DETERMINATION OF ENERGY DEMAND IN DAIRY FARMING

Simone Kraatz, Werner Berg

Abstract: *The cumulative energy demand in dairy farming is strongly determined by feed supply and reproduction. More than the half of the total cumulative energy demand is required for feed supply, about one quarter for reproduction. The specific cumulative energy demand per animal place and year calculated for the building and for the technical facilities is about 5% respectively. Different building shells cause only minor differences in the cumulative energy demand. Whereas the cumulative energy demand for a dairy cattle building without slurry channels and pits is about one third less than for a building with channels and pits. The cumulative energy demand for the technical facilities is about 60% less when sand is used as flooring material instead of a rubber mat.*

Key words: *Energy Demand, Dairy Farming, Animal Husbandry.*

INTRODUCTION

In agriculture, we record a constantly growing consumption of raw materials and fossil energy due to the intensification and mechanisation of production technologies. In crop production, this involves direct and indirect energy inputs into the manufacturing and application of fertilizers and plant protection agents as well as machines and implements. In livestock keeping, direct and indirect energy inputs are caused not only by the supply of farm-produced or externally purchased feeding stuffs, air-conditioning, manure disposal and spreading of farm manure, milk production and storage, but also by buildings and constructions. So far, there is a poor knowledge of the energy efficiency of production technologies in livestock keeping, as well as their share in the total energy consumption of a farm and the influence of targets and the intensity of production on the energy efficiency. Nevertheless, any analysis and evaluation of environmental effects and the sustainability of farming systems must consider also the energetic aspects. Energy balancing allows to characterise farming systems, overcome labour bottlenecks and elaborate optimisation strategies.

Objectives

The investigations aim at the development of a method for calculating energy balances in livestock keeping. In this context, not only inputs and outputs are regarded in the form of a "black box" analysis, but rather the relationships between livestock keeping and soil and plant related to the farming via internal energy and mass fluxes. The methodology will be integrated into the "farm and environment management system REPRO (reproduction of organic soil matter)" (Hülsbergen, 2003). The REPRO software allows to analyse and evaluate environmental impacts. Different from other approaches, it reflects a systematic consideration and description of interrelated mass and energy fluxes on the farm level.
Using vegetable as primary products, the procedure of forage preservation is analysed and the resulted amount of feed stuff is calculated. the energy efficiency can be calculated per initial product (original content of a feed-stuff) or per end product (preserved plants). The energy efficiency of an end product contains extra work cycles of preservation. Feed-stuffs are energy inputs of animal husbandry. Considering the procedure, feeding method and performance of fertiliser application in husbandry the required amount of organic and mineral fertiliser will be estimated. The produced fertiliser will be energetically assessed on the basis of their material composition. (Hülsbergen, 2003)

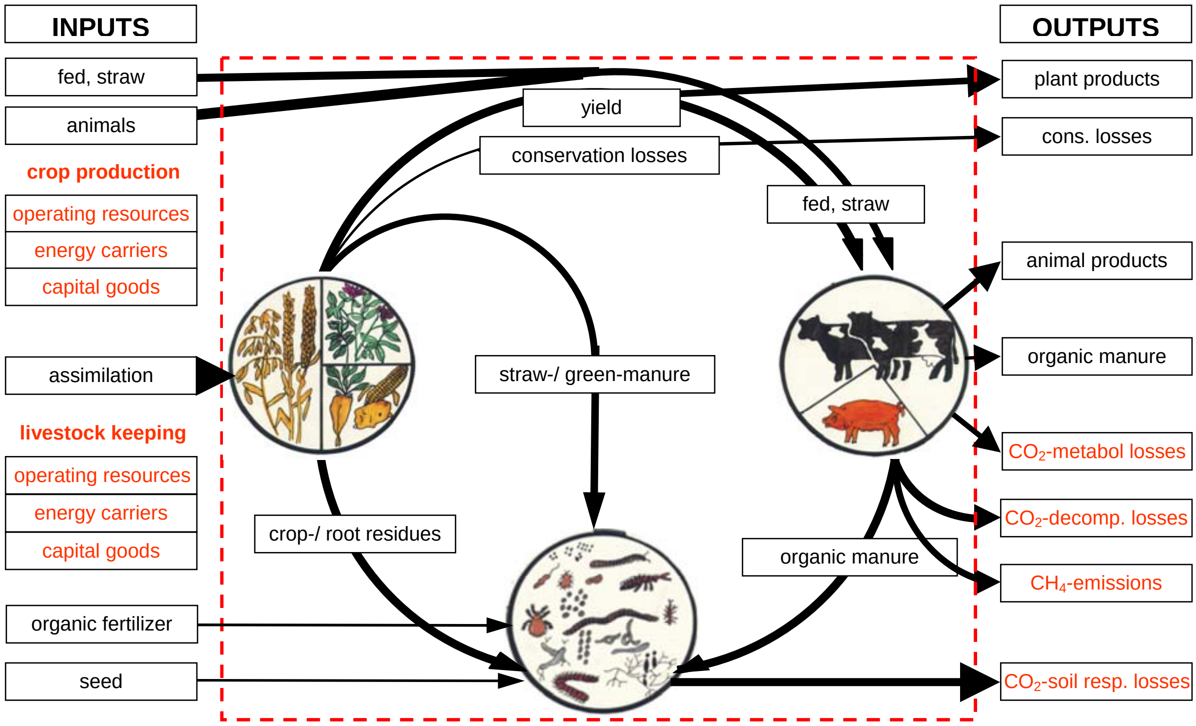

Figure 1: Linked up substance fluxes of the model REPRO (Hülsbergen 2003)

METHODS

Energy inputs in livestock keeping are ascertained on the basis of direct and indirect energy demands. Direct energy is used in form of fuel, oil and electricity (for example in feeding, milking and manure disposal). Indirect energy includes the energy input for manufactured machines and technical facilities (e.g. feeder-mixer wagons and milking parlours) as well as animal houses and storage facilities.

The VDI guideline 4600 "Cumulative Energy Demand – Terms, Definitions, Methods of Calculations" shall assist in making technological data available and comparable within a uniform framework. It allows the evaluation and comparison of products and services with respect to energy criteria (VDI-Richtlinie 4600, 1997). The method development of energy balancing in dairy farming is based on this VDI guideline (Fig. 2).

The investigations are done at the example of dairy farming. At first a standard technology is defined. The next step is to draw up a ration plan, which includes the division into two performance groups; the proportionately grazing and the feeding during the dry period. Based on the number of the livestock a feeding plan is calculated. That means it is calculated how much roughage and concentrate per cow and year are needed. Deduced from it, the demand of food storage is calculated, as well as the cropping plan. Farm-produced fodder is the roughage and a part of the concentrate. The decision for the design of the livestock building and the determination of the size of an excrement store depends on the livestock, feeding- and manure removal system. In addition, the milk production has to be taken into consideration.

At the example of the described standard technology different livestock buildings and their components are analysed. The determination of the cumulative energy demand of the animal houses is based on a standard service life of 25 years. Differences consist in the shell of the buildings. The different building components are analysed separately, considering their different functions and materials they are made of. The energy demands are calculated on the basis of the mass of the separate components and the specific cumulative energy demand for these materials is generated by the database GEMIS.

The database GEMIS is used for calculations of the energy demand of the different building materials. GEMIS is the acronym for Global Emission Model for Integrated Systems. The model can perform complete life-cycle computations for a variety of emissions, and can determine the resource use. In addition GEMIS analyses costs – the corresponding data of the fuels as well as data for energy and transport processes are included in the database. It offers information on energy carriers (process chains and fuel data) as well as different technologies for heat and electric power generation (www.gemis.de).

Additionally to the buildings and structures, the technical facilities are analysed. Calculations are based on a standard service life of 12 years for the technical facilities, only for the rubber mats or sand as cubicle flooring material a service life of 8 or3 years is assumed respectively.

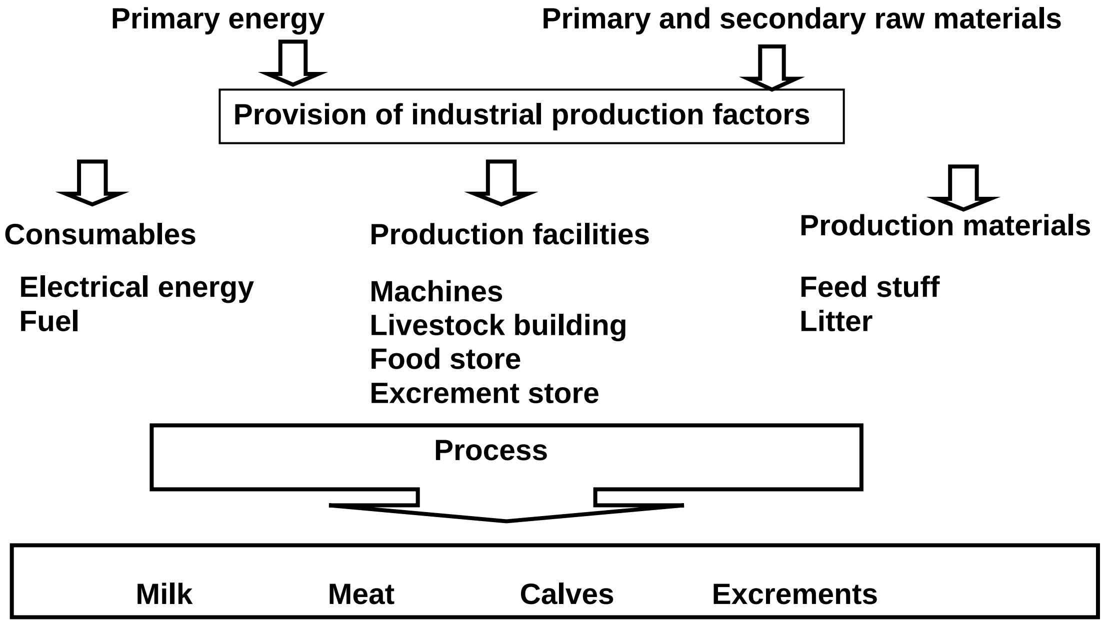

Figure 2: Energy fluxes in dairy farming (acc. to VDI guideline 4600)

RESULTS

The standard technology for dairy cattle has been defined for scenario estimations as follows: a cubicle housing system for 180 cows and liquid manure disposal. This keeping procedure was chosen because about 55% of the dairy cattle in Germany are being kept in such systems. (Statistisches Bundesamt, 2004) The cattle are fed with a total mixed ration by a feeder mixer wagon. In summer, the cattle are pastured half-day. The milk performance is 8000 kg FCM per cow and year and as milking equipment a herring-bone milking parlour is used.

The cumulative energy demand for the production of milk calculated for the described standard technology is about 2.7 MJ/kg FCM. Figure 3 shows the shares of the different sections of the procedure. More than the half of the total cumulative energy demand is taken by feed supply. It includes the whole energy expenditure of plant production. About one quarter of the total energy demand is required for the reproduction, and

about 10% for milking. The energy demand for buildings and structures, as well as for machines and technical facilities is about 5% respectively.
As a concrete example, a dairy farm with a productive area of 125 ha and a total number of 101 livestock units was analysed by the use of the balancing model program REPRO. The dairy cattle are kept in a cubicle house for 61 cows with liquid manure disposal. The mean milk performance of the farm is about 8,400 kg milk / cow and year. In summer, the cattle are pastured half-day. The cumulative energy demand is about 0.8 MJ/kg FCM higher than the value calculated for the standard technology. Main reasons for this difference of almost 30% are a high fertilisation rate and a great extent of feed supply.

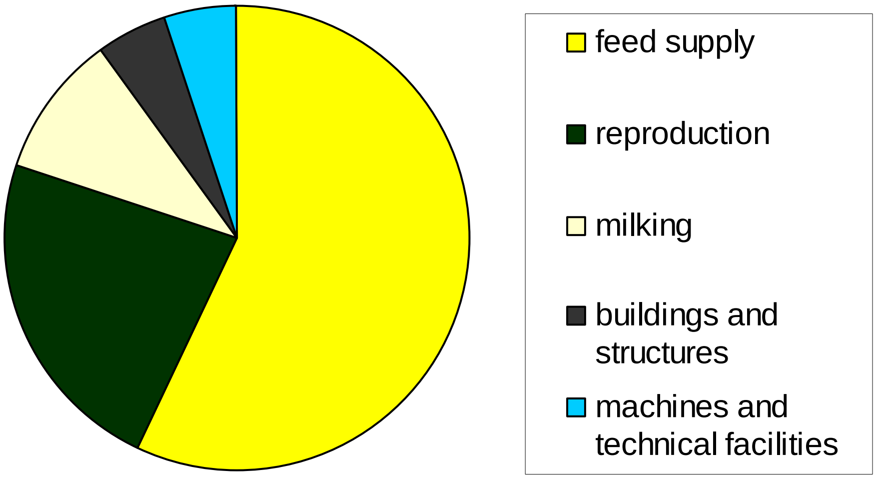

Figure 3: Share of the different sections of milk production of the cumulative energy demand calculated for the standard technology

The calculations for the cumulative energy demand for buildings are done for 4 different designed livestock building. The 4 variants of buildings have the same floors with slurry channels and milking house. Differences consist in the shell of the buildings. The variants are described as follows.
Variant 1 is a closed, cold / thermal non-insulated animal house common for newer cattle houses in Germany. The pillars and walls are made of wood, the roofing is made of fibre-cement plates with a light-band ridging.
The 2^{nd} variant is an outdoor climate house becoming more and more common in Germany. One sidewall is completely open, the open gable is equipped with a wind protection net, the other walls are made of wooden space boards. The roof is similar to variant 1.
Variant 3 is a closed, warm / thermal insulated animal house as an example for a massive construction very common in Germany, especially for older buildings. Important characteristic features are the pillars of reinforced concrete, the exterior walls of concrete and a roof covered by fibre-cement plates. In difference to a thermal non-insulated animal house (variant 1), the building has an intermediate ceiling between roof and floor. This intermediate ceiling consists of fibre-cement plates and a thermal insulation.
Variant 4 is a light construction, completely different from the other variants. The building shell is made of a steel space structure covered by a canvas, and wooden sidewalls.

The cumulative energy demand of the four different dairy cattle houses described above is shown in figure 4. The closed, thermal non-insulated animal house and the outdoor climate house have the same energy demand, so they are summarised. The thermal insulated building has a slightly higher cumulative energy demand than the other three variants. It is caused by the massive construction with reinforced concrete pillars, the walls of concrete and the intermediate ceiling. The light construction has a slightly smaller cumulative energy demand than the other, because of its simple construction. The design of the floor has a much stronger influence on the cumulative energy demand of the building. The share of the slurry channels and pits is about one third of the total cumulative energy demand of the building.

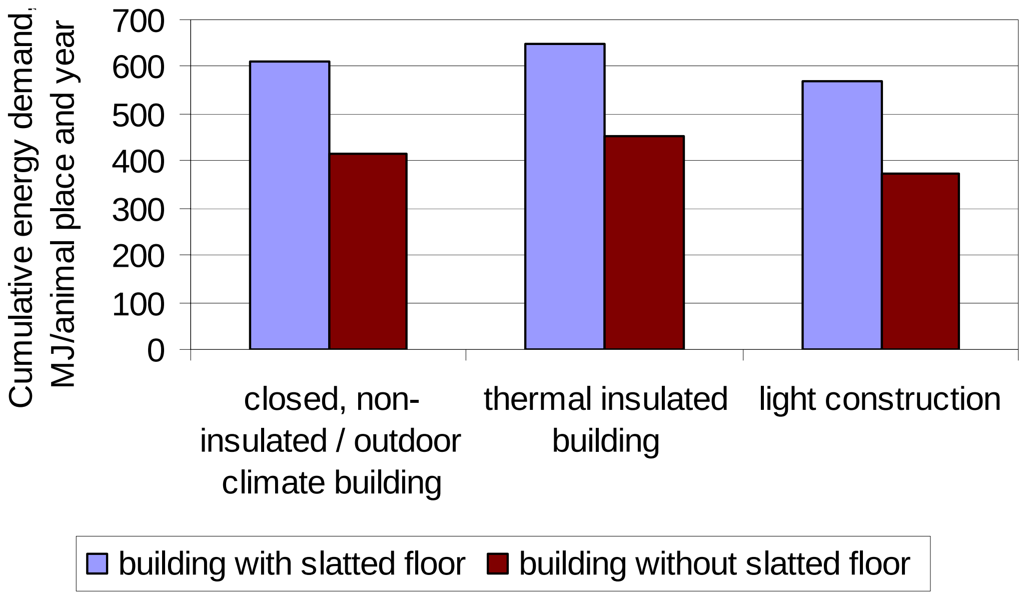

Figure 4: Cumulative energy demand of four different dairy cattle houses with two different manure removal systems respectively

The cumulative energy demand for the single components of the building shell in relation to the total cumulative energy demand of the building shell is shown in figure 5. In all variants about two third of the total cumulative energy demand of the building are caused by the floor. There are nearly no differences between the closed, thermal non-insulated and the outdoor climate building. But in comparison to the other variants there are appreciable differences between the building shells. The cumulative energy demand for the shell of the thermal insulated building is about 40% higher, that one of the light construction about 40% lower than that one of variants 1 and 2.

The specific cumulative energy demand per animal place and year calculated for the technical facilities is similar to that one of the buildings and structures. The specific cumulative energy demand of the single technical facilities in relation to the cumulative energy demand of the technical facilities in total is given in figure 6. The rubber mat takes more than 60% of the cumulative energy demand of the technical facilities, the cubicle about one fifth.

The cumulative energy demand for sand as cubicle flooring material is only one hundredth of that one for a rubber mat.

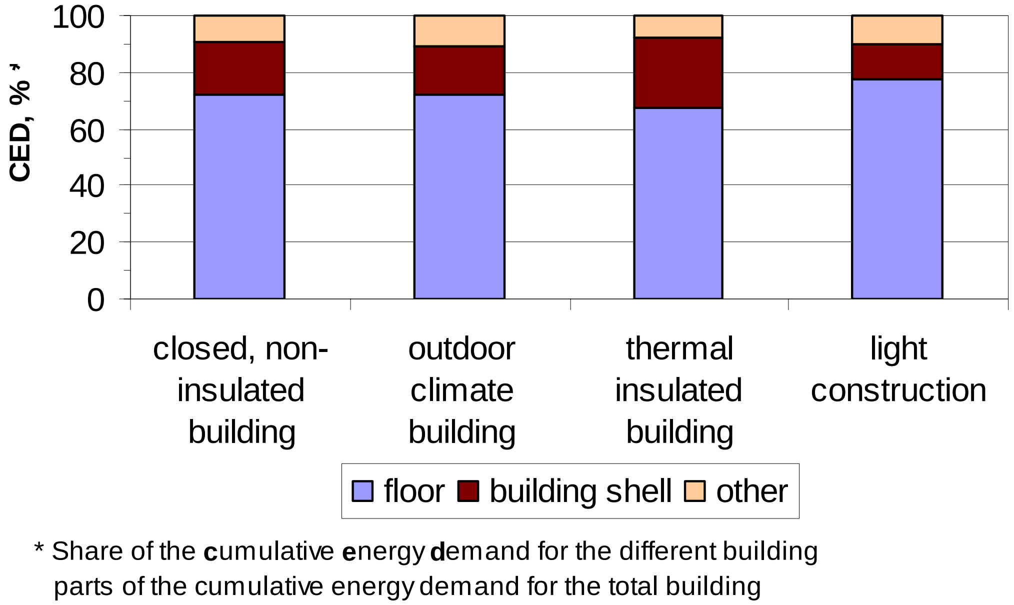

Figure 5: Share of the cumulative energy demand of the different components of the different dairy cattle houses in relation to the total cumulative energy demand of the building

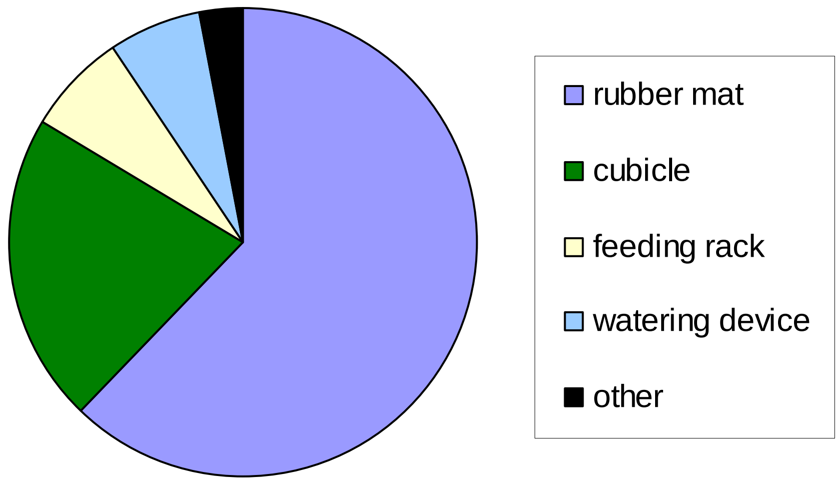

Figure 6: Share of the cumulative energy demand of the different technical facilities in relation to the total cumulative energy demand of the technical facilities

CONCLUSIONS AND FUTURE WORK

The cumulative energy demand in dairy farming is strongly determined by feed supply and reproduction. More than the half of the total cumulative energy demand is required for feed supply, about one quarter for reproduction.

The analyses of the cumulative energy demand for different dairy cattle houses inclusive the technical facilities show, that there are only minor differences between different building shells. Whereas the design of the floor has a much stronger influence on the cumulative energy demand of the building. About two third of the total cumulative energy demand of the building are caused by the floor. Half of that account for the slurry channels and pits. So the cumulative energy demand for a dairy cattle building without slurry channels and pits is about one third less than for a building with channels and pits.

The specific cumulative energy demand per animal place and year calculated for the technical facilities is similar to that one for the buildings. More than 60% of the cumulative energy demand of the technical facilities is taken by the rubber mat, about one fifth by the cubicle. The use of sand as cubicle flooring material necessitate only one hundredth of the cumulative energy demand of a rubber mat. So the cumulative energy demand for the technical facilities is about 60% less when sand is used as flooring material instead of a rubber mat.

Future work focus on the cumulative energy demand for feed supply and reproduction.

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