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CONVERSION ROUTES FOR ENERGY CROPS; INTEGRATING AGRICULTURAL AND ENVIRONMENTAL OPPORTUNITIES IN EUROPE

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Introduction

Energy crops are interesting for both the agricultural and energy sector. Several conversion routes exist for the transformation of these crops into electricity, heat and/or transport fuels.The major environmental advantage lies in avoided CO_2 emissions to the atmosphere in comparison to the use of fossil fuels. Those conversion routes are analyzed with respect to technical/financial and environmental characteristics.

Conversion routes

Energy crops are considered as an alternative for food crops in the agricultural sector. After harvest, they can be converted into electricity and/or heat and into transport fuels. For energy crops with high cellulose contents, like poplar, willow and miscanthus, thermo-chemical conversion routes which convert the crop into electricity are most viable. Important thermo-chemical conversion technologies are combustion, gasification and pyrolysis. For high oil-content or sugar-content energy crops physical-chemical (extraction) and biochemical (anaerobic digestion or fermentation) routes are available. Those routes produce respectively gaseous and liquid fuels that can be used in transport applications. Upgrading of the secondary products of the gasification and pyrolysis technology processes also can lead to the production of methanol or bio-diesel. In Figure 1 these routes are presented.

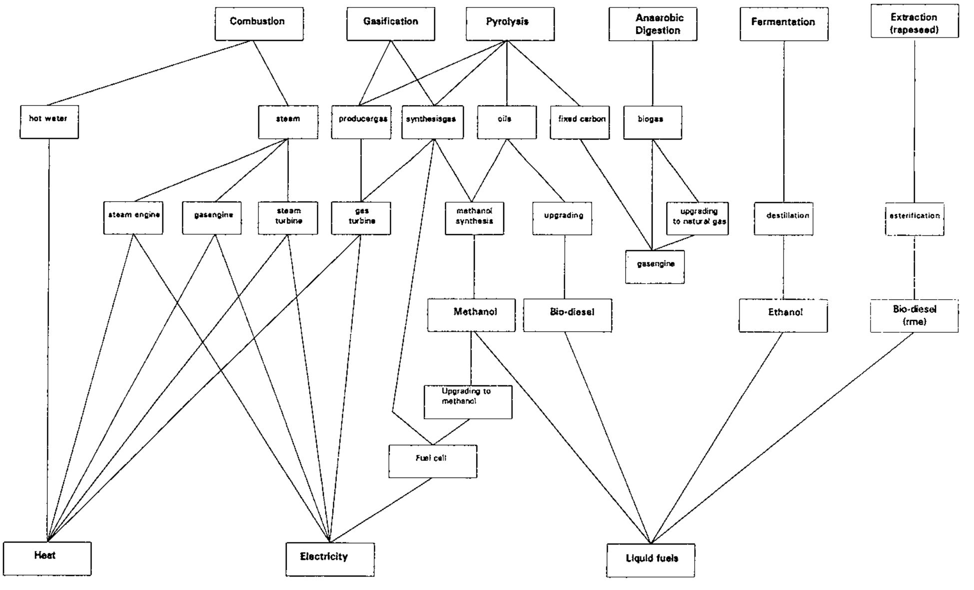

Figure 1: Available conversion routes for energy crops

The technical, financial and environmental aspects of energy crops based electricity generation and production of transport fuels has been investigated. Large scale power generation based on combustion technology and application of steam cycles is technically mature. The same holds for the use of biogas in gas engines. Also the production of ethanol from sugar and grain crops as well as the production of rapeseedmethylester (RME) is technically viable. Biomass gasification integrated with a combined cycle (gas turbine and steam turbine utilization), co-combustion of pulverized or gasified biomass in conventional large-scale coal or gas fired electricity plants and production of methanol through gasification are currently demonstrated and expected to become technically mature around the year 2000. Newer technologies like the use of pyrolytic oil in a combined cycle applications or the use of synthesis gas from biomass gasification as a fuel source for fuel cells still need further research and will certainly not be commercial before 2010.

Some options for conversion routes

Several conversion options have been analyzed through spreadsheet models in order to determine:

- the specific production costs (Fl/kWh or Fl/l fuel);
- the specific amount of avoided CO_2 (ton CO_2/ha) generated; and
- the specific costs of avoided CO_2 (Fl/ton CO_2), calculated as the difference between the annual financial returns and the conversion option costs divided by the amount of avoided CO_2.

The options (numbers correspond to numbers in Figures 2 and 3) considered are:
<u>Conversion routes for electricity generation</u>:

1 Small-scale co-generation of heat and power with combustion technology (5 MW_{el}/ 10 MW_{th});
2 Medium-scale electricity generation with combustion technology (50 MW_{el});
3 Co-combustion of pulverized miscanthus (max 10% on energy basis) in conventional powder coal electricity plant of 500 MW_{el};
4 Small-scale co-generation of heat and power with circulating fluidized bed gasification and gas turbine technology (5 MW_{el}/10 MW_{th});
5 Medium-scale electricity generation with integrated circulating fluidized bed gasification and combined cycle utilization (50 MW_{el});
6 Gasification of energy crops and combustion of the resulting producer gas in coal fired conventional electricity plant;
7 Gasification of energy crops and combustion of the resulting producer gas in natural gas fired conventional electricity plant;

<u>Conversion routes for production of transport fuels</u>:

8 Fermentation of wheat for ethanol production (100 million l/year), with combined heat and power generation through combustion based on wheat straw;
9 Fermentation of sugar beet for ethanol production (100 million l/year), with purchase of required heat and power; and
10 RME production based on oil-extraction and esterification of rapeseed (1 million l/year).

Results

All technologies mentioned above are technically mature, except for the integrated gasification combined cycle (gas and steam turbine) technology, which is still in a demonstration phase.

The specific production costs figures for electricity and transport fuels and the specific amount of CO_2 avoided are presented in Figure 2. The specificproduction costs for electricity are lowest for the large scale gasification option and the co-combustion options in large scale coal or gas fired electricity plants.

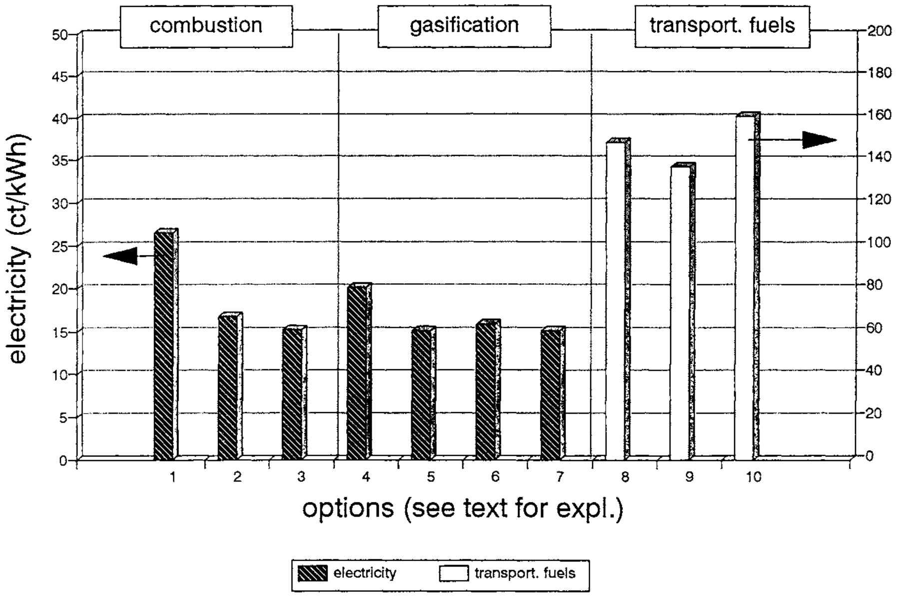

Figure 2: Specific production costs of several conversion routes

At the moment, with current fossil fuel prices, none of these technologies are economically viable. The annual returns are lower than the annual costs. Utilization of sustainably grow energy crops for electricity generation results in avoided CO_2 emissions, because fossil fuel based electricity is replaced. For each option the amount of annually avoided CO_2 emission is calculated and from this the specific costs of avoided CO_2 emission are determined. The results are summarized in Figure 3.

It can be concluded that thermochemical conversion routes, like combustion and gasfication processes, for electricity production have the highest potential for reducing CO_2-emission (given as tonnes CO_2/ha). This indicates that per ha of land used for energy crops through thermochemical conversion routes most CO_2 emission will be avoided. At the same time the specific costs for CO_2 emission are also much lower for electricity production as compared to the production of transportation fuels. It is therefore concluded that future research activities must concentrate on high-efficiency electricity production, from energy crops. The most promising routes seem to be large scale gasification and the co-combustion in existing power plants. This justifies research to further develop these technologies. The major problems with gasification lies in the required producer gas cleaning for gas turbine utilization and in the adaptation of gas turbines to low heating value gasses. For co-combustion it must be researched whether to co-combust producer gas or pulverized biomass.

A study on the environmental impacts of the Netherlands Center for Agriculture and Environment (CLM) has shown that utilization of the energy crops miscanthus, poplar, willow, hemp and reed, under the Dutch agricultural system, will probably have the lowest negative impacts. Therefore, these crops will be considered in future research.

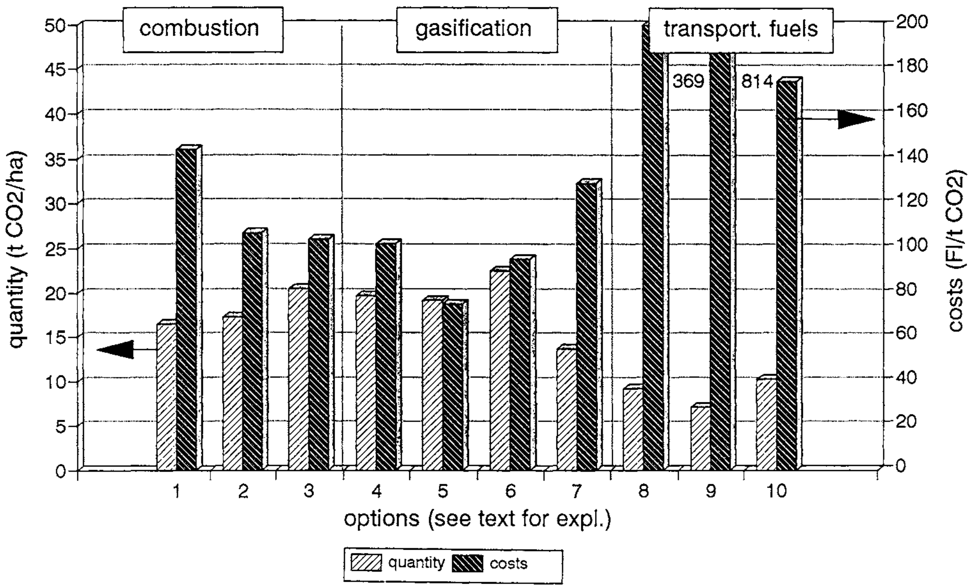

Figure 3: Avoided CO_2 emission

References

Johansson et al. (eds.), 1993, Renewable energy, sources for fuels and electricity, Island Press, Washington DC. USA.

Lysen E.H. et al., 1992, The feasibility of the production of biomass for the Dutch energy sector, Novem, Utrecht, the Netherlands.

Heuvel, E.J.M.T. van den, Stassen, H.E.M., 1994, Electricity from biomass, a comparison between combustion and gasification, Novem, Utrecht, the Netherlands.

Siemons, R.V. 1993, Electricity generation through co-combustion of straw and grass residues in conventional power plants, BTG, Enschede, the Netherlands.

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