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Utilization of Biogenous Soild Fuels for Energy Generation by Means of Thermo-Chemical Conversion

Under certain conditions, electricity- and heat generation from biomass can be a sensible economic and ecological alternative for farms as compared with the consumption of primary energy from outside sources. Profitability, however, depends on necessary plant size and the variability of process control as well as the real farm-specific requirements for the supply chain of the energy carriers used. Given these conditions, process- and energy-technical optimization in upstream process steps can provide savings potential.

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Keywords

Solid fuels, gasification, process engineering

Literature

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Since most bio-energy carriers are solid fuels, combustion and, hence, heat supply are currently still the main area of application for energetic use in the private and commercial sector (chip- or pellet heating systems). During combustion, thermal efficiency based on the upper calorific value is approximately 70%. Since cogeneration is not applied, energetic efficiency reaches only values below 10%. For comparison: During the gasification process, 40 to 50% can be achieved.

Material and Methods

In contrast to the fermentation products of a biogas plant, which are generally cost-free residual and by-products of animal production (cattle- and pig slurry, chicken faeces) and plant production (silo maize, grass silage, cut grass), the use of renewable raw materials in a gasification plant may cause additional expenses for the operator, which reduce the profitability of the entire process significantly depending on the conditions on the individual farm or even call it into question [1]. The costs of biogenous fuels free plant can be divided into "supply costs" (cultivation, care, harvest/collection, fixed costs), "transport costs", and expenses for storage (pre-drying), processing (shredding, pressing, pelleting), and the filling of the storage container (silos). The sum of these costs competes with the market-dependent fuel prices of the fossil energy carriers heating oil and natural gas. This comparison is necessary because all energy carriers largely use the same plant technology for electricity- and heat generation. The decisive factors for the evaluation of profitability are the determined real electricity- and heat generation expenses for each energy carrier.

Literature information [2] supplemented with the authors´ own studies and surveys among different agricultural operations shows a range of potential costs of different bio-energy carriers. According to these results, not only small or residual wood from forestry, landscape care, or the wood-processing industry, but mainly also residual and by-products of primary plant production, such as straw or low-quality grain can provide a monetary advantage over fossil energy carriers. This is possible in the case of straw, for example, because a large part of the supply costs from sowing to collection can be attributed to grain production.

Using the real requirements of a gasification plant (thermal output: 200 kW) as an example, the supply costs of wood, straw, and solid manure will be considered in more detail.

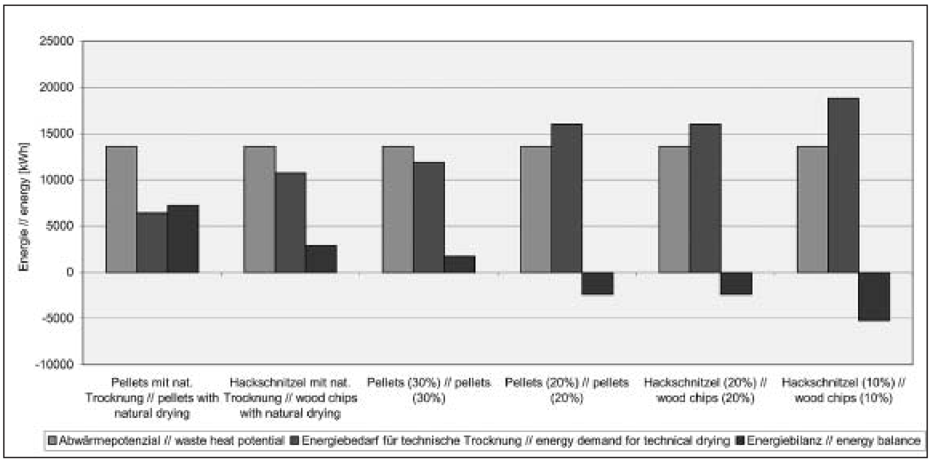

Fig. 1: Energy balances for the different process models

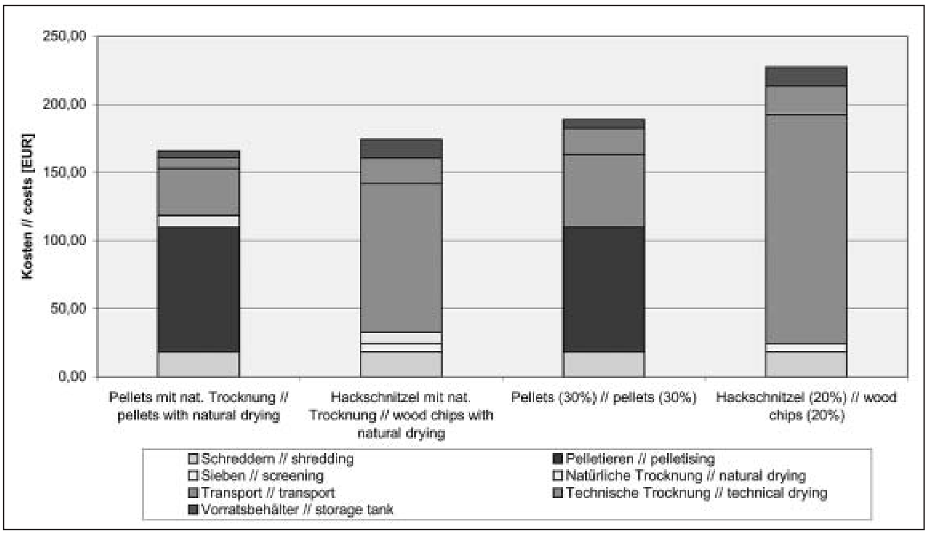

Fig. 2: Cost comparison of the different process models

Results and Discussion

If one assumes that the entire process chain of bio-energy carriers in the steps "supply" and "transport" is already characterized by efficient structures, the optimization potential for cost reduction primarily lies in the areas of storage, processing, and the feeding of material into the plant.

Approaches in this direction are provided by constructive solutions for appropriate storage- and processing technology as well as the use of energetic possibilities of heat transformation within these upstream processes.

For this purpose, different plant concepts are being examined for their energetic efficiency. Variant 1 is a combination of natural and technical drying, whereas variant 2 is exclusively based on technical drying.

The variants are compared using natural soft wood as an example, which is used in the form of wood chips or pellets. Based on the assumption of storage for one week (168-hour model), the initial variant-dependent quantitative parameters for the existing gasification plant are determined. For the weekly period considered, necessary thermal work potential is 33,600 kWh. This requires a fuel quantity of approximately 15.3 t. Natural or technical drying would allow this quantity to be reduced to 9.9 t (moisture content: 30%) or 8 t (moisture content: 20%). At the same time, the energy and time required for shredding and pelleting as well as the transport volume and the necessary size of the storage container of the gasification plant diminish. Under monetary aspects, the reduction of fuel density from 50 to 20% leads to purchase expense reductions of 16.5% for chips and almost 50% for pellets for the storage container alone due to greater bulk density as compared with wood chips. The same relations also apply to the necessary transport volume from the intermediate store to the gasification plant.

Thus, the central process- and energy-technological optimization problem is the search for efficient possibilities of moisture reduction and, hence, greater energy density of the fuel. Parallel to this, a comparison of the technical and energetic requirements of chips and pellets within variants 1 and 2 is necessary.

If one assumes that the usable heat potential is 45 to 50% of the initial thermal output of the gasifier [3] and losses due to heat radiation during technical drying amount to 10% and if local crop moisture fluctuations are not taken into account, the energy balances shown for the different plant concepts can be determined (*Fig. 1*).

For the 168 hour model under consideration, the available waste heat potential of the plant ranges from 13,600 to 15,100 kWh. This is sufficient to dry the pellets or the chips, whose initial moisture contents are 30% or less. Calculated energy requirements for the reduction of moisture from 30 to 20% in the pellet line of variant 1 are 6,400 kWh. Given room heat requirements of 70 kWh/m^2 and year, the remaining heat potential of 7,200 kWh and 8,700 kWh can be used to heat an area of 5,400 and 6,800 m^2. These figures diminish to approximately 50% of the initial area if a value of 150 kWh/m^2 and year is assumed for more poorly insulated stall facilities or storage rooms. In order to dry the chips from 30 to 10% residual moisture (variant 1, 2), 10,700 kWh are required, which still leaves enough warmth to heat 2,100 m^2 to 3,200 m^2 of living space. If the wood is not pre-dried naturally (variant 2), moisture can only be reduced from 50 to 30% because this process requires approximately 11,850 kWh. A further reduction to 20 or 10% residual heat cannot be achieved by using the waste heat potential of the existing thermo-chemical gasification plant.

The percentage of energy required for pelleting (cf. *Fig. 2*) is 55.2% (variant 1) or 48.5% (variant 2). The transport expenses for pellets are considerably lower (20.8 or 28.3%) than the transport costs of wood chips (62.3 or 73.9%). Obviously, the prevailing assumption that the expenses for wood chips are smaller than those for pellets cannot be generalized. This is primarily due to the smaller transport- and container volume for pellets.

Summary

The energy density of gasifiable solid biomass can be increased efficiently by means of a combination of natural and technical drying of both pellets and wood chips. The usable waste heat potential of the gasification plant can cover the heat requirements for technical drying completely and provide additional warmth for heating purposes.

If wood is not pre-dried naturally to at least 30% residual moisture, the waste heat potential is not sufficient to provide the same energy densities in the material to be gasified. This also applies if the entire heat potential of the plant is used for purely technical drying.

Under monetary aspects, some process-technological advantages of pellets over wood chips are offset by the greater energy requirements for their production.