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Strategies for combined use of power conditioning units in vehicles and buildings

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Abstract

Concepts for a dual use of "micro-combined heat and power units" (CHP) in vehicles and buildings can also be designated as "micro-power conditioning units" (PCU). In electric vehicles (EV), the thermal conditioning of the battery pack needs special attention. In an ongoing research project, micro-PCU concepts with a mechanical power in the range of 1 to 15 kW are investigated. A PCU integrated in a vehicle is not in use during parking periods, therefore a mobile integration and additional application of the PCU in adjacent fields could increase the overall sustainability in energy utilization. It is intended to transfer the CO_2-reduction potential of a battery electric vehicle (BEV) to the owner's house in order to increase the acceptance of BEVs. To introduce the dual use of PCUs in housings, it is necessary to characterize the typology of buildings and the respective standards of heat insulation, as well as the common energy requirements. Additionally, it is calculated, whether the use of PCUs in residential buildings could decrease it´s CO_2-emissions. In Germany, 42% of residential buildings are detached houses. Using the example of a detached house, the potential application and benefits of PCUs with a mechanical power in the range of 1 to 3 kW are studied. The analysis shows that the use of fuel-operated PCUs in a single-family house may result in 14% reduction of the total CO_2-emissions. Without major modifications, conventional fuel-operated engines could also be run by the use of liquefied petroleum gas (LPG). If LPG-operated PCUs could be used in a building, the potential of CO_2-reduction rises up to 35 % in comparison to a standard heating unit. However, the CO_2-reduction could not be increased by enhancing the power of a PCU (4 kW) because in contrast to smaller units (2 kW) the higher thermal output of 4kW units cannot be used, and therefore the thermal efficiency is decreased. To summarize, it could be possible to reduce CO_2-emission by integrating a PCU of a BEV in the buildings heat unit; however only in a narrow range of power is the implementation of PCUs of a significant benefit.

Keywords: CHP; combined heat and power, range extender, auxiliary power unit, electric mobility, CO_2-emissions

1. *Introduction*

Pure battery electric vehicles (BEV) have not been successfully established in the car market in Germany so far since there are still challenges like low distances, which could be covered by using a BEV, and lack of comfort, like the insufficient heating, ventilation, and air conditioning (HVAC) of the interior. The maximum range of BEV depends on size and capacity of the

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battery, and is furthermore influenced by topological, thermodynamical, and dynamical driving effects. This gap could be closed by the use of a range extender (RE). Range extenders (RE) use a combustion engine connected to a generator-unit or to a fuel cell (FC), which can be used for charging the battery while driving. The Power Conditioning Unit from the IAV Company (Gifhorn, Germany) is a further development of the RE-concept. This system additionally uses thermal losses to either heat the car's interior of the passenger compartment, or the battery packs and produces electricity in order to charge the vehicle's battery. Moreover, this system is upgraded with additional couplings a cooling compressor, and therefore also allows the cooling of the interior or the battery (Fig.1 and 2).

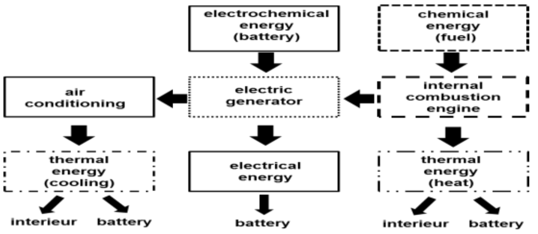

Fig. 1. Modes of the micro-PCU

Fig. 2. PCU, prototype from IAV

The PCU offers the possibility of a more efficient use of the energy derived from fuel, raises the comfort of the BEV, and therefore leads to a higher efficiency of electro mobility. To achieve the goal of the government, to register 1 million BEVs in Germany until 2020, a combined use of RE or PCU, not only in BEVs but also in buildings, could help support the successful achievement of this target. Moreover, such a possibility could additionally increase the customer's acceptance of BEVs. The scalability of mobile RE-concepts and the possible integration of PCU systems in buildings is currently a research topic at the University of Applied Sciences and Arts Hanover, Germany. The main intention is to minimize the above mentioned negative aspects of BEVs (short driving range, low comfort, etc.) and to reduce the CO_2-emissions from a vehicle and/or building.

2. Scenario for using-periods of micro-PCUs in buildings

The present study examines whether the use of a PCU in a building could reduce its CO_2-emissions. The duration of use of the PCU-system depends on the runtime, the kind of fuel used, and the energy demand of the building itself. The runtime of a PCU would directly depend on the user attitude.

Table 1. Periods of use of a BEV in a hypothetical model of a family of three persons

usage the car	**hours on weekdays**	**hours at weekend**	**usage during holidays**	**hours per annum**
driving to work	9	0	0	2340
shopping	2	4	0	936
transports/transfers	2	6	8	1144
others	1	4	6	676
sum	**14**	**14**	**14**	**5096**

A hypothetical model is created to analyse the possible benefits of PCUs. For this model an average family of three persons, living in a detached house, and using one BEV is chosen. Other usage profiles will be examined in the future; however similar results are expected (Tab. 1). The calculated average using the time of a car is 14 hours, meaning that the car would be in the garage for 10 hours per day (Tab. 1). During this time, the usage of the PCU in the family's house could start, while the battery of the vehicle charges. This charging process takes between 3 and 6 hours on average, according to the technical data provided by manufacturers. The total usage time of the PCU for the building would be 3414 hours per year, as the car would be 3664 hours in the garage, and subtract 250 hours for public holidays while the vehicle would not be available in the building (Tab. 2).

Table 2. Usage times of the power conditioning unit (PCU) in the building

usage time	hours
total hours per annum	8760
by the car	5096
during holidays	250
total using time for the building	**3414**

3. Heat demand in residential buildings, basic modelling

In the German residential building sector, detached houses are the most common type representing 42% of all buildings [2]. To model the possible integration of a BEV with RE/PCU into the building management, only this building type was examined. A detailed analysis of the detached house model shows different energy demands resulting from different building ages. Upcoming strict regulations for heat insulation and rising energy prices lead to a re-evaluation in Germany regarding thermal and energetic efficiency. During the oil crisis in the 1970s, better insulation standards for buildings were introduced to decrease heat costs and since then insulation standards were further developed up to the standard "Passivhaus", a type of house which needs no active or only minimal additional heating. Consequently, there is a variety of different heat insulation standards and heat requirements in buildings. To model the heat requirements for a possible use of PCUs in buildings in Germany, three representative insulation standards widely used in detached houses were chosen (Tab. 3) [3].

Table 3. Heating demand depending on the thermal insulation standard of a detached house

thermal insulation standard	heat requirement [kWh/m²a]
„Passivhaus“	**≤ 15**
KfW 85	**≤ 55**
Ø Germany	**≤ 160**

The Energy Saving Ordinance 2009 EnEV, defines maximum limits for heat requirements to be followed in new buildings. For comparison reasons with the "EnEV", mapping is necessary. The insulation standard "KfW Efficiency House 100" (KfW 100) corresponds, for example, completely (100%) to the requirements of the EnEV. A building with the thermal insulation standard "KfW Efficiency House 85" (KfW 85) needs 85 % of the energy of a comparable new building according to EnEV [4]. The insulation standard "average Germany" (Ø Germany) takes all existing insulation standards into account and provides a reference. The thermal insulation standard

"Passivhaus" however, provides the optimal thermal insulation standard [5]. As a reference point to calculate the possible implementation of PCUs in buildings, a detached house located in Hanover according to the VDI 4655 guideline, is chosen. The floor space is supposed to be 110 m², and a three-member family is assumed to live in the house. PCUs with a mechanical power in the range of 1 to 4 kW and a thermal output between 2 and 8 kW are used in the model. Figure 3 summarizes the energy requirements per year of the selected type of building (detached house) with the respective different insulation standards, and compares this to the thermal and electrical output of an implemented PCU (mechanically 2 kW). A cooling demand is not addressed in the present model, because in this climatic region it is only used in office and commercial buildings.

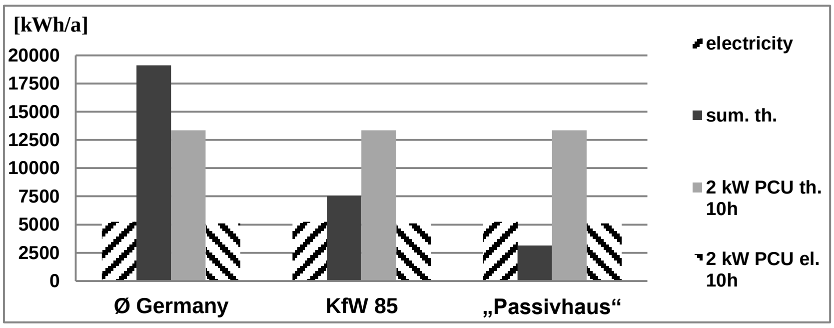

Figure 3. Annual requirements in a detached house with different energy demands for different insulation standards in combination with a 2 kW mechanical PCU (th=thermical, el=eletrical), based on VDI 4655

The calculation shows that annual electrical demands of the building can be covered by the use of a PCU with a mechanical power of 2 kW. The sum of the thermal requirements varies because this depends on the insulation level of the building (Fig. 3). The model shows that the thermal requirement of a detached house with an insulation standard "KfW 85" and "Passivhaus" can be completely covered by including a PCU, whereas that of the "Ø Germany" insulation standard cannot be covered.

4. Mobile micro-PCU reduces CO_2-emission in buildings

The basis for the calculation of CO_2-emissions are the energy requirements of the presented three types of insulation standards in buildings.

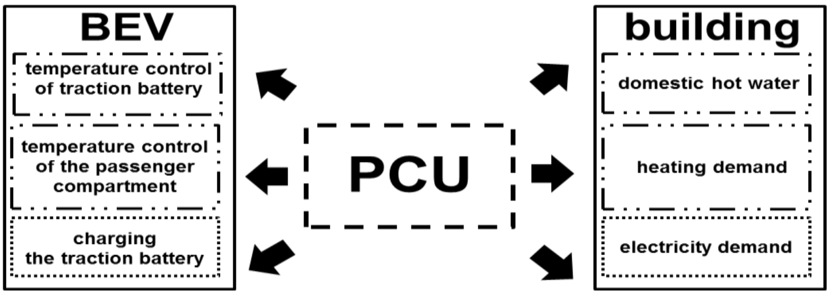

Figure 4. Interfaces of BEV/building and PCU

Using a self-developed calculation tool, electricity, hot water, heating demands, and the resulting CO_2-emissions are calculated in the present survey. Figure 4 represents the interfaces between BEV/building and the PCU. CO_2-emissions for conventional covering of energy requirements in a building is investigated by the use of “Strommix Germany”, and the heating demand using a condensing boiler (Tab. 4), as well as the covering of the energy requirements, by integrating a PCU (1-3 kW mechanical power) [6, 7, 8]. With the use of the calculation tool, it is possible to determine the hypothetical CO_2 -reduction (Fig. 5). It can be seen that the use of gasoline-powered PCUs (1-3 kW mechanical power) in a detached house with insulation standard "Ø Germany" is able to reduce the CO_2-emission (14%) compared to a conventional energy supply. This is possible, if the PCU could be used for 10 hours per day through the distributed usage of the CHP-effect (Fig. 4). While comparing different PCUs (1-3 kW mechanical power), only the use of a PCU (1 kW mechanical power) leads to the desired reduction in CO_2-emission in a detached house with insulation standard "KfW 85".

Table 4. Basis for calculating CO_2 –emissions

energy source	CO_2-emissions [g CO_2/kWh]
“Strommix Germany”	**576**
condensing boiler	**260**

Since, in a detached house with insulation standard "passive house" has very low thermal requirements, according to the standards of thermal insulation, the use of a PCU would not lead to a reduction in CO_2-emission
(-6% to -89%) because the CHP- effect did not apply (Fig.5).

5. Which CO_2 reduction is possible by alternative fuels?

Without major modifications, fuel-operated engines can also be run by the use of liquefied petroleum gas (LPG). By applying LPG-powered PCUs (1-3 kW mechanical power) in a detached house with thermal insulation standard "Ø Germany", a reduction of CO_2-emission up to +35% can be illustrated. In the detached house with thermal insulation standard "KfW 85", the use of a LPG-PCU (1-2 mechanical power) could achieve up to 27% CO_2-reduction. Moreover, even in a single-family house with thermal insulation standard "Passivhaus”, a CO_2-reduction of +13% by applying a LPG-PCU with a mechanical power of 1 kW could be calculated. By using a LPG-PCU with a mechanical power of 2 kW still +5% CO_2-saving was possible (Fig. 5).

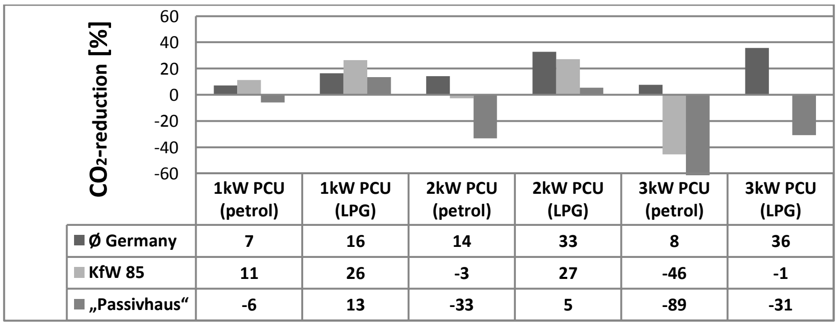

Figure 5. Savings in CO_2-emission in percent (%) with fuel and petrol with PCU in different engine-power classes

6. Conclusions

A combined use of a RE or PCU, not only in battery vehicles but also in buildings, could reduce the CO_2-emission effective, particularly if alternative fuels (LPG) would be used. However, enhancing the power of a PCU up to 4 kW does not lead to a further CO_2-reduction in buildings caused by an unusable power excess. Moreover, if PCUs with lower power (e.g. PCU with 2 kW mechanical power) and longer usage periods are applied, a benefit of CO_2-saving is possible. This is the energy requirements of the building and the energy produced by the PCU match each other, therefore optimal utilization of the CHP-effect is possible. Further studies will examine whether the PCUs could also be integrated in other building types, such as office buildings. Here it would be possible to use the produced energy during the parking periods while the employees are working. Additionally, it will be investigated whether the PCU could cover cooling requirements of office buildings while the BEV is charged. The results of this study show the potential of CO_2-reduction by the use of alternative fuels, like LPG. This issue will be addressed in a following project of the Lower Saxony Institute of Technology (NTH) focussing on multi fuel capability of mobile micro-CHP.

7. References

[1] Bas U. Entwicklung eines innovativen Range Extenders für Elektrofahrzeuge FH Aachen Germany; (2011).

[2] Corradini R. Regional differenzierte Solarthermie-Potenziale für Gebäude mit einer Wohneinheit University Bochum, Germany; Publisher Forschungsstelle für Energiewirtschaft e.V. (FfE) Munich, Germany (2013).

[3] Loga T and Diefenbach N and Born R. Deutsche Gebäudetypologie. Institut Wohnen und Umwelt GmbH (IWU) (2011).

[4] Backwinkel L. KfW-Berechnung für einen Wärmeschutz für ein Bestandsgebäude Berlin. Publisher GRIN Verlag GmbH, Munich, Germany (2013).

[5] Feist W. Heizlast in Passivhäusern-Validierung durch Messungen. Passivhaus Institut Dr. Wolfgang Feist Germany (2005).

[6] Machat M and Werner K. Umweltbundesamt : Aktualisierung auf Basis des Bandes „Climate Change 1/2007“(2007).

[7] Schakenda V and Askham C. CO2-emmisions assiociated with diffenert eleltricity mixe. Ostfold Research; (2010).

[8] Millo F and Rolando L and Fuso R and Mallamo F. Real CO_2 emissions benefits and end user's operating costs of a plug-in Hybrid Electric Vehicle. Applied Energy. Vol.114 pp. 563-571 (2014).