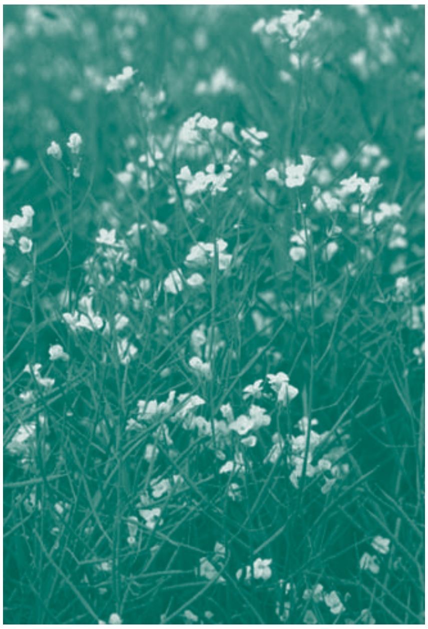
Present European agricultural policy framework stimulates research on renewable energy like energy crops. "Energy self-reliance in organic farming – is it feasible?" was the subject of the work-shop of the international society of organic farming research (ISOFAR) organised after the Organic Congress in Denmark in the early summer of 2006. Contributions to the workshop mainly dealt with production of energy crops and derived fuel and biogas. Energy self-sufficiency and a closed nutrient cycle is a basic principle of organic farming ever since. However, does this mean that the mission of organic farming includes both food production and energy production for consumers outside the farm organism? This question rose but was not discussed officially hence the majority of the attendants shared the opinion, that the main concern of organic farming is production of food. Here I compare efficiencies of energy crops with technical alternatives of renewable energy production. As an example, I present production of rape as energy crop.

Energy crops and renewable energy: overall and process efficiency

Engineering: the Cinderella of organic farming research?

Engineering sciences lead a shadowy existence within organic farming research. However, agricultural machinery and buildings cause up to 40 % of the production cost in organic farming too. The high costs of technical input force towards specialisation of farm production, narrow crop rotations and dependency from fossil fuels and counteracts to organic farming principles. However, a physical and technological approach and engineering proficiency may contribute to the aims of organic farming in respect of energy issues too. The crop scientist focuses his research on high quantity and quality of yield based on a sustainable tilth. The engineer interprets this approach as maximisation of photosynthesis efficiency. As an example of the involvement of engineering sciences methods, I use rape as energy crop. I compare the results from a literature review with efficiencies of solar techniques using solar energy without diversion into photosynthesis.



The sun is the source of renewable and fossil energy

The sustainability of energy crop production depends on the overall efficiency that is the energy yield divided by the overall energy input. The energy yield is the calorific value of the biomass or the derived fuel respectively. The most important energy source of crop production is the solar radiation followed by the energy input caused by cultivation measures like tillage and harvest and the energy demand for processing the biomass into fuel. Both, the annual solar radiation intensity and the crop cultivation area are limited locally and worldwide like the fossil energy sources too. In southern Finland, the solar radiation intensity is about 1000 kWh/m^2 and year. The efficiency of photosynthesis confines the energy yield and reaches in the tropics about 5 % of solar radiation. The maximum technically possible energy yield in Finland may reach up to 22,2 kWh/m^2 or about 40-fold the average of energy input of Finnish agriculture. On principle, the caloric yield of crops decreases with raising energy density of the crop component: Lignin > starch > sugar > oil. This means, that oil crops produce less energy per ha and year than sugar beets, potatoes, reed canary grass or wood.

Process energy of cultivation

The energy input for crop cultivation varies in a wide range depending on habitat, crop species and variety, intensity of production, and employed tools and machinery. Generally Finnish agriculture consumes in average 0,75 kWh/m^2 and year of which 0,3 kWh/m^2 and year are fossil fuels. The engineer considers the cultivation measures as a production process and calculates the process efficiency dividing the energy yield by the energy input from seed to harvest. Numerous research results show that the process energy of organic farming is substantially better than that of conventional farming systems. However, this benefit is negligible if we calculate the overall efficiency including the energy input from solar radiation. The first two columns of figure 1 show the energy input for rape production.

Process energy to convert biomass into fuel

The most efficient way to use biomass as renewable energy is to burn it for heat production. The efficiency depends only on energy input for transport of biomass and ash and the efficiency of the heating system. Additional treatment like pelleting, extraction of oil, anaerobic digestion, ethanol fermentation etc. may considerably raise the process energy input. According to leading American scientists, the production of ethanol from maize causes always a negative energy balance due to the thermodynamic laws. Breeding energy crops and improved process techniques may lead to better energy efficiencies. Crop processing may result in several different products. Some of these products may be used for energy production others for fibre production, human nutrition or animal feed. This fact causes a methodical problem, called allocation. E.g., the rape crop produces both straw and seeds. However, how to split the energy demand of the production process between straw and seed? Moreover, how to split the process energy demand between rape methyl ester (RME), rape meal, and glycerine after extraction, refining, and esterification of rapeseed oil? Depending on the allocation method, the energy balance results vary in a wide range. Figure 1 shows additionally the energy input for processing of rapeseed into fuel and the energy yield or energy content of the whole plant and processing products as energy output.

Production efficiencies

Figure 2 shows the production efficiency of rape and its processing products. I calculate the process efficiency by dividing the energy output of the final product (straw and seed, rapeseed, oil, and rape methyl ester (RME) respectively) by the sum of the energy input presented in figure 1, except solar radiation energy input. This figure shows very clear, why rape seems to be a suitable energy crop for organic farming too: The energy output of straw and seed exceeds 6.5 to 9.5 fold the energy input for production. Even after processing the rapeseed to RME, we have an energy surplus up to 40 %. If we allocate the energy input to RME and meal, which can be used for fodder, the efficiency of RME still rises according to the allocation ratio.

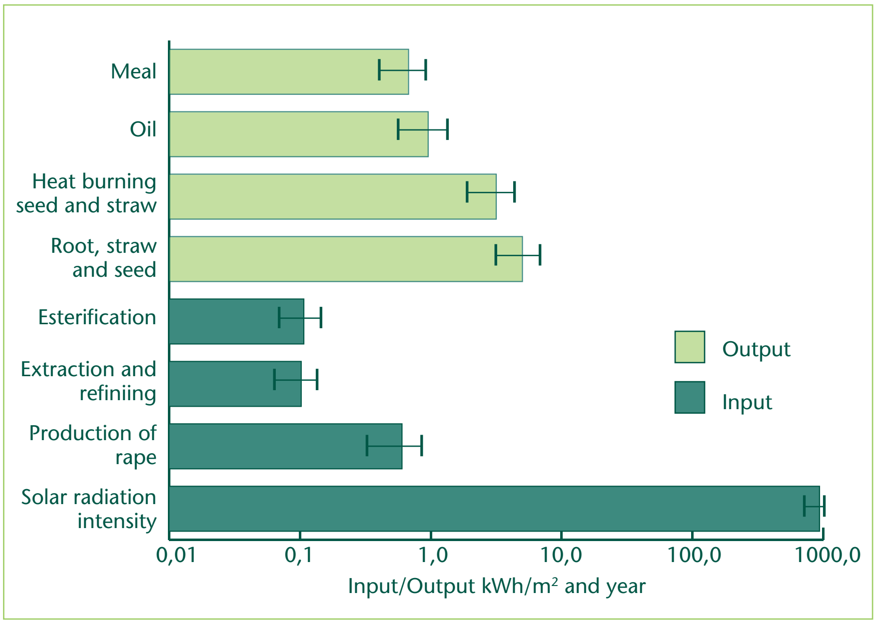


Figure 1. Energy input for production and processing of rape and energy output of rape and rape processing products. Please, note the logarithmic scale.

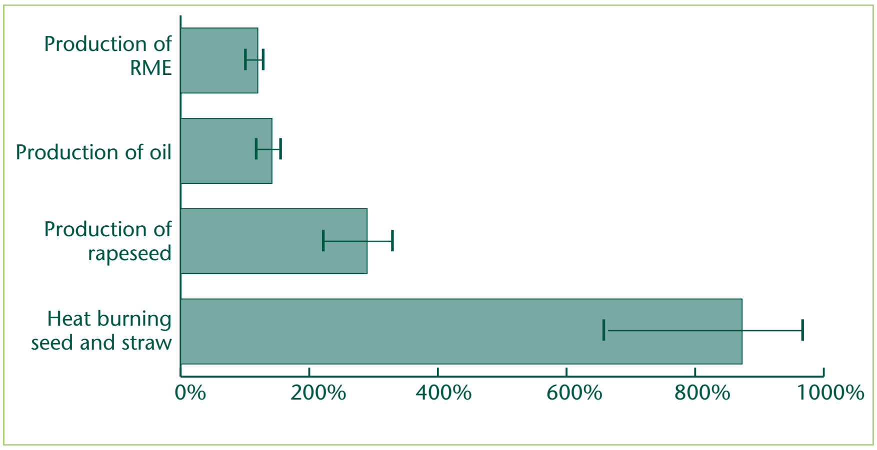


Figure 2. Energy efficiency of production of straw and seed, rapeseed, oil, and rape methyl ester (RME). 100% means, that energy input is equal to energy output.

Overall efficiency

If we include the solar radiation as energy input into the efficiency calculation, the overall efficiency falls dramatically, see figure 3. Even doubling the rapeseed yield improves the overall efficiency only marginally. In turn, the improved process efficiency of organic rape production raises the overall efficiency only a little bit. The whole rape crop (root, straw, and rapeseed) contains only 3 to 6 ‰ of the overall energy input, RME 1

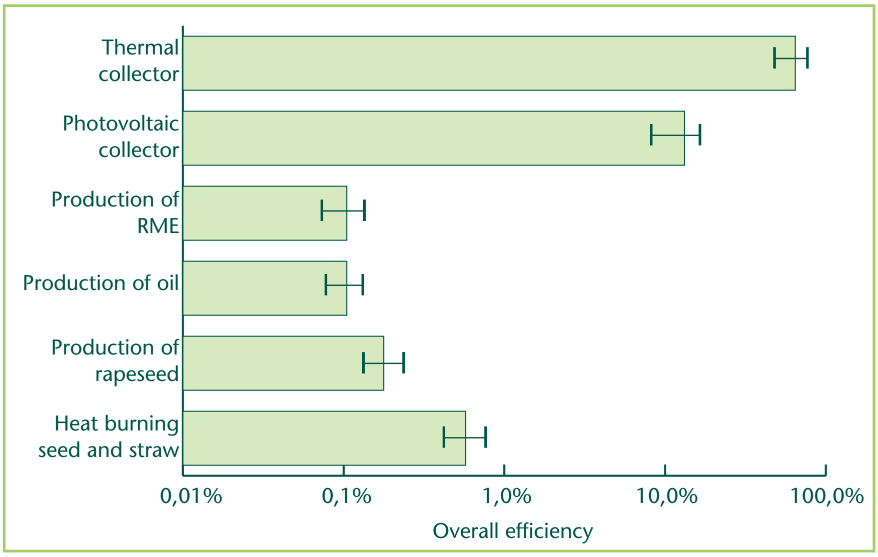


Figure 3. Overall energy efficiency of production of rapeseed and straw, rapeseed, oil, and rape methyl ester (RME) compared to solar energy harnessing technologies. Please, note the logarithmic scale.

House using solar energy. Photo: W. Schäfer.

to 2 ‰ yet. We may continue the chain and feed the meal as protein fodder for dairy cows. Then we win about 34 % of the fodder energy as manure. Anaerobic digestion of the manure and the glycerine, a by-product of esterification, may add 0.2 to 0.5 ‰ of the input energy. For comparison: The efficiency of the photovoltaic solar collector is 40 to 140 fold compared to electric power production from incineration of the whole rape plant or incineration of methane produced by anaerobic digestion of the whole rape plant. The efficiency of the thermal solar collector exceeds the heat production from incineration straw and rapeseed 100 to 400 fold. However, storage and continuously production of solar heat or photovoltaic electric power is very limited. Consequently, future biotechnology will focus on producing hydrogen as well as liquid carbon hydrates from carbon dioxide and water powered by solar energy.

Conclusions

The technical efficiency of the photosynthesis is too low to replace sustainable fossil energy sources by energy crops. However, the high process efficiencies of technical processes to convert biomass into fuel justify the production of renewable energy from organic waste, particularly on-farm. The present objectives of the EU-energy policy, to develop energy crop production is captivating with various win-win situations: environmentally neutral bio-fuels replace polluting fossil fuels, farmers get better prices for energy crops, the agrochemical industry gains from intensification of energy crop production, turn over of power industry grows due to increasing energy consumption to produce agrochemicals and to process biomass into fuel. As a following, the state tax income improves too. Because in the future the major part of biomass comes from tropical countries due to the higher overall efficiency, environmental pollution is exported to developing countries at the expense of food production. Organic agriculture should not resume energy crop production but produce high quality food environmentally friendly. Organic agriculture is capable to cover its own energy demand from organic waste. Sustainable replacement of fossil fuels outside agriculture is reasonable only by employment of bio-technical processes to produce hydrogen as well as liquid carbon hydrates from carbon dioxide and water powered by solar energy without diversion into photosynthesis.

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