FINAL REPORT OF THE RESEARCH PAPER

RENEWABLE ENERGY:

PRESENTATION OF THE DIFFERENT POSSIBILITIES OF ENERGY CONVERSION IN ELECTRICITY, AS WELL AS AN ANALYSIS AND COMPARISON OF THE DIFFERENT APPLICATIONS AND THE ASSOCIATED EFFECTS IN THE USA AND AUSTRIA FOR PRIVATE HOUSEHOLDS

for the

AUSTRIAN MARSHALL PLAN FOUNDATION

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STATUTORY DECLARATIONS

"I hereby declare that I have written the present research work independently and without outside help and that I have not used any sources or aids other than those specified in the editing and drafting as well as marked literal and meaningful citations as such. Furthermore, this work was not used elsewhere, or submitted for credits or academic achievements. "

Edmond, OK, USA, December 15, 2018

GENDER CLAUSE

For reasons of readability, gender-specific spelling has been dispensed with in the present research paper and only the masculine form has been used. In terms of equality, however, it should be expressly pointed out that all statements equally apply to the female sex.

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ABSTRACT

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Abstract of the research work “Renewable Energy: Presentation of the different possibilities of energy conversion in electricity, as well as an analysis and comparison of the different applications and the associated effects in the USA and Austria for private households”

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Content of this scientific work is the consideration of renewable energy systems for private operators and to figure out, on the one hand, whether an operation is profitable and, on the other hand, how a possible installation can be evaluated. On the basis of the research results of this thesis, this topic should become more transparent for private individuals and a template should be developed with regard to possible applications and important points for the decision-making process as well as for an implementation and acquisition. The first part mostly deals with subject-specific explanations, definitions and the validation of associated equipment that are needed in the main part and are derived from literature research. In the further course, three established energy systems have been selected and compared with specific figures. Based on a defined example, a possible suitable plant crystallized out of a utility analysis, which was then theoretically examined in more detail. Furthermore, the installation of a wind turbine at two different locations, Edmond and Kufstein, was considered economically. The final chapters contain the possible future prospects for the countries in general as well as the summary and the findings of this work.

December 15, 2018

1 INTRODUCTION

The scientific paper entitled "RENEWABLE ENERGY: Presentation of the different possibilities of energy conversion in electricity, as well as analysis and comparison of the different applications and the associated effects in the United States and Austria for private households" is primarily concerned with the different technologies that transform the most diverse renewable energies into electric power. Furthermore, the research focuses mainly on the specific application of private operators in Austria and the US of sustainable systems that provide electrical power. In addition, it discusses the various possible applications, advantages and disadvantages of the use of renewable electricity generating systems and also the associated effort for an installation. The main objective is to make the different technologies for private households transparent, that an interested individual does not have to become a technician in order to understand the different associated relationships. Often, individuals are faced with the question of generating their own electrical energy, and it is very difficult for them to make an appropriate decision. In this context, there are many different parameters and information that must be considered. In addition, the status of the current use of renewable energies and possible future prospects for the countries in general will be made.

However, the influence, importance and dependence on electricity is immense. There is no private household where no electricity is needed, and the number of electrical appliances is growing very fast. All of humanity relies on electricity, and this situation will continue to increase in the future. The fact that fossil fuels will not be available in large quantities or so cheap forever, the focus must be more on renewable energy, on the one hand, to counteract the global warming and on the other hand, to provide the large amounts of electricity at low costs. In this context, we also must not forget the nuclear waste, which is very difficult to dispose of. To cope with the fast-changing technology and the digitalization we need to inform people about these trends, the possibilities and the hazards. Therefore, the relevancy of this topic is very high.

In order to arrive at a suitable result, the state of the art is researched, various plants compared and finally carried out some exemplary economic calculations of a plant, which has been crystallized by a specific selection process.

2 DEFINITIONS

For this scientific work, some technical terms are first defined, so that even persons without technical skills can follow the progress of the work. In addition, some other words are defined to provide a framework for this research paper and to have clear boundaries.

Energy

> *'(Physical) energy is the measure of the ability to generate motion.' (Schiller 2018, p. 110)*
>
> *'Energy is the ability to perform work.' (Schiller 2018, p. 111)*

According to the first law of Thermodynamics, which describes the natural law of energy conservation, energy can neither be created nor destroyed. (Refer to Reich and Reppich 2013, p. 41)[1]

Conversion

> *'the act of changing from one form or use to another' (Merriam-Webster´s online dictionary 2018a [Online])*

Electricity

> *'a fundamental form of energy observable in positive and negative forms that occurs naturally (as in lightning) or is produced (as in a generator) and that is expressed in terms of the movement and interaction of electrons' (Merriam-Webster´s online dictionary 2018b [Online])*

Private household

In the context of this research work, a private household is understood as an ordinary single-family dwelling that is not used for business purposes.

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[1] own translation from German to English

3 ENERGY FORMS AND ENERGY CONVERSION

This chapter shows the basic three primary sustainable sources that are being converted. In addition, the physical effects used, the types of power plants and the resulting energies are shown. In addition, there are some important advantages and disadvantages associated with sustainable energy conversion.

3.1 Overview of renewable energy sources

As a basis, three different primary energy types are distinguished:

- the solar radiation because of nuclear fusion in the interior of the sun
- the geothermal energy because of radioactive decay in the earth's core
- the tidal energy because of planetary motion and gravity

Primary Energy	Energy Type	Used Physical Effect	Power Station Type	Provided Energy-Type
Solar Radiation	Solar Radiation	Radiant Energy (photovoltaic effect)	Photovoltaic cell	- Electric final energy
		Radiant Energy (thermal energy)	Heliothermic power station	-Electric final energy -Thermal final energy
			Solar collector	-Thermal final energy
		Ocean current due to temperature differences	Ocean current power station	- Electric final energy
		Warming of the earth's surface	Ocean temperature gradient power station	- Electric final energy
	Wind-Energy	Airstream	Wind engine	- Electric final energy
		Wave motion	Wave power plant	- Electric final energy
	Water-Energy	Water cycle	Water power station	- Electric final energy
	Biomass	Biomass growth through photosynthesis	Biogas plant, Biomass heating plant	-Electric final energy -Thermal final energy

Geothermal-Energy	Geothermal-Energy	Geothermal energy in near-surface layers	Heat pump	-Thermal final energy
		Geothermal energy in deeper layers	Geothermal power plant	-Electric final energy -Thermal final energy
Tidal-Energy	Gravitation	Occurrence of tides	Tidal power station	-Electric final energy

Table 1: Overview of renewable energy sources
(Refer to Reich and Reppich 2013, pp. 44–45)[2]
(own representation)

3.2 Advantages and disadvantages regarding renewable energy

One of the main advantages of using renewable energy sources is that renewable primary energy sources have virtually unlimited availability, and this use, of course, conserves the limited resources of conventional energy sources. Furthermore, it can be stated that the direct use of renewable conversion plants does not cause any or only minor negative effects on the environment. The same applies to the dismantling of the plants, which leave no dangerous residues. Moreover, when it comes to domestic primary energy offers, even the transport of energy carriers and import dependency are eliminated, which determines the price of energy in the shortest possible consequence.

Among the most well-known disadvantages include the problems that occur in the upstream and downstream operating processes. This can be understood as the following negative activities. Release of greenhouse gases by intensively operated agriculture, monocultures for the cultivation of energy crops, elaborate production of photovoltaic modules based on silicon or significant interventions in landscape design through the construction of hydroelectric power plants. In addition, the availability of some renewable energies is subject to the weather and that therefore the energy supply is predictable only with limited accuracy. (Refer to Reich and Reppich 2013, pp. 46–47)[3]

[2, 3] own translation from German to English

To summarize the advantages and disadvantages, it can be said that many advantages arise about the use of renewable energies. One of the most important for the author is limiting the use of limited resources and curbing atmospheric warming by minimizing greenhouse gas emissions. In contrast, the disadvantages are minor and most occur only in upstream or downstream processes. Based on this knowledge, it can be assumed that the follow-up and closer illumination of this topic is reasonable and justified.

4 RENEWABLE WAYS TO COME UP WITH ELECTRICITY

This part focuses on the most important and already established renewable technologies in order to make different forms of energy economically viable. Furthermore, the physical effect associated with the respective conversion plant will be explained and the schematic structure of the power plant discussed. In this context, it is very important to note that this scientific work focuses only on electricity, not on thermal energy. Furthermore, there are many different levels of expansion of each system, making it difficult to reproduce them all. Therefore, for each type of conversion only one possible variant, which could fit for private households, is shown.

4.1 Photovoltaic-Cell

Technique description

With photovoltaic technology, solar radiation is converted into direct current (DC) with the help of semiconductors. The available final energy is measured in watts (W) and released when the solar cell is illuminated by photons. Solar cells never need to be charged like a battery, they only release electrical energy as long as light shines on the PV element. (Refer to Luque and Hegedus 2009, p. 3)

Physical basis

The basis of each solar cell consists of a semiconductor material, which have weakly bound electrons in a valence band (energy band). If the energy exceeds a certain threshold, the so-called band gap, then the bond is broken, and an electron becomes "free". This electron is then able to move in a conduction band. The energy needed to liberate the electrons is supplied by the photons contained in the solar radiation. The liberated electrons are pumped via the conduction band to a selective contact, from which the electrons are driven to the external circuit (electrical consumer). By working in the consumer, such as a light bulb, the electrons lose their energy. These are then returned to the valence band via a second selective contact or the feedback loop with the same energy as they started. The movement of the electrons in the outer circuit and the selective contacts is called an electrical current (see Fig. 1). (Refer to Luque and Hegedus 2009, pp. 3–4)

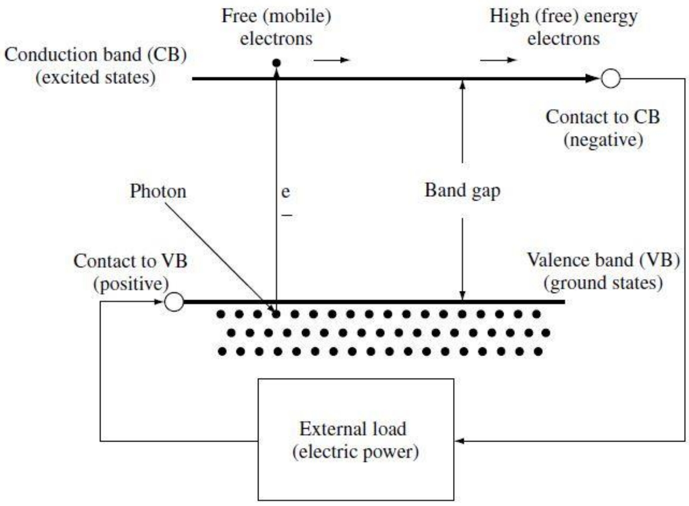

Figure 1: Schematic of a photovoltaic cell (Luque and Hegedus 2009, p. 4)

Overall system

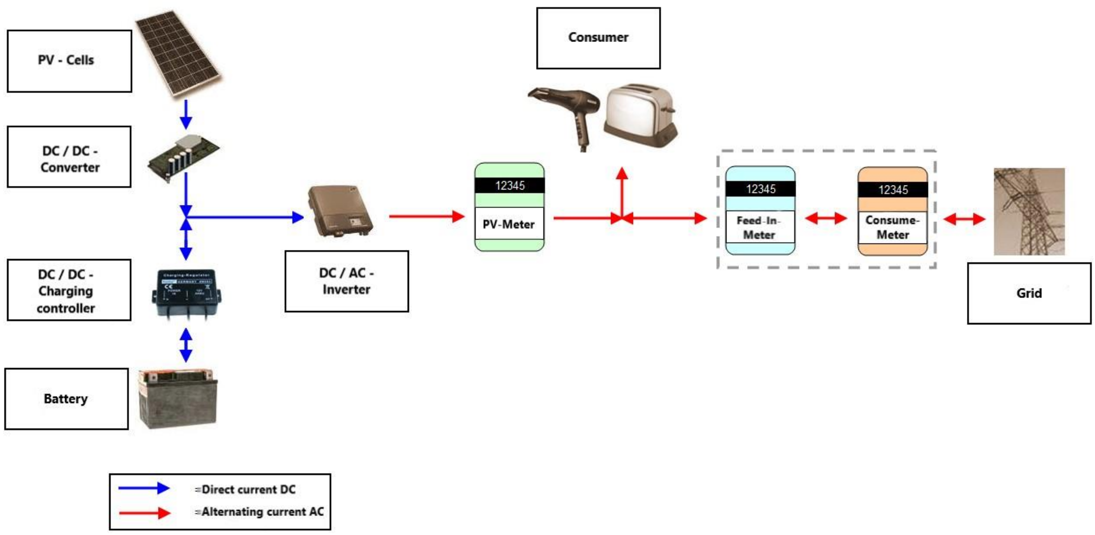

Figure 2: Block diagram of a PV-System with battery storage system (Adapted from Photovoltaik-Web 2018 [Online])

Figure 2 shows a DC solution for a PV battery storage system as an example. There are many ways to design a PV system, but the basic features are always similar. As can be seen from the figure, the PV cells always have direct voltage at the output, which must be converted into alternating current with an inverter in order to use it in the normal household network, since all consumers need an AC voltage as connection voltage. Furthermore, it can be decided whether one's own energy is used or partly fed back into the grid and receives energy from the local electricity provider.

Energy quantity

Of course, it is very difficult to predict how much electrical energy an installed PV system will have, as significant factors such as the duration of solar radiation and the month of the year play a role. But it can be assumed that a standard photovoltaic system produces approximately 330 watt per square meter and with approximately seventeen of them it can be enough energy provided for one household. (Refer to U.S. Department of Energy 2000, p. 18)

4.2 Wind-Power

Technique description

A wind turbine basically converts the kinetic energy of the air or the wind. Furthermore, with a rotor, in whatever form, the kinetic energy, which is the energy of an object that it possesses due to its motion, of the wind is converted into mechanical work. Subsequently, a generator converts the existing mechanical energy into electrical energy, which can then be made available to the electrical consumers. (Refer to Hau 2014, p. 81)[4]

Overall system

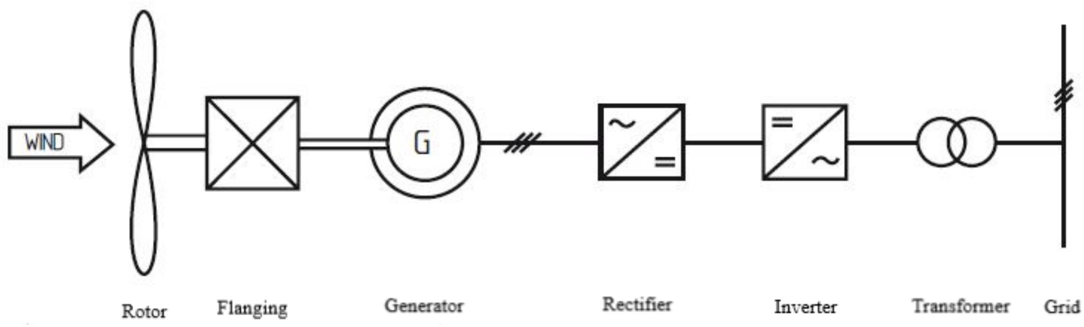

Figure 3: Block diagram of a Wind-Power-Station with full-conversion (Adapted from Hau 2014, p. 436)

[4] own translation from German to English

Figure 3 explains a theoretical design of a wind power plant with "full conversion". It was chosen the method of full conversion, since this is the one most likely to be implemented by a private household. The special feature of this technique is that the voltage generated by the generator is first rectified and then reversed immediately afterwards. With this concept, a large speed range is possible because the DC intermediate circuit causes a complete decoupling of the rotor and thus the generator speed of the grid frequency. If only one alternator were used, the rotor speed would be coupled to the grid frequency, which must be stable (USA = 60 Hertz, Austria = 50 Hertz). Basically, this concept can be realized with any type of generator, that is with a synchronous or asynchronous generator or with a generator with electrical or permanent magnet excitation. In most cases today a synchronous generator is combined with a full converter, especially if it is a direct driven generator. The good controllability of the synchronous generator also offers some advantages in combination with a converter, while eliminating the problematic dynamic characteristics of the synchronous generator with direct network coupling. (Refer to Hau 2014, pp. 436–437)[5]

Synchronous-Generator

The synchronous generator is an electro-mechanical machine which converts a movement triggered by, e.g. the wind, into electrical energy. Basically, the synchronous generator outputs a three-phase alternating current which is phase-shifted by 120 degrees. This generator has two main components, once the stator, which represents the output for the generated voltage. Furthermore, there is also the rotor on which the rotor of the, e.g. wind turbine, is flanged. The rotor must have a magnetic field, either via permanent magnets, or through a supply of DC voltage provided by brushing. The provision of a magnetic field is very important, otherwise the Faraday-Effect would not work. The Faraday-Effect uses electromagnetic induction, which causes an electrical voltage when the magnetic flux density changes. Frequency converters and power electronics are used to keep the frequency of the generated output voltage at 50

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[5] own translation from German to English

or 60 hertz. This circumstance is necessary because the rotational speed and the number of poles of the rotor determines the output frequency and especially the rotational speed can often vary (Refer to Alternative Energy Tutorials 2017 [Online]).

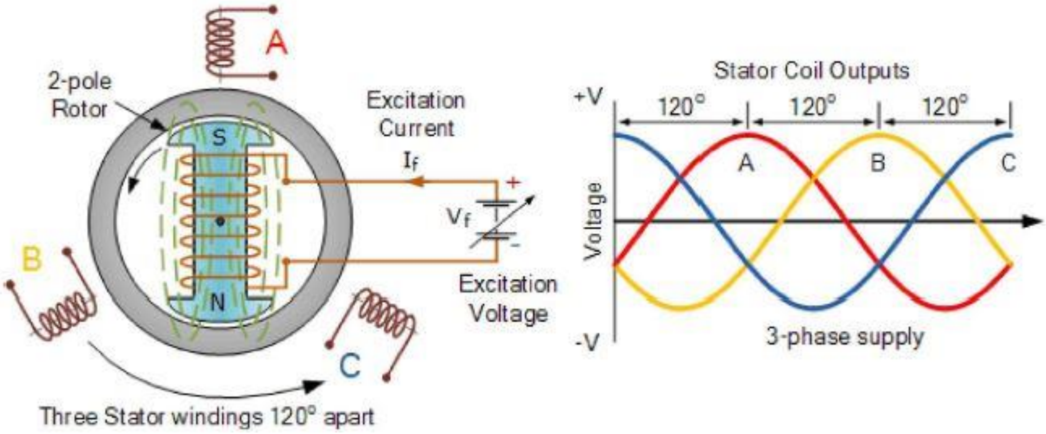

Figure 4: Construction of a Synchronous-Generator
(Alternative Energy Tutorials 2017 [Online])

Energy quantity

The energy quantity which can be provided by a wind turbine is difficult to unify. However, the fact is that the energy output is determined by the wind speed and by the selected turbine or generator. From experience, however, a 1.5-kilowatt turbine and an average wind speed of 6.26 meters per second can supply a single-family home. (Refer to U.S. Department of Energy 2000, p. 16)

4.3 Water-Power

Technique description

With the use of hydropower to generate electricity, mankind uses the potential energy or mechanical energy which water has due to its position relative to a reference level. Further, the basic idea of hydropower is now to make the potential energy of the water by, e.g. juxtaposing several dams along a watercourse harnessed by the so concentrated locally fall height one behind the other. In addition, to the potential energy, the kinetic energy, which is the energy that water has due to the movement, is also used in hydropower utilization. The origin of hydropower is solar, because only by the solar radiation the hydraulic circuit is kept going. (Refer to Giesecke et al. 2014, pp. 27–29)[6]

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[6] own translation from German to English

However, with the positional or kinetic energy, a mill or a turbine is again driven, similar to wind energy, which transmits the mechanical energy via a transmission and drive to a generator, which then provides electrical energy at the output.

Overall System

The components and construction of a small hydropower plant varies. Basically, the water must be discharged from the river and dammed by means of a pre-bay or dam. Subsequently, the water is transported via a pipe or shaft to the turbine or mill, which, as already mentioned above, converts the kinetic energy of the water into electrical energy with the aid of an electric generator. When the water has left the turbines, it has to be directed back into the river. Furthermore, the generated voltage is used either in a decoupled system itself, or in a coupled system via a transformer fed. (Refer to Alternative Energy Tutorials 2014 [Online])

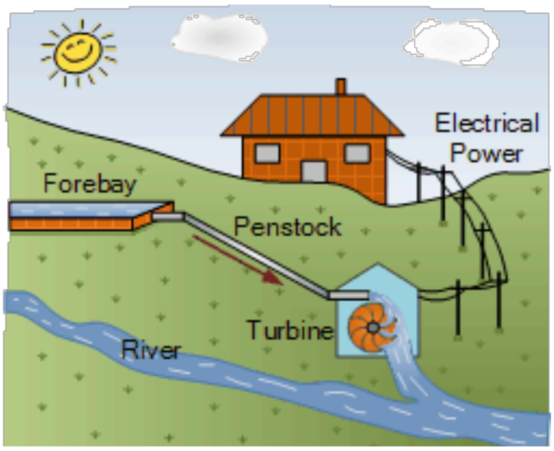

Figure 5: Schematic of a Small-Scale-Hydro-Plant

(Alternative Energy Tutorials 2014 [Online])

Generator

In principle, the same generators can be used with the hydroelectric power plant as with the wind power plant. The operator only has to decide whether he wants to use a stand-alone grid with, e.g. only direct current (12/24 V) for his home, or if he wants to use or feed AC voltage (USA = 110 V, Austria = 230 V). After this decision the right generator or inverter has to be chosen. Basically, the synchronous generator with direct current intermediate circuit, which produces the speed independence, is recommended again, since it is most stable and trouble-free for direct operation and use of energy.

Energy quantity

Also, in this case, the usable output power (P = Watt) varies depending on the factors such as drop height (H = meter), utilization rate (η) of the generator, transmission, converter and so on. Furthermore, the volume flow (Q = cubic meters/second), the acceleration of gravity, which is a natural constant (g = 9,81 meters/square second) and the density of water (ρ = 1000 kilograms/cubic meters) must be considered. (Refer to Giesecke et al. 2014, p. 31)

$$P = H \cdot \eta \cdot Q \cdot g \cdot \rho$$

4.4 Other Systems

There are many more renewable energy systems to come up with sustainable energy, but they still have other end-use energies, such as heat. Further, possibilities are shown in Table 1. A further investigation of these systems is not carried out, because on the one hand, it would be too extensive and on the other hand, this work deals with plants, which offer only electrical energy as final energy.

5 EVALUATION OF THE SYSTEMS

This section is on the one hand, about the advantages and disadvantages of the systems which are listed under point 4. On the other hand, the most important criteria are shown, which should be considered when choosing a renewable energy system. Furthermore, a utility analysis will help to choose a possible suitable energy system.

5.1 Advantages and disadvantages

Photovoltaic-Cell

When it comes to solar photovoltaic, it usually means the use of PV panels. There are of course many advantages associated with this. These include, among other things, the use of the endless energy of the sun, which is freely available. Furthermore, no harmful greenhouse gases are released during use and the maintenance and operating costs are very low, since no mechanically-moving parts are needed, unless sun tracking devices are used. Furthermore, the PV panels work silently and are very easy to mount on roofs or racks. What is more, PV panels are becoming cheaper and cheaper on the market, making them more lucrative for the buyer.

As it is the case with any renewable energy system, the PV modules also have problems of inconclusiveness in terms of weather and time. By this is meant that PV modules at night or during the day when it is cloudy causes strong energy losses. Furthermore, these are very fragile and mechanically sensitive. The operation of a PV system requires not only the modules but also DC/AC converters in order to be able to use the output power in the normal power grid. Often batteries are also needed for storage to compensate for days with low energy production. (Refer to Green 2012 [Online])

Wind-Power

Most renewable energy systems are not associated with a pollution of the atmosphere, even when using wind turbines. The potential of wind energy is enormous, and we can never use up the resource as the wind comes from the sun. Furthermore, wind energy systems are very space-efficient, and the operational costs associated with wind are low.

Of course, some negative points are associated with the wind energy. One of the biggest problems, also generally with renewable energy sources, they are all a very fluctuating source, which means they can not always provide enough energy, so you need batteries to store when less wind is available. Furthermore, wind turbines are very loud and can be disturbing for the wild animals. (Refer to Maehlum 2018 [Online])

Water-Power

There are some benefits associated with water energy. To come up with electrical energy with the help of water, no air pollution, as with the use of coal or fossil fuels, is caused. Furthermore, water is a local resource and does not have to be purchased. In addition, the sun is responsible for the circulation of the water and it is also a renewable source of energy. Water energy can be controlled very well by the engineers and relates to on-demand availability. In addition, some side effects, such as flood prevention, can be used by the water reservoir.

Of course, there are some disadvantages associated with producing electricity using hydropower plants. Newly built power plants destroy the landscape or take away the space, in some cases more important facilities such as new homes. Furthermore, animals living in the water are either expelled or a complex reconstruction, such as fish ladders, has to be set up. Since the turbine, which absorbs the flow energy of the water, is directly in the water, not only the water quality and the oxygen content is lowered, but also the water flow is restricted. In addition, during a drought, little or no water is available and thus no electrical energy can be obtained, which leads to a certain uncertainty (Refer to U.S. Department of Energy 2005 [Online])

General advantages regarding private households

If the above-mentioned advantages and disadvantages, which also refer to the general, not only private operation, it can be stated that the benefits of renewable energies far outweigh the disadvantages. Since one of the greatest benefits, the avoidance of global warming, is essential for the continued existence of humanity. There are also other benefits for private operators. One could be electrification by means of renewable energy in areas where there is still no electrical energy, for example in urban areas. Since the connection to the public power grid is very expensive, this could be a suitable solution. In addition, more and more electric cars are used, and it makes no sense to drive an electric car, but charge it with electricity, which comes from a nuclear, coal or natural gas power plant. The spread of electric cars is increasing more and more, so also the power requirements, so it makes sense to own a system, which provides electrical energy. Furthermore, the uncertainty, which often depends on the weather or the time of day, can be well compensated with either batteries. Another way would be, if a surplus of electricity is produced, it will be fed back into the public grid and you will get money and, if there is a shortage of energy you will simply get power from the public grid. Either money can be earned, but at least the uncertainty of not having electrical energy available can be compensated. However, now it can be stated that the further pursuit of the topic with respect to private households proves to be useful.

5.2 Criteria to select the most suitable plant

This section seeks to contrast the various installations and to provide points that should be considered when choosing the renewable energy system.

System	Capacity factor	Efficiency	Lifespan	Costs per kW	EROEI	Installation effort
PV-Cell	~10-20 %	~17 %	~15 years	~1500 Euro	~7	Low
Wind-Power	~25 %	~30 %	~20 years	~6500 Euro	~16	Middle
Water-Power	~40 %	~85 %	~40 years	~>6500 Euro	~50	High

Table 2: Comparison of the systems with different factors
(own representation)

The table above contains some specific values for each device, coming from the most diverse sources and articles and they reflect the average. It is important to understand that these must be approximations, because many different and specific environmental values are involved to achieve those values. Basically, the table should only give an overview and a feeling for the respective plants. (Refer to Jüttemann 2012; Ozgur 2013; Bockhorst 2016b; solaranlagen-ratgeber.de 2013 [Online])[7]

To briefly talk about the lifetime of the plants: It usually does not mean, for example, the PV panels or the rotors, but rather the electrical equipment such as inverter or generator, which must first be serviced or replaced. Furthermore, the installation costs will be briefly explained. It is associated with much greater effort to build a hydroelectric power plant because usually structural changes in the river must be made. In contrast, photovoltaic can be easily mounted on the roof and connected to the existing household power grid. The wind power plant can be different, because it can be mounted on the ground on the one hand, but a foundation must be built on the other hand, you can also mount this on the roof, but the mast must be designed mechanically.

Another good method, not just to determine the minimum selling price for electricity, is the Capacity Factor. The capacity factor is simply a ratio of energy generated over a period of time (typically a year) divided by the installed capacity. This factor is therefore crucial for the conversion of the installed capacity into the actual output power of the respective system. In addition, the capacity factor differs from different locations. (Refer to Ozgur 2013 [Online])

The Energy Returned on Energy Invested (EROEI) is a number which answers the following question: "How much energy does a power plant produce during its lifetime in relation to the energy input required for construction, operation and disposal? "On the side of investment are the energy, which is spent on the construction of the work, used during operation, for maintenance of the technology as well as the energy expenditure for the demolition of the power plant. On the other side is the "energy yield," the amount of energy that can be made available by the power plant. Both items are calculated over the life of the asset: Energy Returned on Energy Invested = (energy

[7] own translation from German to English

yields) / (energy investments). Only an EROEI factor with a value greater than 1 allows the recovery of energy over the operating time of a power plant. (Refer to Bockhorst 2016a [Online])[8]

Energy is transformed to make energy of a different quality available: for example, in a hydropower plant, the kinetic energy of the water is used to transform it into mechanical energy and then into a generator of electrical energy. The efficiency of this conversion is determined as follows: Efficiency = (amount of electrical energy made available) / (amount of kinetic energy used). Alternatively, the power that a device gives off can be compared to the power it consumes. Efficiency = (power output) / (power consumption). This definition applies both to the conversion of one type of energy into the other, for example from electrical energy to mechanical energy, as well as to the conversion of high electrical voltage to a lower level, specifically a conversion within one type of energy. (Refer to Bockhorst 2016b [Online])[9]

This means that the first important consideration for private households is to analyse the home environment and determine which system suits best into the available environment. Furthermore, if someone owns a mountain hut with a river, for example, it is a good idea to install a pico- hydroelectric power station, as these not only have the highest efficiency, but also the longest lifespan. If someone lives in a housing estate, you can consider a PV system, as this works silently and can be installed to save space. The wind turbines are similar to the hydropower plants, which are easier to build compared to PV.

The second important consideration is analysing the total consumption (load) of electrical energy. The load can be determined in such a way that from each used device, which is connected to the electricity grid, the wattage is taken. In addition, make sure that no device is forgotten, such as devices that are only used in winter. If no wattage is available, simply the terminal voltage (volts) has to be multiplied by the current consumption (ampere) and as a result of the calculation the wattage occurs. Now, when the electric power is defined, the last step is to multiply the wattage by the usage time

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[8, 9] own translation from German to English

(hours) and as a result the required watt-hours which are crucial to choose a renewable energy system derive. Finally, all watt-hours are added together, and the sum is a basis for the design of the renewable energy system. (Refer to U.S. Department of Energy 2000, p. 15)

5.3 Description of an example

In order to be able to put the facts explained so far into practice, an example household is needed, which will support the further calculations and decisions. This example is a family with 4 persons that lives in a densely populated residential area, as is customary today. In addition, at the house no river flows past.

Load	Daily Use (hours)	Wattage	Total Energy Consumption
Radio	1	25	25
Lamp	2	60	120
Television	4	150	600
Clothes Washer	1	500	500
Dishwasher	1	300	300
Fridge	24	600	14400
Total Daily Energy Consumption			**~16 Kilo-Watt-Hours**

Table 3: Sample-Load-Analysis
(own representation)

To have a base on which to continue working, a load analysis was carried out. In this context, it should be noted that this is just a hypothetical example. It should also be pointed out that more energy is consumed per day in the USA than in Austria. For the further calculation, however, the same household in the USA and in Austria is assumed. Furthermore, as already described above, the power consumption (= average value of various equivalent devices) of the various electrical appliances were searched together and then multiplied by the operating hours. The calculation results in a daily energy consumption of approximately 16 kilowatt-hours.

5.4 Benefit-Analysis

Now, a benefit analysis is performed to process the data listed above as well as advantages and disadvantages. The purpose of the utility analysis should be to find the most suitable plant for the actual situation. The result can then be redirected to other examples. Basically, a benefit analysis works with a weighting of the specified criteria. The system with the highest utility value should be followed up. At this point it is important to mention that a benefit analysis is not just based on facts, but also incorporates a little bit of one's own opinion. Especially when it comes to the point, which criteria should receive what importance.

Criteria	Weighting	Renewable Energy systems					
		PV-Cells		Wind		Water	
		Eval.	Value	Eval.	Value	Eval.	Value
Costs per kW	8	9	72	6	48	2	16
Capacity Factor	7	3	21	6	42	7	49
Lifespan	6	2	12	6	36	9	54
EROEI	5	2	10	6	30	9	45
Efficiency	4	2	8	4	16	8	32
Installation effort	3	9	27	7	21	2	6
Advantages	2	8	16	8	16	5	10
Actual Example	1	10	10	10	10	0	0
Sum			176		**219**		212
Project position			3		**1**		2

Table 4: Benefit-Analysis to find the most suitable system (own representation)

To understand the benefit analysis presented above, it needs some information and justification, which can be represented as follows. The weighting of the criteria ranges from eight to one in descending order, whereby this allocation is very much dependent on the importance of the criteria. For example, the point Costs per kW has received a very high weighting (8), as these costs are crucial for an economic use of this plant. However, in order to follow the evaluation, which ranges from ten to zero, on the one hand, the information from Table 2 and, on the other hand, Section 5.2 is required. The criteria from the comparison of the specifications (Table 2) were assessed so that the better indication received the higher value. Furthermore, the advantages mentioned above as well as the hypothetical example were used for the evaluation. Subsequently, the weights were then multiplied by the evaluation numbers to arrive at a value for each criterion and system. Then all the values of a system were added together to get a grand total. Finally, as it can be seen from Table 4, the wind power system has reached the highest utility sum just before the hydropower system and thus also comes to the fore as the most suitable renewable energy system. The result now shows that it is worthwhile to follow the use of wind power in this case. In contrast, the result does not mean at the same time that a small wind turbine is the best decision, this will show the profitability calculations. However, with this method only a certain pioneering indicator has been set, which now has to be checked.

6 Installation of a Small-Wind-Energy-System

This chapter now deals with some topics related to the installation of a micro-wind power plant for private use. First, a small-wind-power-plant (< 30 KW) has to be defined: Small wind turbines are installed directly next to the consumer (e.g. building, machine or device) in order to supply them with energy for their own consumption. A contrast to the utilization concept of multi-megawatt wind farms. These are placed on concentration zones as far as possible from settlements to feed and sell electricity.

6.1 Attention by setting up your own energy conversion system

This paragraph is an indication that not everyone can simply build a renewable energy system themselves. On the one hand, it requires a lot of know-how and technical skills, and on the other hand, there are rules in every country and every region. Basically, no consistent statement can be made about it, therefore, all future private operators with the manufacturing company of the selected plant and the regulations of the selected region, as well as with the local energy supply company have mutually challenged and vote. In addition, especially in wind turbines, which, as often mentioned, are placed on the ground, make sure that they do not fall over in bad weather. Therefore, it is important to consult specialists who calculate the effective loads. This hint can be given by the author without source proof due to many different searches from the most diverse sources.

6.2 Power-Determination of the turbine

In this context, two different locations will be investigated. The two locations were chosen because the exchange university is located in Edmond, OK, USA and the home university in Kufstein, Tyrol, AUT. Now the suitable turbine is selected based on the following table.

Criteria	Edmond, OK, USA	Kufstein, Tirol, AUT
Energy consumption	16 kWh/day = 5,840 kWh/year	16 kWh/day = 5,840 kWh/year
Wind speed	5.81 m/s	2.11 m/s
Mast height	15 m	15 m
Rotor diameter	5.5 m	5.5 m
System losses	10 %	10 %
Total costs	25,000 Euro	25,000 Euro
Lifespan	20 years	20 years
Type	Horizontal rotor axis	Horizontal rotor axis
Rated capacity	5 kW	5 kW
Output Energy	**11,921 kWh/year**	**640 kWh/year**

Table 5: Used parameters to define the output energy of the systems (own representation)

In Table 5, some important parameters for the turbines and plant selection have been defined and looked up. Due to the complexity and limitation of the scope of this work, it was decided to use an online calculator. On the one hand, this can consider the wind speed at different altitudes as well as other values regarding the energy output. With the help of the online calculator: https://www.klein-windkraftanlagen.com/klein-windanlagen-rechner/, the calculations of the different locations, which differ only by the wind speed, were carried out. The average wind speeds were looked up for the two cities. (Refer to weatherspeak.com 2018a; weatherspeak.com 2018b [Online]) This assumption is not entirely correct because, as already mentioned, a wind measurement should be carried out at each location, but this possibility was not given. Furthermore, the parameters mast height, rotor diameter, system losses, lifetime, rated power, type and total costs are to be taken from the manufacturer. In this case, only a 5-kW system had to be selected and the other parameters were already stored. Now, as a result, the two maximum output energies of the system, which can be achieved annually, emerged. As already mentioned, the locations can only be distinguished by the wind speed and the result is amazing. In Edmond it is possible to generate 11,921 kilowatt-hours per year with a 5-kilowatt turbine, and in Kufstein with the same plant only 640 kilowatt-hours per year. From the amount of electricity produced annually, since only self-consumption is lucrative, the plant in the USA is much too large. Nevertheless, this system was chosen to make the two locations comparable.

6.3 Performance and yield of small wind turbines

In addition to costs and yields are the decisive factors when assessing the profitability of a small wind turbine. The annual income of a small wind turbine should be adjusted to the own consumption. Because only self-consumption is economical in Austria and the USA, the feed is not. The trend is that the higher the output and the rotor diameter of a system and the higher the average annual wind speed, the higher the annual electricity production. Since the wind conditions at individual locations can differ considerably, general statements about the yields of an installation are difficult. Security for the yield potential at your own location is only provided by on-site wind measurements, since the wind speed differs also with the mounted height. (Refer to klein-windkraftanlagen.com 2014 [Online])[10]

7 ECONOMIC EVALUATION

This chapter tries to calculate in the first step a so-called amortization calculation for the two locations figure out how many years it takes for the investment to pay off. In the amortization calculation, the decision size is the time to recovery of initial capital expenditure (= acquisition cost) from the surplus revenue of the project (= amortization period). In this context, surplus income is defined as the savings made by not buying the electricity from the local energy provider. Furthermore, in the second step the Net-Present-Value and the Internal Rate of Return of the projects for the given lifespan of the facilities are considered.

7.1 Amortization

7.1.1 Amortization-Method

The cumulative anticipation is used to calculate the amortization time targeted in this context. In the cumulative approach, the income surpluses are first calculated for each period and accumulated until the sum of the income surpluses equals the acquisition

[10] own translation from German to English

cost. Such a procedure is recommended if, contrary to the premises of static procedures, the profit pattern is irregular. The use of the amortization calculation also combines some advantages. Assessment of the advantageousness of a single investment: Actual payback period must be less than or equal to the target payback period, where the target payback period may either be formulated as an absolute value or derived from the relative percentages of the projected service life. (Refer to Schierenbeck and Wöhle 2008, p. 405)[11] Since it can be assumed that the price of electrical energy increases by two percent per year, this method can be used. In addition, it is assumed that the entire acquisition costs will be paid in full without any credit balance and thus no discounting to the cash value will be made in the calculation. Furthermore, ten percent of the investment will be added to cover repair or service costs over the lifespan of the equipment.

7.1.2 Pay-Back-Time

Edmond, USA, OK

In order to be able to figure out the amortization calculation, some data must first be collected. The first important factor that reduces the investment level is the promotion of construction. The subsidies in the US for the construction of a small wind power plant amount to 30 % of the construction costs, which can be withheld through the tax bill. (Refer to Lips 2018 [Online]) The second factor is the current purchase price for electrical energy in the state of Oklahoma, which must first be first determined. The level of the price is about 10 US cents per kilowatt hour in the preparation of this work, which is about 8.6 euro cents. (Refer to Electricity Local 2018 [Online]) However, for the Edmond site, it can be seen from Table 5 that more electrical energy is provided by the wind turbine than the private household consumes. As a result, surplus energy is fed back to the electrical public grid and sold. This yield leads to a minimization of the investment and therefore has to be considered in the amortization calculation. The US has many different regulations for the so-called Feed in Tariff (FIT), which indicates a guaranteed feed-in tariff per kilowatt hour of electrical energy for a certain

[11] own translation from German to English

period of time. Unfortunately, the feed-in tariffs of the different states are very different and an average assumption of 5 US cents per kilowatt-hour fed had to be made, which is about 4.3 euro cents. Moreover, the feed-in tariff is fixed, so there will be no increase in the next 25 years. Furthermore, information from Table 6 is used which can be seen on the next page.

Total Investment = 25000 Euro (Small-Wind-Energy-Facility) + 1250 Euro (Service & Repair costs = 5 %) – 7500 Euro (Subsidies tax reduction = 30%) = **18750 Euro**

Information	Value
Total Investment	18750 Euro
Output Energy	11921 kWh/year
Used Energy	5840 kWh/year
Sold Energy	6081 kWh/year
Consumption Tariff	0.086 Euro/kWh
Feed in Tariff	0.043 Euro/kWh
Annual increase of Consumption Tariff	2 %

Table 6: Information used for amortization calculation for the city Edmond (own representation)

The following table (Table 7) shows the exact residual investment values in each period. The calculations were done with the software Microsoft Excel but sample calculations are given. As described in the cumulative method, the profitable values (saving by not buying electricity plus the proceeds for the unused refeed energy) are deducted from the previous value until the residual investment value becomes positive.

Year 1: RIV = -18,750 € + (5840 kWh/year * 0.086 € + 6081 kWh/year * 0.043 €) = **-17,986.277 €**

Year 2: RIV = -17,986.277 € + (5840 kWh/year * 0.086 € * 1.02 + 6081 kWh/year * 0.043 €) = **-17,212.509 €**

Year	Residual Investment Value (RIV)
0	-18,750.00 €
1	-17,986.277 €
2	-17,212.509 €
3	-16,428.496 €
4	-15,634.032 €
5	-14,828.908 €

7	-14,012.911 €
8	-13,185.825 €
9	-12,347.426 €
10	-11,497.488 €
11	-10,635.782 €
12	-9,704.808 €
13	-8,818.853 €
14	-7,920.408 €
15	-7,009.224 €
16	-6,085.046 €
17	-5,147.614 €
18	-4,196.663 €
19	-3,231.923 €
20	-2,253.118 €
21	-1,259.966 €
22	-252.180 €
23	770.531 €
24	1,808.467 €

Table 7: Exact residual investment values in each period / City Edmond (own representation)

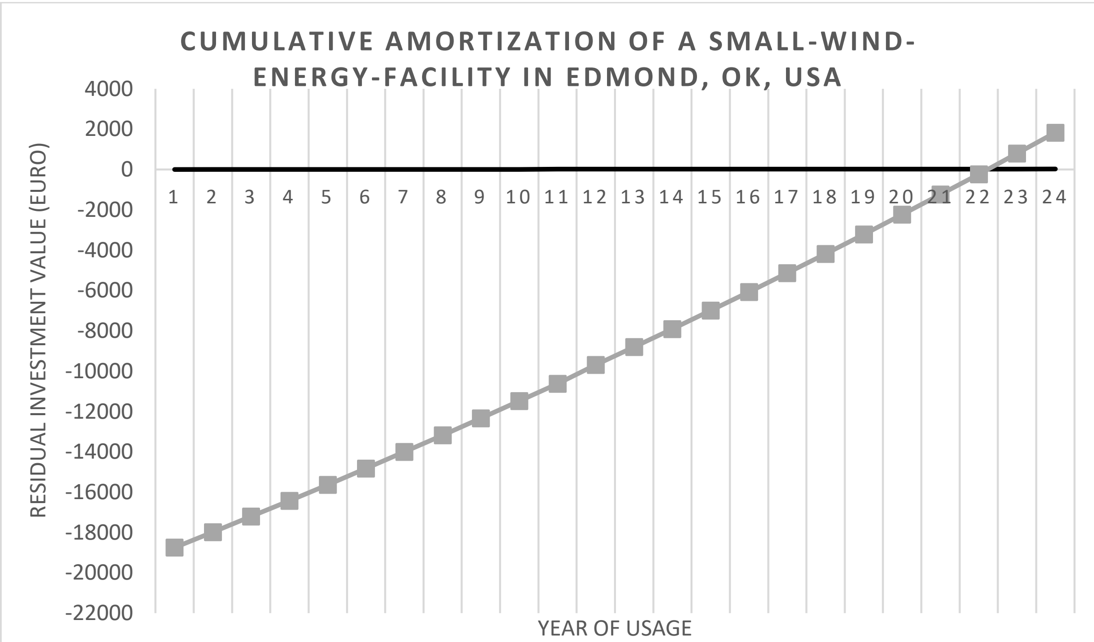

Figure 6: Cumulative amortization of a Small-Wind-Energy-Facility in Edmond, OK, USA (own representation)

Figure 6 now shows Table 7 as a graph showing the years of use on the x-axis and the residual investment values in euros on the y-axis. It also provides information that the investment of a small wind turbine in Edmond, OK, USA, would pay off in the 24th year, which means that the residual investment value is positive for the first time, indicating a profit from the 23th year. Furthermore, it must be pointed to the premises that no unexpected service or repair costs may occur, and the price of consumed electricity increases by 2 percent annually. However, comparing the amortization period with the lifetime in Table 5, it can be stated that the lifetime of the plant (= 20 years) is below the payback period and under the given information and circumstances the investment and use of a small-scale wind facility in Edmond, Oklahoma, USA is not profitable. The investment could be worthwhile if a smaller investment were chosen, since on the one hand the costs would decrease and on the other hand the current plant now provides too much electrical energy, which is reflected in an inefficiency. But that was not changed to make the two selected locations comparable. Furthermore, the reason for the unprofitability may also be the low purchase price for electrical energy in the USA.

Kufstein, AUT, Tirol

Now the same amortization calculation is carried out as for the Edmond location, except that this time it is the construction of a small wind turbine in Kufstein. The Kufstein site is slightly different from Edmond, as shown in Table 5, much less electrical power can be supplied by the facility than in Edmond, even though it is the same facility. In this example, therefore, no surplus energy can be generated, which means that the entire energy produced is consumed itself and still needs to be purchased energy. However, the purchased energy does not need to be included in the investment calculation as it does not increase or decrease the investment value. In addition, no support was found for a construction project of a small wind turbine, so that the total investment is only reduced by the assumption that upon request from the country a special subsidy of 15 percent of the total investment can be granted. Nevertheless, for the city of Kufstein, the latest electricity price must be discussed, to begin the calculation, only the search after the FIT can be saved, since no electricity is sold. The current electricity price for Tyrol can be estimated at the time of writing this scientific work with 18.57 euro cents per kilowatt hour of electrical energy. (Refer to stromliste.at

2017 [Online])[12] Furthermore, the information in Table 8 was used to arrive at a reasonable estimation.

Total Investment = 25000 Euro (Small-Wind-Energy-Facility) + 1250 Euro (Service & Repair costs = 5 %) - 3750 Euro (Subsidies tax reduction = 30%) = **22500 Euro**

Information	Value
Total Investment	22500 Euro
Output Energy	640 kWh/year
Used Energy	5840 kWh/year
Sold Energy	0 kWh/year
Consumption Tariff	0.1857 Euro/kWh
Feed in Tariff	-
Annual increase of Consumption Tariff	2 %

Table 8: Information used for the amortization calculation for the city Kufstein (own representation)

The following table (Table 9), again as in the calculation for the city of Edmond, shows the exact residual investment values in each period. The calculations were done with the software Microsoft Excel, but example calculations are given. The values were only displayed up to the 24th year of use and the calculation was aborted because the predicted useful life had already been exceeded

Year 1: RIV = -22,500 € + (640 kWh/year * 0.186 €) = **-22,381.152 €**

Year 2: RIV = -22,381.152 € + (640 kWh/year * 0.186 € * 1.02) = **-22,259.927 €**

Year	Residual Investment Value (RIV)
0	-22,500.00 €
1	-22,381.152 €
2	-22,259.927 €
3	-22,136.278 €
4	-22,010.155 €
5	-21,881.510 €
7	-21,750.292 €
8	-21,616.450 €
9	-21,479.931 €
10	-21,340.682 €
11	-21,198.648 €

[12] own translation from German to English

12	-21,053.773 €
13	-20,906.000 €
14	-20,755.272 €
15	-20,601.529 €
16	-20,444.712 €
17	-20,284.758 €
18	-20,121.605 €
19	-19,955.189 €
20	-19,785.445 €
21	-19,612.306 €
22	-19,435.704 €
23	-19,255.570 €
24	-19,071.834 €

Table 9: Exact residual investment values in each period / City Kufstein (own representation)

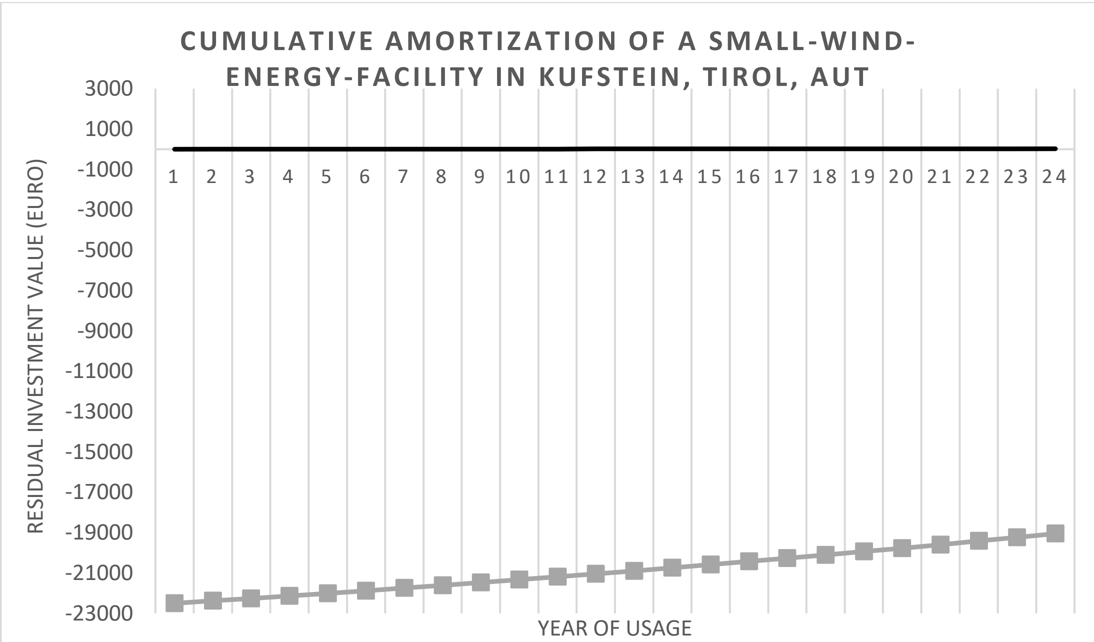

Figure 7: Cumulative amortization of a Small-Wind-Energy-Facility in Kufstein, Tirol, AUT (own representation)

Figure 7 determines again the course of the cumulative amortization, whereby it is immediately apparent at first sight that this was discontinued after the 24th year. The reason is that the remaining acquisition costs in the 20th year of use are still so far from a positive value. This means that an investment in a small wind turbine for the location Kufstein, Tyrol, Austria under the given premises and circumstances at the present time is economically unprofitable because the predicted lifetime of the plant is

20 years. However, since the amount of output energy is very significantly dependent on the wind speed, it can be concluded that at this location the wind speed is too low to extract and use the potential electrical energy.

7.2 Profit-Calculation over time

In this section, the investment projects in Edmond and Kufstein are also examined for their Net Present Values (NPV) and the Internal Rate of Return (IRR). These values include the time value of money and are therefore very important when making long-term investment decisions.

7.2.1 Net-Present-Value

Net Present Value is used in capital planning to analyse the profitability of a planned investment or project. In addition, NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. A positive net present value indicates that the revenues made by a project or investment exceed the expected costs. In general, a positive NPV will be profitable, and an investment with a negative NPV will result in a net loss. (Refer to Investopedia 2018b [Online])

$$NPV = \sum_{t=1}^{T} \frac{Ct}{(1+r)^t} - Co$$

7.2.2 Internal-Rate-of-Return

The Internal Rate of Return (IRR) is the interest rate at which the net present value (NPV) of the expected total capital flows of a project, both positive and negative, adds up to zero. The IRR of a project is used as a benchmark. If the IRR of a particular project is higher than the required return of an investor, then the project can be accepted. However, if the IRR of a project is calculated to be below the required return of an investor, the project will not be moved forward. (Refer to Investopedia 2018a [Online])

Edmond, USA, OK

The calculations were carried out again with the Microsoft Excel program. For the calculation on the one hand, Table 6 was used and on the other hand, a plausible discount rate of 3.3 % (possible Government-Savings-Bond) was assumed.

Solutions	Value
NPV	-6,118.969 Euro
IRR	-1 %
Consumption Tariff where NPV = 0 & IRR = 3.3 %	0.149 Euro/kWh
Investment costs where NPV = 0 & IRR = 3.3 %	12,429.10 Euro

Table 10: Solutions for the Profit-Calculation over time / City Edmond

(own representation)

In order to evaluate the results of these calculations (For an exact description see appendix!), some explanations are needed. The negative NPV from the Edmond location now says that the investment does not generate enough profit over the 20-year lifespan and is therefore not profitable. This unprofitability is also presented by the negative IRR. In addition, it was determined by some target value analysis (what-if-analysis in Excel), at which minimum purchasing consumption price per kWh of energy (0.149 Euro) and also at which investment costs (12,429.7810 Euro) for the whole facility, the NPV would equal zero and the IRR would equal the discount rate. To sum up, this project is not worth pursuing it at the moment unless the purchasing consumption price rises, or the investment costs fall.

Kufstein, AUT, Tirol

The calculations were carried out again with the Microsoft Excel program. For the calculation on the one hand, Table 8 was used and on the other hand, a plausible discount rate of 3.3 % (possible Government-Savings-Bond) was assumed.

Solutions	Value
NPV	-19.800,937 Euro
IRR	-14 %
Consumption Tariff where NPV = 0 & IRR = 3.3 %	2.043 Euro/kWh
Investment costs where NPV = 0 & IRR = 3.3 %	2,045.63 Euro

Table 11: Solutions for the Profit-Calculation over time / City Kufstein

(own representation)

The calculation (For an exact description see appendix!) for the location Kufstein was proceeded similarly as for Edmond, only, that in this case no energy can be sold. Also, for this project, the NPV and the IRR are extremely negative, suggesting a halt in following-up the project. In addition, a target value analysis (what-if-analysis in Excel) has determined that one kWh of electrical energy has to cost 2.043 Euro so that the NPV is zero and the IRR again equals the discount rate. In addition, a second scenario has shown that to reach a minimum of NPV and a maximum of IRR, investment costs would have to go down to 2,045.63 Euro. In summary, this project can not be worth it because the wind speed is far too low and therefore the energy output is extremely small.

8 COMPARISON OF THE LANDSCAPE OF RENEWABLE ENERGY SYSTEMS IN BOTH COUNTRIES

This section presents and compares the energy production structures of Austria and the United States. It should also be noted that not only private households but also the whole country is respected, as the differences in progress are to be discussed. The reason why the whole country is shown here is that this section discusses the overall progress of the countries. On the one hand, it shows from which sources and conversion plants all the electrical energy supplied originates and on the other hand, the distribution of the regenerative energy systems is represented individually again.

United States of America

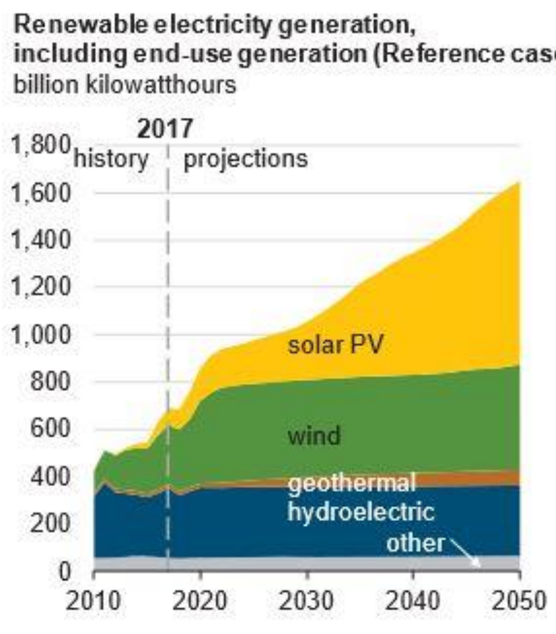

Figure 8: Distribution of origin of electrical renewable energy in the US (U.S. Energy Information Administration 2018, p. 93)

Austria

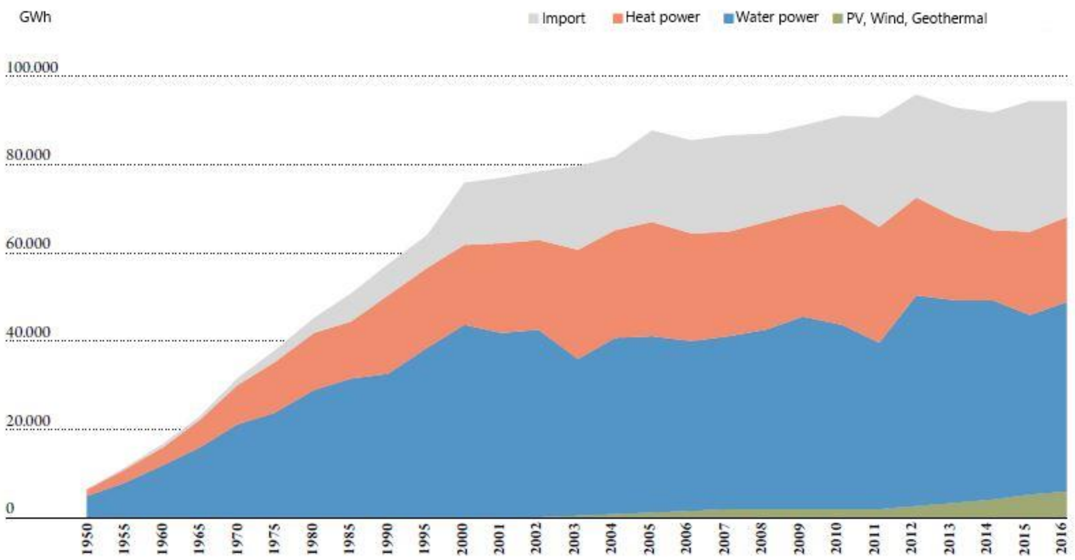

Figure 9: Distribution of origin of electrical renewable energy in Austria (Adapted from Biermayer 2017, p. 17)

Now, the Graphs 9 and 10 are compared which respectively represent the generation of electric power compared to the various renewable energy systems. At first glance, it immediately stands out that wind energy in the US has a much higher priority than in Austria, which is due to the greater profitability (higher wind speed) in the US. Furthermore, the use of water energy is relatively equally attractive in both countries, and at the same time represents the system that is most frequently used. It can also be seen that PV and geothermal energy in both countries contribute very little to the generation of total energy. Furthermore, it is noticeable that Austria extracts a lot of electrical energy from thermal power, which apparently has not gained much momentum in the USA until now, as this kind of energy did not appear in US statistics. In addition, Austria has to import some electrical energy, which the US does not have to do. The US is well known for its booming energy industry, but more likely due to its non-renewable energy resources. Many raw materials are exported because there is a surplus of non-renewable energy resources. For example, natural gas is present in large quantities in the USA because fracking is very popular here. In fracking, sand is mixed with water and chemicals and pumped into high pressure wells to crack the earth shells and extract the natural gas.(Refer to Gold 2014, p. 8) This circumstance could also explain why the purchase prices for electricity in the US is much lower than in Austria.

9 FUTURE PROSPECTIVE

In this section it is tried to make possible future perspectives regarding renewable energies (PV, Water & Wind). Furthermore, the general trend, as well as general possibilities in this regard are discussed.

United States of America

To discuss the future of renewable energy in general for the United States of America, Figure 8, which is in the previous section, is needed. As you immediately notice, the US will focus very much on photovoltaic in the next few years and greatly expand the use of this technology, since the current installation number is very low and there is a lot of potential. This is also the biggest change to the current state. Also, the use of wind energy is to be increased by a bit, which is not the case for the use of water energy. Furthermore, the facilities of geothermal energy will be expanded slightly. In this context, it should be noted that geothermal energy was not really noticed in the entire research work, as it does not only provide electricity but also heat, which could be a good future trend.

Austria

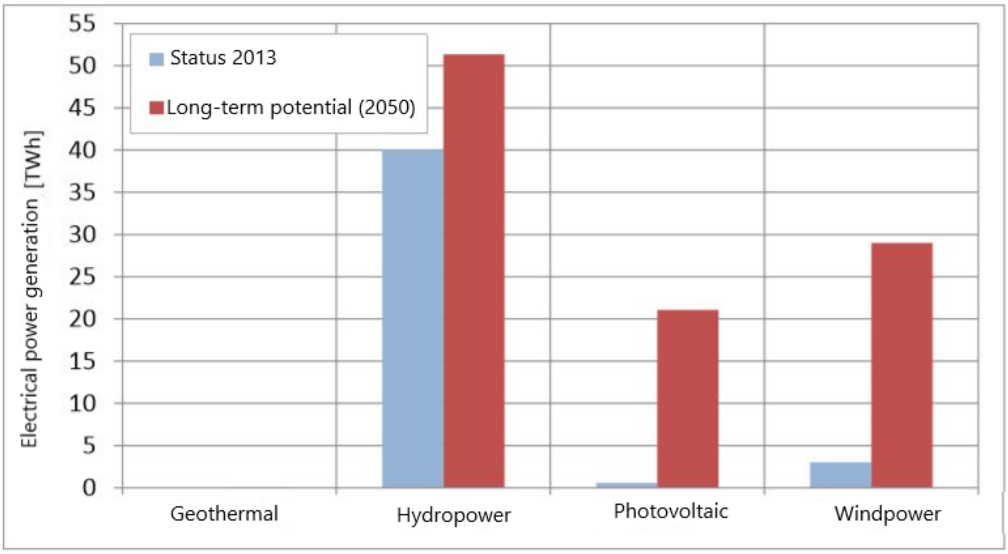

Figure 10: Long-term potential for electricity from renewable energies in Austria (Adapted from Resch et al. 2017, p. 19)

Looking at Figure 10, which shows the future potential for electricity from renewable energy in Austria, a similar trend can be seen as in the US. The potential for photovoltaic use is similar for Austria to the US, suggesting a focus on this technology. Furthermore, the use of wind energy is also to be expanded, since there, possibly not for private operators, but for commercially used facilities (other locations of the installation are possible) there is a great potential for energy. According to the graph, in addition to the very strong two other trends, the use of the hydropower could also be expanded, which is already being used very well in the current state. Further, in the figure above, biomass is not included in the long-term potential of renewable energies in the electricity sector, since the broad range of energy sources subsumed under this category can be used not only for electricity, but also in the heating sector as well as in the transport sector.

In general, and for private operators

In general, for the future, it should be noted that when more and more limited resources from the earth are consumed, eventually the time will be reached, where all resources are consumed. Precisely for this reason, mankind should be sparing with the available energy and the usage of facilities that provide electrical energy, because the resources that are needed for it, are limited. It is precisely this point on the future timeline, where all resources have been used up, that should not be achieved, so more and more renewable energies must now be used. As a side effect, the further heating of the earth is stopped, which is also associated with a lot of advantages. (Refer to Gold 2014, p. 18) Furthermore, due to the advantages and disadvantages of the systems mentioned so far, it can be concluded that a mixture of the system for private households could be a possibility. On the one hand, an energy self-sufficiency can be achieved, which leads to a decoupling of the purchase price for electricity. On the other hand, with the mixture of systems, the disadvantages of the other system are compensated. Moreover, in this context, it will also be important to optimize the battery systems, to compensate the time lag between production and consumption of energy, since only self-consumption of electrical energy is efficient, but this should not be the topic of this scientific work.

10 Findings

In order to reflect this scientific work again and to clarify the most essential aspects in connection with it, a summary is needed, which at the same time should point out the most essential found aspects. Basically, there are several different ways to provide electricity on a renewable and sustainable way. In this context, the various advantages and disadvantages for photovoltaics, wind energy and water energy have been found. With the evaluation of the advantages and disadvantages could not be decided which plant is most suitable. However, the three mentioned facilities differ significantly in terms of Capacity Factor, Efficiency, Lifespan, Energy Returned on Energy Invested and Cost per Kilowatt-Hour of electricity, which are very good parameters to compare different systems. To make a possible decision, the next step is to evaluate the environment where the system should be installed. Furthermore, it is very important to figure out the amount of energy the household needs, as the supply to the grid of surplus energy is uneconomical. For the selected theoretical example, a benefit analysis revealed that a small wind turbine could be suitable. In connection with wind energy, the wind speed, the rotor diameter and the height of the rotor from the ground are decisive for the energy yield. In general, again, it should be mentioned that an installation of a private renewable energy system can not easily be carried out without the approval and assessment of outside agencies. However, in the next step, a profitability calculation using the cumulative method for the two different locations Edmond and Kufstein was carried out. Both investments do not seem to be economical efficient, as the payback period is higher than the expected lifetime of the facilities. For the installation in Edmond, however, a smaller facility could be very economical as the country's subsidies and wind speed are high enough. Furthermore, the payback period exceeds the lifetime of the chosen system only a little bit. Currently, the price of electricity in the USA is very low, which also contributes to inefficiency regarding payback time. In contrast, for Kufstein there are hopeless opportunities for private operators of indigenous plants, because on the one hand, the wind speed is too low and on the other hand, the subsidies of the country are far too low to operate economically. However, the purchase price for electricity is very high, that is a reason why it would be worth to investigate, if another private renewable system (e.g. Photovoltaics) would be an economical opportunity. In addition, it could also be a good opportunity to use both a small-scale-wind-facility and a e.g. photovoltaic system in combination to compensate for the disadvantages of both. But this hypothesis would have to be further investigated. However, the investigation of the economic viability for photovoltaic in Kufstein was not carried out afterwards, since it would go beyond the scope of this work. In addition, to further examine the economics of the two investments, the net present value and the internal rate of return were used, which were also negative for both projects and thus confirm that, under the given circumstances, a follow-up of the projects is also not recommended. Furthermore, the purchase price for electricity in Edmond would have to increase to 0.149 Euro/kWh and in Kufstein to 2.043 Euro/kWh, or the investment costs would have to decrease in Edmond to 12,429.10 Euro and in Kufstein to 2,045.63 Euro, so that the NPV equals zero and the IRR is at its maximum under the given lifespan. As a result, this research project gives at least the certainty that a small wind turbine for Kufstein and for Edmond under the current circumstances is very unprofitable. In general, it should be pointed out, that once the purchase price of electricity increases and the technologies of the plants and the subsidies of the countries are improved, a private renewable-energy-facility can be worthwhile, which is very difficult to generalize since the location and the energy consumption are decisive. Finally, the trend of increased future use of renewable energy can also be found in the forecasts of the two countries. To complete this work, it is necessary to appeal again to save energy, because once the end of consumables is reached, it can not be drilled further into the past and renewable energy systems become indispensable!

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12 ATTACHMENTS

Profit Calculation over time / City Edmond

Profit Calculation over time / City Kufstein

Profit-Calculation over time / City Edmond

Profit-Calculation over time (Edmond)

Used Parameters	
Total Energy Produced (kWh/year)	11921,00
Energy consumed (kWh/year)	5840,00
Energy sold (kWh/year)	6081,00
Consumption Tariff	0,086 €
Feed in Tariff	0,043 €
Discount Rate (Assumption Savings Bond)	3,30%
Years (Life-Time of Facility)	20
Total Investment (overnight costs)	18.750,00 €
Energy Cost Escalator	2,00%

Year	0	1	2	3	4	5	6
Cash-Value of Energy consumed	- €	502,240 €	502,240 €	502,240 €	502,240 €	502,240 €	502,240 €
Consideration of increasing Consumption Tariff	- €	502,240 €	512,285 €	522,530 €	532,981 €	543,641 €	554,514 €
Cash-Value of Energy sold	- €	261,483 €	261,483 €	261,483 €	261,483 €	261,483 €	261,483 €
=							
Revenue	- €	763,723 €	773,768 €	784,013 €	794,464 €	805,124 €	815,997 €
Costs	18.750,000 €	- €	- €	- €	- €	- €	- €
Profit	- 18.750,000 €	763,723 €	773,768 €	784,013 €	794,464 €	805,124 €	815,997 €

Profit-Calculation over time (Edmond)

7	8	9	10	11	12	13	14	15	16
502,240 €	502,240 €	502,240 €	502,240 €	502,240 €	502,240 €	502,240 €	502,240 €	502,240 €	502,240 €
565,604 €	576,916 €	588,454 €	600,223 €	612,228 €	624,472 €	636,962 €	649,701 €	662,695 €	675,949 €
261,483 €	261,483 €	261,483 €	261,483 €	261,483 €	261,483 €	261,483 €	261,483 €	261,483 €	261,483 €
827,087 €	838,399 €	849,937 €	861,706 €	873,711 €	885,955 €	898,445 €	911,184 €	924,178 €	937,432 €
- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
827,087 €	838,399 €	849,937 €	861,706 €	873,711 €	885,955 €	898,445 €	911,184 €	924,178 €	937,432 €

17	18	19	20
502,240 €	502,240 €	502,240 €	502,240 €
689,468 €	703,257 €	717,322 €	731,669 €
261,483 €	261,483 €	261,483 €	261,483 €
950,951 €	964,740 €	978,805 €	993,152 €
- €	- €	- €	- €
950,951 €	964,740 €	978,805 €	993,152 €

NPV	- 6.118,969 €
IRR	-1%

Profit-Calculation over time / City Kufstein

Profit-Calculation over time (Kufstein)

Page 1

Used Parameters	
Total Energy Produced (kWh/year)	640,00
Energy consumed (kWh/year)	640,00
Energy sold (kWh/year)	0,00
Consumption Tariff	0,186 €
Feed in Tariff	- €
Discount Rate (Assumption Savings Bond)	3,30%
Years (Life-Time of Facility)	20
Total Investment (overnight costs)	22.500,00 €
Energy Cost Escalator	2,00%

Year	0	1	2	3	4	5	6
Cash-Value of Energy consumed	- €	118,848 €	118,848 €	118,848 €	118,848 €	118,848 €	118,848 €
Consideration of increasing Consumption Tariff	- €	118,848 €	121,225 €	123,649 €	126,122 €	128,645 €	131,218 €
Cash-Value of Energy sold	- €	- €	- €	- €	- €	- €	- €
=							
Revenue	- €	118,848 €	121,225 €	123,649 €	126,122 €	128,645 €	131,218 €
Costs	22.500,000 €	- €	- €	- €	- €	- €	- €
Profit	- 22.500,000 €	118,848 €	121,225 €	123,649 €	126,122 €	128,645 €	131,218 €

Profit-Calculation over time (Kufstein)

7	8	9	10	11	12	13	14	15	16
118,848 €	118,848 €	118,848 €	118,848 €	118,848 €	118,848 €	118,848 €	118,848 €	118,848 €	118,848 €
133,842 €	136,519 €	139,249 €	142,034 €	144,875 €	147,773 €	150,728 €	153,743 €	156,817 €	159,954 €
- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
133,842 €	136,519 €	139,249 €	142,034 €	144,875 €	147,773 €	150,728 €	153,743 €	156,817 €	159,954 €
- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
133,842 €	136,519 €	139,249 €	142,034 €	144,875 €	147,773 €	150,728 €	153,743 €	156,817 €	159,954 €

17	18	19	20
118,848 €	118,848 €	118,848 €	118,848 €
163,153 €	166,416 €	169,744 €	173,139 €
- €	- €	- €	- €
163,153 €	166,416 €	169,744 €	173,139 €
- €	- €	- €	- €
163,153 €	166,416 €	169,744 €	173,139 €

NPV	- 19.800,937 €
IRR	-14%