10. Other Technologies for Electric Power Generation

For small-scale CHP production, i.e., district heating plants, institutions, and farm-scale plants, there is a potential market both domestically and internationally. There are several development projects currently underway aiming at small-scale electrical power generation based on biomass with acceptable electrical power efficiencies. Of these, flash pyrolysis, Stirling engine, and steam engine will be described.

Flash Pyrolysis

By pyrolysis of biomass, the volatile compounds of straw (75-80% of the calorific value) are converted to gases by heating in the absence of oxygen. If the pyrolysis process is very fast with subsequent rapid quenching of the gases developed, a very high output (typically 60-70%) is achieved of an oily product, pyrolysis oil.

For some years, ELKRAFT Power Company Ltd. has participated in several pyrolysis projects in Canada and Finland, and under the auspices of the EU in order to both investigate the suitability of the process for pyrolysis of straw, and also to investigate the applicability of the pyrolysis oil (technically and financially) in diesel engines and boilers. So far, results have shown that straw can be converted to pyrolysis oil without problems in the process itself, but that further development of methods for separating solid particles from the gas before condensing it is necessary. In Finland and England, short-term experiments have been carried out on pyrolysis oil as a fuel in diesel engines in the size of 60, 250, and 1,500 kW. In terms of combustion, the pyrolysis oil is unproblematic in behaviour, but it will be necessary with modifications of all components that are in contact with the pyrolysis oil due to its low pH value (3-4). Other experiments show that the pyrolysis oil is relatively easy to use in both small and large boilers.

CHP production based on pyrolysis oil could, e.g., consist of a central flash pyrolysis plant and a distribution system (tankers) and several small CHP plants that, e.g., consist of an unattended diesel engine. The low contents of ash, chlorine, and alkali in pyrolysis oil also make it interesting for alternative applications as co-firing at power plants. In terms of finance, this solution is not attractive, though, when considering the present prices of straw and wood chips.

Stirling Engine

The design of the Stirling engine makes it particularly suitable for difficult fuels, because the combustion does not take place in the cylinders but externally as in a boiler. Depending on the design of the engine and the design of the firing equipment, it is thereby possible to use both gaseous, liquid, and solid fuels. It is therefore an obvious possibility to apply the technology to biomass-fired CHP plants.

At the Technical University of Denmark, development work is currently taking place in order to develop three engines generating electrical power outputs of 150, 35, and 9 kW, respectively. Development and testing of the three engine types are carried out in several projects. The 150 kW electrical power project is financially supported by ELKRAFT Power Company Ltd. and the Danish Energy Agency and is based on gasification technology. The 35 kW electrical power engine is supported by the Danish Energy Agency via two projects, and the work is carried out in co-operation with the industrial enterprises REKA A/S and PlanEnergi A/S. The 9 kW electrical power engine is supported financially by Naturgas Midt-Nord and the Danish Energy Agency. This engine is designed for gaseous fuels and is not described in more detail. It is necessary to develop Stirling engines for direct use of biomass in stationary plants for electrical power generation. This means that the engine heating surfaces are adapted to experiences gained from the use of biomass in large steam boiler plants. In addition, the engine is hermetically sealed, since the generator is built into a pressurised crankcase. By at the same time using lubricated, sealed bearings, the problem of leakage of the working mediums gas and oil in the working volumes is solved.

The temperature in the engine heating surfaces should be as high as possible in order to achieve a good efficiency. This means in practice that the temperature of the heating surfaces should be at least 650-700°C. The temperature of the flue gas leaving the heating surfaces will be high. Therefore, an air preheater is used that preheats the combustion air by means of the hot flue gas. The hot combustion air does not constitute any great problem in a natural gas burner, but with wood chips or straw being fired instead, there is a risk of the high temperatures causing the ash to fuse and deposit on the heat transferring surfaces. An important part of the Danish Stirling engine activities are therefore the development of an efficient combustion system.

The 150 kW electrical power and 35 kW electrical power engines are designed with regard to being used for biomass as the energy source, either via combustion or gasification. This results in the combustion chamber and the boiler sections being much larger than those of a Stirling engine for natural gas or oil. The burnout time for solid fuel is longer than those of oil and gas, and the particle content necessitates a great distance between tubes and fins of the Stirling engine heating surfaces. The heating load in the heater is approx. 50 kW/m^2 which is equal to the heat load in a steam boiler for wood chips, but it is only 1/4-

	Unit	Stirling 35	Stirling 150	Sunpower Inc
Electrical power output	kW	33	142	2.5
Heat output	kW	102	350	Unknown
Electrical power effic., net	-	21	26	20
Specific cost of constr.	DKK/kW_{el}	20,000	15-20,000	20,000

Table 10: Stirling engine. Electrical power efficiency at full load. The annual efficiency will be lower depending on operating conditions. The cost of construction is budgeted price. The data stated are based on test results and on wood chips being the fuel.

1/5 of the load in a gas-fired Stirling engine. The development projects are primarily based on wood chips being the fuel, but straw is also a possible fuel. The chlorine and alkali contents of straw result in corrosion of the heating surfaces, but washing of the straw offers the possibility of reducing the aggressive components (see Section 2) /ref. 3 and 49/.

The American enterprise Sunpower Inc. in Ohio manufactured in 1996 six prototypes of an 2.5 kW electrical power Stirling engine with a linear generator directly connected to the piston without a crank. The fuels being wood, bagasse, rice hulls, straw etc. By an annual production of 10,000 engines, the price has been fixed at US$ 6,000, equal to approx. DKK 20,000/kW electrical power.

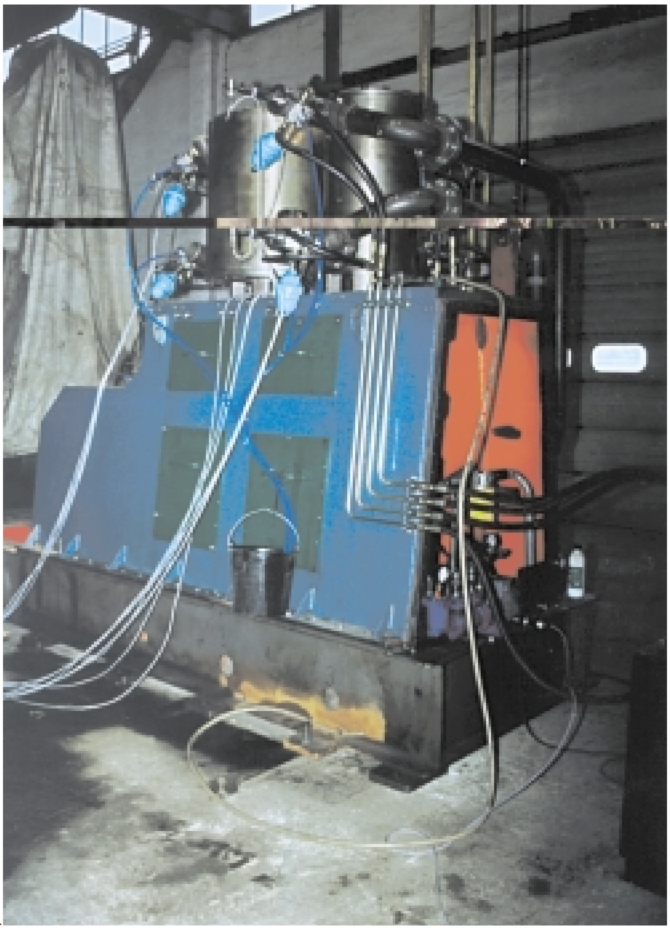

photo: dk-teknik

The prototype of a Danish manufactured steam engine installed for testing. The steam tubes supply steam for the high-pressure cylinder and afterwards for the bigger low-pressure cylinder. The hydraulic valves can be seen in the upper left corner behind the low-pressure cylinder.

Steam Engines

Steam engines can be an alternative at CHP plants up to approx. 1 MW electrical power, i.e., small plants that can cover the heating requirements in small towns up to 500 houses.

The advantages of the steam engine are:

- that this size of steam engine is capable of competing with the steam turbine in respect of price and efficiency,
- that the technology is relatively simple,
- that the working medium is steam that is produced in a boiler capable of running on vario biofuels.

The disadvantages of the steam engine (or the development requirement) are:

- that an engine should be developed that does not have to be lubricated with lubricating oil, since oil leakage to cylinders destroy the steam quality,
- that the conventional slider valve system yields a lower efficiency than that of modern hydraulic valve guide.

With a view to developing a modern steam engine, a two-cylinder prototype with a steam pressure of 24 bar and a steam temperature of 380°C with oil-free piston rings of carbon fibres and with hydraulic valves has been constructed. The steam engine is capable of generating an output of 500 kW electrical power. The project is being carried out by dk-TEKNIK and the engineering firm Milton Andersen and is financially supported by the EU and the Danish Energy Agency. After satisfactory testing of the prototype, it is planned to construct a steam engine running at 70 bar and 550°C.

A commercialised product of a size of 1 MW electrical power and with a net electrical power efficiency of almost 20% may be commercialised and marketed during 2000-2005. The specific cost of construction is estimated at DKK 20-25 million per MW electrical power/ref. 3, 12, 50/.