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Energy consumption and energy saving potentials in piglet production

For agricultural farms, a considerable share of variable costs is due to the energy consumption for agricultural production processes. In particular, piglet production and nursery have a high thermal and electric energy demand. For the planning and the redevelopment of pig housing systems, a good knowledge of the energy demand of different consumers is of great importance. With this knowledge, it is possible to derive measures for improving energy efficiency and reducing energy consumption.

Keywords
Energy efficiency, energy saving potential, piglet production

Abstract
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Within our research on the efficiency of energy use in pig production (particularly breeding sows), we combine measurements of individual energy consumption with operational data of specialized farms. Beside the assessment of the production systems, the aim is to derive energy saving concepts for individual farms. Therefore, we measure energy consumption of production facilities and retrieve data from plant and equipment data bases. For energy efficiency analysis, a three-stage approach is taken that starts with the collection of bulk data on energy consumption of agricultural farms and continues with long-term measurements on experimental farms and, finally, calculations for individual devices (**figure 1**).

Evaluation of data on electricity consumption

Data from 2007 on electricity consumption are combined with operational data of individual farms and evaluated according to specific criteria that are relevant for agriculture. From this a basic table with an overall 26441 data sets could be generated. To establish reference values and benchmarks, farms were classified and clustered with respect to region, farm size and branch in accordance with the SDB („Standarddeckungsbeitrag" – Classification of agricultural farms according to the EU-wide classification system).

Energy consumption measurements on experimental farms

For the measuring of electricity and heat consumption and the determination of technical characteristics, eleven experimental farms at 14 sites with a focus on piglet production were selected in close cooperation with the regional departments for nutrition, agriculture and forestry. The aim was to cover a broad range of piglet production situations in Bavaria, including buildings and technical equipment. Therefore, farms of different size and with various production facilities from all administrative districts (and agricultural regions) were selected for long-term measurements.

Energy consumers and measuring equipment in piglet production

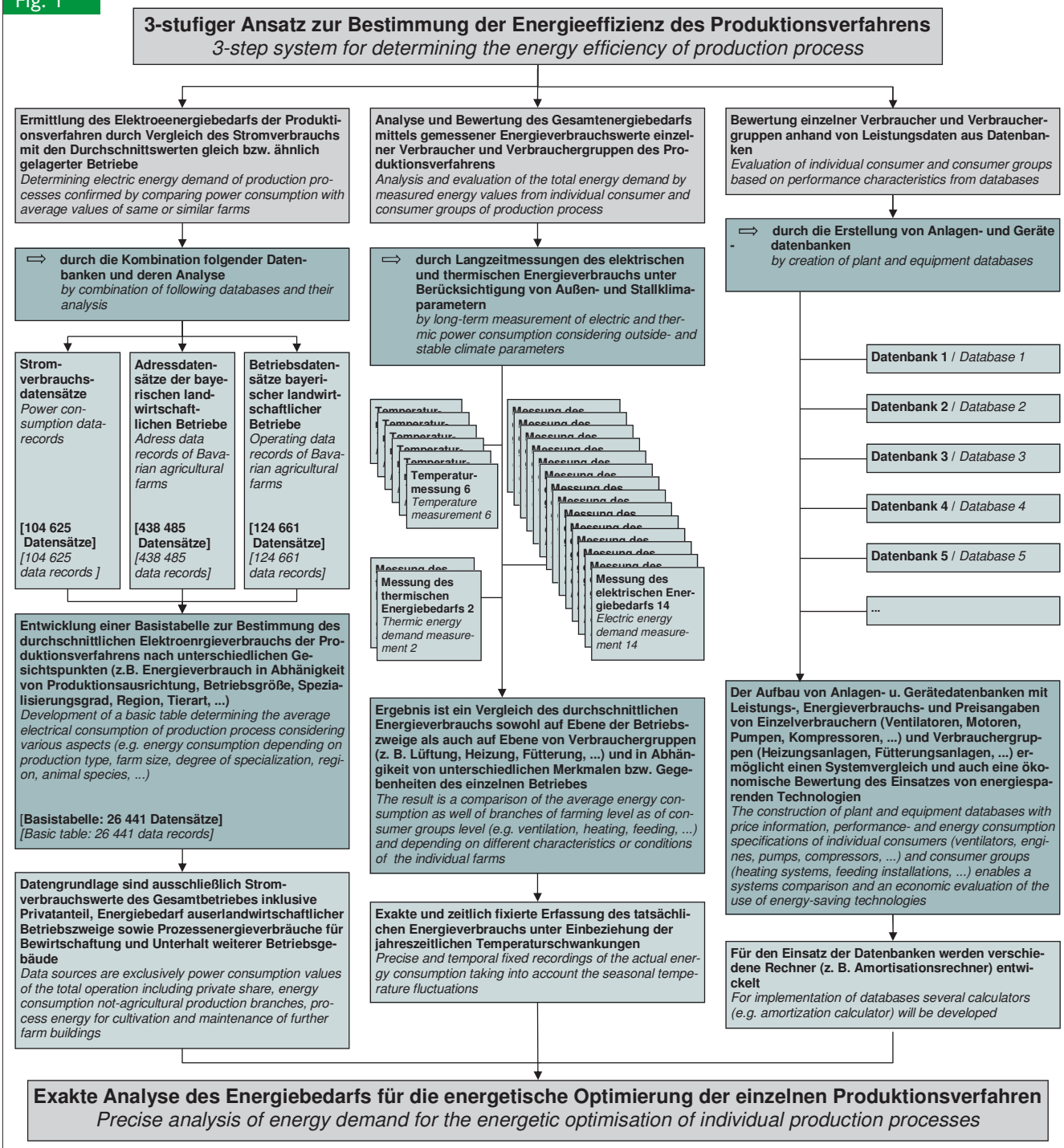
According to measurements taken in northern Germany, the energy consumption of piglet farms is very diverse. On average, the share of heating energy with respect to total farm energy demand was 66 % for breeding sows and 87 % for nursing piglets. Ventilation causes 25 % of total energy consumption for sow breeding and 10 % for piglet nursery, on average [1]. Overall, compared to other consumers, the energy demand for heating and ventilation is very high. To equalize seasonal variations of temperature and other climatic conditions (relative humidity, ambient pressure, wind speed etc.), energy demand for heating and ventilation depending on inside and outside temperatures is measured over a time period of twelve months at least. In addition, energy consumption of feeding systems, lighting, cleaning and other relevant equipment is determined. Permanently installed meters (for electricity and heat), data loggers and data transfer devices, as well as other measuring instruments provide values of actual energy consumption.

Further measuring equipment includes a thermal imaging camera, a device for heat transfer coefficient measurement, several energy meters, an IR-thermometer, an IR-rangefinder and other instruments, e.g. for measuring humidity and concentration level of air pollutants.

Plant and equipment data base

The basic idea of this data base is the comparative calculation of energy consumption values using performance characteristics of technical equipment. This is used to infer economic and energy efficiency. The data base includes a list of all technical

Fig. 1



Energetic analysis of agricultural production process

components that are used for piglet production. It is developed and updated on a continuous basis. The information for typification and characterization of these components is retrieved from company specifications, DLG-assessments and internet searches.

Electrical energy consumption of agricultural farms

For the 26 439 farms evaluated, which cultivate an area of 721 136 ha, a total electrical energy consumption of about 370 GWh per year was determined. The average electrical energy consumption per farm is 13 984 kWh per year and the average land area per farm is 27.27 ha [2].

To determine energy consumption of individual production processes, farms are grouped with respect to similar economical and production orientation. For specialized nurseries (pig nursing and breeding) the average electrical energy consumption is 35 043 kWh per year, and for farms, that achieve considerable additional income from crop production, this value is 26 952 kWh per year. Compared to other groups such as specialized crop and forage growers, dairy farms and farms with diverse sources of income, theses energy consumption values are the highest.

Electrical energy consumption of specialized sow breeding farms depending on site conditions

Based on the twelve agricultural regions of Bavaria, it was investigated whether site conditions have an influence on electricity and heat demand of specialized sow breeding farms. Agricultural regions AR 1 (Alps) and AR 2 (Alpine forelands) were excluded from the analysis, as there are few sow breeding farms in these regions for which data on electrical energy consumption is not available. Overall, 1 084 specialized sow breeding farms with a total of 57 637 sows were evaluated. Average energy consumption of these farms was 26 584 kWh per year with a mean value of 500 kWh electrical energy demand per sow and year. In the northern and southern Tertiary hills (AR 4 and 5) both 58 % of sow breeding farms and of sows are located. Only electrical energy demand could be determined in this investigation. Therefore, it is not possible to give a reliable estimate of the total energy demand of farms with respect to site conditions (differences in temperature between Northern and Southern Bavaria).

Electrical energy consumption with respect to farm size

Figure 2 shows average electrical energy consumption per sow as a function of farm size. From a total of 1 110 specialized sow breeding farms, 1 051 farms (95 %) were included in the boxplot analysis after eliminating extreme values. The majority of farms (61 %) belongs to the size group with up to 50 sows. Farms with more than 100 sows constituted only 9 % of all sow breeding operations in this investigation. Specific electrical energy demand per sow decreases with increasing farm size. Farms with less than 50 sows show the largest variability of specific electricity consumption. For many of these farms, parts of the electricity consumption for the private household and other branches of the farm are included in these values. Using interquartile ranges (or the regression function) reference values of specific electricity consumption as a function of farm size can be established.

Potential for saving electrical energy in piglet production

Figure 3 presents a scatter plot of the quartile analysis of 1 082 specialized sow breeding operations, weighted by average electricity consumption per sow (kWh per sow).
The breeding operations are divided as follows:

- 25 % with low electricity consumption
- 25 % with high electricity consumption
- 50 % with average electricity consumption

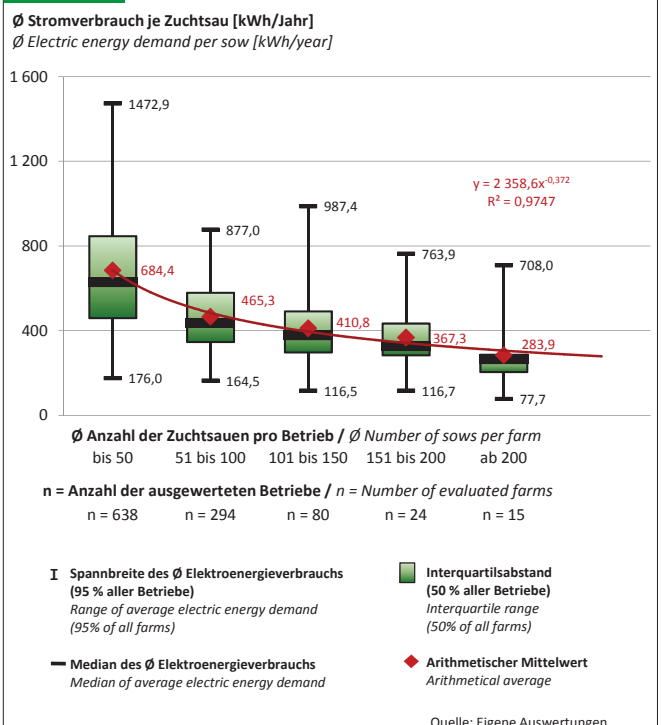
The range between the linear trend lines for the low and high electricity consumption sectors represents potential energy savings. From this, for animal populations with 50 sows, an energy saving potential of about 30 000 kWh per farm and year can be derived. For farms with 100 sows the yearly electrical energy saving potential is about 60 000 kWh, for farms with 150 animals it is about 90 000 kWh.

Preliminary evaluation of energy consumption measurements on experimental farms

On six experimental farms the complete equipment for measuring the electricity consumption of individual components and assemblies has been installed and data from remote transmission are being recorded. On three other farms preparations for measuring electrical and heating energy consumption are made, and on another two farms planning of installation work will begin shortly. For the first six farms the complete data of electricity and heat consumption for Juli and August of 2010 have been recorded. Due to seasonal variations of temperature and weather conditions affecting energy demand, it is not useful to extrapolate from these data to the whole year. **Figure 4** presents mean values of energy consumption in kWh per sow according to the present state of our research.

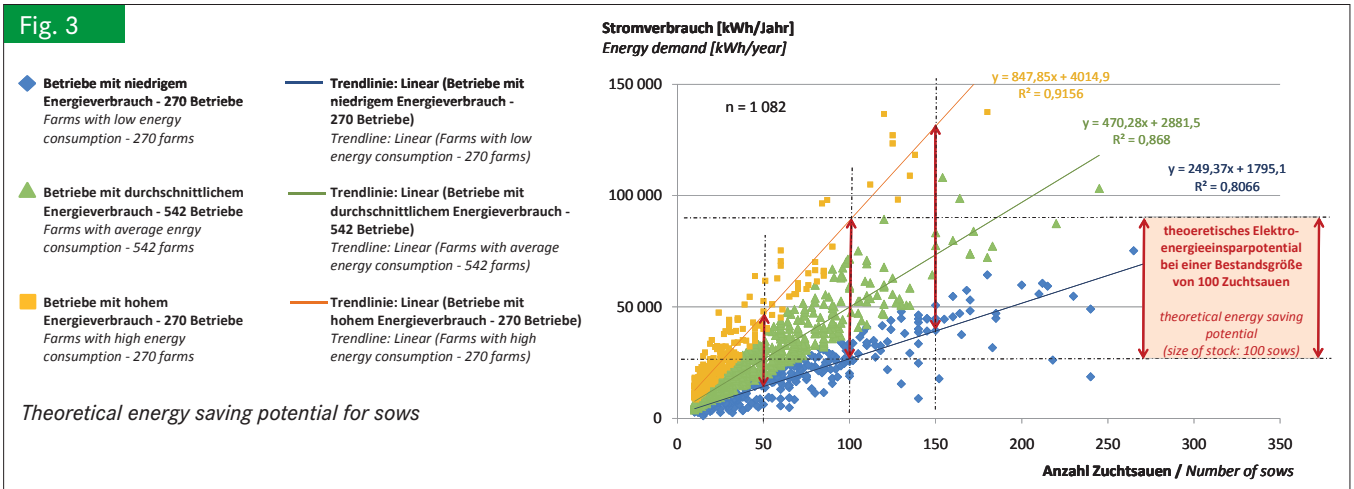
In July, the mean heating energy demand of the experimental farms is 14.4 kWh per sow and the total electricity demand

Fig. 2



Electric energy demand depending on size of farm

Fig. 3



Theoretical energy saving potential for sows

is 15.8 kWh per sow. In August, the energy demand per sow is 18.2 kWh for heating and 16.5 kWh for electricity. Ventilation was responsible for 64 % of electricity consumption with a small reduction of about 1 kWh per sow in August compared to July. The results of our measurements confirm literature reports about the excessive heating energy consumption and the high share of electricity demand for ventilation (59 % of total electricity demand in piglet production) [3; 4].

Mean temperature dropped from 21.2 °C in July to 17.2 °C in August. As a result, heating energy demand increased significantly. Decreasing temperatures require the prolonged use of IR lamps resulting in higher electricity demand. This sector is responsible for about 10% of total electricity consumption. Since they are not influenced by changing weather conditions, the other sectors show smaller variations in energy consumption given stable animal populations. Three farms did not incur operating cost for preparing animal feed, since this was done by contractors with mobile feed mixing units. For the other three experimental farms about 11 % of total electricity demand was for feed preparation.

Conclusions

Using the results of our investigations it is possible to derive information on the energy demand of individual production sections such as for farrowing, mating, weaning and breeding if applicable. We are also collecting building data for barns (wall and ceiling structures, insulation, isolation, size and number of windows, measurements and calculations of heat transfer coefficients, size and building volume) to interpret heating energy demand. In addition, consumption of heating oil, gas, wood and

Fig. 4

Mittelwerte der Verbrauchsbereiche der 6 ausgewerteten Praxisbetriebe im Juli/August

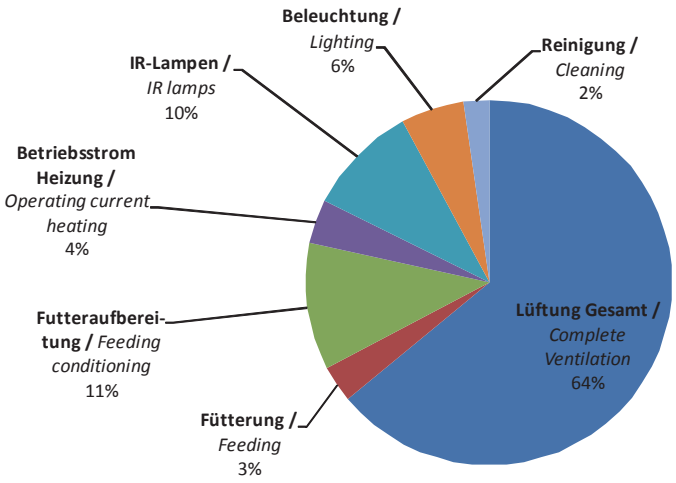
Arithmetic mean of consumption rate from 6 evaluated pilot farms in July/August

	Juli	August
Außentemperatur *Outside temperature*	**21,2° C**	**17,2° C**
Heizenergie *Energy for heating*	**14,4 kWh/ZS**	**18,2 kWh/ZS**
Stromverbrauch Gesamt *Complete electric energy demand*	**15,8 kWh/ZS**	**16,5 kWh/ZS**
Lüftung Gesamt *Complete Ventilation*	10,8 kWh/ZS	9,8 kWh/ZS
Fütterung *Feeding*	0,5 kWh/ZS	0,5 kWh/ZS
Futteraufbereitung *Feeding conditioning*	1,9 kWh/ZS	1,7kWh/ZS
Betriebsstrom Heizung *Operating current heating*	0,6 kWh/ZS	0,7 kWh/ZS
IR-Lampen *IR lamps*	0,8 kWh/ZS	2,4 kWh/ZS
Beleuchtung *Lighting*	0,9 kWh/ZS	1,0 kWh/ZS
Reinigung *Cleaning*	0,3 kWh/ZS	0,4 kWh/ZS

Average energy consumption of 6 pilot farms in July/August 2010

Anteil der Verbrauchsbereiche am gesamten Stromverbrauch - Juli/August

Consumption rate of complete electric energy - July/August



Quelle: Eigene Auswertungen

other fuels is recorded to determine the efficiency of the heating system and derive measures for optimization. The energy demand of the individual components of the ventilation system (fans, actuators, controllers, etc.) is measured, and the use of heat exchangers to save heating energy is investigated. To calculate specific energy demand per piglet and thereby provide the basis for economical assessment, characteristic figures of production output and process technology are determined, which are then compared with energy consumption measurements. With a measuring interval of 15 minutes it is possible to illustrate load profiles and identify peak load times. Although energy suppliers offer load related tariffs only for customers with higher electricity consumption, this aspect should not be neglected due to economical reasons.

Combining the average values for energy consumption that we calculated from mass data with the results from our measurements at experimental farms and the values from our plant and equipment database, it is possible to derive planning values for the whole farm and individual production sectors. Specific recommendations that serve to realize energy saving measures on individual farms and give assistance for new and replacement investments form the basis for improving the energy efficiency of agricultural operations.

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