown on slide 12, grid connected photovoltaic power systems mainly consist of:

- **Modules** convert solar power into electrical power.
- In order to adjust modules in the perfect angle to yield as much solar energy as possible, **installation components (roof/open space)** are necessary. For open space systems there are 2D or even 3D movable systems, that follow the movement of the sun. These systems are a lot more expensive than regular installation components.
- The power generated by modules flows through **inverters and transmission** stations and is converted into power with suitable voltage and frequencies for the grid.
- **Weather resistant electrical wiring with big diameters (high currents)** is necessary to connect all components of the power station.



3.2 Advantages and Disadvantages

3. Advantages and Disadvantages

Overview

Advantages	Disadvantages
• Low emission, no emission of greenhouse gases • Energy for manufacturing and construction is produced within a few months • Noiseless • Low maintenance • Long life cycles	• Rather high land use • Energy production dependent on weather (solar irradiation) • Energy production only during the day • Recycling rather complex

Photovoltaic power systems have a lot of advantages. However, a system with more and more photovoltaic power generation also has to deal with disadvantages of this technology.

There is no emission of greenhouse gases. In addition, energy payback times are very low. The energy payback time is the time the power plant needs to produce all the energy that was used for manufacturing, transportation and the building phase. For a modern photovoltaic power plant, it is lower than one year. Photovoltaic power systems are noiseless, they are always very low maintenance and live cycles are very long.

But land use, especially compared to wind power systems is rather high. For one MW about 1,3 hectares are necessary. Power can only be generated in sunlight, so it is highly volatile and weather dependent.

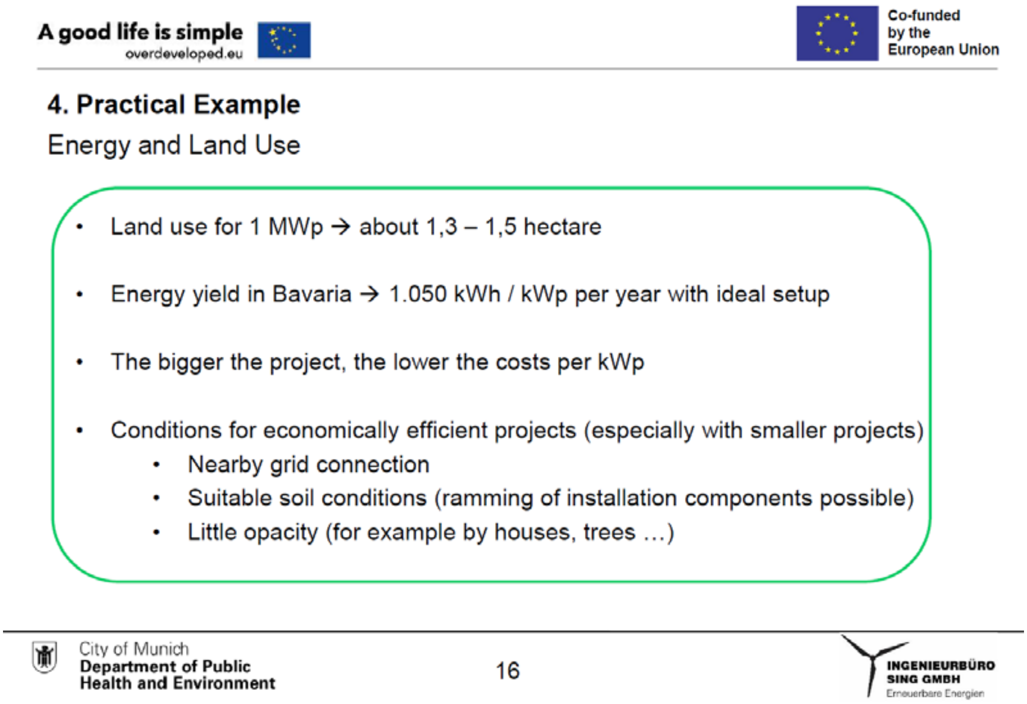
Recycling is rather complex, but a lot of research is done right now as recycling becomes more and more relevant.

3.3 Practical Issues

The following chapter gives an overview on practical issues concerning open space PV systems.

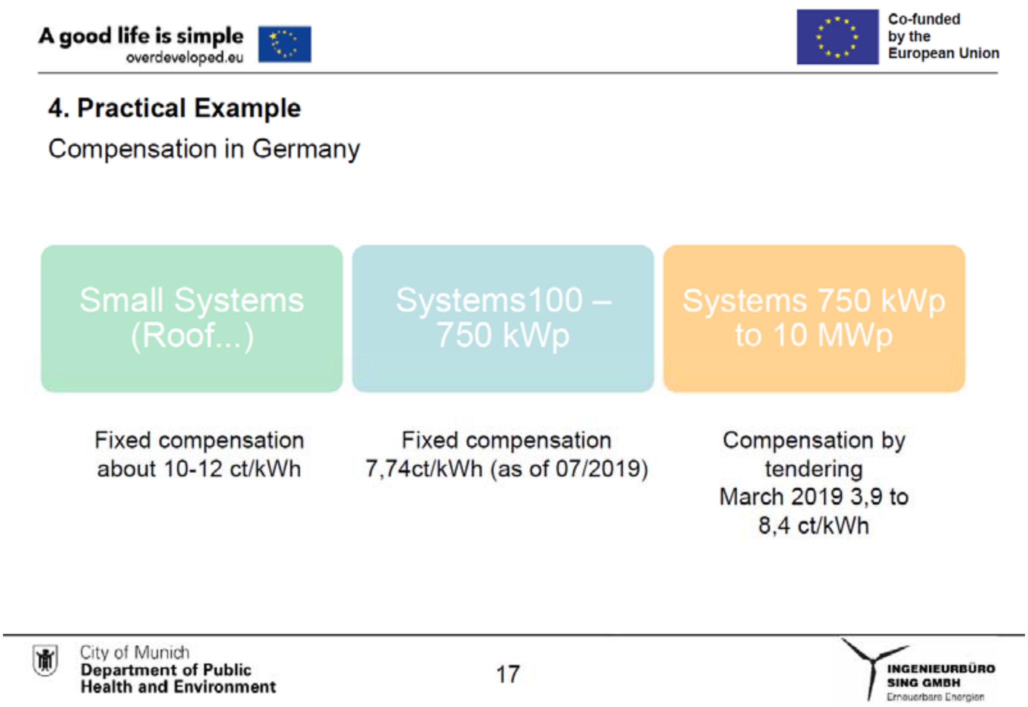
The most important figures concerning photovoltaic power systems are described on slide 16.

- Tables with PV-Modules need to be installed with some distance so they do not create opacity. Therefore land use for 1MWp is about 1,3 to 1,5 hectares
- Energy yield depends on the site of the power plant. In South Germany, it is about 1.050 kWh per kWp installed capacity. However, it can be as high as 1500 kWh/kWp in more sunny countries like Spain. Sweden however has an average of 900 kWh/kWp.
- Especially for smaller projects, there are some conditions (grid connection, soil, opacity) for economically efficient projects.



In Germany there are different types of compensations for different project sizes, as shown on slide 17.

Smaller roof or open space systems get a fixed compensation as defined by German Law. Compensations for bigger projects are determined by several rounds of tendering a year with a pay-as-bid system (everyone gets the compensation they bid for). A tender round only has to award a certain amount of megawatt. If the amount of megawatt is used up there is no longer a surcharge for the tender.

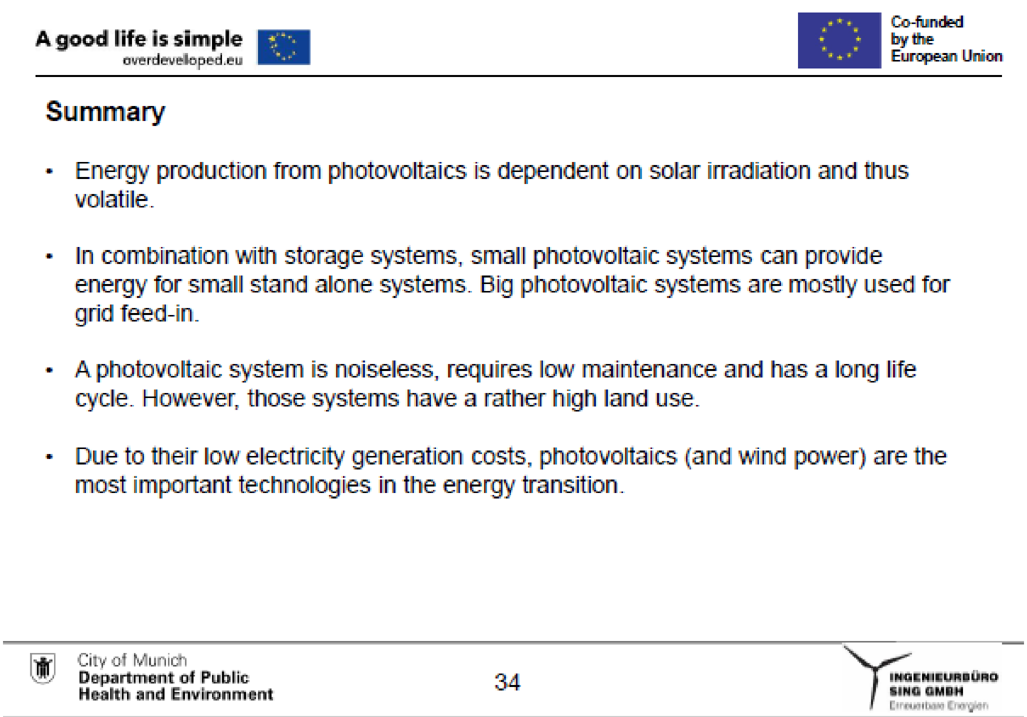


A typical open space system has several steps in Germany. Pictures of the steps can be found in slides 21 to 33.

The most important phases of a project are:

- Land use planning by municipality: Without land use planning, Photovoltaic power plants do not qualify for monetary compensation by the German Renewable Energy Act (EEG)
- Permit planning for building permit
- Soil assessment: Tables are positioned in the ground, therefore soil conditions need to be assessed.
- Survey: topographic circumstances as well as land parcels need to be assessed before the construction phase.
- Blinding assessment to determine possible negative emission on houses, train tracks and roads
- Building of the fence: This is done first in order to protect expensive building components.
- Installation components: Columns are mostly put into the ground by drilling or ramming.
- Installation of Modules and Inverters
- Electrical Wiring (AC and DC components)
- Installation of Stations (transformer and transmission station)
- Grid connection

3.4 Summary

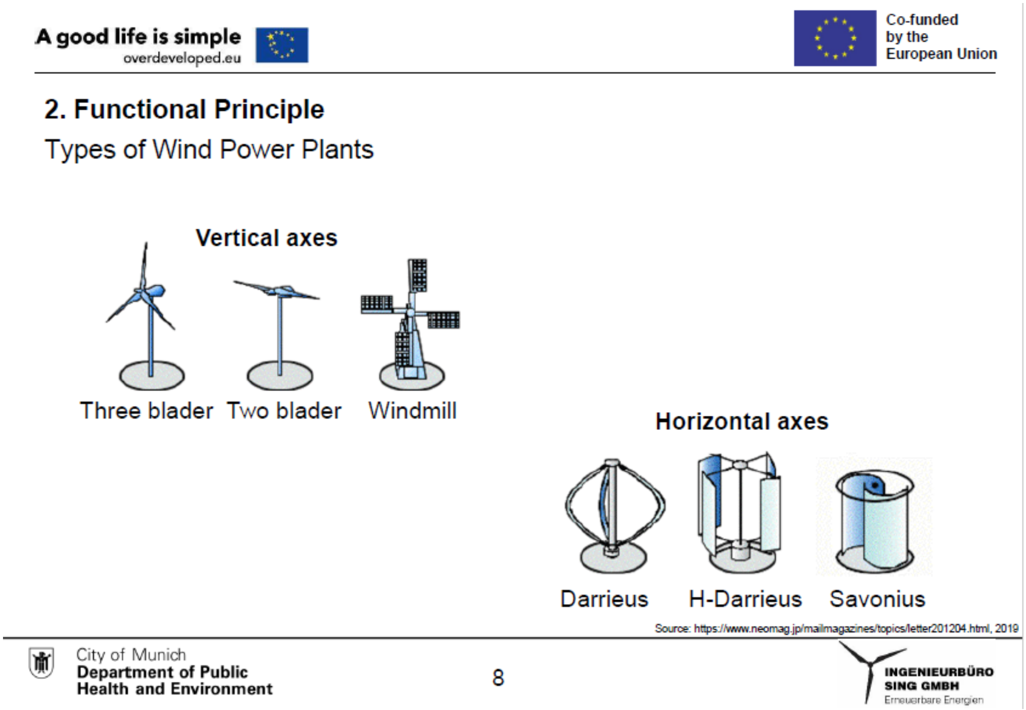


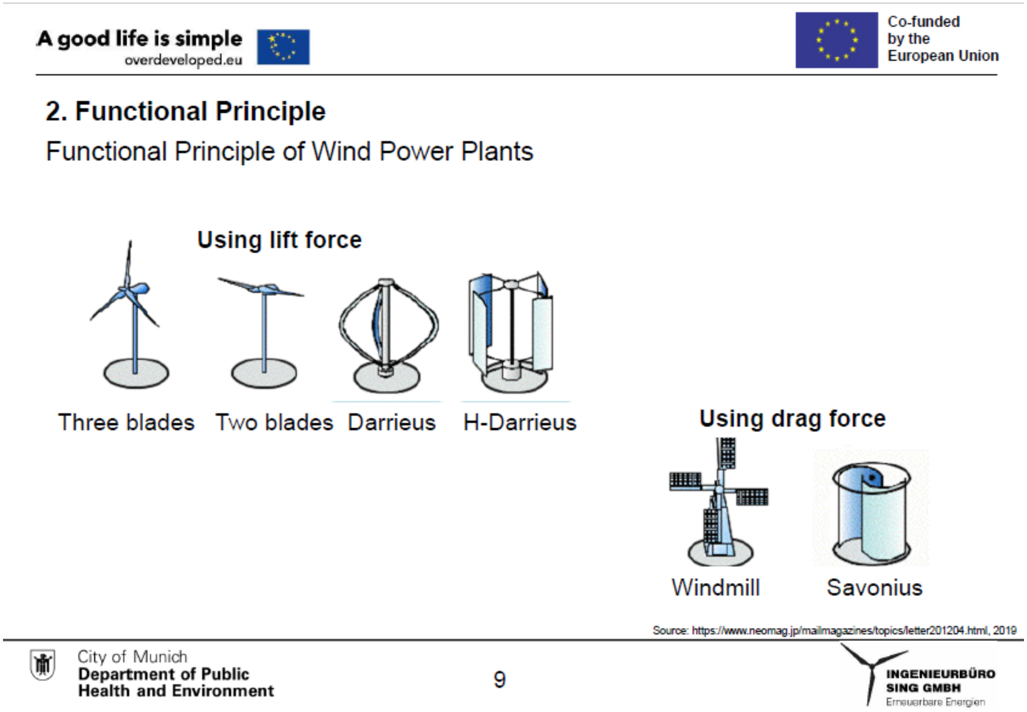
4 WIND POWER

4.1 Functional Principle

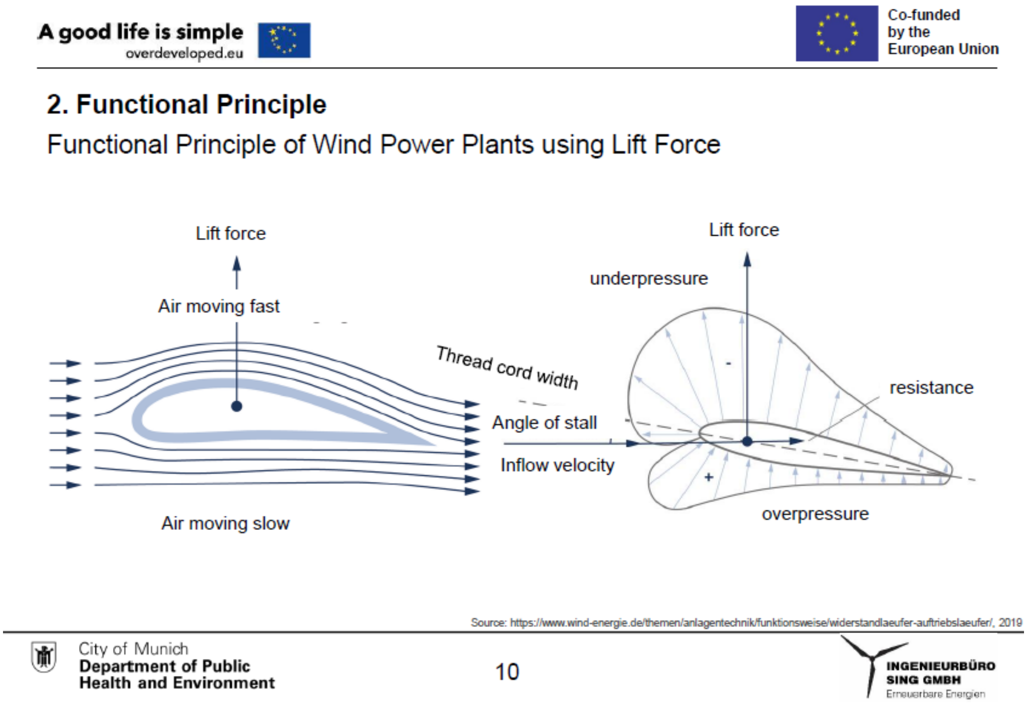
4.1.1 Types and working principle of different wind power plants

Wind power plants are mostly distinguished according to two criteria: type of axis or functional principle. Axes can be either horizontal or vertical. Wind power plants operate either using lift or drag force. The classification is shown on the following slides.





Turbines using lift force work because they have a special diameter as shown in the following slide. The air has to cover a bigger distance on one side. Therefore, an underpressure is created on this side and an overpressure is created on the other side. This discrepancy in pressures creates a lift force that results in a rectangular movement (rotation) of the rotor blade.



Although there are different types of wind power plants, there is only one type that is being used for all larger scale applications: The three bladed power plant with a horizontal axis (using lift force)

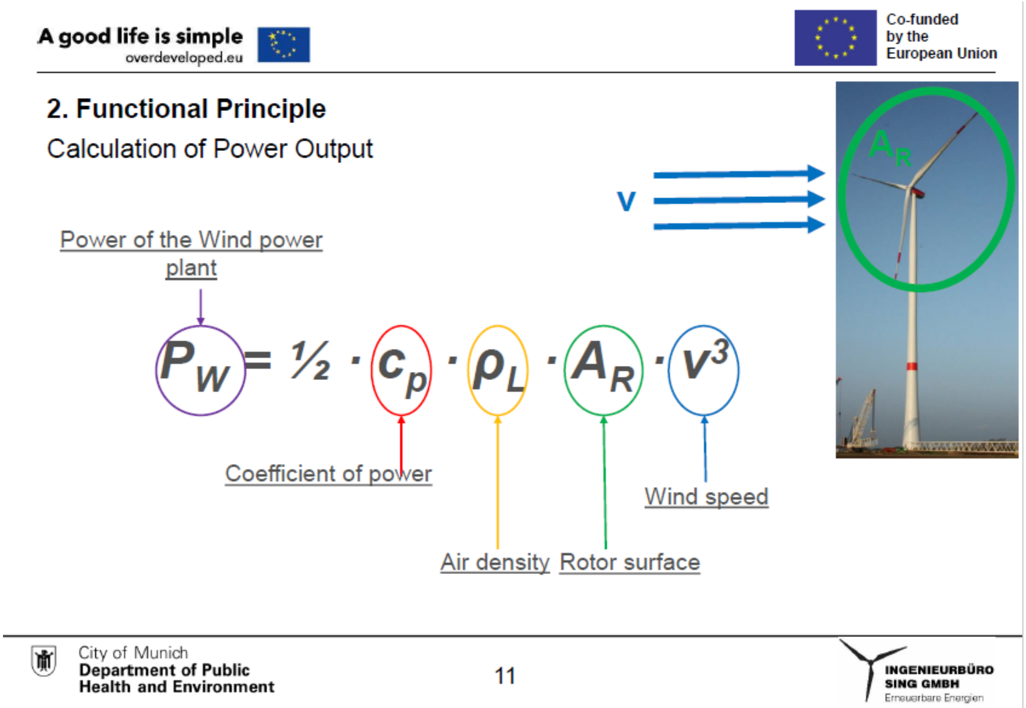
The main reasons for that are:

- Highest efficiency over 50 %
- Best balance between smooth operation (as compared to one or two bladed turbines) and costs for rotor blades (as compared to four or more winged blades)

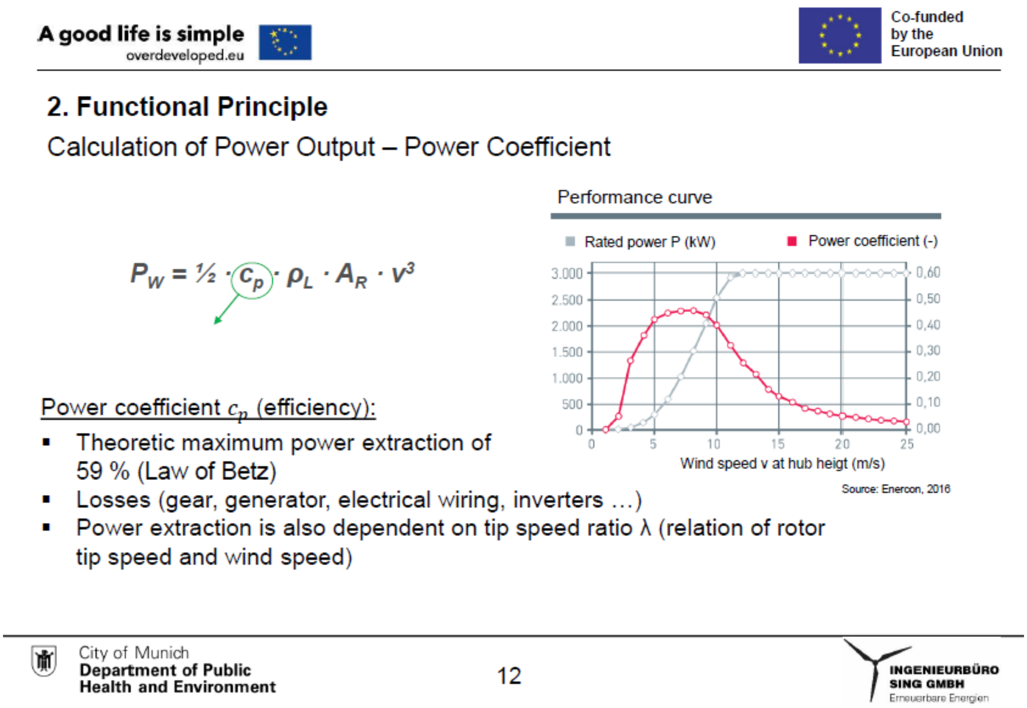
Depending on site, modern wind power plants have hub heights of up to 170 m and rotor diameters of more than 150 m.

4.1.2 Calculation of power output

Power output of a wind power plant is calculated using the formula on slide 11.



The power coefficient c_p is the part of the energy of the wind that gets converted into electrical power. This factor is limited, because if all the energy would be taken out of the wind, the wind would have to stand still after the wind power plant, which is of course impossible. Thus, the theoretic maximum power extraction from the wind are about 59 % (Factor of Betz). Also, losses of the mechanical and electrical components have to be taken into consideration.



Power output is direct proportional to rotor area. Rotor area increases as the square of the rotor length. Therefor rotor length is a very important factor in power output of the turbine.

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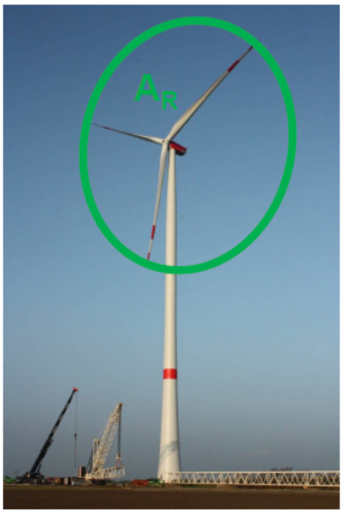
2. Functional Principle

Calculation of Power Output – Rotor Area

$$P_W = ½ \cdot c_p \cdot \rho_L \cdot A_R \cdot v^3$$

Rotor area

Rotor area increases as square of the rotor length A = r² π



Source: Ingenieurbüro Sing GmbH, 2014

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The power output depends on the third power of wind speed. Therefore, wind speed is the decisive criteria for suitable sites. Wind speeds increase with distance from the ground. Thus, the higher the power plant gets, the higher energy yields are.

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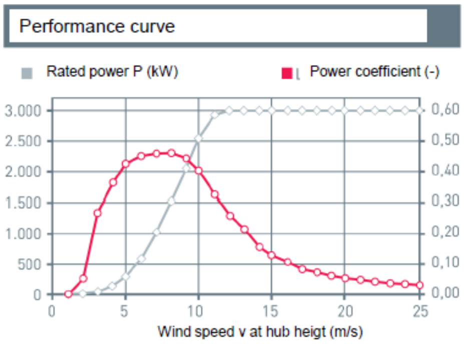
2. Functional Principle

Calculation of Power Output – Wind Speed

$$P_W = ½ \cdot c_p \cdot \rho_L \cdot A_R \cdot v^3$$

Wind power

Power depends on the third power of wind speed



Source: Enercon, 2016

→ Decisive criteria for suitable sites
→ The higher the wind power plant the higher wind speeds it can utilize (logarithmic wind speed profile)

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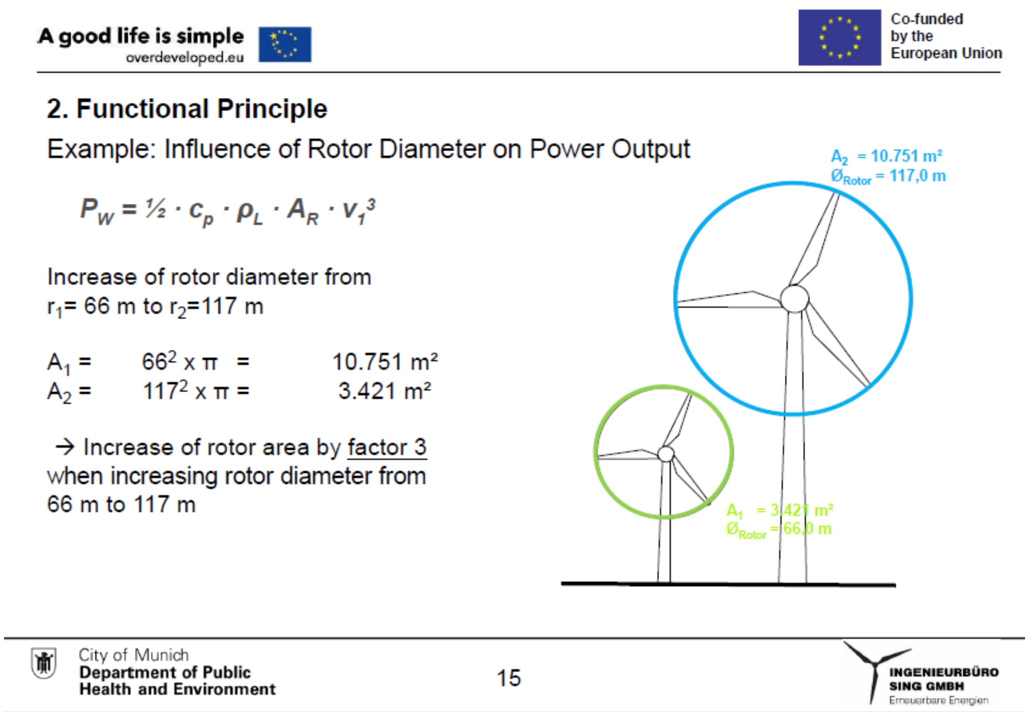
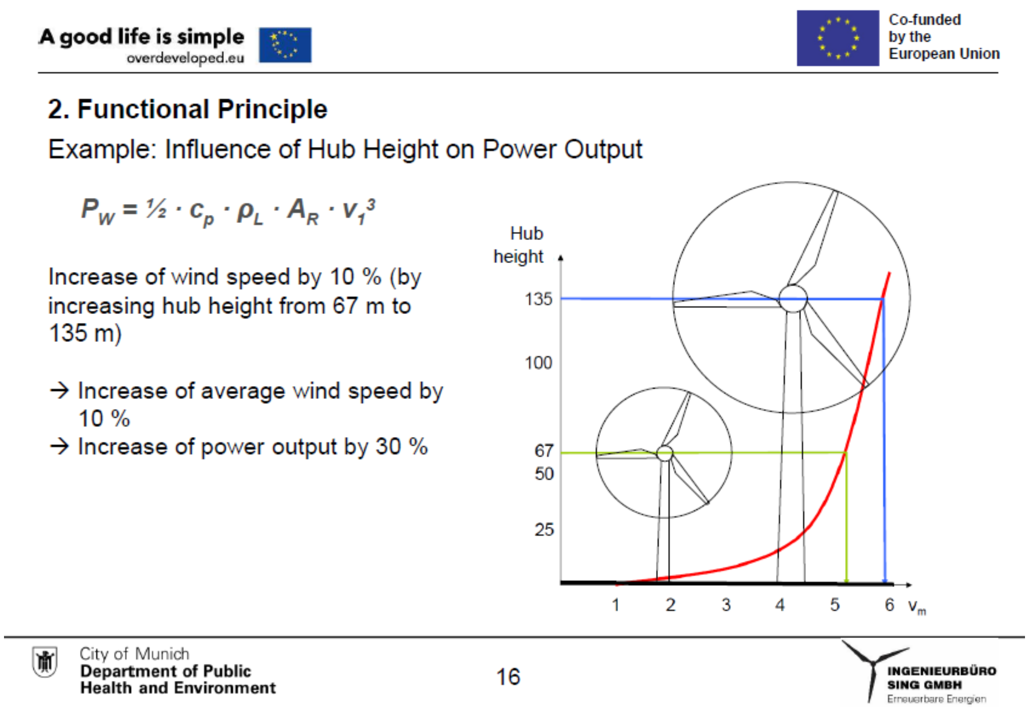
The following slides 15 and 16 show two examples of influence of the different variables on power output.

As the rotor area is dependent on the square of the rotor (Area = Rotor x Rotor x π), an increase of rotor length from 66 to 117 meters increases rotor area (and therefore power output) by factor 3.

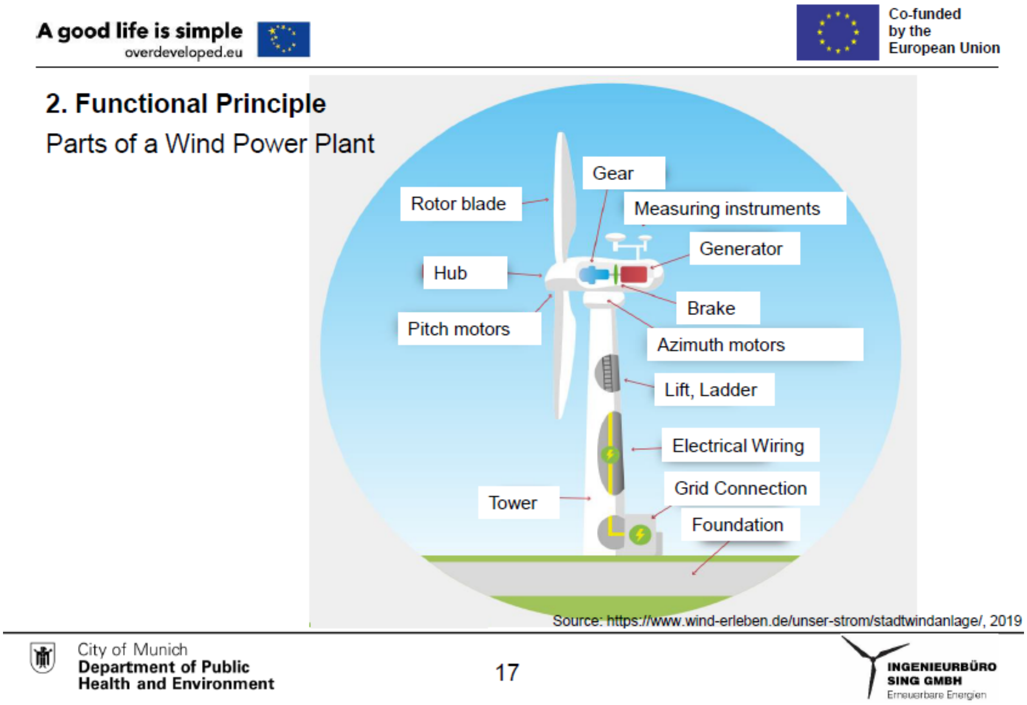


Wind speeds increase logarithmically for bigger heights. Median wind speeds above the ground are shown in the red line in the diagram on slide 16. So increasing the hub height from 67 to 135 m increases median wind speed by 10%. As wind speeds appear in the third power in the formula for power calculation, the effect is an increase in power output by 30 %.



As shown by these two examples, the right site and design of a wind power plant are crucial, as wind speed and rotor area are decisive factors in calculation of power output.

4.1.3 Components of a wind power plant



A modern wind power plant has three **rotor blades**. They are connected to the **machine house** with the **hub (nacelle)**. They make up the moving part, the so-called **rotor**. The rotor of a wind power plant rotates by taking out the kinetic energy of the wind. Modern turbines rotate around 10-13 times per minute. The **gearbox** increases the rotations per minute for the **generator**. The generator turns the rotational energy into electrical energy. Some wind power plants work without a gearbox. However, those need really big generators.

The rotor blades and therefore the power extraction from the wind is regulated using the **pitch motors**. Pitch motors turn the rotor blades around their own axes in order to find the right angle of stall for maximum power extraction. Pitch motors can also be used to stop the turbine by rotating the rotor blades for airflow breakaway.

Azimuth motors rotate the machine house into the wind direction.

The **brakes** are mostly used for maintenance purposes. During operation, braking processes are done by using the pitch and azimuth motors.

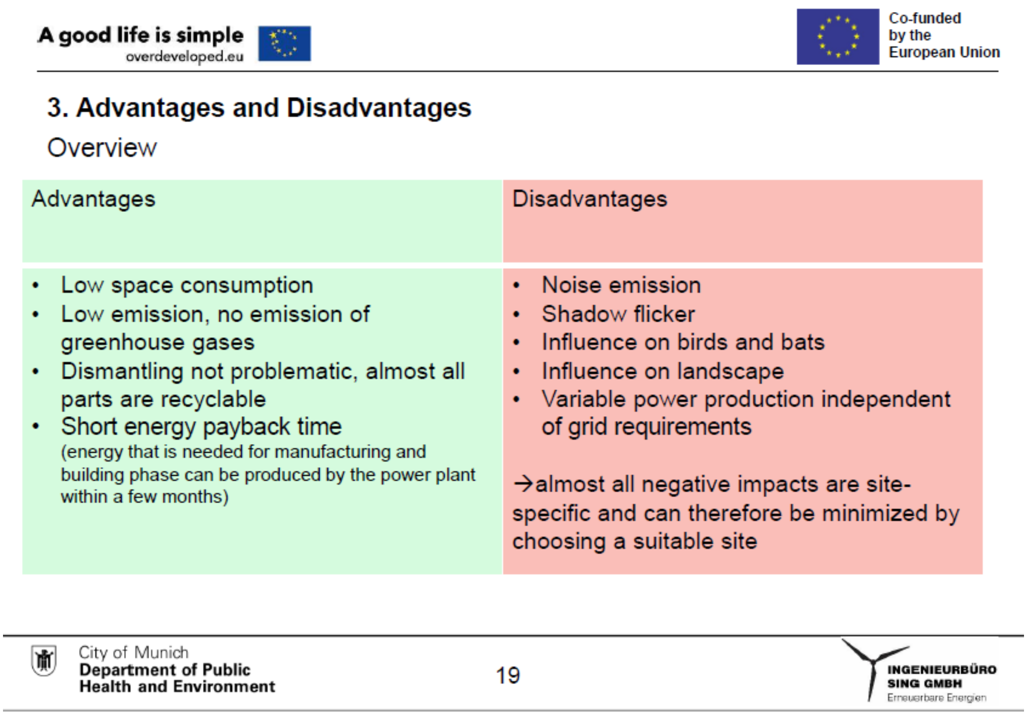
Regulation of the wind turbine is of course dependent on ongoing information on wind speed and direction. Therefore, the roof of the wind turbine several **measuring instruments** for wind speed, wind direction etc. can be found.

Inside the **tower** a **lift** and a **ladder** allow access to the machine house and tower.

The **electrical wiring** takes the electrical power from the generator through inverters and a transformer into the ground where underground cables go to a transmission station connecting the wind power plant to the electrical grid.

The **foundation** is buried in the ground and ensures stability of the wind power plant. A modern wind power plant needs a foundation with about 25 m in diameter and 4 m depth.

4.2 Advantages and Disadvantages



A big advantage of wind power is its low space consumption. For a wind power plant, permanent land use is only about 2.500 m².

Of course, there is no emission of greenhouse gases. In addition, energy payback times are very low. The energy payback time is the time the wind power plant needs to produce all the energy that was used for manufacturing, transportation and the building phase. A modern wind power plant needs less than a year to produce this much energy.

Wind power production, like power production from photovoltaics is dependent on the weather. Therefore, the variable power production is independent of grid requirement.

There are some problems in connection with wind energy like noise emission, shadow flicker, influence on birds, bats, and landscape. However, these impacts are all site specific and can be minimized by good planning and choosing a suitable site.

All in all wind power has very big advantages and is a high-performance technology. Wind power and photovoltaics are the most important pillars of the energy transition.

4.3 Practical Example

Wind projects are very time-consuming. In average, they take three to six years to complete. This chapter shows the most important steps in planning, building and operating a wind power plant.

a) Site analysis: Checking of all known knock out criteria Before starting the permit procedures, the site has to be analysed because many factors can prevent the construction of a wind power plant:
    - land use planning: Some areas are not suitable for wind energy use, so existing land use planning has to be consulted. An assessment of influence on landscape helps arrange the wind power plants in an agreeable way

- aviation (military and civil): wind power plants can be in the way of planes and of radars used for aviation. This has to be excluded.
- species protection: A pre-survey of existing flora and fauna has to be done before starting a project in order to reduce risk of a later cancellation of the project due to ecological aspects
- shadow flicker: There are limits of shadow flicker affecting houses.
- noise emission: Depending on land use planning different limits for noise emission are defined by German Law.
- directional radio: Wind power plants can harm directional radio used by mobile phone companies. However, this can easily be prevented by adequate planning.
- wind: The availability of wind is the decisive criteria for choosing of a site. Therefore, a wind assessment, ideally in combination with a wind measurement over a period of several months has to be taken.

b) bird-and bat assessment (mapping) Before starting permit procedures a bird and bat assessment is necessary. Over one season the planning area is observed by specialists especially mapping all endangered species. In Germany, for example birds like the Red Kite, the Eagle Owl or the Honey Buzzard are relevant.

c) Permit planning (incl. grid connection and access routes)
A permit application in Germany usually has the following contents:
- Report and plans
- Technical documents for the specific wind power plant
- Noise and shadow assessment
- All assessments for nature protection
- Landscape protection assessment
- Obligation for dismantling
- Contracts for rotor area, roads, grid connection
- Building application

d) Approval procedures (6 to 20 months)
Getting the permit usually takes more than half a year.

e) Tendering for compensation
Tendering for wind power compensation is compulsory by law in Germany since 2017. Power plants with a rated power of more than 750 kW have to take part in the tendering. Condition for tendering is a valid permit. Power plants with citizen participation get special conditions
The original idea before introducing this system was to create more competition in the market. However, the new system in Germany is not working too well right now.
The median compensation after tendering in August 2019 was about 6,2 ct/kWh.

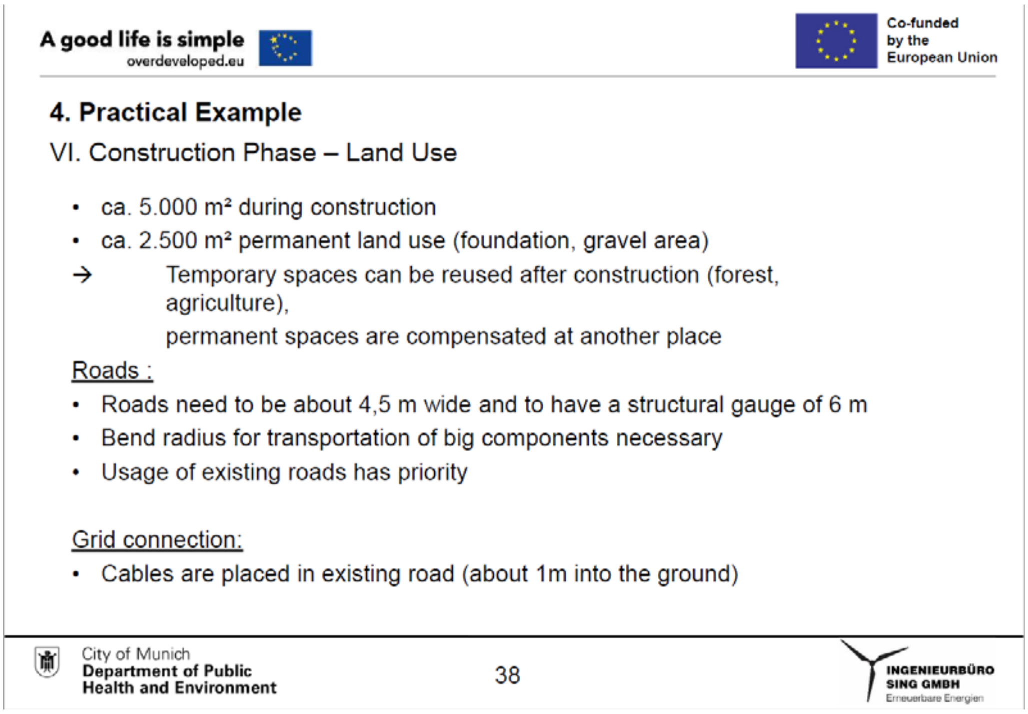
f) Construction and commissioning of wind power plant
The steps of construction and commissioning a wind power plant are:
- Site and soil investigation and subsoil improvement if necessary
- Building of crane areas

- Foundation
- Building of the tower
- Construction of machine house and assembling of the rotor
- Electrical wiring, grid connection
- Commissioning

g) Operating management
During the operation of a wind power plant technical as well as bureaucratic works need to be taken care of.

h) Dismantling, possibly construction of new wind power plant.

The following slide shows how much land is being used for one power plant during construction and operation



4.4 Summary

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Summary

- Modern, efficient wind power plants have horizontal axes and three rotor blades.
- Power production is mostly dependent on wind speed and rotor diameter.
- Planning and realization of wind power plants takes a lot of time.
- Most negative impacts (species protection, land use, shadow, noise) can be minimized with good planning.
- Wind power is (amongst photovoltaics) the most important technology for the energy transition.

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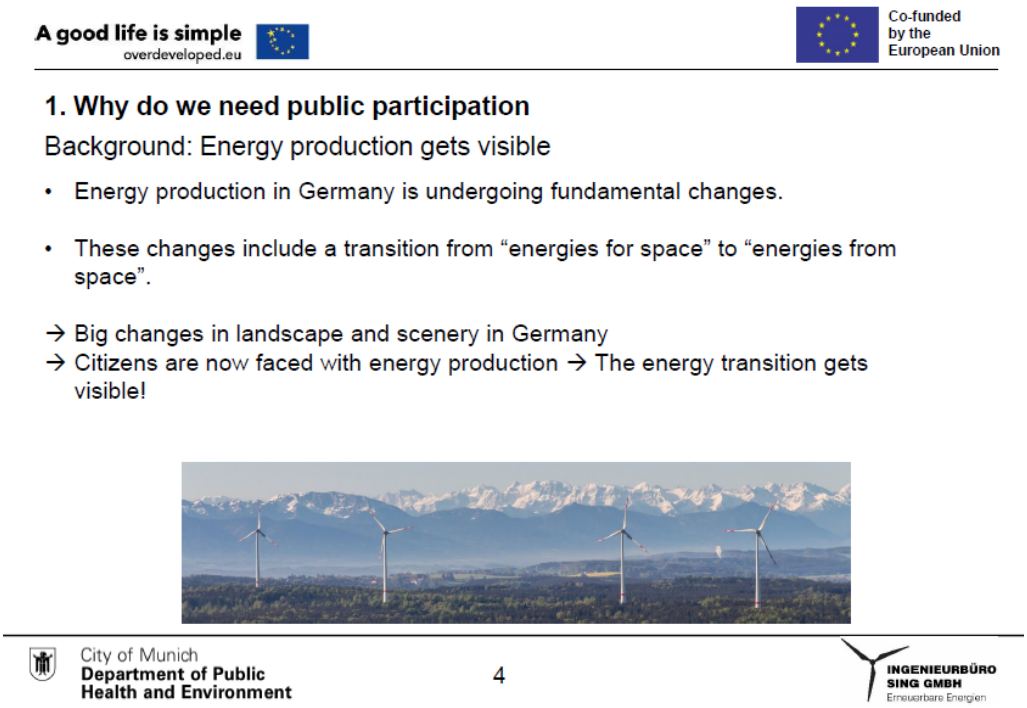
5 PUBLIC PARTICIPATION IN RENEWABLE ENERGY PROJECTS

5.1 Why do we need public participation?

Energy production with renewables is visible. There is a transition from “energies for space” to “energies from space” taking place in Germany and worldwide.

“Energies for space” means a lot of energy was generated in one place and then used to power large areas or cities. Now, with “energies from space” the land, the topography, the weather determine the place of energy production.

Therefore, of course, the landscape changes, and citizens are faced with energy production in a major way. Photovoltaics, wind, biomass are highly visible. The landscape itself changes, and this kind of change is not a thing all people value. Therefor projects with renewable energies are often regarded with a lot of concerns and fears as shown on the following slide.



Other than the visibility, there are concerns and fears that address the effects of renewable energies on the human health and on the environment. Concerns for human health include effects like subsonic noise and the disco effect of wind power plants. Species protection issues include the possibility of collision of birds and bats with wind rotor blades, the damage to fish populations in hydro power plants, the loose of space due to photovoltaics and the change of feeding habits of all sorts of animals due to monocultures for biomass production.

However, discussions about these topics are rarely really based on facts. Scientific studies prove some of these arguments to be false; others can be prevented by sensible choices within the planning process – the choosing of the site.

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1. Why do we need public participation

Background: concerns and fears

Discussions concerning the expansion of renewable energies are often very emotional and hardly based on facts.
Therefore some prejudices are hard to get rid of.

For example:

- Species protection
- Subsonic noise
- Disco-Effect
- Shadow impact

These fears and concerns have to be taken seriously and be invalidated.

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Nevertheless, as discussions are very emotional, and prejudices prevail. These fears and concerns have to be addressed constantly.

All factors mentioned before eventually result in problems with the acceptance of renewable energies. Still in order to succeed in the transition from conventional to renewable power production, acceptance of the citizens is a decisive criterion.

Studies prove that most Germans think renewables to be very important and 75% vote an increased expansion as good. But this does not automatically lead to high acceptance of specific projects.

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1. Why do we need public participation

Background: Acceptance

Surveys show high popularity of renewable technologies in Germany. However this doesn't automatically lead to high acceptance of specific projects. (NIMBY).

→ Like with all big construction projects, resistance tends to arise with renewable projects.

Acceptance is a central component in the success of a energy transition

turning affected persons into participating persons

PUBLIC PARTICIPATION creates ACCEPTANCE

Source: https://www.zeit.de/wirtschaft/2011-05/erneuerbare-energien-protest, 2019

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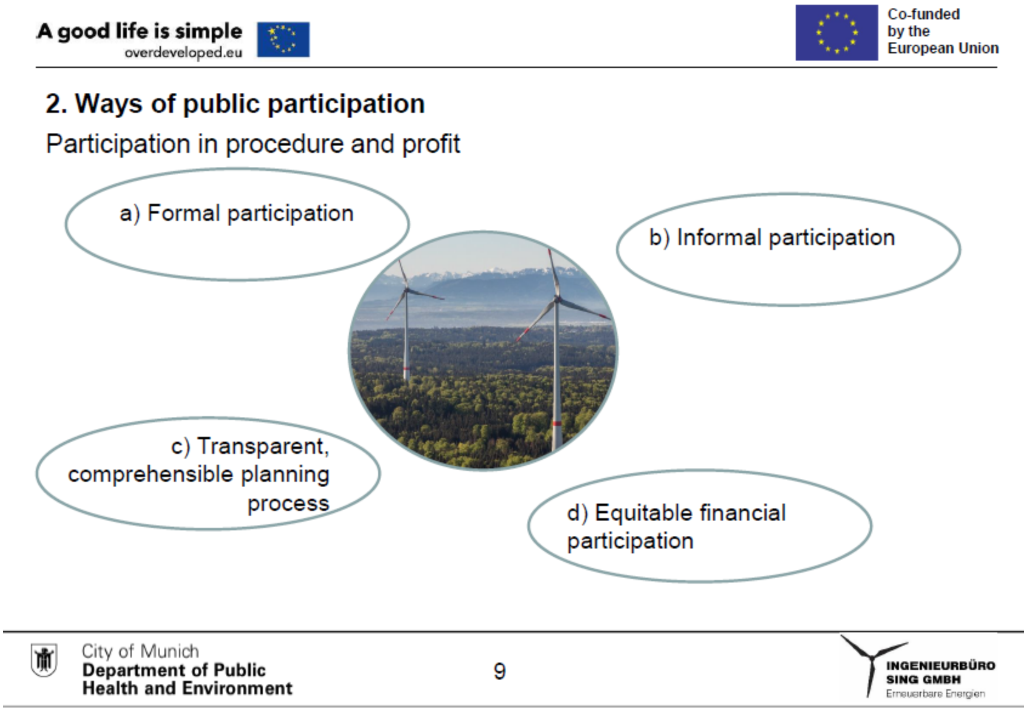
As people are affected by renewable energies, participation is important, because participation creates acceptance.

5.2 Ways of public participation

In order to allow participation of the public, there are different ways of participation as shown on slide 9.



Formal participation are all participation processes that are mandatory by law.

In Germany, formal participation is for example necessary in:

- Approval procedures
- Environmental impact assessment

Most of the time citizens, institutions and authorities can analyse all planning documents and comment on them.

While this is very important, the discussions about energy are emotional and often accompanied by fear. So, further ways of participation are necessary.

This can be done by a combination of **transparent, comprehensible planning** and **informal** participation to communicate planning processes.

Informal participation includes all additional forms of participation that can be carried out while realizing a project. First, you can reach a lot of people with events for information and the opportunity to discuss the matter. With press reports – about these events or about the project itself – you reach even more people. A very good example for informal participation are public tours of construction sites or renewable power plants. Surveys and the publication of the results address topics like species conservation. Homepages are a great way to keep people posted about the projects progress. In addition, if there still are resentments from citizens, authorities or other parties, a mediation, maybe in form of a round table, can be offered to talk it out.

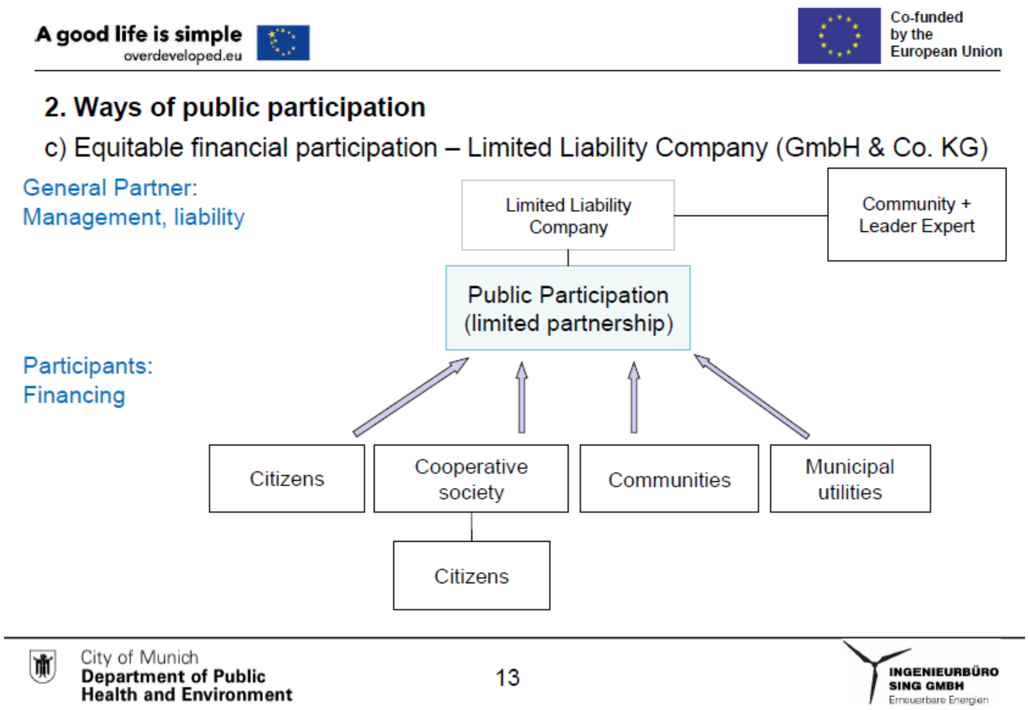
In addition to formal and informal participation, people can also take part in renewable projects with **equitable financial participation**.

With this, Citizens and municipalities become part owners of power plants. Earnings remain within the region, often even within the municipality, and therefore the participating partners profit from the plant, not some big investors.

Participation generates direct earnings for the local municipality and therefore for all citizens. These earnings can be used for all kinds of municipal expenditures and are often used to improve infrastructure.

Financial participation creates acceptance, helps citizens to benefit from power plant earnings and boosts regional value creation.

One example is the German "Limited Liability Company (GmbH & Co. KG)" as shown on slide 13.



The GmbH & Co. KG holds the advantage of a limited responsibility of some or many owners, combined with the possibility of having one person or institution to run the company.

Example given for the GmbH & Co. KG during the talk by Dr. Petra Hutner:

> *"Say, Kristina and I want to build a wind power plant. I am fully committed, but Kristina rather wants to spend her days at the beach and not have too much risk. What we do is we found a KG. A KG consists of two parts: a "Komplementär", which is me, and "Kommanditisten", which in this case is Kristina. Or could be all of you, then we would put a "Co." here.*

Kommanditisten are each liable only with the money they put into the business – let's say 5.000 €. While I am liable with all of my fortune, my house, my car. In turn, I am the one to make the decisions – I am the managing director.

Well, now, looking at all of you as my business partners, I actually do get a bit afraid. I do not want to be liable with all my private fortune. Rather, I found a GmbH, a LLC. With me as the main shareholder, I am still the managing director, but no longer are liable with my private fortune, but only with as much money as I choose to give to the GmbH: the corporate assets.

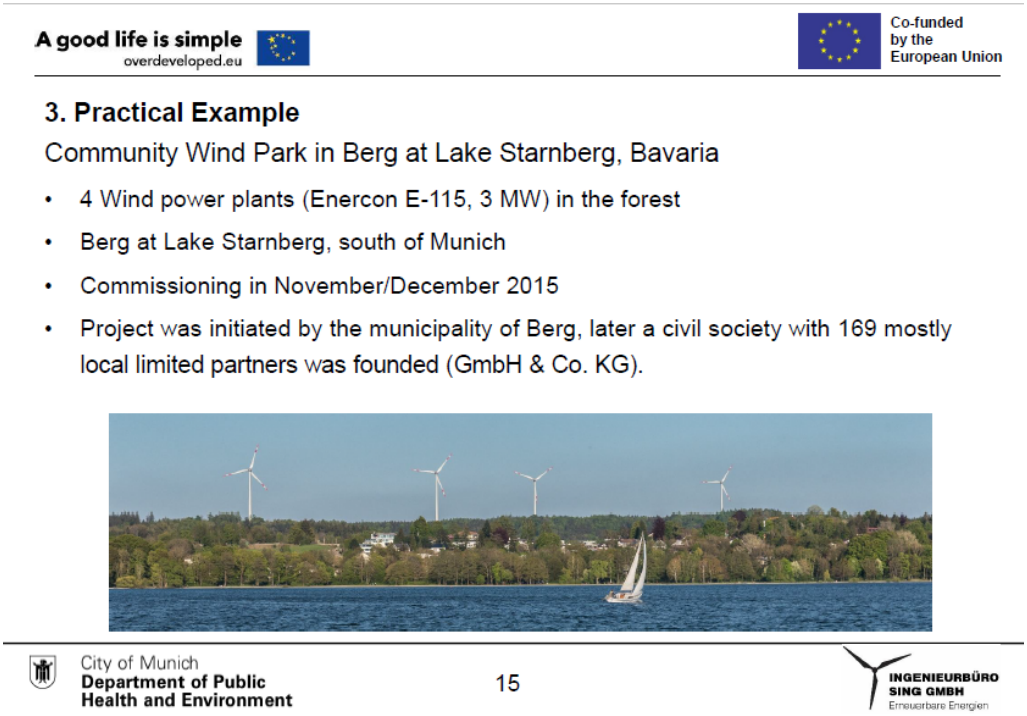
Therefore, this is what happens with renewable energy projects.

Therefore, this is all you, the public: Kristina, you, the city of Munich. You all participate with however much money you choose. In return you all are the owners of the wind power plant.

Up here is management. The LCC, consisting of an expert, and maybe of other big stakeholders like towns or communities.

5.3 Practical Example

The following practical example shows how a wind power project was executed with public participation.



The example given was of the community wind park in Berg at Lake Starnberg in Bavaria that started operation in 2015.

The district of Starnberg had made the decision to be energy self-sufficient until 2035 in 2005. Then the whole district was analysed concerning potential areas for wind power utilization. The project of the wind park with four wind power plants was first started by the municipality of Berg in 2012. A concentration area in the forest was determined. Throughout this process, the public was constantly informed. There were formal participation steps but also informal steps like information events and press releases.

The project is quite special, because the municipality of Berg acted as project developer until the permit was obtained. This means, that all decisions concerning the project were made in municipal council. In addition, the municipality of course owned all project rights.

The project was reconfirmed by Major Monn being re-elected in 2014.

Throughout the planning process, the people responsible were always recognizable. There were multiple information events, press releases and disclosures of current statues of planning.

After the building permit was obtained, a civil society with 169 (mostly local) limited partners (citizens, municipalities, banks, cooperatives, public utility companies) was found. In addition, the municipality of Berg is one of those 169 owners of the wind park. The projects rights were transferred to the Bürgerwind Berg GmbH & Co. KG.

As described before, this form of participation has some great advantages:

- Direct participation of stakeholders in earnings and decisions
- Participants are owners of the wind power plants
- Earnings remain with the regional participants
- Municipality is still part of all decisions made (financial participation of municipality, supervisory board)

In 2014 the construction phase started. During the construction phase, there were several press releases and construction-site tours a week. There was also a homepage with weekly updates on the project and photos of the construction.

After the wind park started operating, there was a big formal opening with all limited partners and parties involved in the project.

The wind park Berg is a great example of a renewable energy project with all different kinds of public participation.

5.4 Summary

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Summary

- The energy transition makes energy production a lot more visible for citizens.
- Major projects need the citizens' acceptance.
- Public participation creates acceptance.
- Informing citizens about projects and taking their fears and worries seriously decreases resistances.
- Financial participation in renewable power plants allows citizens and municipalities to earn money with power production in their neighborhood.
- This way earnings from renewable power plants remain within the region.

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