Potentials of Renewable Energies (RES) in MV Analysis, balances and usability

PROJECT: RES-CHAINS

PROGRAM: SOUTH BALTIC PROGRAM

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1. Preface

This paper is a short abstract of a report, written for a project to research RES-Chains for the district of Northwest-Mecklenburg, sponsored by the EU. The full report will discuss different technologies for renewable energy, focusing on the productivity and life cycle management, but also on the possible combination of different types of renewable energy sources. This paper will build upon existing potential analysis for Mecklenburg-Vorpommern (MV). These evaluate the regionally available potentials, but only count technical potential for every single technology. Several technologies however use the same resources, so they can not be fully developed side-by-side. For a realistic outlook on the future development it is essential to analyse the economic potentials of the energy sources. The regional value can also be increased by combining several technologies into an energy concept for each parish, according to local preferences and advantages/ disadvantages.

The existing analysis show a large potential for renewable energy in MV, but this is only tapped to a small degree. MV is an ideal state for renewable energy. It has the smallest population of all the German federal states, but a large overall area. There are very few energy intensive industries and a large support for renewable energy. Figure 1 shows all parishes in MV that are in the process of, or aspiring to be, self sustaining communities (data used were provided from the *Network Regional Energy MV* and from the *Academy of Sustainable Development MV*, both located at Güstrow). Furthermore the greater cities are labelled, where are municipal energy supplier established. The concentric circles with varying diameters around the cities should symbolize potential areas for acquisition of biomass. These areas also assign municipalities in the periphery of each city, which are suited for a type of regional energy cooperation, so called *Stadt-Umland-Allianzen* (energetic city-periphery-alliance).

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This paper concentrates on the analysis of biomass, geothermal energy and solar energy (photovoltaic and solar thermal energy). Wind energy follows special rules because of its rate of return and the concentration in development areas. Hydropower only has a small potential in MV because of local geologic surface conditions (to low differences in altitude).

Which source is the best for a specific location is determined by a number of factors. These can be classified as follows:

Demand

- what kind of energy is needed (electrical and/or thermal),
- which kind of form and condition energy is demanded (e.g. electricity, biogas, district heating – amount, temperature level, purity et cetera),
- can excess energy be transferred into a higher network (e.g. national power grid)

System

- what kind of energy is delivered, is a combination possible,
- when is it delivered (yearly/daily cycles),
- is it possible to influence demand (efficient and saving use of energy),
- is it possible to store energy,
- are necessary resources close by (e.g. biomass)

Financial

- costs of investment, running costs et cetera,
- how much is to pay for energy delivered / transferred to a higher network stage,
- how to use agricultural crop land (e.g. cropland for biomass production).

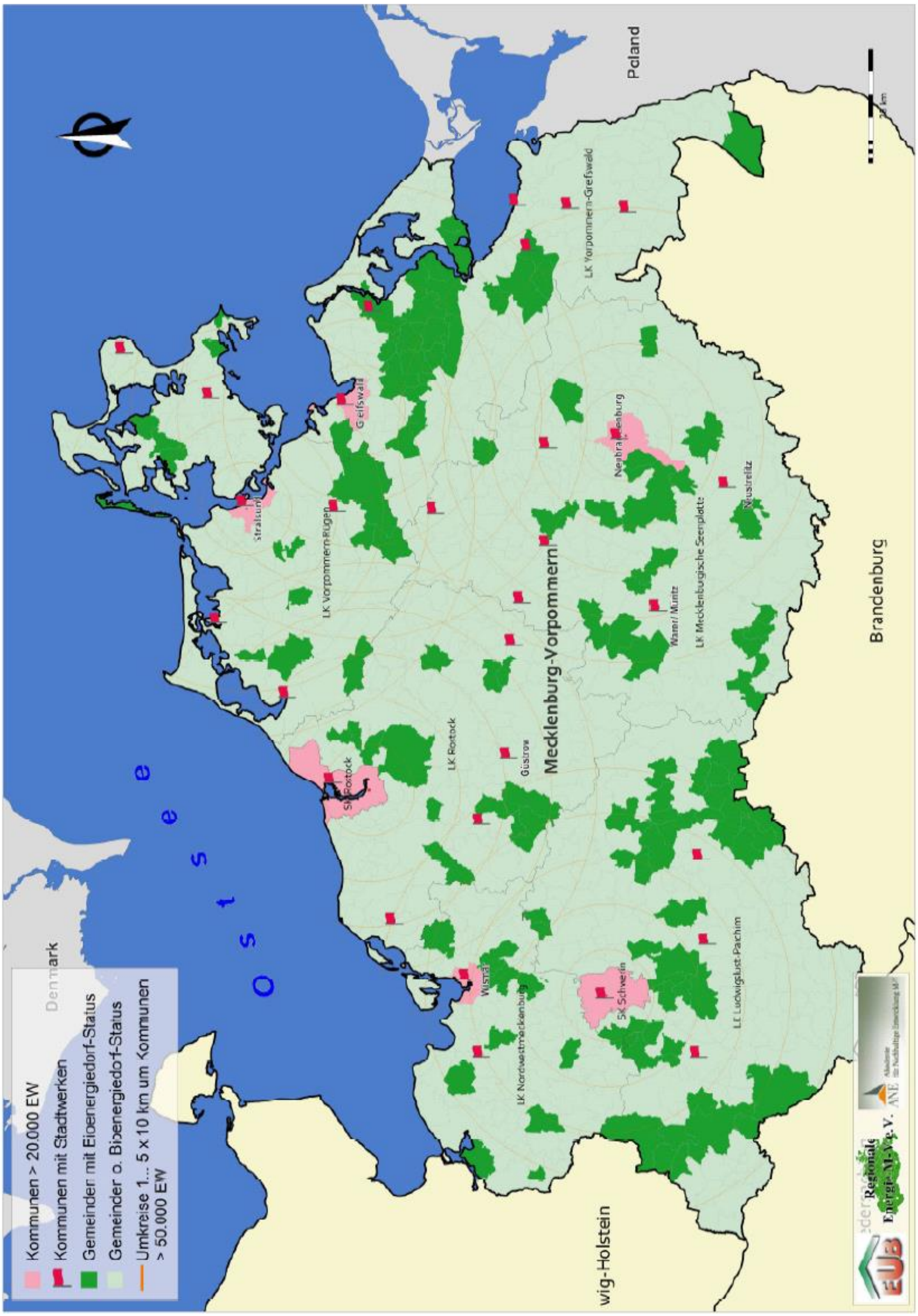

Fig. 1: Self sustaining communities in Mecklenburg-Vorpommern[1]

[1] For a currently updated listing of bio energy villages see also: http://www.bedeg.de/bio-energiedoerfer/bio-energiedoerfer.html (last access: April 24, 2013).

2. Influencing variables for using renewable energy sources (RES)

Renewable energy sources can be classified according to primary energy delivery: Some for electrical energy only, for instance wind power, photovoltaic and hydropower. Others are only for thermal energy. Solar thermal and geothermal energy are in this group. Some technologies can deliver both electrical and thermal energy, like some forms of geothermal power, biomass, biogas etc. These can also deliver energy in the form of gas and fuel, which can be converted into energy when it is needed.

To analyse regional potentials one must first study the natural potential. This is determined by factors such as regional radiant intensity (for solar power) and availability of cropland. Next one must determine the part of the natural potential that can be used with modern technologies (technical potential). The economical potential is the part of the technical potential that is economically viable. However, for an actual project to be realised, there must be both an economical potential and an interested party (e.g. local government). This is the actual potential.

The technologies for renewable energy are parts of a complete system. This system is not simply the sum of all technical potential, as some technologies compete for resources. (e.g. a roof that is reserved for photovoltaic cannot be used for solar thermal energy typically, at least not with current technologies). The potentials must be weighted against each other to find a realistic and feasible mix of technologies for future developments.

2.1 Solar energy

Photovoltaic and solar thermal energy both produce energy directly from sunlight. There are two possible solutions for installing solar power: either on the roof of a building or on stands on the ground. The government however prefers the installation on either roofs or “lost” ground (e.g. next to railway lines or highways) The primary use of photovoltaic are systems for detached houses and small power stations. Solar thermal energy is, in Germany, usually only used for supporting the production of warm water in residences. The primary driving forces are the regional solar radiation and the availability of space on roofs. For this they compete only with each other.

2.2 Biomass

Biomass is a concept for fuel that is not of fossil origin. This fuel can be solid or liquid and be combusted directly or in the form of raw biomass, that is fermented which produces biogas. This biogas is made up of 50-70% of methane and can either be used directly in a CHP-plant or purified to be fed into the gas grid. CHP-plants exist in very different sizes: from small kilowatt-plants for a one-family dwelling or farm to massive modular plants with outputs of several megawatt electricity. In contrast to most other RES, this technology needs a constant supply of biomass, which in turn needs large areas of cropland. This makes up high running costs. Also depending on what type of biomass is used, or indeed what kind of crop is used, there are large differences in quality of biogas (percentage of methane) and the amount of biogas per acre.

2.3 Geothermal energy

Geothermal energy can be used to make thermal energy and electricity. There are two major classes of geothermal technologies: Deep systems, including hydrothermal, petrothermal systems and deep downhole heat exchangers and shallow systems, including collectors and shallow downhole heat exchangers.

Deep systems use the high temperatures at depths of up to 3,500 m, sometimes in excess of 100 °C. Hydrothermal systems need an aquiferous layer in the underground. Water is pumped into this layer via a bore-hole and extracted via another. There is such a layer under large parts of MV, making this technology viable. Petrothermal systems do not need such a layer. The rock at the end of the bore-hole is cracked using high-pressure water (or oils) which can then be used the same as a hydrothermal system.

Shallow geothermal technologies only go to a depth between 10 and 400 m. Small, but constant temperatures (10 – 50 °C) do not permit the production of electricity. A heat-pump is used to transfer the energy into warm water to be used as heating for a building.

Geothermal power generation is possible almost everywhere in MV and does not compete with any other source for resources.

2.4 Hydropower

Hydropower can be used in several ways: inland as a storage power plant, run-of-the-river hydropower and wave- and tidal power on the coast. The geology of MV does not permit large power plants of this type. There are no high mountains that are needed for storage plants and the local rivers do not have large volume flow rates needed for operating-of the river plants. The Baltic Sea has almost no tide, making coastal systems largely uneconomic. There are a few hydropower plants, however most of these date from the beginning of the 20th century or earlier.

3. RES-potentials of MV

3.1 Potentials of "Landesatlas Erneuerbare Energien MV 2011"

The method of this paper will be shown on the example of biomass potentials, which are described more detailed in the Landesatlas. The technical potentials are averaged over the boroughs and can differ slightly from the actual potentials in the boroughs.

The potential analysis treats the types of biomass as if they where specific for one technology each. Some types are mostly converted into biogas (animal excrements, whole plant silage (Corn, wheat), green waste etc.). Others are used for direct combustion in thermal power plants, such as logs, waste wood, wood fuels. Liquid biofuel is used in diesel engines. All biomass can also be used in CHP-plants.

The Analysis starts at the theoretical potential of all biomass, which is available for local energy production. By using parameters for accessibility this is converted into the technical potential an expressed in amount of energy (GJ/a) or electrical energy (MWh/a). Also plants already built or planned to be build shortly are deduced from the technical potential.

Table 1 shows the technical potential as electrical energy in MWh/a. The potentials are averaged for the (former) districts and district free cities. The upper part shows the total potential for biogas from different sources, which amounts to about 1.242 TWh of electrical energy per year. The lower part shows the potential for solid (ca. 3.18 TWh/a) and liquid biomass (ca. 0.232 TWh/a). The entire potential amounts to about 4.65 TWh/a. (for comparison: total energy consumption in MV in the year 2005: 6.56 TWh).

4. Economical aspects of the development of potentials

The previous chapters discussed parameters that limit the potential of RES and analysed the technical potential for MV. This alone however does not make it possible to predict the future development of these technologies. Some of the RES technologies use the same resources in different ways. These can for instance be croplands, roof space or costumers for products. The technologies are competing for these resources. An analysis on the technical level cannot evaluate this competition, as it is determined by economic parameters.

To predict the economical potential, his paper uses economical models for the most important RES with parameters that can be adjusted to simulate different scenarios. With this, one can compare the potential of RES in direct competition, e.g. for a specific location.

4.1 Biomass

The most common variants for using biomass are:

- biogas plants,
- feeding Biogas into the gas grid,
- heating systems using solid biomass and,
- seed oil mills for the production of biofuel.

These technologies produce different end products. Rather than with each other, the end products are in competition with conventional energy sources.

However, all technologies need cropland for substrate cultivation and they compete with each other for this. Since cropland, what can be reserved for RES, is limited in MV, it is advantageous to compare the technologies with each other.

The variants differ in the specific substrate used, its form of use (fermenting, combusting or squeezing out oil), storage, transport, and the sale of products.

The consideration of all options is beyond the scope of this study. There are 9 model variants presented below in Table 1. These systems and their assumed modes of operation are chosen in such a way to represent the average existing plants in MV according to the plant directory of the state government /1/.

The systems G1 to G4 represent biogas plants, composed of a fermentation unit and a micro-CHP. The size of 500 kW_{el} is a typical dimension. All four plants work almost continuously throughout the year, running at 8.000 hours per year.

G3 and G4 systems operate in a typical mode of operation, they produce almost exclusively electrical power, but do not sell heat. In contrast the plants G1 and G2 sell both electric and thermal energy completely. This is not a realistic mode of operation, but represents the maximum profit these plants can generate. Real plants will be somewhere between these extremes.

M1 and M2 are mCHP using solid biomass for fuel. M1 uses woodchips with a residual moisture content of 20%, while M2 uses wood pellets.

There is only one plant to feed biogas into the gas grid in MV, so examples E1 and E2 are modelled after this. The plants feed 46 million m³ of biogas of natural gas quality (L- gas quality) into the grid, which corresponds to a continuous power of about 50 MW. System K1 represents a typical seed oil mill.

The most important factors determining the used technology and location are of economical nature. For Biomass plants these are the following:

- profitability
- profit per area (of cropland)
- availability of channels to sell products
- competition to existing systems
- flexibility in the choice of substrate
- maturity of technology

Table 2 shows the results of the results of the technical potential for each example. This compares the use of space that can be reserved for RES and shows the maximum possible energy production and CO_2-saving possible with each type of plant.

Table 1: Biomass plants studied in this paper

No.	substrate	size	end product
Biogas plants (running time: 8.000 h/y)			
G1	65 % corn whole plant, 35 % grain whole plant	500 kW_{el}	electricity, thermal energy, fermented residue
G2	65 % corn whole plant, 35 % animal waste	500 kW_{el}	electricity, thermal energy, fermented residue
G3	65 % corn whole plant, 35 % grain whole plant	500 kW_{el}	electricity, fermented residue
G4	65 % corn whole plant, 35 % animal waste	500 kW_{el}	electricity, fermented residue
Solid biofuel plants			
M1	woodchips (WG20)	500 kW_{el}	electricity, thermal energy
M2	wood pellets	500 kW_{el}	electricity, thermal energy
Plants for feeding biogas into the gas-grid			
E1	65 % corn whole plant, 35 % grain whole plant	46.000.000 m^3/y	biogas (natural gas quality), fermented residue
E2	65 % corn whole plant, 35 % animal waste	46.000.000 m^3/y	Biogas (natural gas quality), fermented residue
Oil mill			
K1	rape seed oil	40.000 t/y	Rapeseed oil, rapeseed press cakes

The most important resources are the area needed for the substrate for each plant. This differs significantly in the above examples. As this is limited in MV it is necessary to compare the specific profit per area for the systems. Figure 2 shows this comparison. The black line represents the fluctuation resulting from the fluctuation of price in substrate. It can be seen that plants G1 and G2 yield the highest profits compared to other biomass systems. However, G3 and G4, yielding the lowest profits, are the same plants without selling heat. Real plants will be between the two possibilities, depending on operating mode. All other plants except K1 are roughly on the same level. K1 however does not sell energy, but oil/diesel. The market is subject to different rules as the energy market. The profit is much lower than for the other plants.

Table 2: Potential for each type of biomass plant compared in this study

No.	Space needed (per plant, [ha])	Animals needed (per plant)	Energy production [kWh]	yield [kWh/ha]	yield [kWh/ animal]	Complete potential [kWh]	CO_2-saving [t]	Potential reached in years
G1	276	0	14,060,606	50,944	0	5,486 Mio.	2,428,436	11
G2	193	8,238	14,060,606	72,853	1,707	2,143 Mio.	948,622	1
G3	276	0	4,000,000	14,493	0	1,561 Mio.	690,993	0
G4	193	8,238	4,000,000	20,725	486	610 Mio.	270,023	0
M1	253	0	14,060,606	55,576	0	2,753 Mio.	1,218,645	3
M2	225	0	14,060,606	62,492	0	3,096 Mio.	1,370,477	4
E1	7,264	0	414,000,000	56,993	0	6,137 Mio.	2,716,608	13
E2	5,765	171,970	414,000,000	71,813	2,407	3,023 Mio.	1,338,163	4
K1	26,549	0	421,739,132	15,885	0	1,710 Mio.	756,950	0

The CO_2 emissions can be reduced by the use of biomass in the long run. Currently, the average CO_2 emission for the nationwide energy production is 576 g/kWh /2/. For growing crops there are two major sources of CO_2: Farming equipment and fertilizer. Fertilizer can further be broken down into the categories of organic and inorganic. Without using fertilizer, 5179 kg of CO_2/ha of cropland land are ejected. This corresponds to 133 g/kWh of electricity. With the usage of inorganic fertilizer this rises to 6105 kg of CO_2/ha (157 g/kWh). Growing crops with organic fertilizer discharges 4.500 kg of CO_2/ha (116 g/kWh) into the atmosphere. The potential saving in CO_2-emission is also shown in table 2 for each type of plant. The values refer to farming without plant using fertilizer.

The criteria for site selection in this paper are based on the old districts of MV before the reform of 2011. Thus, the potential can be classified more accurately than for new districts. The criteria for choosing locations depend on the proximity to croplands, but also to demand for the products of the plant. This favours locations close to larger towns, especially for plants that sell heat, as costumers for heat are more commonly found here and it cannot be transported over long distances. Through well-developed electricity and gas grids, it is however possible to feed in at most locations. A complete table of the suitability of boroughs for different kinds of biomass is included in the full report.

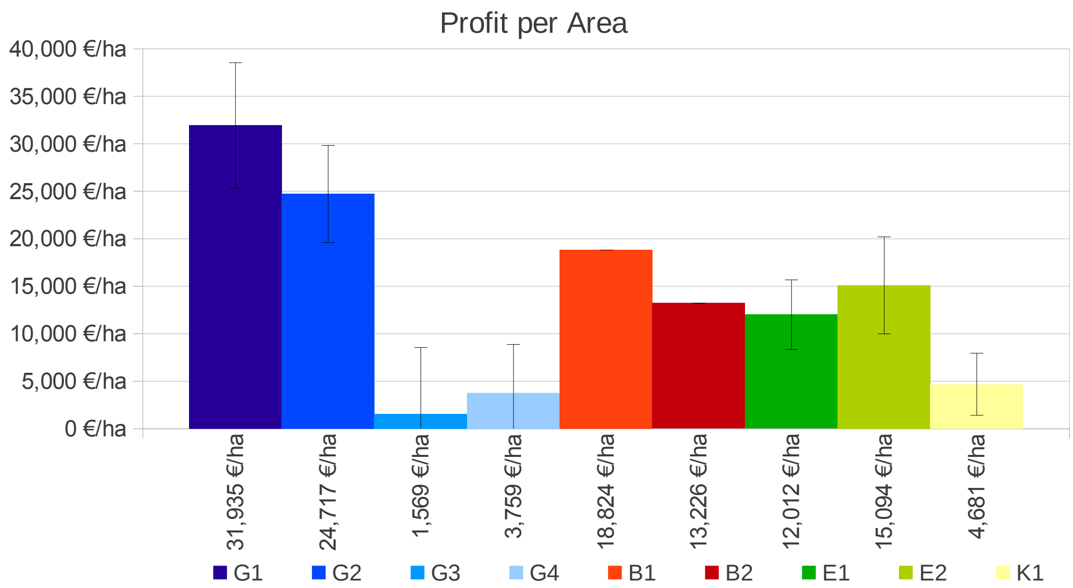

Fig. 2: profit per area (of cropland) for each type of biomass

4.2 Solar energy

For renewable energy, solar power can be used in two ways:

- direct conversion into electrical energy (photovoltaic),
- conversion into thermal energy (solar thermal).

However, Germany and especially MV is not a highly efficient solar country since the radiation on the surface is a lot less than in more southern countries, e.g. Spain. However, compared to other energy sources, solar energy has the advantages that it requires very low maintenance, and that even unused, sealed surfaces like roofs can be used. A disadvantage is the very large seasonal and daily variation in energy production, as well as the partial unpredictability due to weather influences.

4.2.1 Photovoltaic

The diversity of applications for Photovoltaic ranges from small stand-alone systems (e.g. parking meters) to several megawatt power plants. The most widespread use is the rooftop system for commercial and residential buildings. The electricity produced is either consumed directly or fed into the grid for fixed prices.

The performance of PV systems is given in watt peak (W_{peak} or kW_{peak}). This is a measure for standardizing performance under laboratory conditions.

In this report, three PV systems are compared to each other. Two are designed as a roof-top systems and have a surface area of 31 m², about half of the roof of an average family home. Both systems have a nominal capacity of 5 kW_p, one system includes a battery for energy storage. The cost of the solar modules amounts to about 800 EUR/kW_p and is derived from current module prices. Additionally, the installation costs about 220 EUR/kW$_p$, a necessary inverter about 2,000 EUR. The energy storage for a solar power plant has a capacity of 12 kWh and costs EUR 8,000. Operating costs are about 2 % of the investment per year.

The third system is an installed outdoor system with 1 MW$_p$ rated power, which receives remuneration (e.g. it is built next to a railway line or motorway). The investment costs amount to around EUR 1 million here (about 1,000 EUR/kW$_p$). The lower unit cost is due to easier installation and a larger inverter with lower cost per kW.

4.2.2 Solar thermal energy

Solar thermal collectors produce hot water (temperature varies according to weather) which is then fed into a hot water tank. This tank needs an additional gas heater as the solar thermal power system is not able to provide all the needed energy throughout the year. Solar thermal energy can be used in both residential homes heating support as well as providing hot water. A solar thermal system consists of solar collectors, a pump and the reservoir. The installation of a solar thermal system or at least the structural preparation is best done in the construction of a residential building, or the replacement of a heating system.

In this report, two solar thermal systems are examined. In contrast to other RES, the economics of solar thermal systems is not calculated by the excess returns to the investment costs, but rather from a comparison of the solar thermal system and an equivalent conventional heating system. The first unit (ST1) is used for pure water heating. For this purpose, about five to six square meters are sufficient. The investment necessary for this plant is 3,135 EUR.

The second system (ST2) has an effective area of 30 m^2 and can additionally support the heating of a residential home. However, systems for heating assistance require a much larger area to cover the demand of heat of a family house to cover and are much more expensive, in this case 10,773 EUR. The storage tank now requires a larger volume, in this example 600 l. Figure 3 shows the output of both solar power systems over the course of a year compared to the demand for heat and hot water. It can be seen that the output of either plant is not nearly enough to cover the demand.

4.2.3 Potential for solar energy

Because of large seasonal uncertainties, a dominance of solar power in the energy market is not possible. However, the most important resource used is rooftops and "lost" space that can not support any other type of RES. So the only competition these systems have is between pv and solar thermal. On the demand side they may complement the renewable energy mix. Both technologies have high investment costs in comparison to yield. This is due to the cost of individual components.

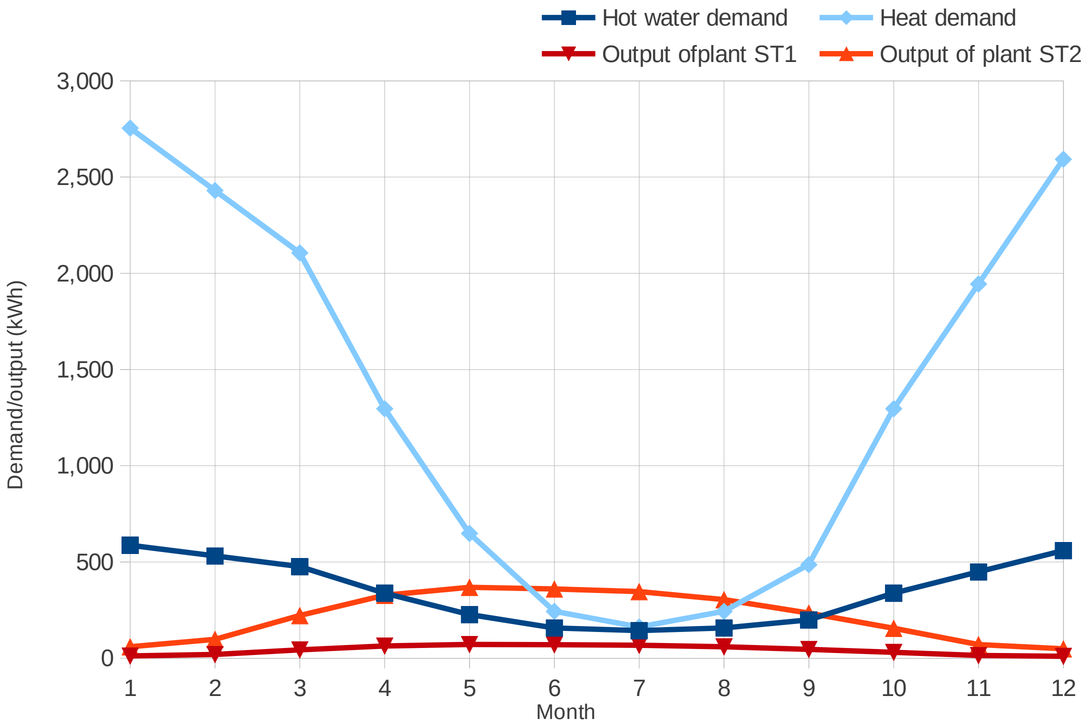

Fig. 3: Output of solar thermal energy systems compared to demand of a detached house

The main costs for Photovoltaic are the modules. During the last few years however, the prices fell sharply (from about 5,000 EUR/kW$_p$ in 2006 to about 2000 EUR/kW$_p$ in 2011). This trend is expected to continue in coming years. The energy prices are partly calculated after this price and accordingly fall as well. When the set price falls under the current raw price for energy (currently about 13 ct/kWh) Photovoltaic systems can be operated in competition to all other energy producers. With a mean yearly construction of 8,500 kW$_p$, this will happen at the end of 2013. Solar thermal energy plants are only able to make narrow profits after about 25 years of operations. Large systems of the type can not be operated profitably especially in comparison to Photovoltaic. The more economical variant is the use of 6 m² of roof space for solar thermal at the most and the rest for Photovoltaic.

4.3 Geothermal power

Geothermal power can be put into two categories: deep and shallow geothermal power generation. The most common plants are shallow systems. These can be installt almost everywhere and are usually installed for detached houses. Such a system has both high investment costs and high operating costs. The high investment stems mainly from the need for usually two bore-holes and a heat pump. This is a large variable. Costs can range from 80 to 150 EUR/m² depending on the conditions of the underground. A shallow system (depth about 50 m) can cost about EUR 8000 to EUR 15000. In addition the heat pump has a cost of about EUR 10000. Thus a typical geothermal plant has an investment cost of EUR 18000 to EUR 25000.

In order to work, the entire system needs electricity (for the heat pump). This is the bulk of operating costs. Electricity providers offer special conditions for this kind of system. This energy costs currently about 23 ct/kWh. To be able to operate economically a heat pump must produce 4 kWh of heat for every kWh of electricity expended. This will reduce the cost of heat to 5.75 ct/kWh (below the cost for gas at about 7 ct/kWh, this is used in comparison as it is the main competitor for heating in most rural areas of MV). Current heat pumps however only make 3.5 kWh for every kWh of electricity, thus not being able to meet the price of gas. In addition the high investment costs make the geothermal power generation not profitable.

Deep geothermal power is able to operate economical, as no heat pump is required and energy can be produced onsite. However, due to much larger investment costs (between EUR 0.5m to EUR 1m for the bore-holes), this variant is only viable for larger operations (e.g. local power stations).

4.4 Wind power

Wind power is already very common in MV. In 2012 alone over 300 MW of new plants have been built. The disposition of installed wind turbines can be seen in relation to the wind potential, defined by local average wind speed, fig. 4.

Costs of onshore facilities amount primarily during the construction phase. Further costs are maintenance costs and operating costs, as well as basic lease of land and insurance. These costs amount to about 2% of the investment costs per year. The electricity production costs amount to about 5 cents per kWh. The set compensation is currently 8.93 ct/kWh during the first 5 years and after then 4.87 ct/kWh. The potential of wind turbines is limited only by the total amount of designated fitness area. Due to the high efficiency, it is expected that the additional construction increases when more suitable sites are assigned. The life cycle of a plant (e.g. a wind turbine) is shown in fig. 5.

4.4 Hydropower

MV is rather inapplicable for hydropower. Due to the predominant small differences in height, it is not economical to operate storage power plants.

Even flow-of-the-river power plants play a subordinate role, as the volume flows and height differences (fall) of the rivers of MV very low.

Existing larger systems have already been built at the beginning of the last century. Policies, natural parks and low potential sizes complicate the creation of new power plants as well as the tourism, which is very pronounced especially in areas with much water.

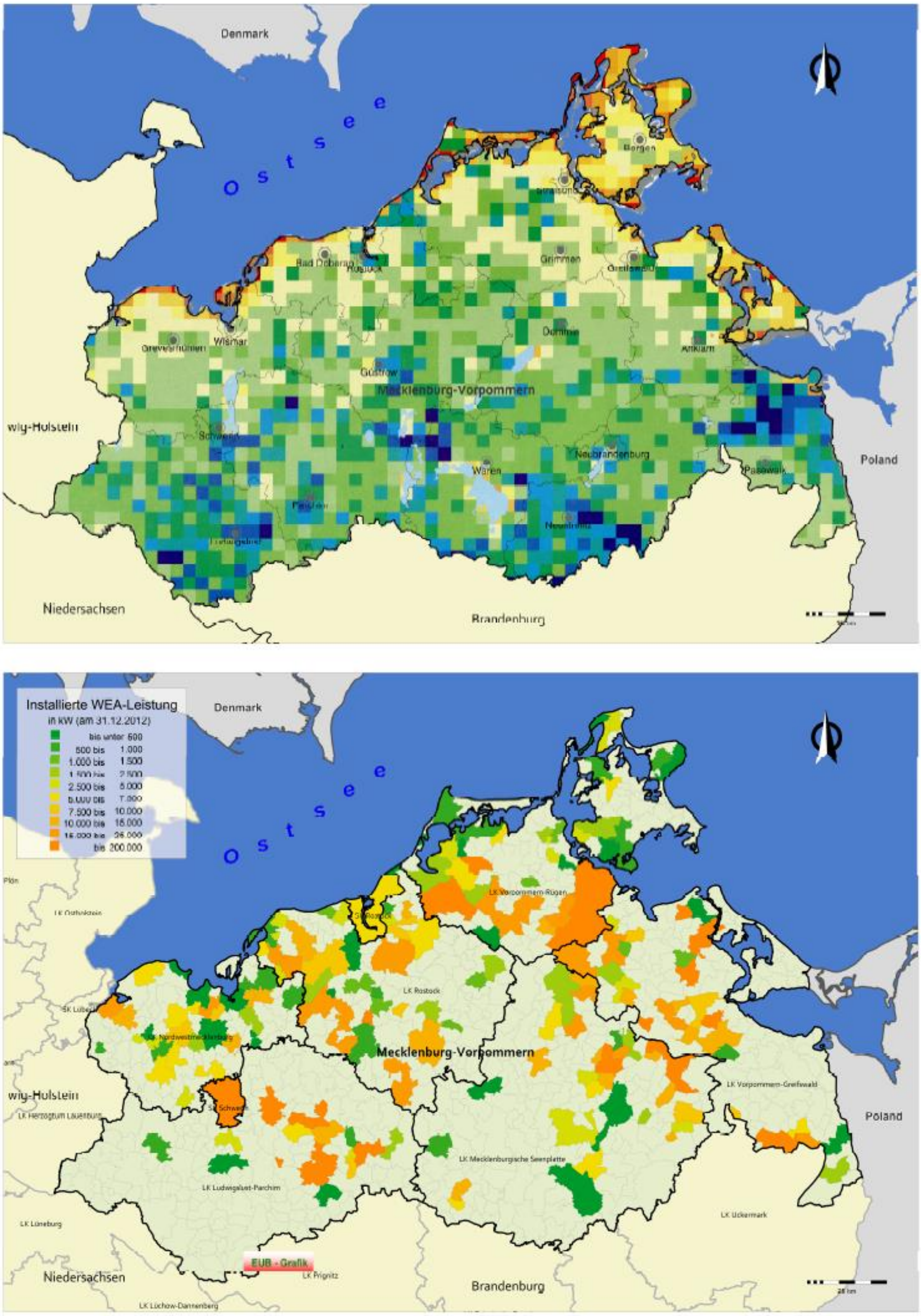

Figure 4: Wind potential /3/ and installed power of Wind turbines

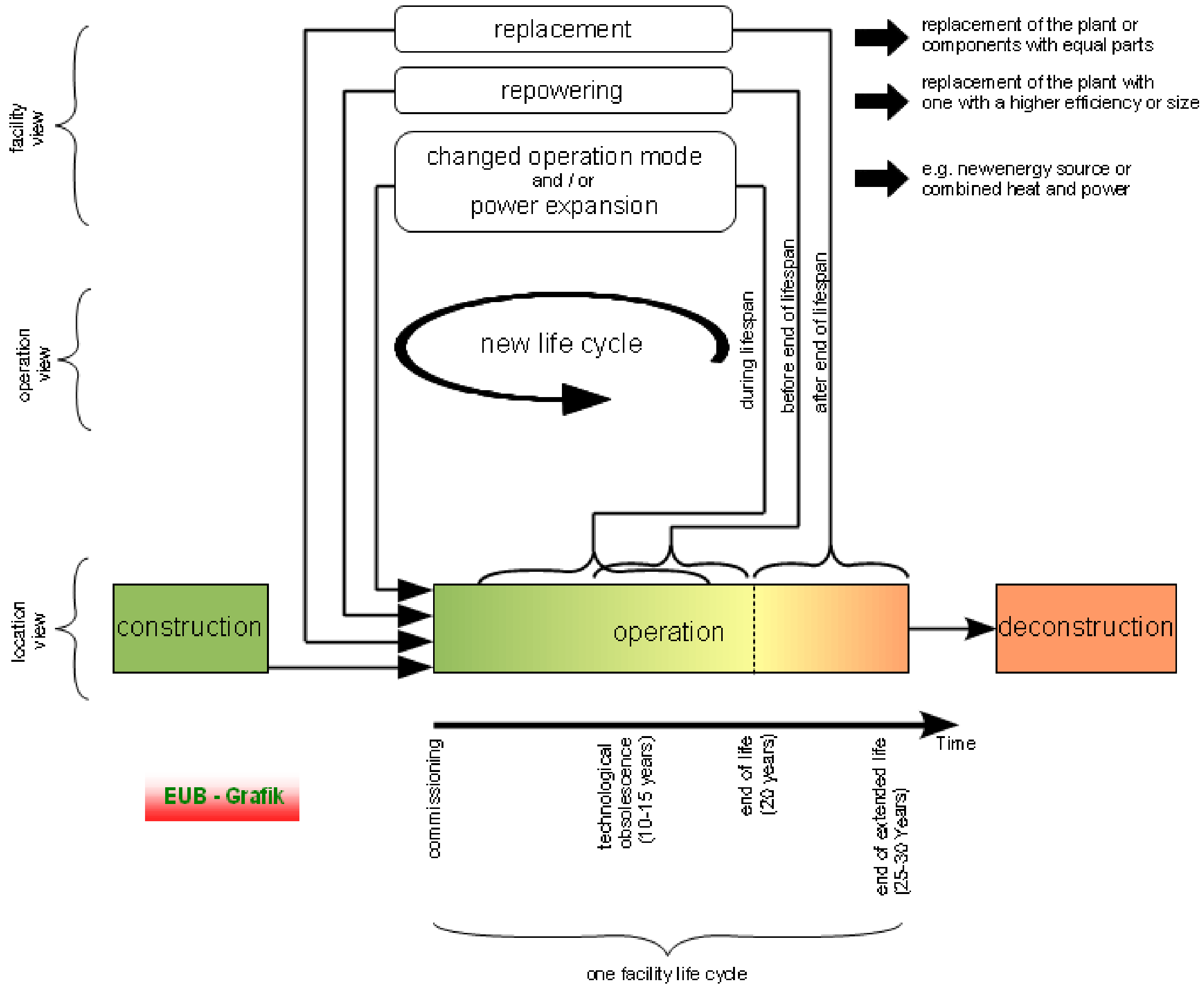

Figure 5: life cycle of a power plant

5. Feasibility studies

The factors for construction of RES as analysed in section 2 are mostly economical. RES systems are built, when a commercial profit can be made or they are able to finance themselves.

The economics of PV, wind power, water power, solar thermal and geothermal energy is mainly determined by investment costs, by the feed-in compensation and by saving on electricity and heating costs. Since the investment costs tend to decline and general energy prices are rising, which is expected to continue even further, the likelihood that such systems will be installed will increase.

This is different for biomass plants. In addition to investment, high operating costs make up the total expenditures. These operating costs vary greatly with plant types (combustion of solid fuel, production of liquid fuel/ biogas), operating modes (power guided management, pure heat production, CHP). These are compared with a specifically designed tool that takes into account the features of different biomass plants.

These examples represent the boundaries of economic operation and identify and profit potential and thus demonstrate the likelihood of installing such systems. The development of economy and profit potential is predicted for the next 20 years.

Based on this forecast economy, it will be possible to compare the individual paths of renewable energies, how they stand to each other in a resource competition. Thus it shall be possible to identify economic potentials and derive expectable developments of its use, as specified by technical potentials in the "Landesatlas Erneuerbare Energien". It also forms the basis for the estimation of the added value. For the latter an attempt to maximize can be done at the regional and local level, where the use of renewable energy proves to be controllable in the future.

6. Conclusion

After the economic considerations of the individual RES and the assessment of potential it is another important issue to define the timing of the potential development.

Most RES have a lifecycle of about 20 to 25 years. It is possible to renew existing plants prematurely, e.g. for repowering, but in most cases it is necessary to exploit the lifespan of the plants to the fullest.

This raises the question as to what time periods are required, e.g. in the field of wind turbines, to bring about a generational change in the investment portfolio. To this end, some model calculations were carried out.

The mixing of existing plants with future (larger) ones leads to an increase in average power, which depends substantially the extent to which assets are replaced and which are used to replace old ones (size/s). Further models show the development of the overall performance of RES.

7. References

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