Biomass as a Source of Heat and Power for a Farm in the Donauries Region

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Abstract

The use of biomass as an energy source for a farm in the Donauries region (Southern Bavaria) will be explained. Various sources of biomass are compared. Heating systems as well as a cogeneration system are valuated by economical and ecological criteria. The decision-making process is explained by a flow-chart, based on current component costs.

Die Verwendung von Biomasse zur Versorgung eines landwirtschaftlichen Betriebes im Donauriesgebiet wird erläutert. Verschiedene Biomassearten werden verglichen. Heizungssysteme und ein BHKW werden nach ökologischen und ökonomischen Kriterien bewertet. Der Entscheidungsprozeß für die optimale Variante wird anhand eines Fließschemas erläutert, wobei aktuelle Preise für Komponenten und Installation zugrundegelegt sind.

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1. Introduction

Sources of regenerative energy vary in a broad spectrum of energy-density and seasonal or daily variation of supply and material. Biomass as a source of renewable energy can be stored easily, so different demands can be fulfilled all over the year. Particularly in the countryside there is a good variety of biomass sources available, some are used already, some can be made usable by modern technology. Against the background of overproduction and closing down agricultural areas in the European Community the cultivation of energy plants will gain more importance.

2. Sources, concepts and valuation

2.1 Available sources of biomass

Table 1 gives an idea of various cultivated and waste materials. There is no region in Germany which is not suited for cultivation or use of biomass due to climatical or structural realities. Therefore routes of transport can be short. The use of biomass for energy generation is accepted by most societal groups /1/. In particular farmers are open minded to learn more about existing technology and resulting operating costs.

In the presented project renewable primary products have been considered which
- find acceptable conditions of growth in Bavaria
- show a reasonable mass-yield
- can be combusted with proven technology
- farmers are familiar with concerning cultivation and harvesting

Table 2 gives an overview on estimated potentials.

2.1.1 Residual organic material

Residual organic material can be found in national economies in many sectors. Here only residual timber and straw will be treated.

Residual timber is timber below industrial quality standards. Removal of residual timber is advantageous for a forest which otherwise would be more vulnerable to vermins. Furthermore there are potentials of industrial residual timber and residuals from management of public areas. The utilization of used wooden products is complicated in smaller installations because of their content of preservatives and coatings.

Straw is used for various other than energetic applications, e.g. interspersing or ploughing in the farmland. Assuming that one fifth of the total mass is available for energetic use there is a potential in Germany of about 100 PJ/a /1/.

2.1.2 Energyplants

Energyplants are cultivated exclusively for energetic utilization, mostly on farmland which is not used for food production anymore. There is a competitive situation to products for the chemical industry. Some material is introduced in the following.

Fast growing trees are varieties which produce at least 10 t dry mass per hectar, e.g. willow-, poplar- or aspen-clones which all require a good water supply. To avoid mechanical irrigation this source of biomass should not be considered in dry areas.

Grain is used as whole crop (grain and straw). For thermal utilization mass yield is the main cultivating issue, not the quality of the grain. Cultivation can be more extensive, the use of fertilizers and herbicides can be limited. Although the alternative to cultivating grain for thermal use mostly is closing down the farmland, there are reservations against burning food, as these plants are regarded /2/.

Miscanthus (Reed) is a so called C_4-plant, showing a specific metabolism with efficient CO_2-utilization resulting in high mass-yield. Although this plant is quite promising for future cultivations it has not been considered here, because it is not winter proof for a wider use in Southern Germany.

Rape is the oil-plant which is best adapted to German cultivation conditions. Although it is also possible to burn the whole plant, rape is mostly used for extraction of oil. The main advantage is the high energy density of the two final products pure oil or rape-methyl-ester.

2.1.3 Further energy sources

Bio-alcohol and biogas had not been considered here. These two biofuels showed to be not competitive in this particular project /3,4/, mainly due to a 50 ha forest which is cultivated by the farmer and thus is serving as an excellent source of material.

	Cultivated renewable energy sources	Waste material
Agriculture	Grain Reed Oil plants	Liquid manure Straw Various products
Forestry	Fast growing timber	Thinning timber Storm timber
Waste industry **Local authorities**		Demolition timber Bush- and tree crop Furniture Green crop
Timber industry		Bark Sawing by-product Residual timber

Table 1: Biomass energy sources [12]

Energy source		Estimated potential in Germany			Today's utilization	
		[Mio. t dm]	[PJ/a]	[Mio. t oe]	[PJ/a]	[%]
Residual material	**Straw**	6.90	100	2.37	0.48	0.48
	Residual timber	10	145	3.45	96.50	43.60
	Bush and tree crop	0.30	4	0.10		
	Processed & used timber	5	72	1.71		
	Total residual material	22.20	321	7.63	97	44.1
Energy plants		30.60	430	10.23	3.6	0.86
Total amount		**52.80**	**751**	**17.86**	**100.60**	**13.40**

[dm - dry mass , oe - oil equivalent]

Table 2: Potentials of renewable energy sources in Germany [5]

2.2 Concepts and technology

2.2.1 Energy demand of the treated farm

The following concepts were designed for the supply of a farm typical for the Donauries region in Southern Germany. The owner intended to enlarge the stables. The future heat-requirements of this farm were estimated by 30 kW for the farmstead, 12 kW for the stables and another 8 kW for hot water supply of the stables, which totals to 50 kW. The high capacity in the stables is due to raising calfs. This also leads to a quite high electrical power demand of about 38,000 kWh per year.

2.2.2 Existing heating system

There is a conventional oil-fired central heating boiler with a capacity of 33 kW which is supported by an electrical hot-water boiler in the stables.

2.2.3 Wood fired boiler (Logs)

There is a good variety of log fired central heating boilers available, and although their technology cannot be discussed here in detail, two requirements shall be mentioned:

- The charging space for the solid fuel must be large enough to obtain reasonable reheating intervals. A minimum of 6 dm^3/kW is acceptable, resulting in approximately 5 hrs. full load or 10 hrs. part load operation /5/.
- A large gas combustion chamber leads to good combustion quality. Including an afterburning chamber sized 1.3 dm^3/kW results in a gas retention period of appr. 0.5 s. The longer the retention period, the more secure an entire combustion is achieved /5/.

The selected boiler is equipped with a draught blower and has a nominal capacity of 58 kW. Operation at part loads under 50 % must be avoided as in this mode an entire combustion cannot be achieved. Thus a buffer is necessary, which has been taken into account in the hydraulic design shown in fig. 1.

2.2.4 Wood-chip fired boiler

Wood-chips can be burnt as same as convenient as operating an oil- or gas-burner. The solid fuel is transported by a screw-conveyor; the boiler can be modulated.

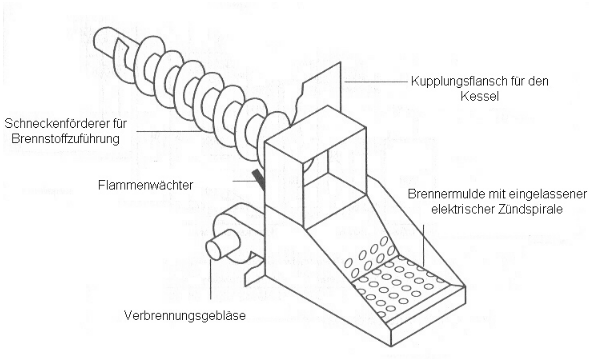

Fig. 2: Screw-conveyor

The selected boiler has a capacity of 50 kW. The resulting hydraulic sketch is similar to fig 1. except of the buffer which is not needed here.

2.2.5 Straw fired boiler

The combustion of straw has to pass in a close temperature range. The ash softening point of straw is quite low (900 – 950 °C) /6/, so some measures must be taken for operating the boiler close to this point to gain a high efficiency. Those measures are a water-cooled grid and a temperature controller.

The selected boiler has a nominal capacity of 49 kW and is suitable for other biomass material also. The hydraulic sketch is the same as for the wood-chip fired concept.

2.2.6 Block-type power station (Rape-oil operated)

A block-type thermal power station generates heat and power (in most cases electrical) which can be

- used for on-site consumption

- fed into the public mains supply

- made use of both ways.

The most economical choice for small consumers is the first one as rewards for feeding in are lower than public electricity costs. *(Please see chapter 4, additional remarks.)* Here a mini-cogeneration plant with an electrical capacity of 5.3 kW and a thermal capacity of 10.4 kW was selected.

As a first step it is planned that it may be operated in addition to the existing fossil unit. The resulting hydraulic sketch is shown in fig. 3.

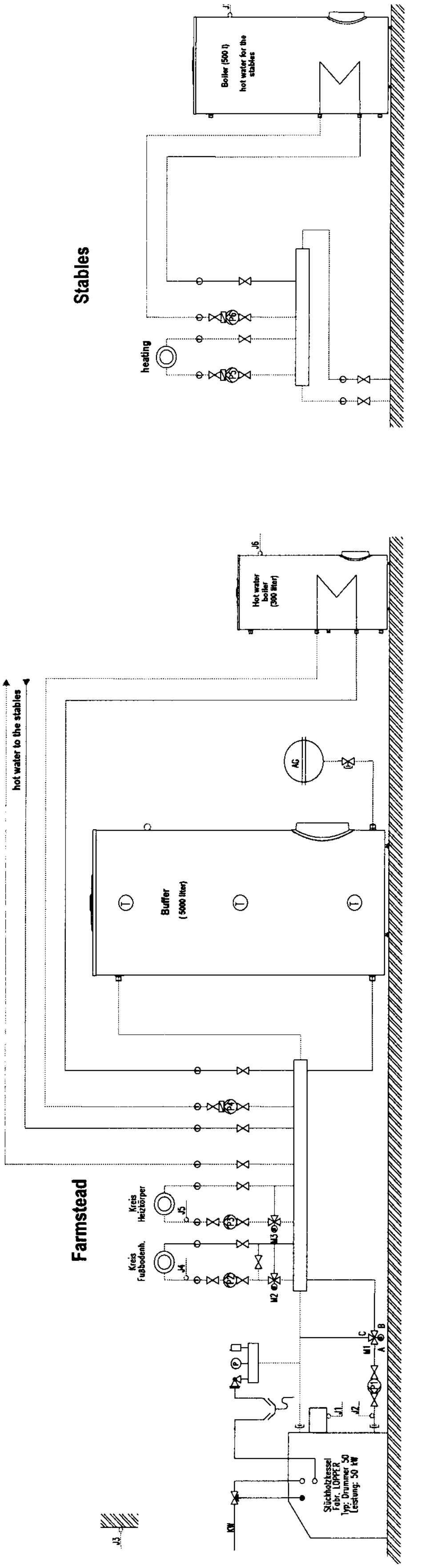

Figure 1: Hydraulic sketch for concept 2.2.3 (Log fired boiler)

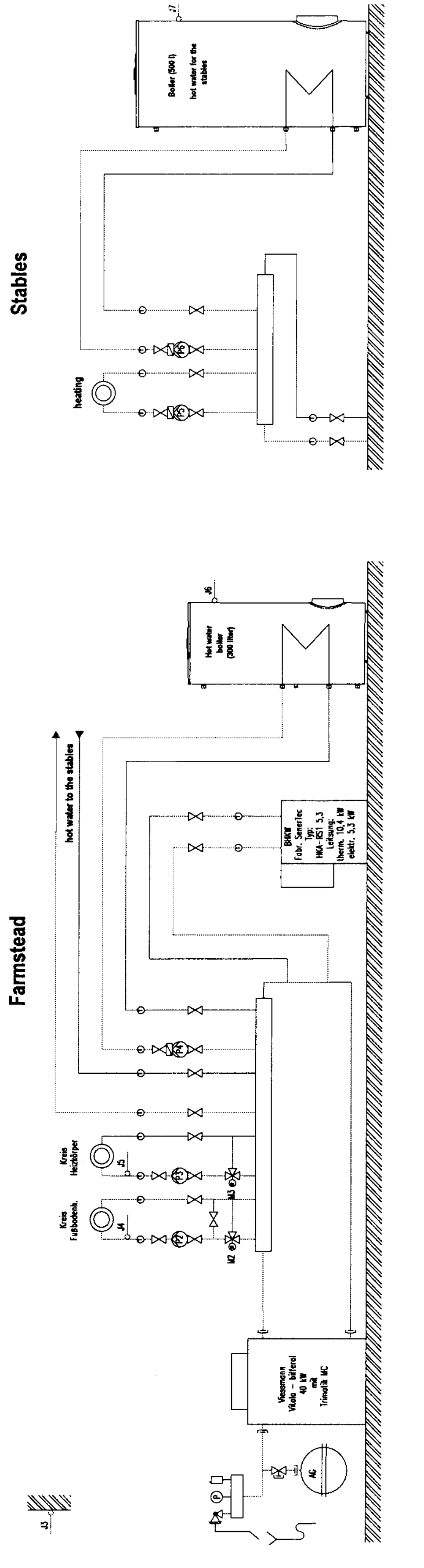

Figure 3: Hydraulic sketch for concept 2.2.6 (Block-type power station)

2.3 Ecological valuation

2.3.1 Balance of emissions

	Timber	Straw	Grain	RME
CO	o	-	-	+
CO_2	++	++	+	++
SO_2	++	+	+	++
NO_x	-	-	-	+
C_xH_y	o	-	-	+
Dust	o	-	o	+
(++) highly advantageous (+) advantageous (o) equal (-) disadv. (--) highly disadv. compared to fossil sources				

Table 3 shows a valuation of different emissions of combusting renewables compared to fossil fuels /7/.

2.3.2 Energy balance

The amount of fossil energy which is needed to prepare and process biomass material has been calculated /8/. The ratio between fossil energy demand and renewable energy gain indicates the chosen material's contribution to substitution of conventional ressources. Although for some fields of processing only rough estimations were available, table 4 indicates the advantage of solid fuels.

2.4 Economical valuation

It has been shown that there are some concepts for thermal utilization of renewable combustibles. Their broad application mostly is restricted by higher investments compared to conventional fossil systems. As biomass in particular is well suited for heat supply by highly efficient direct thermal utilization, it has to be investigated whether lower operating costs can motivate an investment in alternative technology.

2.4.1 Cost factors

The total cost of biomass material consists of
- raw material cultivation
- harvesting, preparation and processing
- transport
- storage
- energetic utilization.

As an example table 5 gives the basic parameters for calculation and comparison of storage costs.

	Mass equivalent	Weight (poured)	Storage space requirements
	[kg/dm^3 oe]	[kg/m^3]	[dm^3/dm^3 oe]
Fuel oil (extra light)	0.84	840	1.0
Rape-me-thyl-ester	0.97	970	1.0
Timber (logs, spruce)	2.39	300 – 500	6.9
Wood-chips (spruce)	2.39	160 – 250	13
Wood-pellets (spruce)	2.39	400 – 650	4.0
Straw (bales)	2.57	60 – 160	17.3
Straw (chaffed)	2.57	40 – 60	42.1
Straw (pellets)	2.57	300 – 600	4.4
Grain (bales)	2.54	200 – 240	11.8
Grain (pellets)	2.45	500 – 600	4.4

Table 5: Fuel parameters /8/ [oe – oil equivalent]

2.4.2 Total investments and operating costs

The total investments for the concepts shown in chapters 2.2.3. to 2.2.6. were calculated in detail /9/, including components like central-heating boiler, buffer, oil-tank, storage space and piping. The operating costs had been worked out in detail as well /8/. Total annual costs are compared in table 6. It can be seen that the use of wood (logs or chips) and the use of straw result in lower costs compared to oil or rape-methyl-ester. These figures even change in advantage to wood fired concepts when governmental investment grants /10/ are taken into account.

2.4.3 Summary of economical aspects

For a first estimation whether an investment into a concept for the use of renewable energy material is economically interesting some criteria had been chosen, calculated and summarized in a flow-chart, fig. 5. The main influence of the mineral oil-price can be seen.

	Timber logs	**Chopped timber**	**Wood chips**	**Straw (Pellets)**	**Grain (Pellets)**	**Rape-methyl ester (RME)**
	[GJ/ha]	[GJ/ha]	[GJ/ha]	[GJ/ha]	[GJ/ha]	[GJ/ha]
Cultivation & Harvesting	0.6 (9.0)	0.6 (9.0)	0.6 (9.0)	0.8	13.3	18.2
Preparation	0.2 (1.5)	0.4 (2.7)	0.8 (5.8)	7.6	7.8	11.9
Total Input	**0.8 (10.5)**	**1.0 (11.7)**	**1.4 (14.8)**	**8.4**	**21.1**	**30.1**
Gross gain from biomass	25.7 (171.0)	25.7 (171.0)	25.7 (171.0)	106.5	156.8	51.0
Nett gain	24.9 (160.5)	24.7 (159.3)	24.3 (156.2)	98.1	135.7	20.9
Fossil per-centage [%]	**3.1 (6.1)**	**4.0 (6.8)**	**5.4 (8.7)**	**7.9**	**13.5**	**59.0**
Numbers in brackets are valid for timber cultivated in short mode operation						

Table 4: Percentage of fossil energy for cultivating, harvesting and preparation of biomass fuels [9,13]

	Mineral fuel oil	**Timber (Logs)**	**Wood chips**	**Straw**	**RME-cogeneration**
Investments [DM]					
Boiler ^{x}incl. buffer	10,000	^{x}23,800	32,900	27,060	22,700
Storage or tank	10,000	---	5,000	5,000	10,000
Installation and others	3,400	4,800	4,200	4,200	4,800
Total Inv.	**23,400**	**28,600**	**42,100**	**36,260**	**37,500**
Operation [DM/a]					
Fuel	7,587	3,960	2,759	3,088	14,031
Oper. salary	---	1,000	450	600	---
Maintenance	580	280	420	250	1,870
Electricity	7,700	7,700	7,700	7,700	1,820
Total Oper.	**15,867**	**12,940**	**11,329**	**11,638**	**17,721**
Investment p.a.	1,560	1,907	2,807	2,418	2,500
Total annual costs	**17,427**	**14,847**	**14,136**	**14,056**	**20,221**
Profit(-),Loss(+)	**---**	**(- 2,580)**	**(- 3,291)**	**(- 3,371)**	**(+ 2,794)**

Table 6: Investments and total annual operating costs [9, 10]

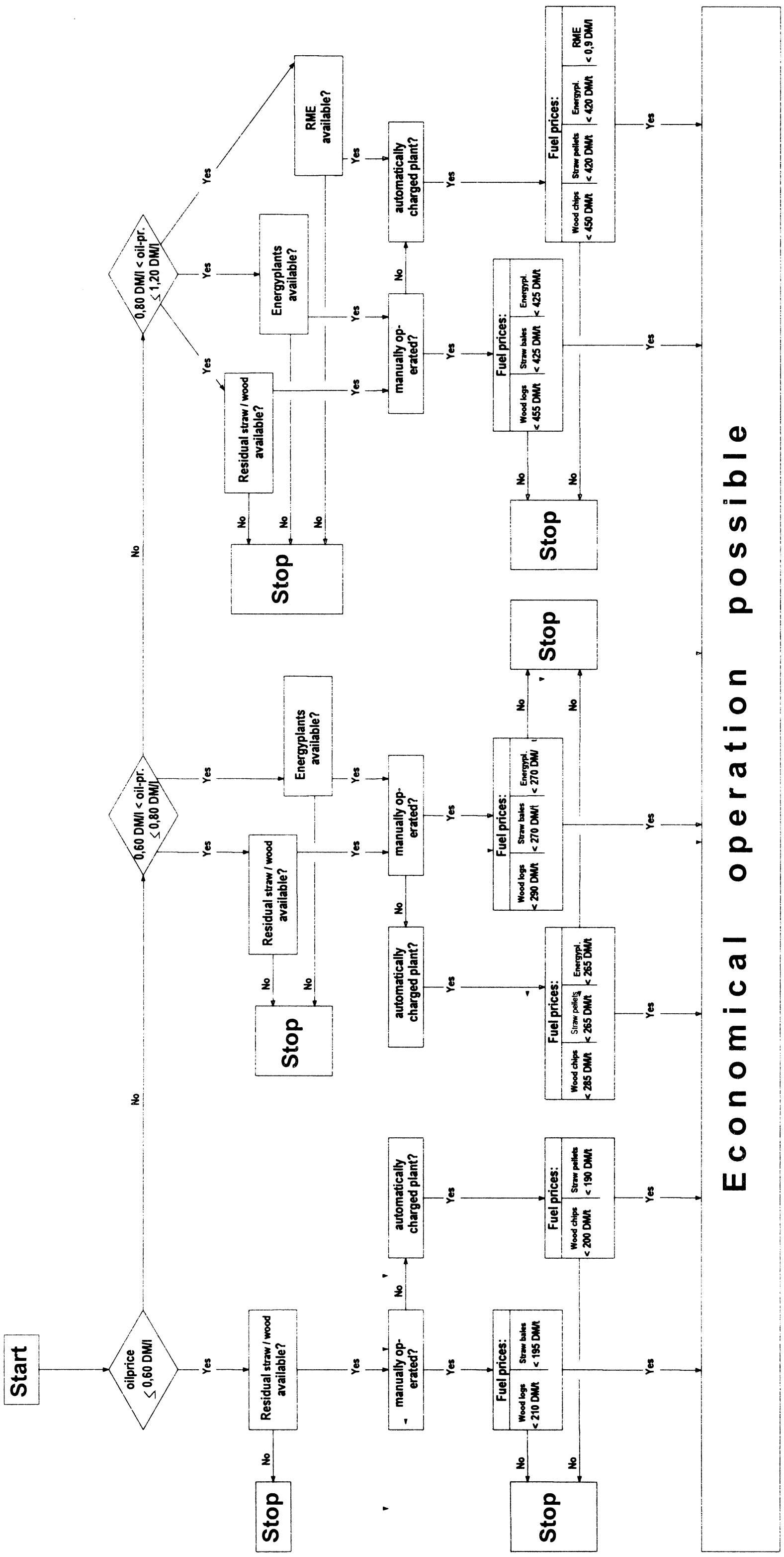

Figure 5: Selection flow chart for different oil-price scenarios

When fuel oil is cheaper than 0.60 DM/l, only residual material is competitive. In the range of 0.60 DM/l to 0.80 DM/l also energy plants and above 0.80 DM/l also RME (rape-methyl-ester) are worth being considered.

It must be indicated here that the design and costs of main components and other equipment are based on the type of farm introduced in chapter 2.2.1. The flow-chart can be used for comparable objects.

3. Conclusion

Thermal utilization of biomass offers two chances:

- the fuel is renewable

- current use of the total potential in Germany is only 13 %

Three sources are very promising here:
- straw
- energy plants
- residual timber

These three sources can provide fuel for economically competitive alternative concepts and may contribute to a reasonable reduction of CO_2-emission.

Additional investments compared to fossil concepts can be made good by governmental investment grants and/or saved by lower operating costs. The later in particular when the biomass is cultivated and collected onsite by the user. In this case the results proved motivating for the farmer. He installed a wood-chip fired central heating boiler and produces rape-oil for use as tractor fuel.

4. Additional remarks

The investigation was done in spring 2000. Some changes in the conditions influencing the valuation must be added now, autumn 2001.

The **mineral oil price** increased from 0.65 DM/l (spring 2000) to about 0.75 DM/l in September 2001. Thus the annual operating costs of the conventional oil-fired central heating increase and alternative concepts become more attractive. Seeing the ranges which had been set while calculating the flow-chart (fig. 5), the oil-price approached the 0.80 DM/l step.

Furthermore, since April 2001 there is an addition to the **Renewable Energy Act** in Germany concerning the regulations on electrical power generated from biomass. This addition fixes the following rewards for feeding into public mains supply /13,14/:

up to 500 kW	0.20 DM/kWh
up to 5 MW	0.18 DM/kWh
up to 20 MW	0.17 DM/kWh

These conditions make the option „block-type-power-station“ more favorable compared to the time when the presented investigation had been completed.

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