# Electric Vehicles as an Integrated Part of Energy Storage Systems in Renewable Hybrid Energy Supply Systems

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## Abstract

An extensive usage of renewable energy sources implies, because of their local and time dependant stochastically behaviour, a decentralised supply structure. Thereby, the different possibilities of renewable energy converter are to be combined with respect to their complementary character, resulting in so-called hybrid systems. But it would not be possible to build up a more effective, rational, and as far as possible renewable future energy supply system and structure, without a consequent integration of the transport and traffic technology. Most important for this is a complex and interconnected view of these problems as one whole undividable unit. Because of the different stochastically and dynamical behaviour, it seems to be unavoidable for such supply systems to integrate sufficient energy storage capacities. A careful dimensioning of hybrid systems and their interconnections can help to reduce these capacities to an absolute minimum only for security. A special capacity would be necessary to cover the peak power short-time demands, in order to avoid an over dimensioning of the hybrid system converter. In this case electric vehicles could serve as (additional) storage capacities, if they were not used for driving.

**Keywords:** sun energy, energy storage, battery management, range, modelling.

## 1 Introduction

Aim of this paper is to present the worked out physical aspects and detailed dimensioning principles of hybrid energy supply systems, including the integration of the storage capabilities of electrical vehicles, to show up a possible over all energy supply structure concept for the future.
Decisive for the construction of a 'renewable' hybrid system is the achievability of a secure supply situation, which could be evaluated by the quality of the "controllability". With other words, the system has to guarantee a sufficient variability to fulfil the individual energy requirements from the consumers view point. For this reason, the additional usage of biomass, especially with combined heat and power, is advantageous because their combustion is usually controllable.
This hybrid system structure should be understood in an abstract manner, that means it is not absolutely necessary to combine the single elements as a localised unit. Important for this hybrid system principle is only the controllable combination of the different converter and connection to the consumer, to guarantee the needed energy supply. Also every thinkable interconnection between such localised systems with different kinds of grid connection models should be included.
Because of the different stochastically and dynamical behaviour of the renewable energy supplies in comparison to the consumer, it seems to be unavoidable for such supply systems to integrate sufficient energy storage capacities. This circumstance is often used as a critical argument to point out a great disadvantage of renewable energy systems. But a careful dimensioning of hybrid systems and their interconnections can help to reduce these capacities to an absolute minimum only for security. A special capacity would be necessary to cover the peak power short-time demands, in order to avoid an over dimensioning of the hybrid system converter. In this case electric vehicles could serve as (additional) storage capacities, if they were not used for driving. During and after their charging period, the vehicles were able to support the equalisation of the power supply and if necessary to increase the availability.
The renewable way to produce electrical energy, for example with the help of photovoltaic plants, has the great advantage, that there are no $CO_2$-emissions with negative effects on climate conditions [1], [2]. Because nowadays, nearly 14% of the world wide $CO_2$-emissions are produced by general traffic activities, as shown in figure1. In Germany this emission rates approximately 20%, with 2/3 from the individual traffic part.

The analysis of encapsulated air bubbles in the ice of glaciers, as well as direct measurements during the last decades, show an increase of the atmospheric $CO_2$-concentration from 280 ppmv at the beginning of industrialisation to now 358 ppmv, as demonstrated in figure 1. This means an increase of 25% in a very short time, compared to geological dynamics. Some prognostics approximate the future increase of the world wide traffic $CO_2$-emissions to 60% up to the year 2030.

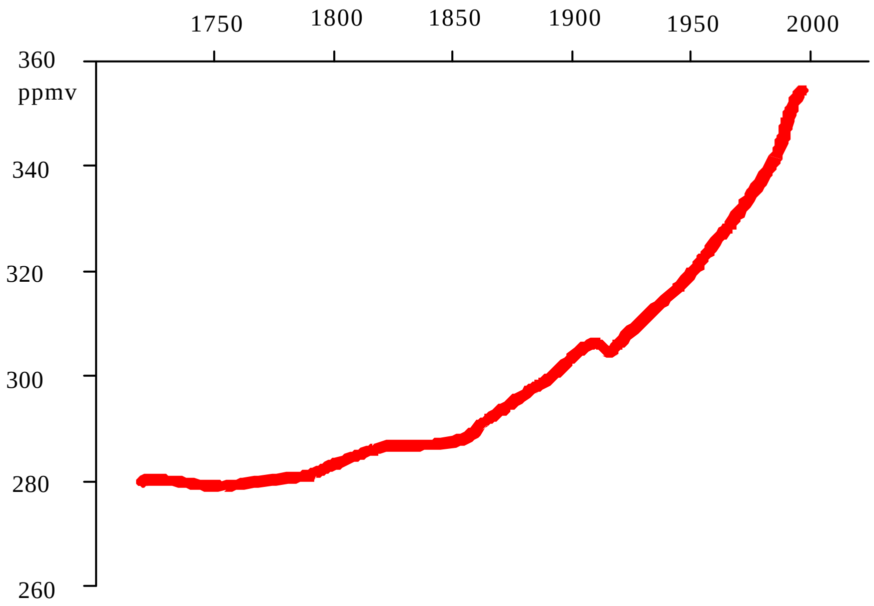



Figure 1: Increase of the Atmospheric $CO_2$-Concentration [1]

In contrast to the "never-ending" renewable energy resources, fossil primary energies like oil, gas and coal are limited. Nowadays, nearly 60% of all oil-products are consumed by the automobile traffic [7].

## 2 Renewable Hybrid Energy Supply Systems

Regarding the fact, that in contrast to the momentary dominating fossil energy supply, the usage of renewable sources causes more expenditure and complexity, therefore it lies in the nature of the needed technology, to handle these renewable sources effectively and rationally, even if these energies are endlessly available on the human time scale.

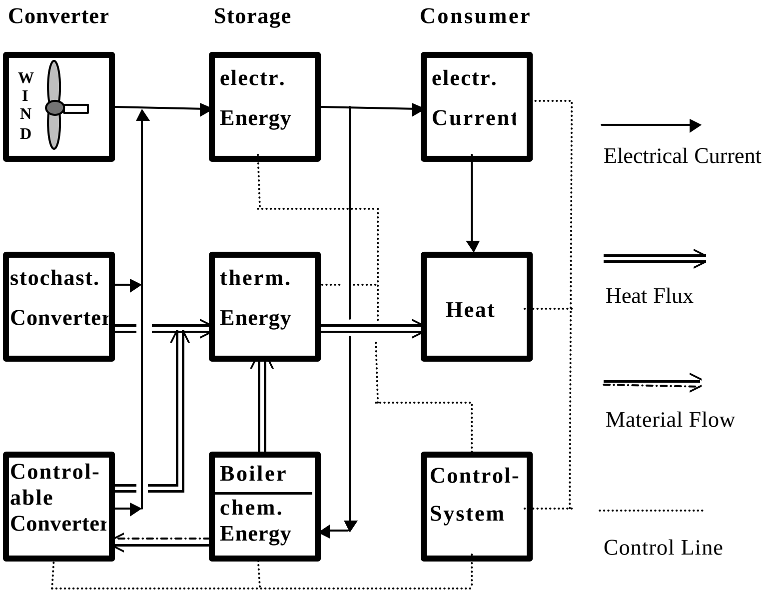



Figure 2: Principle Scheme of a Hybrid System [3]

To reach a most effective exploitation of renewable primary energy sources, it is very important to pay attention not only to the electrical energy, but in the same way to the heat demand [3], [5], because the heat demand is in the most cases a multiple higher than that of electrical current. This implies the necessity of an integration of the principle of combined heat and power, whenever it is possible [4]. The necessary combination of renewable energy converter is given because of the stochastically character of their availability, how it can be seen for example for wind and solar energy.

## 2.1 Principle Structure of Renewable Hybrid Systems

Figure 2 shows the general realisation principle of hybrid systems with combined heat and power, the integration of additional converter is optional. Here the basic element is exemplary chosen to be a wind turbine. The additional converter to the wind turbine could be distinguished between *stochastic* and *controllable* converter. In each group, combinations of these converter are also possible.

Possible ***stochastic converter*** are, apart form the basic element wind turbine, the following converter:

- *Photovoltaic System*
- *Small Hydro Power Plant*
- *Thermal Solar Collector (heat only).*

Thermal solar collectors could be used in the most cases for only a partially covering of the heat demand, and their required insolation area is in concurrence to the photovoltaic. So-called hybrid collectors for thermal as well as photovoltaic conversion are still in the research and development status. Basis for the use of controllable converter is in general also solar energy in stored form like biomass.

Possible ***controllable converter*** are:

- *Fuel Cell ($H_2$, biogas reforming, etc.)*
- *Vegetable Oil Motor*
- *Biogas-Motor*
- *Stirling-Motor (external combustion of Biomass)*
- *Steam Engine (external combustion of Biomass)*
- *Thermoelectrically Converter (bio fuels)*
- *Geothermal-Converter.*

These converter are principally also suitable for combined heat and power.

Decisive for the construction of a 'renewable' Hybrid System is the achievable of a secure supply situation, which could be evaluated by the quality of the "controllability". With other words, the system has to guarantee a sufficient variability to fulfil the individual energy requirements from the consumers view point. For this reason, the additional usage of biomass, especially with combined heat and power, is advantageous because their combustion is usually controllable [4].
But the unrestricted availability most of such converter could only be guaranteed, if the storage of biomass fuels is sufficiently dimensioned and/or the delivery of the fuels is well correlated to the consumption. This is especially of importance, if the fuel is produced with the help of surplus stochastically produced electrical energy, to be stored as chemical energy.
An example for this is the production of hydrogen with the help of an electrolyser. This hydrogen could afterwards be used in a controllable way, for example by a fuel cell or a gas motor with combined heat and power or simply for a heat boiler.
If the heat demand of a consumer is not too high, it may also be possible to use electrical energy for heating purposes; in this cases it would be advantageous to integrate heat pump systems.

An important role in such hybrid systems comes to the energy storage equipments, because they have to serve as equaliser for the energy supply and therefore to unburden the controllable converter; this for electrical as well as for thermal energy.
These storage systems have principally to be distinguished between storages, which can be refilled by the hybrid system itself and those who need a recharge from outside. The last ones are especially for chemical energy to supply the additional controllable converter, exceptional chemical fuels which could be produced internally with the stochastically converter.

Regarding the explanations concerning the energy storage systems, the following *classification of storage systems* gives an overview of the surely not completely possibilities:

a) Internally chargeable storage systems:

i) *Electrical Energy*
- Fly Wheel (short time)
- Condenser (short time)
- Storage Batteries (i.e. lead acid batteries, batteries in electric vehicles)
- Hydrogen Fuel Cell with $H_2$-Storage

ii) *Thermal Energy*
- Sensitive Heat (i.e. water)
- Latent Heat (Paraffin i.e.)

iii) C*hemical Energy*
- Hydrogen (via Electrolyser)

b) Externally chargeable storage systems:

- Solid Fuels (wood, biomass-pellets i.e.)
- Liquid Fuels (bio oil, alcohols i.e.)
- Gaseous Fuels ($H_2$, biogas, clear-gas i.e.)

Depending on the dynamical behaviour of the consumer, a combination of these different storage systems may be advantageous, for example a fly wheel for short time peak demands and a fuel cell for normal middle range fluctuations.
In cases with the possibility of a grid connection, an exchange of energy with other suppliers influences the dimensioning criteria for the electrical storage system, perhaps it is not necessary.
The exchange and equalisation of energy supply with a grid interconnection needs a sufficient grid capacity. The problem of the grid integration of a growing amount of decentralised renewable energy supply systems would increase in future. This is strongly attached to the grid and conventional power plant control and regulatory strategies.

Not less important than the above mentioned components for a hybrid system is the *control system*. The effective coordination of all the components depends on this. Of course the energy storage is the boundary between the energy converter and the consumer, the energy storage management gets the key function of the control system. Even the lifetime of the storage batteries depends on a well working charge management system.

The control system includes also as an important part the registration and indication of the working status, the energy flux balance and the control of all functions with error indications and alarm settings. Even the possibility, to drive the system for test purposes with sufficient variability to influence the working situation manually in order to find malfunctions or to drive the system in a half automatic way to guarantee the minimum supply necessities, has to be implemented.

A further task for a control system would be a so-called load management, which is able to switch on and off some power extensive consumer with the help of a priority list, in order to avoid a not necessarily simultaneous operation of for example the washing machine and the electric-hearth furnace. This kind of management would help to limit the maximum nominal power of such a hybrid system.

## 2.2 Dimensioning of Hybrid Systems

In the following, the dimensioning principles for a hybrid system (Figure 2) with a PV-Plant as additional stochastically converter are demonstrated, especially for the conditions of private households as a calculation unit, exemplary concerning climate conditions in middle Europe.

The today's annual ratio of electrical to heat energy consumption of average private households in Germany is nearly one to ten. Essentially for the determination of the dimensioning criterion for hybrid system, as shown in figure 2, is the correlation of the time dependent consumption functions for electrical power as well as for heat [3].

With a photovoltaic system as additional stochastic converter to the wind turbine, it is necessary to correlate the effects of the stochastic parameters current consumption, heat consumption, insolation and wind energy.

An average household in Germany for 2,2 persons with 80 m² consumes annually 3146 kWh electrical energy. The seasonal consumption in winter is greater than in summer. It is possible to approximate the daily consumption as a cosines-function, with the whole year as period.

$$\overline{P}_{d,Current} = \left\{ 8{,}6 + 1{,}6 \cdot \cos\left( \frac{2p}{365} \cdot d \right) \right\} \left[ \frac{kWh}{d} \right],\ d \equiv day\ . \qquad (1)$$

The daily power consumption in a typical week in summer is 7,439 kWh and for a typical week in winter 10,123 kWh. The following annual ratios are valid:

$$\frac{power}{heating} \approx 0{,}11 \quad and \quad \frac{power}{process\_heat} \approx 0{,}56\ . \qquad (2)$$

It is also possible to approximate the daily heat-consumption as a cosine-function with sufficient accuracy, similar to (1) in [*kWh/d*] [3], [4]:

$$\overline{P}_{d,heat} = \left\{ 15{,}4 + 78{,}36 \cdot \left( 1 + \cos\left( \frac{2p}{365} \cdot d - 0{,}232 \right) \right) \right\}. \qquad (3)$$

For a general private household, the following scaling could be used:

$$P_{general} = z \cdot P_{average} \quad \text{with} \qquad (4)$$

$$z = \frac{annual \quad power - consumption}{3146 \quad kWh}\ . \qquad (5)$$

With these formulas for power and heat, an approximated daily ratio of power to heat could be given:

$$s\,(d) = \frac{P_{electrical}\,(d)}{P_{heat}\,(d)}\ . \qquad (6)$$

The function has a significant maximum in summer, as shown in figure 3 below, therefore the curve path of the expected power generation of a PV system is advantageously correlated to this characteristic.

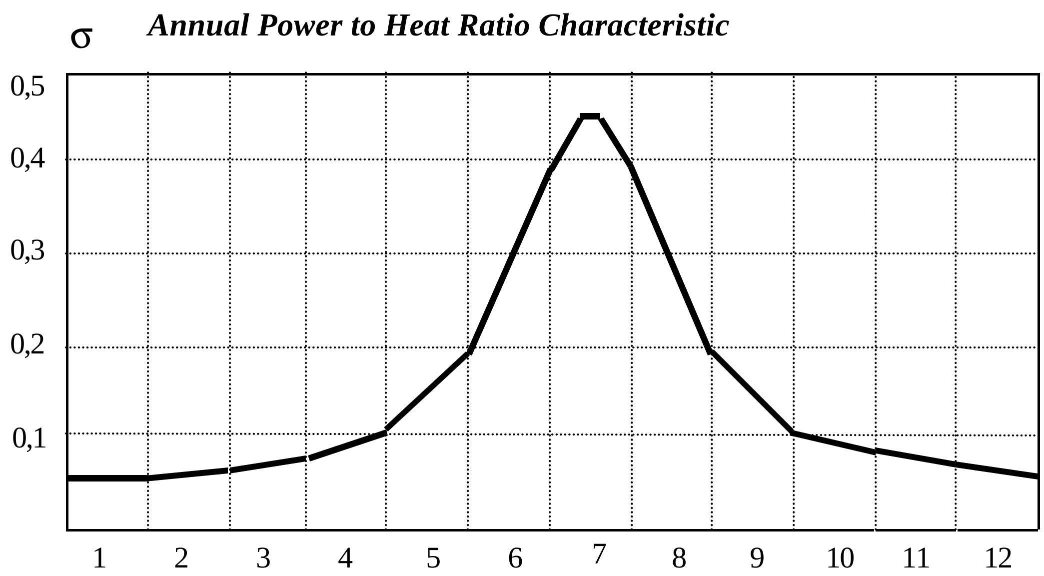



Figure 3: Annual Power to Heat Ratio for Private Households in Germany

The annual power generation of a '1kW$_{ref}$-Plant' in Germany can be estimated by the following function:

$$\overline{P}_{d\,P\,V}\left(1kW_{ref}\right) \cong \sum_{i=0}^{6} a_i \cdot d^i \left[\frac{kWh}{d}\right] \text{with} \qquad (7)$$

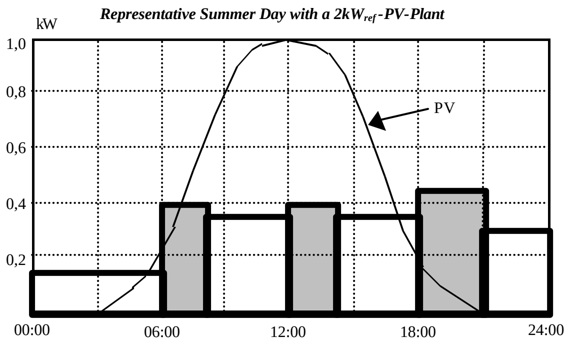
$a_0 = 6{,}347505E-01$ , $a_1 = 3{,}7224486E-03$

$a_2 = 1{,}818859E-04$ , $a_3 = 2{,}818560E-06$

$a_4 = -3{,}168738E-08$ $a_5 = 9{,}383729E-11$

$a_6 = -8{,}807513E-14$ ,

whereas 1 kW$_{ref}$ is defined as 1 kW-Peak divided through the so called 'performance ratio', which regards the individual efficiency conditions of a PV-plant [4].



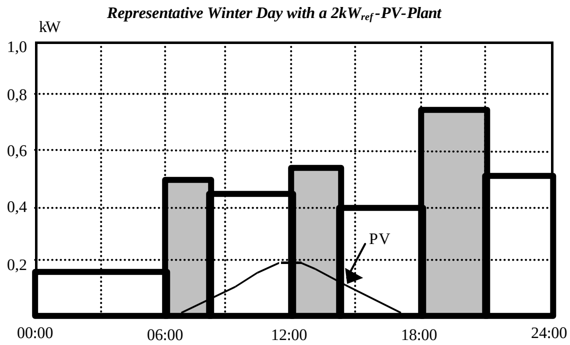




Figure 4: Private Household with a PV-Plant in Germany, Solar Energy vs. Consumption

In order to allow a simple conversion to individual different local conditions, the average time dependent insolation characteristic in Germany has been standardised to an annual total global insolation of 1000 kWh/m².

In contrast to the PV, the typical wind energy production is less significant periodically dependent on the seasonal conditions and its approximation with a formula has more uncertainties. The same is observable for the short-time variations.

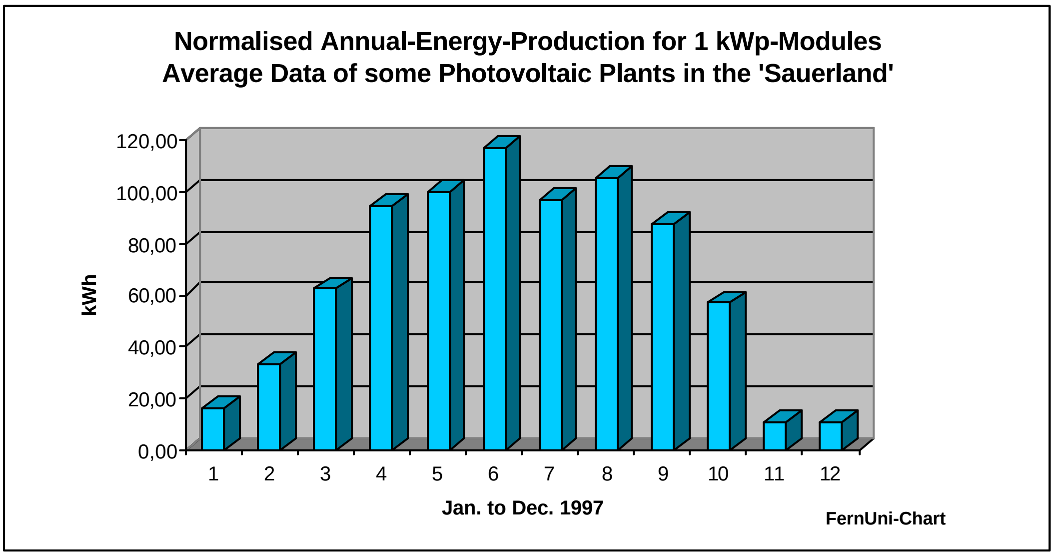



Figure 5: Normalised Energy Production of PV-Systems

Figure 6 shows the annual energy production of several wind energy converter in the region of the 'Sauerland' in middle Germany 1997 [3].

This shape is typical, but it shows also, that the month January is weak and breaks the symmetry of the envelop curve. The same phenomenon can be seen in figure 7 for the month November. Nevertheless, it is possible to realise a statistically equalised electrical energy production with the combination of wind power and PV energy.

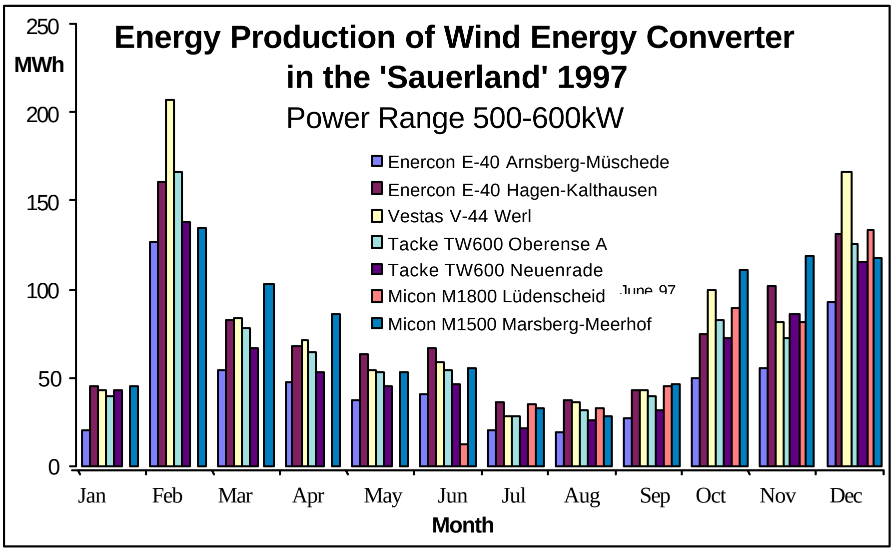



Figure 6: Annual Energy Production of Wind Turbines

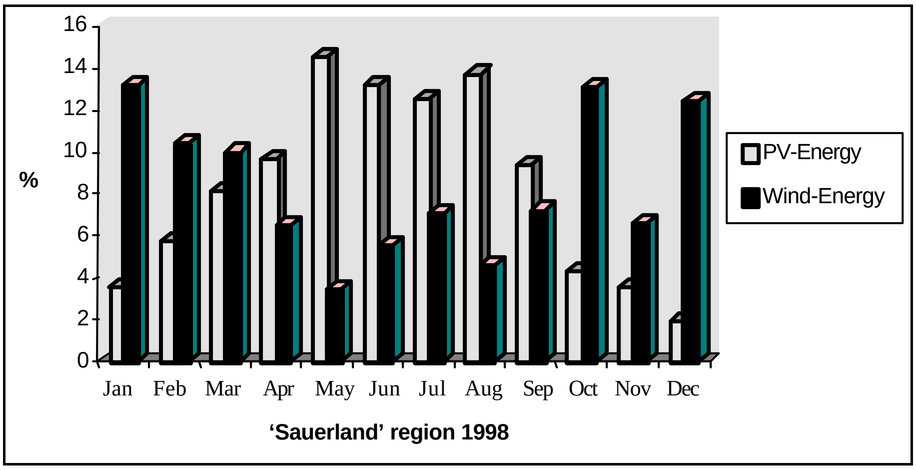



Figure 7: Combination of Wind and PV Energy

Because of these above mentioned reasons, it is advisable for the dimensioning of such hybrid systems, to estimate the energy production of the wind turbine with the help of a constant average value. With respect to a single representative household and the energy scale of the PV-plant, it is advantageous to calculate with a wind turbine, which average power production value is normalised to constant 1kW:

$$\overline{P}_{dWind} \cong 1kW = 24\frac{kWh}{d}. \qquad (8)$$

To realise this in practise, the wind energy converter has to be dimensioned individually, with respect to the local conditions and amount of households.
The installation of a wind energy converter and a PV-Plant for the household results in an additional power supply and reduces the residual ratio of power to heat, which is left for the combined heat and power system:

$$s\,(d)_{W,PV} = \frac{P_{electrical}(d) - P_{Wind}(d) - P_{PV}(d)}{P_{heat}(d)} \qquad (9)$$

with $P_{Wind}(d) = x_W \cdot \overline{P}_{dWind}$, $P_{PV}(d) = x_{PV} \cdot \overline{P}_{d,PV}(d)$, and $x_{PV}, x_W \in R^+$ as scaling factors.

With respect to the possible degree of efficiency $h$ of the combined heat and power, the realisable ratio of power to heat is limited to be smaller than $u$:

$$s_{W,PV} \le u \quad with \quad u = \frac{h}{1-h}. \qquad (10)$$

For example, the usual electrical efficiencies of realised combined heat and power systems for the usage of biomass with piston-type steam engines are today about 16% [4], [5]. These information lead to a basic formula to determine the main components of the hybrid system. The following condition allows to adjust the wind energy converter and PV-Plant to the controllable engine with combined heat and power:

$$x_W \cdot \overline{P}_{dWind}(d) + x_{PV} \cdot \overline{P}_{dPV}(d) \ge P_{electrical}(d) - u \cdot P_{heat}(d). \qquad (11)$$

This condition has to be fulfilled for every day of the year. To justify each of the parameter $x_W$, $x_{PV}$, $u$ to another, physical as well as economical influences have to be considered. Therefore, there exists no common optimal solution. Every hybrid system project requires an individual dimensioning with respect to formula (11).

For example, the addition of a wind energy converter to a PV-plant with a statistically averaged constant power gain of 0,2 kW ($x_W = 0,2$, $x_{PV} = 2$) per household lowers the curve of the residual ratio of power to heat characteristic as demonstrated in figure 8.

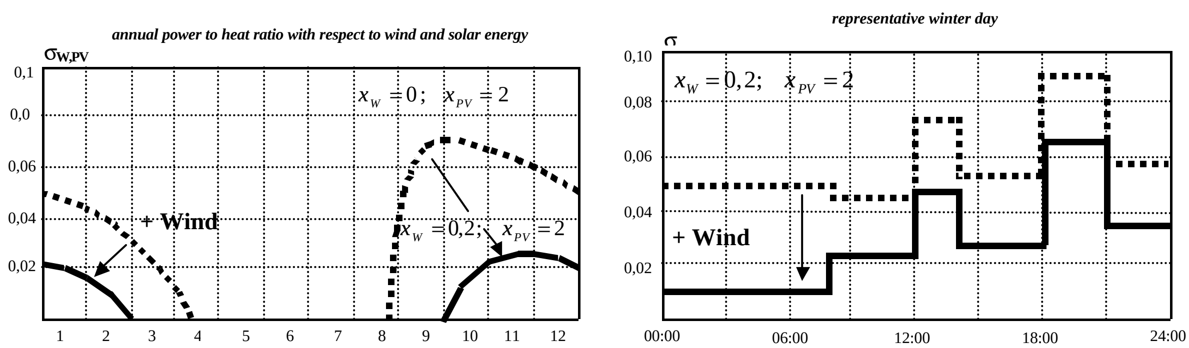



Figure 8: Residual Ratio of Power to Heat with Wind Energy and a PV-Plant

The PV-system is able to supply a household sufficiently with electrical energy during summer time, and an additional wind energy converter increases the availability. In consequence, the required capacities of storage batteries decrease. In this season, the combined heat and power system could be used nearly only for hot water production, or in very improbably situations with simultaneously low insolation and not sufficient wind. In winter time, the contribution of the PV is very weak. In this case, the combination of wind energy and combined heat and power builds the responsible supplies. In contrast to the summer time, there is a simultaneous demand on electrical power and heat, which implies the usage of such complex systems for combined heat and power.

The figure 8 above shows simplified the power demand of an average private household in Germany for a typical day in winter. The contribution of the PV system is negligible. The ratio of power to heat is not high, because of the dominating demand on heating. The dotted line is the usual ratio, whereas the solid line is the result of a contribution of wind energy. A basically reception of the presented explanations to the dimensioning principles for 'renewable' hybrid systems is the fact, that the remaining expected requirements concerning the electrical efficiency of combined heat and power engine are very low. Even a modern steam engine is surely able to fulfil the worked out conditions [4].

It could be advantageous to combine carefully many households with a greater wind turbine [3], instead of many small, whereas the PV-systems are installable decentralised, preferably on each roof. But there are many different individual concepts possible.

# 3 Electric Vehicles as a Part of the Energy Storage System

Storage batteries for electrical energies are necessary to guarantee a gap free energy supply. Even the average required power for a private household is in most cases less than 1 kW, short time demands of more than 10 kW are possible (Table 1).

Table 1: Classification of the Electrical Power Demand of Private Households in Germany

| kW | 0 - 1 | 1 - 2 | 2 - 3 | 3 - 4 | 4 - 5 | 5 - 6 | 6 - 7 | 7 - 8 |
|---|---|---|---|---|---|---|---|---|
| % | 84 | 10,9 | 3,28 | 1,98 | 0,54 | <0,15 | <0,05 | < 0,05 |

But the equalised power conversion with the combination of wind and solar energy minimises the required capacity of storage batteries. In this context the following explanations regard the possibility to integrate electric vehicles in such storage systems. In this case the electric vehicles are additional electrical consumers as well as they serve as storage capacities.

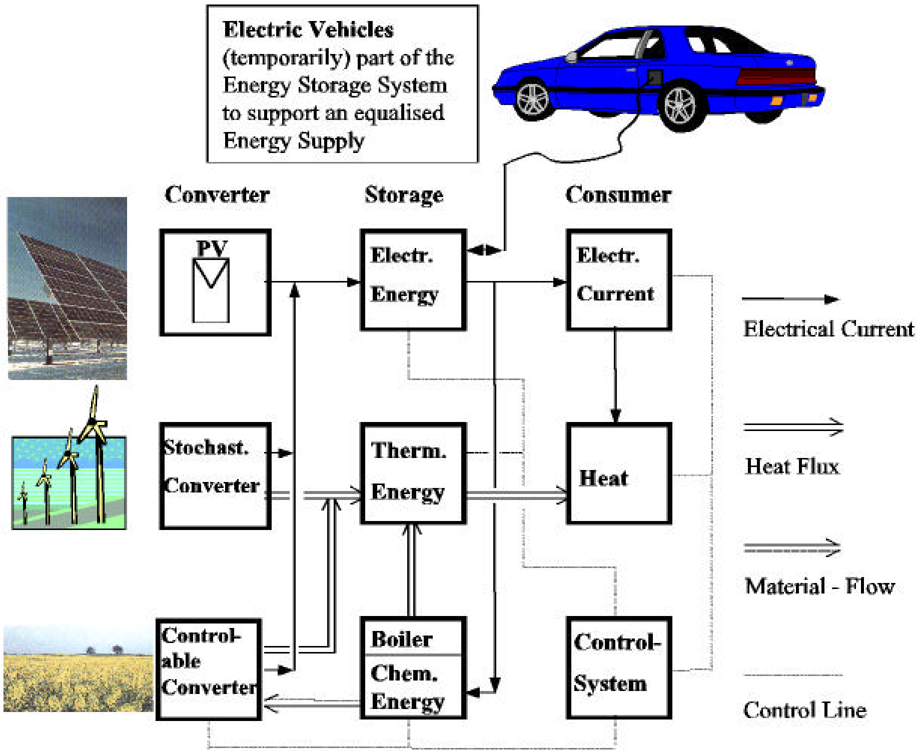



Figure 9: Electric Vehicle as a Part of the Electrical Storage System

Essential for the approximation of the storage battery capacities are the summer conditions, because the combined heat generator is in winter able to deliver the needed energy in a controllable manner, if the hybrid system is well dimensioned. Without the integration of an electric vehicle, a hybrid system with $x_W = 0,2$ and $x_{PV} = 2$ produces statistically a surplus energy of more than 6kWh in May up to 8kWh in June. For a week this means an amount of electrical energy for the demand of 5 to 8 days, concerning average private households in Germany. In order to store all this energy one needs a capacity of 52kWh, this are for example 36 batteries with 12V and 120Ah each. Only a part of this would surely be necessary, regarding the availability as demonstrated in figure 7.

## 3.1 Energy Demand of Electric Vehicles

In Germany there exist more than 37 Mio passenger cars, that means nearly 50% of the habitants have a vehicle. Each vehicle drives nearly 13000 km/year with usually one or two passengers. Each person uses a car for averaged 44 km daily [6], [7].

The range of the electric vehicles amounts usually 40 to 80 km. After this, they have to be recharged. The following figure 10 gives an overview of the energy consumption of electric vehicles, which took part at the Tour de Ruhr for at least three times [2], [8]:

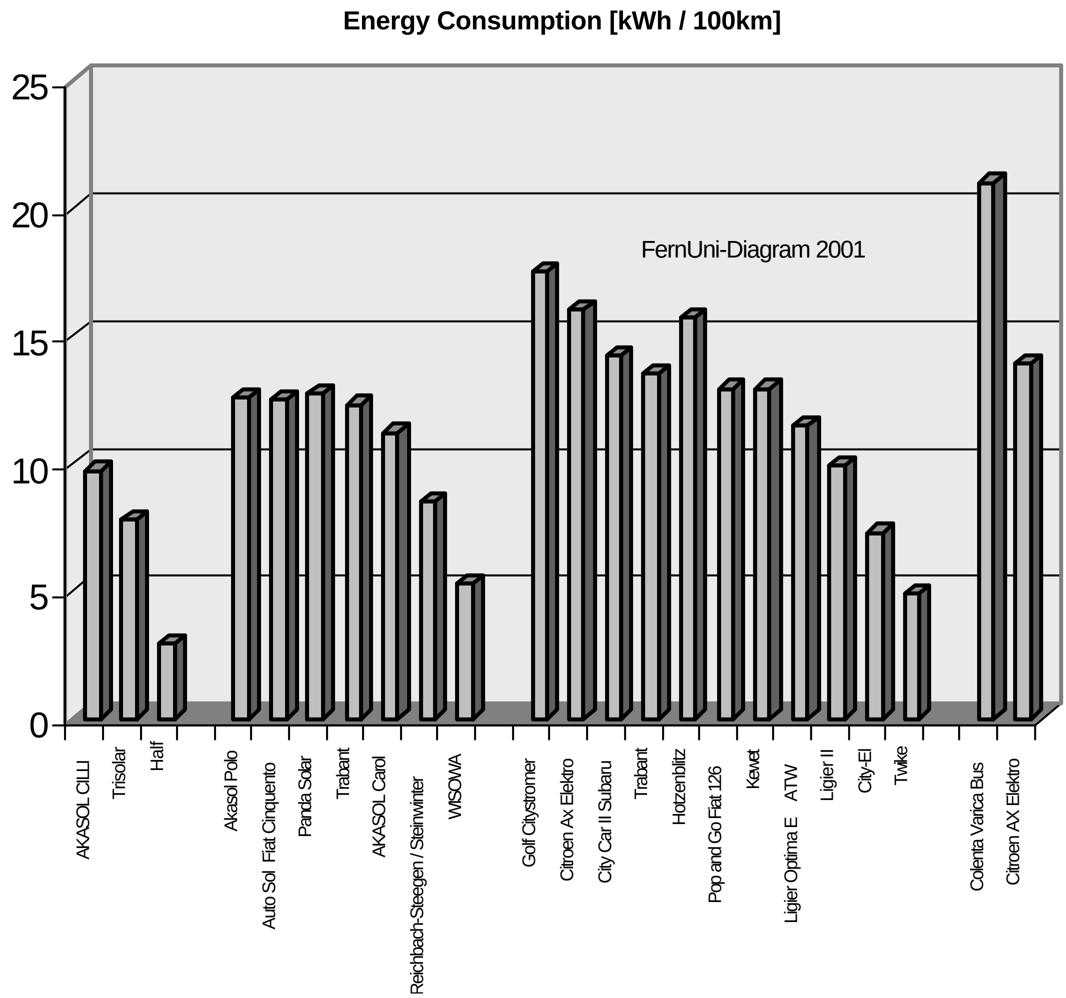



Figure 10: Average energy consumption of some electric vehicles for 100 km at the Tour de Ruhr [8]

Underlying the results from figure 10, assume an energy demand of 15 kWh / 100 km. This means 6,6 kWh for the above mentioned 44km. Therefore a battery capacity of approximately 10 kWh would be sufficient for nowadays usual electric vehicles, in good agreement with the data given from the producers.
The following types of batteries were mainly used in electric vehicles [8]:

i) Lead / Acid Batteries
ii) Lead / Jelly Batteries
iii) Lead / Fleece batteries
iv) Ni / Cd Batteries

One of the most used type is the lead / jelly battery. The energy evaluation made at the tour depends on the consideration of a battery capacity concerning a C5 characteristic (figure 10). This means a discharge during five hours.
For the charging procedure the participants of the tour de Ruhr get a time of approximately 3,5 hours. Therefore some of the used battery sets are afterwards only partially loaded. But this time is sufficient to charge the main portion of energy. Figure 11 shows the typical charge characteristic [8].

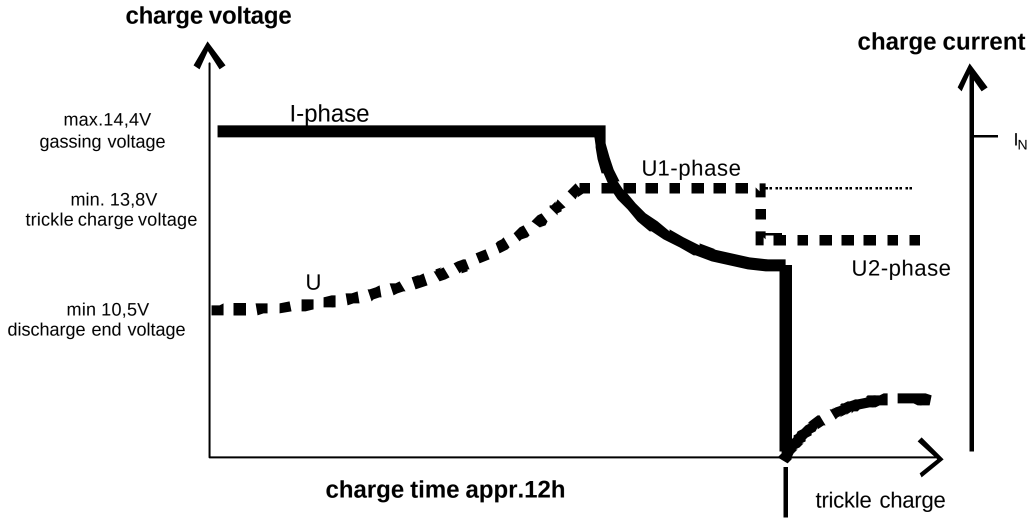



Figure 11: Principal charge characteristics of a lead-jelly battery

The main reason for the amount of partial load is the limited charge current of the different charge management systems of the individually used charge controller. There still remains a great necessity of research and development activities to reduce the energy demand of electric vehicles as well as for the charge control, to minimise the charging time with respect to weight, capacity and lifetime optimised batteries [2].

### 3.2 Dimensioning Criteria of Hybrid Systems including Electric Vehicles

In order to integrate 'one' electric vehicle into the structure of a hybrid system as described above, first the additional energy demand has to be regarded. This leads to the question, if the dimensioning with $x_W = 0,2$ and $x_{PV} = 2$ has necessarily to be changed. If yes, which converter would be scaled up advantageously? With respect to the battery capacity of 10kWh for the electric and the daily demand of nearly 7 kWh, the additional amount of electrical energy to be produced would be 10kWh/day. So the formula (1) changes to

$$\overline{P}_{d,Current+Vehicle} = \left\{18,6 + 1,6 \cdot \cos\left(\frac{2p}{365} \cdot d\right)\right\} \left[\frac{kWh}{d}\right],\ d \equiv day\ . \qquad (12)$$

As a consequence, the ration of power to heat doubles approximately, and the dimensioning criteria given by formula (11) modifies to

$$x_W \cdot \overline{P}_{d,Wind}(d) + x_{PV} \cdot \overline{P}_{d,PV}(d) \geq P_{el,house}(d) + P_{el,vehicle}(d) - u \cdot P_{heat}(d), \qquad (13)$$

with $P_{el,vehicle} = 10 \frac{kWh}{d}$ constant.

As it is shown in figure 8 the PV-plant alone is normally able to supply the private household with electrical energy even with a surplus of 1,8kWh to 3kWh a day in summer times. The additional wind energy converter increases the availability (figure 7) as well as the amount of surplus energy, and it decreases the necessary efficiency of the combined heat and power in winter.

Figure 8 shows, that the wind energy together with the combined heat and power could be expected to have enough potential to produce all the needed energy. Perhaps the nominal electrical power rate of the combined heat and power has to be doubled with respect to the possible efficiency. This will result in an increasing consumption of (biomass) fuels. The decisive season for the storage capacity is the summer, therefore the PV-plant should be increased, but equation (13) has no unique single solution.

For example a hybrid system with $x_W = 0,2$ and $x_{PV} = 3$ would be sufficient, and the amount of surplus is equal to a hybrid system without electric vehicle with $x_W = 0,0$ and $x_{PV} = 2$, but with an increased availability with respect to figure 7. For that reason, apart from the electric vehicle, a battery capacity of 20 kWh in the hybrid system may be sufficient to store the surplus energy of one week. If the supply security is not sufficient, the amount of the wind energy portion could also be increased.

It would be a great advantage, if many such hybrid systems were integrated into a complex interconnecting structure with the possibility of grid equalisation. Then it would be possible to connect the electric vehicle most of the time to a common electric line. This would increase the availability of each hybrid system and help to decrease the amount of additional battery capacity, the better, the greater the complex system is. In this way, the electric vehicles serves as equaliser in the electric grid of hybrid systems. Of course, this purpose presupposes a bi-directional charge control management for the electric vehicles. It would be also necessary to define a minimum charge status to cut these batteries off the line, in order to reserve a minimum driving range. Further calculating simulations and experimental studies are necessary to find the best dimensioning of such systems.

# 4 Conclusion

The above given explanations demonstrate the possibility to supply an average German private household self-sufficient with heat and power with the help of combined converter to a so-called hybrid system, basing on renewable energy resources. Especially the dimensioning criteria for such systems are worked out including the integration of an electric vehicle. This is an additional energy consumer, but has also the positive effect to support the electrical energy storage system in order to equalise the energy supply fluctuations.

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# Electric Vehicles as an Integrated Part of Energy Storage Systems in Renewable Hybrid Energy Supply Systems

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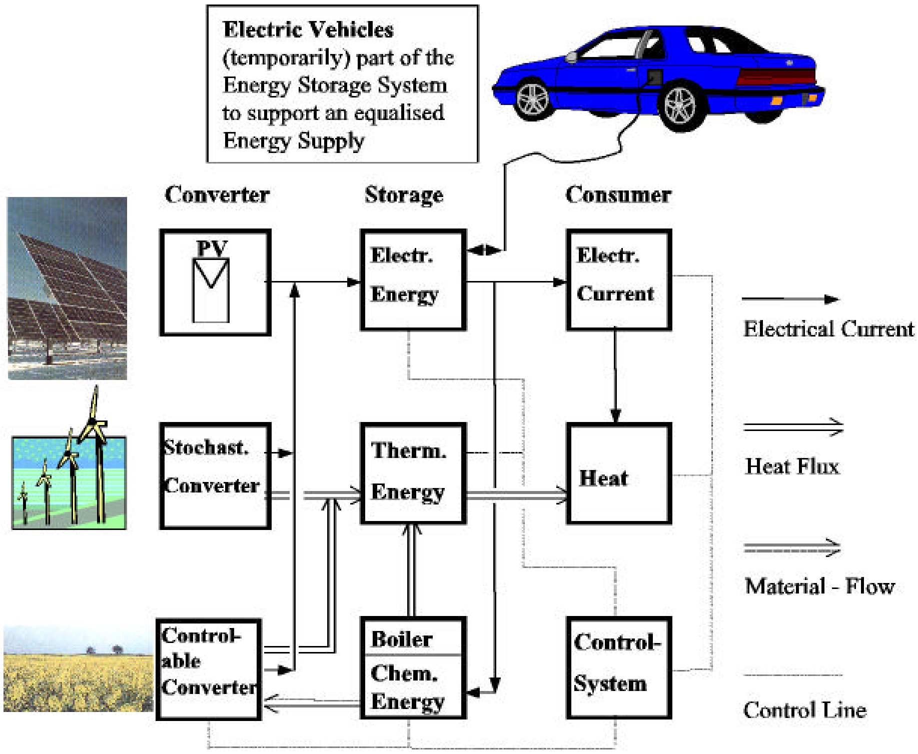
Aim of this paper is to present the worked out physical aspects and detailed dimensioning principles of hybrid energy supply systems, including the integration of the storage capabilities of electrical vehicles, to show up a possible over all energy supply structure concept for the future.




The presented explanations demonstrate the possibility to supply an average German private household self-sufficient with heat and power with the help of combined converter to a so-called hybrid system, basing on renewable energy resources. Especially the dimensioning criteria for such systems are worked out including the integration of an electric vehicle. This is an additional energy consumer, but has also the positive effect to support the electrical energy storage system in order to equalise the energy supply fluctuations. It would be a great advantage, if many of such hybrid systems were integrated into a complex interconnecting structure with the possibility of grid equalisation. Then it would be possible to connect the electric vehicle most of the time to a common electric line. This would increase the availability of each hybrid system and help to decrease the amount of additional battery capacity, the better, the greater the complex system is.