

## The Danish Energy Crop Research and Development Project – main conclusions

By

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### Background

The current Danish Energy Policy is based on 4 political main targets:

- \* Stabilisation of the annual energy consumption at 800 PJ.
- \* Maintaining continued economic growth.
- \* Reduce CO<sub>2</sub> emissions
  - 20% by year 2000
  - 50% by year 2030.
- \* Sustainable development.

Several means are in operation in order to fulfil the political targets within the planning period (2030) of which the most important in this context is a conversion from coal in the central power plants to natural gas and renewables at a rate of 1% annually from a total of 8% in 1996 to approx. 30% in 2030.

Table 1 shows the targeted shares of the different renewable energy sources within the planning period.

**TABLE 1. Targets for the use of renewable energy in Denmark (PJ)**

	1996	2000	2005	2010	2030
Wind power	4.4	9	14	23	60
Other	3.5	1	3	4	29
Biomass	61.4	77	85	96	146
- solid municipal waste	25.4	23	23	23	22
- straw	13.7	25	27	28	34
- wood chips	20.3	24	26	27	24
- energy crops	0	0	0	5	46
- biogas	2.0	5	9	13	20
Total	69.3	87	102	123	235
% of total consumption	8	10-11	12-14	17-19	35

As can be seen from table 1 the current biomass resources for energy purposes almost exclusively stems from agricultural and forestry by-products and municipal waste. However by the year 2005 it can be foreseen that these resources will be almost fully utilised and new resources should be found if the "Energy 21" targets should be met.

Energy crops are seen as the most important new resource in order to create a balanced input mix of renewables in the energy system.

The energy crops are mainly seen as fuel in small and medium sized CHP plants and in the big power plants.

### **The Danish Energy Crop Project**

Production of energy crops is more or less non-existent in Denmark at the time being. However, as described above the need for biomass on the other side of year 2005 exceeds the existing biomass resources and a substantial amount of energy crops will be necessary in order to fulfil the goals in "Energy 21". Given an average yield of 10 tonnes of dry matter per hectare the necessary acreage of energy crops will be close to 300,000 hectares in year 2030.

To aid this development, a working group with expertise within crop production and energy production set up a "Demonstration and Development project concerning production and utilisation of energy crops" with a duration of 4 years.

The overall purpose of the project has been to develop and demonstrate an economic optimal and environmentally sustainable production of energy crops, and thereby collect and create a comprehensive knowledge base for decision making and advise concerning energy crops.

The budget of the project was 1.6 M ECU, financed jointly by the Danish Ministry of Environment and Energy and the Danish Ministry of Food, Agriculture and Fisheries.

### **Content of the project**

The project consists of three main parts: a demonstration part, a research and development part, and an overall assessment part.

Both thinnings from afforestation areas and annual and perennial crops on agricultural land are considered as energy crops within this project.

The project was carried out as a number of interrelated and coordinated subprojects and covered the entire production chain from growing to end use for selected representative energy crops (including afforestation schemes).

However the project activities did not cover all elements in all production chains. For resource-related reasons, efforts were concentrated on priority areas where the knowledge base was considered weak, table 2 shows the activities for the individual production chains.

Areas without project activity are covered by already completed projects and ongoing projects. The results from these projects have been incorporated in the overall assessments. Only results obtained under conditions close to normal practice are used.

The overall assessment covers economic, technical and environmental aspects and the individual energy crop production chains are compared on their relative advantages and disadvantages.

TABLE 2. Overview of activities in the energy crop project

	Afforestation	Willow coppice	Miscanthus	Reed Canary Grass	Hemp	Rye	Triticale
<b>Demonstration part</b>							
Establishment/growing	*	+	+	+	+	*	*
Harvest/storage and transport	+	+	+	+	+	*	*
<b>Research and Development part</b>							
The influence of variety on fuel quality and yield	+	+	*	*	*	*	*
Fuel characteristics of potential biofuels	+	+	*	*	*	*	*
Fuel analysis and combustion tests	+	+	*	*	*	*	*
The effects on surface and ground water from growing energy crops			*	+	+	*	*
The effects on surface and ground water from energy forestry	*	+					
Harvest, pelletizing and storage of miscanthus			*				
The effects of perennial energy crops on flora and fauna		*	*				
Visualisation of the influence of energy crops in landscape	*	* +					
Carbon balances in energy forestry	*						
<b>Coordination and assessment</b>							
Planning and coordinating fuel deliveries and end use	* +	* +	* +	* +	* +	* +	* +
Technical and fuel related follow up	*	*	*	*	*	*	*
Assessment and economic evaluation of annual and perennial energy crops	* +	* +	* +	* +	* +	* +	* +

\* Activity in the project.

+ Published material is used.

## Organisation

The project was carried out by a project group consisting of:

- The Danish Agricultural Advisory Centre
- DIAS - Dept. of Agricultural Engineering - Research Centre Bygholm
- DIAS - Dept. of Soil Science - Research Centre Foulum
- DIAS - Dept. for industrial Crops, Research Centre Flakkebjerg
- Danish Forest and Landscape Research Institute
- Techwise A/S
- Danish Technological Institute
- National Environmental Research Institute
- Danish Institute of Agricultural and Fisheries Economics

The individual partners have been responsible for their own subproject(s) concerning implementation, reporting and budget. To ensure the overall project implementation and coordination Head of section Morten Gylling, Danish Institute of Agricultural and Fisheries Economics has acted as project coordinator.

All subprojects have been active and the workplans have been fulfilled with only minor deviations. A detailed description of content, methods and results for the individual subprojects can be found in the final reports from the individual partners. Due to a delay in the starting time for the afforestation projects, the final reports for this part will not be ready before the end of 2001, and therefore the following will only cover energy crops grown on agricultural land.

## **Energy crops on agricultural land**

### *Demonstration*

A total of 102 hectares of triticale as energy grain has been grown within the project for demonstration purposes.

Two different cultivation plans were made out, a “conventional” and a “sustainable”, the “sustainable” using 60% of the “conventional” nitrogen application and no pesticides.

A number of different harvesting methods were demonstrated including:

- Swathing and baling (whole crop)
- Stripper harvest and baling (stripper mix + swathed straw)
- Forage harvester (whole crop)

The baled “energy grain” and stripped straw has been handled as conventional straw bales.

The “stripper mix” and the chopped whole crop was intended to be handled as bulk material by a loader in the field and dumped in an unloading pit at the power plant.

In miscanthus different harvesting and handling methods have been carried out including:

- Exact chopping (fall and spring harvest)
- Big baling (spring harvest)

Yields and inputs have been measured together with machinery and labour use as input for the economic analysis.

### *Fuel quality*

The influence of variety on fuel quality and yield has been investigated in the three harvest years –97 to –99. Material from the existing annual species trials carried out by the Danish Institute of Agricultural Sciences has been used.

Parallel samples of different varieties and triticale has been taken from different locations each year, and grain and straw have been analysed separately for ash content, energy content and minerals.

A number of these samples have been tested at the utility company laboratories using their standardised methods for fuel characterisation in order to test whether these methods can be used over a wide variety of biofuels as a measure of fuel characteristics and behaviour. These analyses are expanded compared to the analyses in the species trials.

### *Fuel analysis and combustion tests*

Different biofuels based on energy crops were tested in a 30 kW furnace. Based on the experiences from a previous project on biofuels a furnace with a moving grate was chosen for the trials.

A total of twenty different biofuel were used of which 10 were samples from the species trials either as kernels or as whole crop. The rest of the biofuels include hemp, willow, miscanthus and reed Canary grass.

### *The effects on surface and ground water from growing energy crops*

Trials have been performed in willow and miscanthus plantations in order to measure nitrate leaching below miscanthus and willow based on different fertilisation schemes.

### *Effects of perennial energy crops on flora and fauna*

The effects on flora and especially fauna from perennial energy crops has been measured and compared to the conditions on intensive farmland.

### *Economic evaluation of energy crops*

The final economic assessment of the production of energy crops has been based on the results from the subprojects together with existing knowledge. A model, which can handle both annual and perennial energy crops has been developed and used for the assessment.

## **Overall conclusions**

Based on the results from the project the following overall conclusions can be made:

- \* Seen from a strictly market and production economic point of view energy crops will not be competitive in a foreseeable future, neither as a production for farmers nor as a fuel at the utility companies.
- \* The costs per GJ of energy crops are still higher than a GJ of straw.
- \* The cost difference between annual and perennial energy crops are slightly in favour of perennials, however the conditions on the individual farms should govern the choice between annual or perennial energy crops.
- \* Energy crops must be seen as a part of an overall environmental scheme covering both agriculture and the energy sector.
- \* Given the right production scheme energy crops can be grown on Environmental Sensitive Areas and on most Ground Water Protection Areas.
- \* Adding the potential sustainability benefits like reduced nutrient leakage and reduced CO<sub>2</sub> emissions energy crops seem to be a sensible and sustainable solution.
- \* Due to different handling, storage and fuel characteristics an all year delivery scheme of energy crops should include a mix of different energy crops to keep overall cost down.

## **Recommendations**

There are not any serious agronomic or technical barriers for production and use of energy crops in the energy system, it is judged that practice will find the necessary solutions and adjustments for large-scale implementations.

Therefore it should be recommended that a number of full-scale semicommercial demonstration projects (> 1000 hectare scale) should be initialised and implemented as a joint effort between agriculture and utility companies.