Biomass: A Renewable Source of Energy for Selected Applications in Australia and Germany

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Abstract

In the first section of this paper we provide details of our investigations of the use of biomass to produce heat and power using conventional cogeneration processes in two Australian hospitals, and to provide heat to one German hospital. For the Australian applications municipal solid waste was considered as the primary source of energy while for the German installation we have studied the use of wood chip which can be produced from biomass cultivated and harvested on site, or from waste biomass purchased from external sources.

In the second section we show that farmers are now able to use abundantly available renewable energy sources at an affordable cost. To demonstrate this concept, with reference to specific applications, we discuss the use of biogas in a dairy farm in Australia and the use of biomass in a farm in Southern Germany.

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1. Covering the energy demand structures of hospitals by renewable sources

Hospital administrators are increasingly seeking assistance from engineering consultants to investigate the feasibility of generating their required heat and power on site using renewable sources of energy such as solar, wind, biomass, etc. Their aim is to reduce operating cost as well as greenhouse gas emission which is significant when fossil fuel is used for heat and power production. In this paper we provide details of our investigations of the use of biomass to produce heat and power using conventional cogeneration processes in two Australian hospitals, and to provide heat to one German hospital. For the Australian applications municipal solid waste was considered as the primary source of energy while for the German installation we have studied the use of wood chip which can be produced from biomass cultivated and harvested on site, or from waste biomass purchased from external sources. Actual heat and power consumption data for these applications are included. Furthermore, the details of the cogeneration plants for the Australian, and those of the heating system for the German applications are provided.

1.1 Introduction

Hospitals like many other industrial applications use a significant quantity of both thermal and electric energy produced primarily from fossil-fuel sources such as coal, natural gas, heavy oils, etc. For such applications, the general trend is that the heat demand is nearly uniform throughout the year, but the demand for electricity varies with the maximum occurring during summer because of the increased need for cooling. Due to the escalating cost of energy world-wide, the adverse environmental effects of these fuels and therefore statutory pollution restrictions, and the age of building services equipment, many hospital administrators have been seeking assistance from engineering consultants to investigate the feasibility of generating the required heat and power on site using renewable sources of energy such as solar, wind, biomass, etc.

The incentive behind these moves has not only been economic factors but also social and political ones. Hospital administrators do not wish to be associated with environmental pollution but to be recognised for providing a health service in the community in a sustainable manner.

In this paper we provide details of our investigations on the use of biomass to produce heat and power using conventional cogeneration processes in two Australian hospitals, and to provide heat to one German hospital. For the Australian applications municipal solid waste was considered as the primary source of energy while for the German installation we have studied the use of wood chip which can be produced from biomass cultivated and harvested on site, or from waste biomass purchased from external sources.

We have then designed a cogeneration plant for the Australian application and a central heating system for the installation in Germany to meet their energy requirements. The details of these facilities in terms of their hardware and heat and power output are provided in this paper.

1.2 Details of cogeneration systems for Australian hospitals

The primary aim of a cogeneration system is to meet the power and heat demands of the application for which it has been designed. It is therefore essential to have access to such data as a function of time so that the system can be designed to generate the required amount of energy and power. For this reason, actual heat and power consumption data are calculated from the available records and included for three different hospitals in Table 1.1; more detailed information is available in [1.1, 1.2]. For optimum design, the hardware of the energy system should be sufficiently flexible to meet the variable heat and power demands of Table 1.1.

Table 1.1: Electricity and Gas Consumption (kW)

	Australia				Germany	
	Hospital A		Hospital B		Hospital C	
Month	Elec	Gas	Elec	Gas	Elec	Gas
1	224	714	248	152	197	491
2	327	571	235	152	165	424
3	280	625	235	152	164	414
4	295	658	188	197	161	308
5	306	722	223	197	153	215
6	226	893	231	238	145	188
7	235	717	249	238	155	126
8	169	873	228	227	136	117
9	209	726	232	227	136	187
10	177	616	211	184	153	270
11	211	640	240	184	153	360
12	262	501	240	152	174	455
Min	169	501	188	152	136	117
Max	327	893	249	237	197	491
Ave	243	688	230	191	158	296
R_{PH}	1:2.83		1:0.83		1:1.87	

After considering the heat and power demand variations for hospitals A and B, the system was designed around two sets of **Perkins SI** natural gas engine model 2006TS1 which has a nominal electric output of 160 kW at 1500 RPM, and a heat output of 320 kW. However, since the system is designed to run on biogas instead of natural gas, based on the literature from the manufacturer, the output of these engines would decrease by as much as 25%. Hence, the total output would be 240 kW electricity and 480 kW heat if both engine sets are operating at full load. The other advantage of such a design is that one of the two engines can be completely shut down when the demand is low.

The power plant described in the above paragraph would rely on a biogas reactor (or digester) for its fuel requirements. The capacity of the digester vessel should be sufficiently large to ensure that the fuel demand of the engines is met at all times. Assuming that each engine set of the cogeneration system has an overall efficiency of about 80%, based on 120 kW electricity and 240 kW heat, the heat flow rate into the system would be 450 kW. Knowing that the calorific value of biogas is around 26 MJ/m^3, the total biogas requirement would be about 1500 m^3 per engine set and day, or 3000 m^3 per day for the entire system. Therefore, the reactor should be able to generate that quantity of biogas daily to keep the system operating.

Bio-decomposition of organic waste in a digester is generally accomplished anaerobically, ie, in the absence of oxygen. There are a number of reactor types which can be used to anaerobically treat organic waste and produce biogas; a full description can be found in [1.3, 1.4]. The reactor which is proposed for the power plant described earlier is of the *contact reactor* type which is a subset of what is known as *the constantly stirred tank reactor* (CSTR). As the name implies, the contents of these digester vessels which are made in the form of a tank are agitated constantly or periodically, and as the raw effluent enters the reactor the same amount of digested sludge is extracted either in a batch or continuous mode. Therefore, the size of the vessel and the loading rate would determine the operating HRT (hydraulic retention time, the time which a **water** molecule spends in the reactor) and SRT (solid retention time, the time which the biologically active **solid** component of the effluent spends in the reactor), which are of the same duration for a CSTR. Since biogas yield increases with SRT (Etheridge and Stafford [1.5]), if there is no control over the SRT, for a given yield, a relatively large digester volume would be required.

However, modern reactors are designed to circumvent this problem by allowing for the recirculation of some of the digested sludge so that a higher SRT than HRT can be accommodated (Van den Berg [1.6]). Such a reactor is generally refereed to as the contact (or recycled floc) reactor; an example of a contact reactor has been described in [1.4] and will not be repeated here. The digestion system can be described in terms of two digestion stages: (1) In the **primary stage** raw effluent is introduced into the vessel where it is exposed to sludge enriched with microbiological floc. Due to the presence of recycled biomass, the bacterial content is larger than that for a CSTR, and hence the quicker digestion process. (2) In the **secondary stage,** the digested sludge from the primary vessel is fed into a sedimentation tank where the effluent is left to stratify. The undigested solids to which the bacteria are attached, being heavier than the digested solids, settle in the bottom of the tank from where these solids can be extracted and returned to the primary digester. The digested solids can then be pumped through a centrifuge to produce dewatered organic fertiliser and bacteria-rich liquid which can be used for irrigation. The heating of the digester is accomplished by circulating the hot water from the Perkins engine-generator sets described earlier.

The volume of the reactor vessels for the system described in [1.4] is 2300 m^3 and 450 m^3 for the primary and secondary stages, respectively. As reported in [1.7], a loading rate of 7.2 kg volatile solids[1] (VS) per day per m^3 of active digester volume with a 20 day HRT at a digester content temperature of 35 °C would generate 1.4 m^3 of biogas (55% methane content) per day. Therefore,

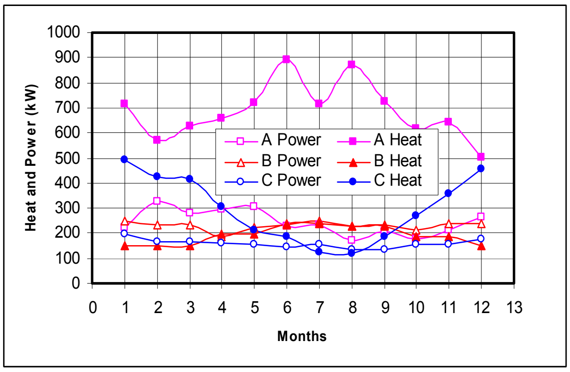

Figure 1.1: Heat and power consumption data for three hospitals.

for the proposed system which has a total digester volume of 2750 m^3, the loading rate would be 19,800 kg of VS/day with a yield of about 3,850 m^3 of 55% methane on daily basis. This is in excess of 3000 m^3 per day needed by the two engine-

[1] Vermuelen et al. [8] have reported that household waste has a relatively low solids content (20-25%) with a relatively high VS content (89-94%). As a result, the C:N ratio is below the optimum value of 20:1 to 30:1 for contact reactors. Therefore, the biogas yield would improve if carbon supplementation in the form of waste paper or straw is available.

generator sets described above. The excess capacity of the reactors can be used to compensate for variation in the quality of the effluent entering the system.

The amount of organic waste which is dumped annually in Australia is reported to be 14 million tonnes (The Age [1.9]). One particular municipality with 120,000 residents is said to have generated 40,000 tonnes annually, or over 100 tonnes daily. Therefore, the 20 tonnes of organic waste per day needed for the plant being designed can be procured in the neighbourhood where the proposed cogeneration system is installed.

1.3 Design details of the central heating system for the German hospital

Due to the low prices of electrical energy in the EC, the benefits of a biomass based concept only for heat supply of hospital C were investigated (Küßwetter and Papperger [1.2]). Figure 1.1 shows that for all three hospitals there is a heat demand all year around. The basic heat load which even exists in summertime is favourable for the use of wood fired boilers as they should not be operated below part loads in the order of 50% to achieve complete combustion. Possible operating strategies are:

a) Matching the boiler's minimum part load with the basic heat demand in summertime and supplying the peak load in wintertime by other fuels.

b) Designing the biomass fired boiler for maximum load in the months of highest heat demand and shutting it off under 50 % nominal capacity.

In this project we decided to follow strategy a) in order to establish an all year around operation of a wood-chip fired boiler. This biomass was selected here because of the good supply structures in Bavaria where the hospital is situated. Residual and thinning timber from state and private forests is collected and processed to wood chips.

Wood or straw-pellets were not considered because they need a good amount of fossil energy for their production (Hilligweg and Wolfrom [1.10]). Thus the total reduction of carbon-dioxide emission is less compared to wood chips.

Figure 1.2 also shows that the daily heat demands favour the implementation of a wood-chip fired boiler. Even in summertime, the demand is steady and can be met by part load operation as per strategy a).

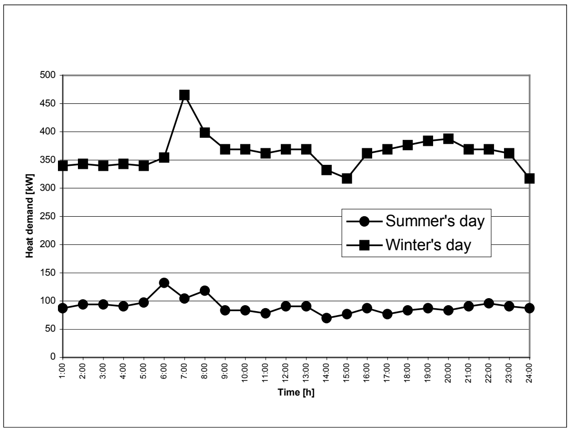

Figure 1.2: Daily heat demand for hospital C

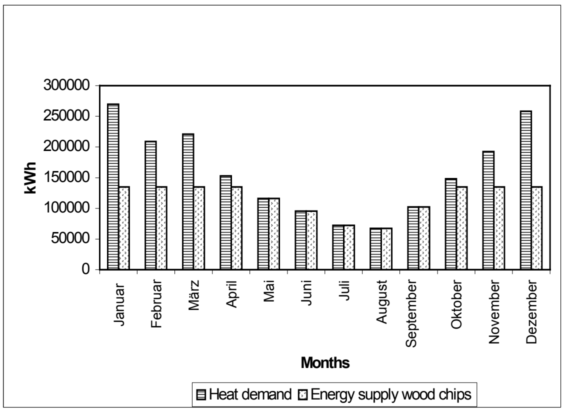

Figure 1.3: Share of energy supplied by biomass

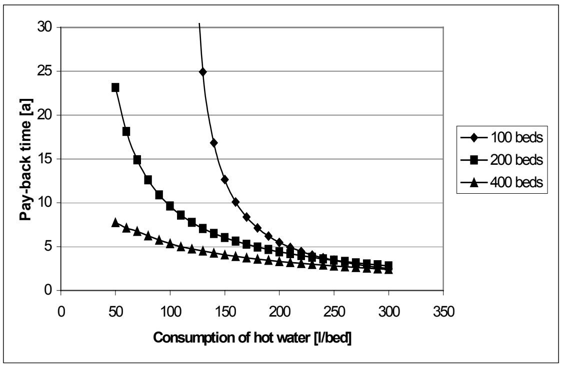

Figure 1.4: Payback times of wood-chip fired boilers.

Following this strategy, Figure 1.3 shows the share of heat supplied by the wood-chip fired boiler designed for all year operation. During summertime (May until September) the heat demand is met by the biomass-fuelled boiler. A relevant reduction in carbon-dioxide emission is resulting. From October to April other fuel has to be added.

Finally the question must be answered whether such a concept is economically competitive. There is an additional investment for the wood-chips' storage and the more costly boiler which mostly includes a screw conveyor for automatical operation. This additional investment can be met by energy costs in the order of 0.01 €/kWh.

Taking current natural gas prices into account, the pay-back times shown in Figure 1.4 (previous page) are obtained. The consumption of hot water per bed was varied according to the widely spread needs in German hospitals (Kramel [1.11]).

The hospitals‘ sizes were set at typical numbers of beds of 100, 200 and 400.

With low hot water need in the order of 50 l/bed, it takes about 400 beds to make the wood-chip fired boiler competitive at a reasonable pay-back time of eight years. Taking German governmental grants into account, the pay-back time reduces to the order of six years. Higher hot water consumptions, resulting in a higher all year around heat demand, make this and other biomass concepts more attractive.

1.4 Conclusions

Energy from biomass and particularly from municipal waste is a concept which has been widely reported in the literature for a variety of applications. Here we have provided the results of our investigations on the use of biomass as a renewable source of energy in three different hospitals under totally different climatic and geographic conditions, i.e., two hospitals in Australia and one in Germany.

For the Australian hospitals, the use of municipal solid waste was discussed and it was illustrated that anaerobic digestion of 20 tonnes per day of such a waste can produce enough biogas to drive two sets of Perkins engine-generator sets which in turn can produce a total of 240 kW of electricity and 480 kW of heat.

For the hospital in Germany, it was shown that introducing a wood-chip fired boiler in a hospital’s central heating system may be a first step towards the use of renewable energy sources even in countries where the cost of electricity is very low. The use of biomass for meeting the heat demand is possible with conveniently operating boilers. The effect of this strategy is explained to be low energy costs and reasonable pay-back times.

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2. Concepts for the use of biogas and solid biomass in agricultural facilities

Farmers are now able to use abundantly available renewable energy sources at an affordable cost. To demonstrate this concept, with reference to specific applications, we discuss the use of biogas in a dairy farm in Australia and the use of biomass in a farm in Donauries region in Southern Germany. In the Australian context, we provide the details of a pilot project which was designed and built to anaerobically treat animal waste. We studied the effect of digestion temperature on the gas yield, and the composition of the biogas generated. For the application in Germany, several renewable primary sources of biomass were considered, and compared with each other in terms of their emission balance, percentage of fossil fuel energy used for cultivating, harvesting and preparation of the biomass, and biomass storage space requirements. These concepts were then evaluated in comparison to a conventional fossil fuel based system.

2.1 Introduction

The main sources of energy in agricultural facilities are electricity, natural gas and biomass (mainly wood). Their main uses are heating, cooling (refrigeration), air-conditioning, lighting, and hot water. Due to the increasing cost of the non-renewable energy sources and their environmental adverse effects, there is a tendency by many farmers worldwide to explore the possibility of using renewable sources of energy to satisfy their needs, to reduce their operational costs, and to help reduce greenhouse gas emission.

The traditional renewable sources of energy are solar and wind which are widely covered in the open literature and therefore not addressed here. However, in this paper, with reference to specific applications, we discuss the use of biogas in a dairy farm in Australia and the use of biomass in a farm in Donauries region in Southern Germany. The objective here is to demonstrate that farmers are no longer restricted to the use of fossil fuels, and can utilise abundantly available renewable energy sources at an affordable cost.

2.2 Biogas production from animal waste in a dairy farm

Anaerobic digestion as a means of waste decomposition and concurrent energy production (biogas) has long been used to produce useable gas in developing countries and some industrialised nations. The viability of using this technology depends on the balance between the cost of useable energy, the cost of implementation and operation of the technology, and the cost of waste disposal. Facilities with larger waste disposal problems can justify the costs involved with the implementation of a gas collection and power generation system but as the amount of waste to be treated decreases the capital cost of installation begins to outweigh any benefits achieved.

In order to demonstrate the feasibility of producing biogas from animal waste in a small-scale agricultural facility in Australia, a pilot project was set up on a 350-acre dairy farm rearing 150 dairy cows. In this farm, the cattle spends an average of 6 hours per day standing on concrete yards and all manure excreted during this time is flushed and drained into a double treatment lagoon system. The first one is an anaerobic lagoon in the shape of an inverted pyramid measuring 10 m by 10 m by 5 m deep. The sludge settles to the bottom of the lagoon and as new manure is added the treated supernatant is pushed out due to gravity into a second aerobic treatment pond measuring 10 m x 25 m x 1 m deep. Treated effluent from the second lagoon is gravity fed onto the paddocks as necessary. The total amount of organic matter treated can be estimated

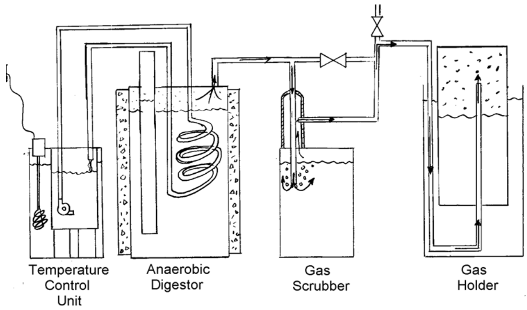

Figure 2.1: Diagrammatic representation of the pilot plant.

knowing that an average 450 kg cow excretes about 10% of its own body weight as manure per day (Stafford et al [2.1]), and 10% of this manure is made up of volatile organic solids. Using the average 6 hour period for the cow standing in the concrete yards results in a pro-rata amount of 169 kg per day of volatile solids excreted on the yard by the 150 cows.

Aerobic and anaerobic digestions are both bacterial processes in which bacteria digest organic matter. A detailed description of the bacterial processes that take place during anaerobic digestion is given in Hobson and Robertson [2.2]. The environmental factors affecting the anaerobic process are temperature, pH-level, hydraulic retention time (HRT) and feedstock characteristics. The optimum temperature for sewage sludge digestion is in the mesophilic range at about 35 °C (Stafford et al [2.1]). The pH of the digesting sludge is a parameter that must be controlled and maintained between 6 to 8 to achieve efficient digestion because the bacterial activity in the early stages of digestion leads to an acidic environment (Isaacson [2.3]). The HRT is the average period that the waste material resides in the digester.

The lagoon temperature affects the gas yield for a given loading rate. Assuming that the lagoon temperature is equal to the ambient temperature which was estimated to be 13.8 °C for this farm, according to Stafford et al [2.1], 0.4 m^3 of biogas can be produced from 1 kg of volatile solids for a 30 day HRT. Therefore, the total daily biogas production for this farm is 67.5 m^3. With a biogas composition of 70 % methane (Gecchi et al [2.4]), the daily methane production would be 47.25 m^3. Using a gas calorific value of 35 MJ/m^3 [2.4], the total energy which can be produced would be 1653.75 MJ. If this methane was used to run an internal combustion engine coupled to an electrical generator, for a 25 % efficiency, the electrical power produced would be 4.78 kW or 115 KWh/day (Constant et al [2.5]). The monetary value of this power based on a peak farm electricity rate of A$ 0.16 per kWh would be over A$ 7,000 per annum (A$ 1 ≅ US$ 0.52).

The pilot plant, constructed from common materials found on the farm, is shown in Fig. 2.1. The **anaerobic digester** was made of a 44-gallon (0.22 m^3) oil drum with a top inlet pipe for feeding the influent, a top outlet pipe for gas flow, and two side outlets for temperature measurement and sludge discharge. An internal copper coil was used for heating/cooling to control digester temperature. The digester was insulated using 50 mm thick mineral fibre bats recycled from a disused household hot water heater.

The **gas scrubber** comprised of a 22-gallon (0.11 m^3) drum filled with water with the gas bubbled through under pressure. The **gas holder** was an inverted plastic barrel inside a steel drum. The steel drum was filled with water to provide sealing and a U shaped copper pipe delivered and removed the gas from the inverted drum.

The **temperature control unit** comprised of a 22-gallon insulated drum with the lid removed and a stainless steel bucket inserted into it. Both the bucket and the drum were filled with water, with the outer heated by an electric resistance heater. A submersible marine pump circulated the heated water through the copper coil placed inside the digester. The temperature was controlled by an open loop control system with calibrated operational cycles of the pump and heating coil, achieving the desired digester temperatures.

The effect of temperature on gas yield is shown in the graph of Figure 2.2. Gas yield is expressed as m^3 of biogas per kg of volatile solids added for a hydraulic retention time of 30 days. This corresponds to the HRT of the lagoon under normal operation. The curve of best fit for the experimental data is a polynomial which has a number of characteristics that can be explained as follows: For temperatures below 15 °C, the yield appears to be constant indicating that any further temperature drop does not cause a significant drop in gas yield.

As the temperature increases above 20 °C the gas yield increases substantially but this trend appears to stabilise at around 30–35 °C.

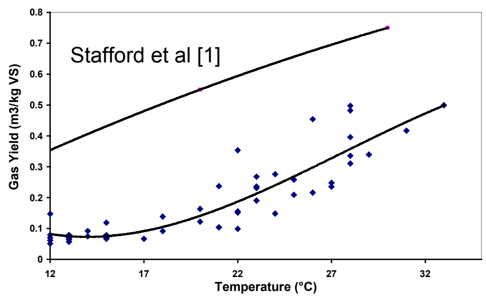

Figure 2.2: Effects of temperature on gas yield.

Figure 2.2 also shows a comparison of our experimental data and those from the literature. Admittedly there is a measurable difference between our measured values and those predicted using Stafford et al's [2.1] correlation. This should not be very surprising because most experimental data in the literature do not agree with each other either. For example, predicted gas yield from dairy cattle manure digested under ideal conditions at 35 °C with a 30-day HRT shows a variation from 0.22 (Wise [2.6]) to 0.93 (Baumann et al [2.7] and Hobson et al [2.8]) kL of biogas per kg VS. The yield for the present data under these conditions was estimated to be 0.58 kL of biogas per kg VS while Stafford et al [2.1] have reported a yield of 0.83 kL of biogas per kg VS. Based on the present experimental data, the total yearly gas production using Fig. 2.2 is 5,089 m^3. Using the method of approach illustrated previously, this will generate a yearly electricity aggregate of 10,700 kWh providing a potential annual income of approximately A$ 1,700.

In order to find the composition of the biogas, six gas samples were stored and then tested using LFG 20 infra red absorption analyser to determine their methane composition. The samples were taken over a wide range of operating temperatures in order to capture any variations. The composition of the generated gas was found to vary from 66 % to 74.1 %. It was found that as the temperature rose the concentration of methane decreased. This agrees with the data obtained from two other case studies carried out during this project. In one application, the effluent was digested at ambient temperatures and the methane composition was measured to be 80 %. In another application, the digester temperature was controlled at 35 °C and the resulting gas composition was measured to be 65-70 %. This is in good agreement with the literature which shows that the methane composition of the gas can vary from as little as 55 % up to 80 %. Although the gas produced at lower temperatures has an improved methane composition, the increased gas yield at the higher temperatures outweighs any benefits obtainable by keeping the temperature low in order to gain better methane purity.

2.3 Use of biomass in agricultural facilities in Germany

Solid or liquid biomass as a source of renewable energy can be stored easily in order to satisfy different demands throughout the year particularly in the countryside where there are many biomass sources available for such purposes. Some of these sources are evaluated as an example for a farm in the Donauries region in Southern Germany. The owner of this farm intended to expand the stables and erect a new energy supply system using biomass. The farm's heat-requirements were estimated to be 30 kW for the farmstead, 12 kW for the stables, and another 8 kW for hot water supply of the stables (50 kW in total).

2.3.1 Biomass selection criteria

In this project, different renewable primary products have been considered in order to show that

- acceptable conditions of growth exist in Bavaria,
- a reasonable mass-yield can be achieved,
- they can be combusted with proven technology,
- farmers are familiar with relevant cultivation and harvesting and/or processing techniques.

2.3.2 Comparison of biofuels

For this purpose, among other aspects, the amount of fossil energy needed to prepare and process the biomass material was calculated (Wolfrom [2.9], Kaltschmitt [2.10]). The ratio between fossil energy demand and renewable energy gain indicates the chosen material's contribution to substitution of conventional resources. Exemplary data are provided in tables 2.1 and 2.2, where numbers in brackets [ ] refer to timber cultivated in short mode operation.

Table 2.1: Percentage of fossil energy for cultivation and preparation of **wood**

	Timber logs	**Chopped timber**	**Wood chips**
	(GJ/ha)	(GJ/ha)	(GJ/ha)
Cultivation & Harvesting	0.6 [9.0]	0.6 [9.0]	0.6 [9.0]
Preparation	0.2 [1.5]	0.4 [2.7]	0.8 [5.8]
Total Input	**0.8 [10.5]**	**1.0 [11.7]**	**1.4 [14.8]**
Gross gain from biomass	25.7 [171.0]	25.7 [171.0]	25.7 [171.0]
Nett gain	24.9 [160.5]	24.7 [159.3]	24.3 [156.2]
Fossil (%)	**3.1 [6.1]**	**4.0 [6.8]**	**[8.7]**

Table 2.2: Percentage of fossil energy for cultivation and preparation of **biofuels**

	Straw (Pellets)	**Grain (Pellets)**	**Rape-methyl-ester (RME)**
	(GJ/ha)	(GJ/ha)	(GJ/ha)
Cultivation & Harvesting	0.8	13.3	18.2
Preparation	7.6	7.8	11.9
Total Input	**8.4**	**21.1**	**30.1**
Gross gain from biomass	106.5	156.8	51.0
Nett gain	98.1	135.7	20.9
Fossil (%)	**7.9**	**13.5**	**59.0**

2.3.3 Calculation of operating costs

For several renewable fuels, suitable boilers were selected, hydraulic sketches were prepared, and the costs of components and installation were calculated. The total costs of using different types of biomass consist of raw material cultivation, harvesting, preparation and processing, transport and storage, and energetic utilisation. These are compared with the costs for using mineral fuel oil and given in tables 2.3 and 2.4.

Table 2.3: Investments and annual operating costs

	Mineral fuel oil	**Timber logs**	**Wood chips**
Investments [€]			
Boiler incl. buffer	5,115	12,170	16,820
Storage or tank	5,115	-	2,555
Installation	1,740	2,455	2,150
Total Inv.	**11,970**	**14,625**	**21,525**
Operating costs [€/annum]			
Fuel	3,880	2,025	1,410
Operation salary	-	510	230
Maintenance	300	145	215
Electricity	3,935	3.935	3,935
Investment	795	975	1,435
Annual Costs	**8,910**	**7,590**	**7,225**
Profit (Loss)	**0**	**+1,320**	**+1,685**

Table 2.4: Investments and annual operating costs

	Mineral fuel oil	**Straw**	**RME-cogen.**
Investments [€]			
Boiler incl. buffer	5,115	13,835	11,605
Storage or tank	5,115	2,555	5,110
Installation	1,740	2,150	2,455
Total Inv.	**11,970**	**18,540**	**19,170**
Operating costs [€/annum]			
Fuel	3,880	1,580	7,175
Operation salary	-	305	-
Maintenance	300	130	955
Electricity	3,935	3,935	930
Investment	795	1,235	1,280
Annual Costs	**8,910**	**7,185**	**10,340**
Profit (Loss)	**0**	**+1,725**	**(-1,430)**

The details of the calculations of the total operating costs and the total investment for the different heating concepts including central-heating boiler, buffer, oil-tank, storage space and piping considered in this study are available in Wolfrom [2.9, 2.11].

It can be seen that the use of wood (logs or chips) and the use of straw results in lower costs compared to mineral fuel oil or rape-methyl-ester (REM). These figures become even more favourable for the two wood fired concepts when governmental investment grants (Förderfibel [2.12]) are taken into account.

For a first estimation of whether an investment into a concept which uses renewable energy material is economically viable, costs were calculated and summarised in a flow-chart (Hilligweg and Wolfrom [2.13]) which showed the main influence of the mineral oil-price. When mineral fuel oil is cheaper than 0.30 €/l, only residual material is competitive. In the range of 0.30-0.40 €/l energy plants become competitive, and above 0.40 €/l also RME (rape-methyl-ester) is worth considering.

It must be noted here that the design and costs of main components and other equipment are based on the type of farm being investigated, and that the results of this investigation may be used only for comparison purposes. In this case, the results proved sufficiently encouraging for the farmer to install a wood-chip fired central heating boiler and also to produce rape-oil for use as tractor fuel.

2.4 Conclusions

The case studies reported here indicate that many farmers have began using renewable energy sources not only to reduce their operational cost, but also to help with waste management and environmental pollution control. The Australian application showed that animal waste can easily be transformed into biogas which can then be used to drive engines for mechanical and electrical power requirements or to produce hot water.

The German case study showed that biomass can provide fuel for economically competitive alternative heating concepts and can contribute to a reasonable reduction of CO_2 emission. The additional investment requirements compared to fossil fuel concepts can be met by governmental investment grants and/or by savings made due to the lower operating costs of installations using renewable sources. The latter is particularly more attractive when the biomass is produced, cultivated and harvested onsite by the user.

2.5 References

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