CHANGE

Research and Policy Newsletter on global change from the Netherlands

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New insights in climate research reviewed

by Cor Schuurmans*

It is probable that coming decades will witness drastic, but to a great extent invisible developments in the climate system. At the same time, an enormous growth can be seen in climate research, in our knowledge of and insights into the climate system. This is the position of Professor Dr. Cor Schuurmans in his report 'Climate Research 1993'. Schuurmans personally writes such a report every year for the University of Utrecht (the Institute for Marine and Atmospheric Research). In the accompanying article, Schuurmans examines parts of this report.

One only has to consider a few years — such as 1993 — in order to come to the conclusion that the knowledge and insight gained from climate research have increased enormously. To begin with, the discussion on the influencing of the climate by humankind (the greenhouse effect, damage to the ozone layer) is proceeding unabated. And, even though the margin of uncertainty about the future developments is not appreciably reduced in such a year (according to some, it is even growing!), insight is growing. For example, there is no longer any doubt about the major role of volcanic ash and aerosols of anthropogenic origin. Partly for that reason, the effect of the increasing greenhouse effect and that of CFCs on the ozone layer is difficult to detect. But this hunt for phenomena and effects that may play a role is accompanied by a broadening and deepening of the flood of fundamental research into the natural variability and predictability of the climate system. An unparalleled effort: one whose breadth and impact may possibly only be realised after many years.

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Just how sustainable is energy from biomass?

The greenhouse issue is one of the reasons why the extraction of energy from biomass has gained increasing attention in recent years. This is not just a matter of the use of organic wastes, but also of the cultivation of crops for the production of fuels and electricity. In various long-term scenarios concerned with a drastic reduction of the emissions of greenhouse gases, including the IPCC accelerated policies scenario, the renewable-intensive global energy scenario of Johansson *et al.*, and Greenpeace's fossil free future scenario, an important role is ascribed to biomass in satisfying future global energy needs.

In the Netherlands, too, there is an increasing interest in the extraction of energy from biomass. In respect to the contribution of sustainable sources of energy to the reduction of CO_2 emissions, the Ministry of Economic Affairs states that the cultivation of energy crops counts as potentially the best option for the Netherlands up to 2015.

Interest in the cultivation of energy crops has it origin not just in a search for options to reduce the emissions of greenhouse gases, but also in connection with the overproduction in the European agricultural sector. As a consequence of this, profits are steadily declining and increasing amounts of land are being (and will have to be) taken out of production. The land so released could be used, wither on a temporary or a permanent basis, for the

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Harvesting the sun using agro ecosystems

by Sanderine Nonhebel*

The amount of solar energy that reaches the land surface of the Netherlands in a year amounts to 110 EJ (1 EJ = 10^{18} J). This is 50 times as much as the annual energy consumption in the Netherlands (2.6 EJ). For the whole earth the ratio is even more favourable: 2.7 × 10^6 EJ insolation and only 350 EJ consumed (0.01%). If, somehow or other, one could trap a part of this energy radiated by the sun, then this could form an important, sustainable energy source.

Plants as solar collectors

One of the possibilities for fixing solar energy is to use the natural solar collectors, used from time immemorial in agriculture: plants. During their growth, plants trap sunlight and use this energy in the photosynthetic process in order to make glucose and oxygen from carbon dioxide and water. Agriculture can also be viewed as a method for transforming solar energy into food.

The agricultural production in Western Europe and the US has risen enormously in recent decades (in the Netherlands the wheat yields per hectare have doubled since 1950). This has led to a reduction in the land area needed for food production, meaning that there is land to spare. This area could be used to grow what are called energy crops.

In order to be usable as an energy source, the plant material must be transformed in some way. This can be done in a variety of ways, so that it is possible to make biofuel from it. In France research is being done into the possibilityy of using rapeseed oil as a transport fuel. It is also possible to make ethanol from grain, maize and sugarcane. The ethanol is also being used as a transport fuel. Another option is to burn the biomass, transforming it into electricity. The various possibilities for the Netherlands have been compared in a NOVEM study (Lysen *et al.*, 1992). This study revealed that the option of transforming biomass into electricity is the most promising. The price per kWh is of the same order of magnitude as the price obtained by the combustion of fossil fuels. The price of biodiesel from rapeseed oil and ethanol is far higher than the current price of motor fuel.

The demands placed on biomass crops are different from those for the regular agricultural crops. Mainly, such a crop must produce a great deal of material containing little moisture, and it must be easy to harvest. In view of the fact that the plant material will be combusted, its composition is scarcely important. In this connection, consideration is being given to the cultivation of fast growing wood (poplar or willow) and some grassy species (reed or miscanthus). Since these are species that are currently not being grown on a large scale, there is a great deal of vagueness about what the possible yields of such

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raising of energy crops or the production of other raw materials (agrification).

Large scale production of biomass for energy purposes may be associated with major ecological and social consequences. These have as yet been insufficiently investigated. For that reason, the NRP has taken the initiative to investigate more closely the sustainability of the raising of energy crops. In collaboration with novem and the Ministry of Agriculture, Nature Management and Fisheries, three related research projects have been initiated, directed at both the possibilities for the production of energy crops and their transformation into fuels and electricity as well as the sustainability aspects. NOVEM is operating as main partner of the Dutch government where it concerns the implementation of Dutch energy policy.

The first phase of the research is investigating the feasibility of a sustainable cultivation of energy crops in the Netherlands. The results are described in three articles in this issue of Change. In a subsequent phase, and in collaboration at a European level under the programme of the EU, the sustainability of energy cropping at a (North-western) European scale will be investigated, together with its significance for the Dutch and European energy supply.

In the articles that follow, Nonhebel first goes into research into the (theoretical) potential for the cultivation of energy crops in Europe. Then Van der Heuvel and Stassen give an overview of the attractiveness of different conversion routes for transforming the various energy crops into electricity. Finally, Van Zeijts reports on the results of an investigation into the sustainability of possible energy crop cultivation in a Dutch agricultural context.

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crops might be. But the possible yield is in fact *the* key factor in all evaluations of the possibility of growing and using these crops. A satisfactory estimation of the yield is thus extremely important.

One of the objectives of the project 'Harvesting the sun using agro ecosystems', which is being conducted in the National Research Programme on Global Air Pollution and Climate Change (NRP-MLK) is to improve existing yield estimates. At the present time a method is being developed to estimate the yield of (presently often unknown) biomass crops.

Yield estimates for unknown crops

Since the sun is the plants' energy source, it is possible to calculate the maximum production of any given crop in a given area. No more energy can ever be fixed by the plant than the sun radiates onto it. The photosynthetic process only occurs in the green parts of the plant. If one knows the period of the year during which a plant has leaves, then one can calculate the maximum amount of plant material that can be produced. Under optimal circumstances (sufficient water, etc.), 1.4 g of plant material is produced for every MJ of solar radiation. These optimal circumstances occur only seldom; current Dutch agricultural production stands at about 60–70% of this maximum. In some areas of Southern Europe it is far lower (30–40%).

How much electricity can you get from a tree?

Table 1 shows an example calculation of the energy yield of a poplar plantation. In the Netherlands the poplars begin to sprout at the beginning of May, losing their leaves in October. Given the amount of radiation that is received during this period, 21 tons of biomass per hectare can be produced. Not all of this total amount of biomass can be used: leaves and young twigs are too wet to burn, for example. This means that the biomass yield (wood) is 14 tons per hectare. The fraction of the total production that can be harvested is an important property of a crop. A crop that can be used in its entirety has a far higher yield (i.e. the total 21 ton/ha).

If all the electricity for the Netherlands were to be obtained from biomass, then we would need 0.25 ha of poplar plantation per inhabitant. For the whole Dutch population this means 3.5 million ha. The total agricultural area in the Netherlands is only 2 million ha, and so it is impossible to base the entire Dutch electricity supply on biomass.

Electricity supply for the whole of Europe

In less densely populated areas, however, such possibilities do exist. In the report 'Grond voor keuzen' [Grounds for Choice], issued by the Scientific Council for Government Policy (WRR), it was estimated that, in the EU over the coming decades, about 40–80 million ha of agricultural land may be released (due to increasing agricultural production per hectare one needs less land for food production). Based on the 0.25 ha poplar plantation per person and 80 million ha of agricultural land, all 320 million inhabitants of the EU can be provided with electricity with the aid of biomass.

The growing conditions vary enormously throughout Europe and thus great differences occur in the potential

able 1. Efficiency of energy fixation by poplar

otal annual radiation in the Netherlands	3.3	GJ/m²
otal radiation during growing season	1.5	GJ/m²
ght use efficiency	1.4	g/MJ
otal above-ground biomass	21	ton/ha
Vood yield (65% of total)	14	ton/ha
leat of combustion of wood	18	MJ/kg
nergy yield of poplar	0.025	GJ/m²
fficiency (based on annual radiation)	0.7	%
fficiency (based on radiation during growing season)	1.7	%

productivity between different regions. Furthermore, it is unlikely that poplars will be cultivated everywhere. In the coming months, therefore, a simple crop growth simulation model, based on the relationship described above between radiation received and production, will be used calculate the maximum yield of a variety of biomass crops in different European regions. This will give an insight into which crops can best be grown, and where, and what their potential productivity will be. At a later stage attention will be paid to the practical possibilities for energy production at field level. For small scale application in the countryside the requirements will probably be very different than for large scale use as described above. The socioeconomic and landscape consequences will also be looked at.

The project described here is being conducted in collaboration between the Centre for Agriculture and Environment (CLM) in Utrecht and the Biomass Technology Group (BTG) of the Technical University, Twente. BTG is investigating the methods for transforming biomass into an energy carrier and CLM is studying the possible environmental effects of biomass cultivation.

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Conversion routes for energy crops

by Eric van den Heuvel and Hubert Stassen*

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 the avoidance of CO_2 emissions to the atmosphere in comparison with the use of fossil fuels. Such conversion routes are analyzed with respect to technical/financial and environmental characteristics.

Energy crops are considered an alternative to 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, thermochemical conversion routes which convert the crop into electricity are most viable. Important thermochemical conversion technologies are combustion, gasification and pyrolysis. For energy crops having a high oil or sugar content, physicochemical (extraction) and biochemical (anaerobic digestion or fermentation) routes are available. These routes produce gaseous and liquid fuels, respectively, 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 biodiesel.

The technical, financial and environmental aspects of electricity generation and the production of transport fuels based on energy crops have been investigated. Large scale power generation based on combustion technology and the application of steam cycles is technically mature. The same holds for the use of biogas in gas engines. The production of ethanol from sugar and grain crops, as well as the production of rapeseed methylester (RME), are also 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 have been demonstrated and are expected to become technically mature around the year 2000. Newer technologies, like the use of pyrolytic oil in a combined cycle application 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.

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