Danish stoves
- a cosy and eco-friendly heat source

Stoves approved by the Danish standardisation body have a worldwide reputation for advanced technique and very high quality - especially as regards design and choice of materials. Approx. 70,000 stoves are produced in Denmark each year, and two thirds of them are exported.

By Torben Skøtt

Since the energy crisis in the 1970s thousands of Danes have bought a woodburning stove, and today many people think of it as a real cosy corner. Others focus more on the economic aspect. Wood is still one of the most inexpensive fuels in Denmark, and if the alternative is oil-based or electrical heating, the stove can give you nice savings on the heating bill. To some people, protecting the environment is a major motivation for using fuelwood, as wood - like other sorts of biomass - is a CO_2-neutral fuel.

Of course, economic and environmental effects depend on the price you pay for the fuel and how efficiently it is exploited. Incorrect firing in a poor stove can easily lead to pollution of the environment and a higher heating bill. On the other hand, correct firing in a modern stove can exploit more than 80 per cent of the energy content in the wood.

The vast majority of stoves produced in Denmark come with the so-called DS certificate (approved by the Danish standardisation body). This approval is a guarantee to the consumer that the stove meets a number of requirements concerning safety, energy-efficiency and eco-friendly combustion.

Correct firing

Correct firing presupposes the use of dry wood only. In practice this means that the tree(s) must have been cut down before spring. Immediately after this, the wood must be sawn and split, as the moisture only emanates very slowly through the bark. Keep the wood outdoors, so that the wind can dry it, but preferably under a roof to protect it from rain.

Stove approved by the Danish standardisation body with external wood pellet magazine.

After a summer outdoors, the moisture content is reduced from 50-60 per cent to approx. 20 per cent. By October the wood will start to absorb moisture from the air again, so it is a good idea to bring supplies for the winter indoors, e.g. in a boiler room.

Simply put, wood is gas in solid form, as 80 per cent of the calorific value consists of gases, which only ignite at very high temperatures (800-900°C). Consequently, the stove calls for a special design, making the open fireplace a hopeless firing device in terms of energy-efficient and eco-friendly combustion - the temperature is much too low, and it is impossible to control the air supply.

The combustion chamber of a stove must have a fireproof stone lining, and it must be possible to supply sufficient quantities of air exactly where the gases are being combusted - i.e. above the fuel. The air can be pre-heated, as it is important that the temperature of the gas/air mixture is above 800°C.

When firing the stove, it is important to increase the temperature as quickly as possible, so that

the gases released can be combusted. Do not use logs that are too big, as they are hard to ignite.

Stoves are too big

When firing wood you must be aware that the gases - which constitute 80 per cent of the calorific value - burn in flames. When the wood has been degassed, the remains consist of charcoal. Charcoal glows while consuming oxygen, until all that is left is ashes.

Experience shows that far too many stoves are too large for the rooms that they are supposed to heat up. A stove combusting 1 kg of fuelwood per hour at an efficiency of 75 per cent yields 3 KW. This corresponds to the heat requirement of a 60 m^2 living room at an outdoor temperature of minus 12°C.

Only rarely do people have a 60 m^2 living room, and minus 12°C is unusual. Therefore, most people find that the room where the stove is located gets too hot.

In most cases the solution consists of turning the air supply down, but in doing so you also lower the efficiency of the stove. This means that you exploit the fuel too poorly and that pollution increases significantly. If the stove is set to half of the output it was designed for, pollution levels triple and lowering the output further is an absolute disaster.

Thus, the conventional stove is not particularly well-suited for dwellings with a low heat consumption level. But on the other hand, if you have a house with large open rooms - possibly made of heavy materials - it may be a very good solution. Especially if you can accept certain temperature fluctuations during the day, i.e. if you avoid firing until it is actually cold and do not put out the stove until the house is well heated.

Other types

If you want a stove that is more easily adapted to the actual heat requirement, a wood pellet-fired stove might be a good solution. These stoves allow you to set the output at a couple of kW without impairing the efficiency.

Some of these stoves have a built-in fuel magazine, whereas others are connected to an external storage facility that can be hidden. The magazine typically holds enough wood pellets for 2-3 days' consumption.

Wood pellets are as inexpensive as fuelwood that has been sawn and split, but it may not be quite as cosy to fire with as fuelwood. On the other hand, it is easy, and the pellets burn well as the moisture content is only approx. 10 per cent.

Stoves built of stone can also yield a low output without impairing the efficiency. The balance between output and consumption is ensured by the heavy stone mass, which acts as an efficient heat storage. Normally, the user only has to fire intensively once a day for 1-2 hours in order to heat up the stone mass. During the rest of the day the heat demand is covered by the 3-4 tonne stone mass releasing heat to the house.

Finally, a number of stoves have a built-in water tank that allows some of the heat to be transferred to a central heating system or be used to heat domestic water. Typically, approx. half of the heat output can be transferred from the room where the stove is located in this way.

Torben Skøtt is a journalist and editor of the magazine Dansk BioEnergi.

Stoves approved by the Danish standardisation body all meet a number of minimum requirements concerning efficiency, environmental protection and safety.

- First of all, the stove efficiency must be at least 70 per cent at nominal output, i.e. the output at which combustion in the stove is at its best.
- Secondly, the amount of carbon monoxide (CO) in the smoke must not exceed 0.3 per cent. In case of too much CO there is a considerable risk that it also contains tar and PAH, which can cause cancer.
- Thirdly, the stove must meet a number of safety requirements, e.g. fire safety requirements. For instance, it must be ensured that embers cannot roll onto the floor when more fuelwood is added; the temperature of the walls surrounding the stove must not exceed 80°C; and the temperature in the chimney must not exceed 350°C.
- Finally, there are certain general requirements concerning door design, ash grate, ash pan, etc.

Before a stove is approved by the Danish standardisation body, it is tested at the Danish Technological Institute in Århus.

Chemical process engineer Sigrid Laursen preparing a boiler for testing at the Test Laboratory for small Biofuel Boilers.

Efficient and eco-friendly boilers

Danish approval and subsidy scheme triggers significant improvement of small straw- and wood-fired boilers. Many plants have already reached approx. 90 per cent efficiency.

By Sigrid Laursen

Since 1995, when the Danish Energy Agency introduced a subsidy scheme for minor biomass- fired boilers, approximately 9,000 subsidized plants have been installed, with a capacity of approx. 320 MW in total. In addition, some 2,000-3,000 plants have been installed without subsidies.

According to the Danish Energy Agency there are approximately 80,000 wood- and straw-fired boilers in Denmark. Some of these boilers need to be replaced by new and more efficient systems.

The subsidy scheme from 1995 was introduced for two reasons; to further the use of straw- and wood-fired boilers in sparsely populated areas, and to promote the application of the best systems in the market.

Consequently, the scheme was designed to ensure that the highest grants are awarded plants that show the best efficiency and the cleanest combustion. Furthermore, it was stipulated that all plants must fulfil certain energy- and environment-related minimum requirements in order to participate in the scheme.

In order to obtain grants the plants must be approved at the Test Laboratory for small Biofuel Boilers, which is funded by the Danish Energy Agency and was established through co-operation between the Danish Technological Institute and Research Centre Bygholm.

This type test allows the manufacturers to have their plants tested under the same conditions as their competitors, and the environmental parameters have become competition parameters along with the traditional ones such as functionality, durability, design and, not least, price.

Consequently, the scheme has sparked comprehensive product development among the manufacturers, partly through the manufacturers' own efforts prior to the test, and partly through the transfer of knowledge from the test Laboratory.

Highly improved straw-fired boilers

In the 1970s several machinery manufacturers began to produce small, simple straw-fired boilers designed for small bales. Later on, boilers for round bales and big bales were introduced.

The efficiency of these boilers was typically a mere 30-40 per cent, but they were inexpensive and the straw was normally free of cost. Thus, there was no economic incentive to improve the efficiency of the straw-fired boilers.

Since 1976 Research Centre Bygholm has tested approx. 70 straw-fired boilers of many different types and sizes. Most of the tests were carried out between 1976 and 1990. The tests always involved a certain degree of product development aimed at improving boiler efficiency and reducing the smoke nuisance. The first methods applied involved better control of the combustion air supply and more efficient smoke cooling.

As regards manually fed straw-fired boilers, the efficiency

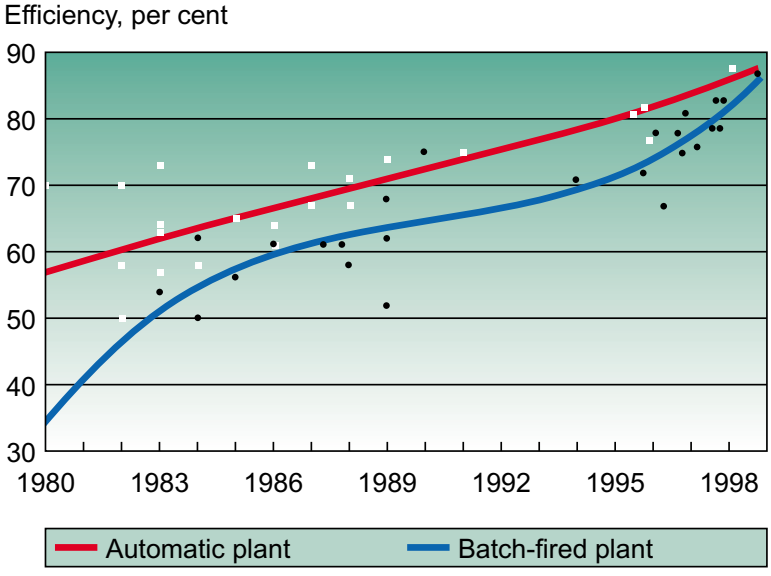

Figure 4: The efficiency of automatic and batch-fired Danish straw fired boilers from 1980 to 1998.

Today, several wood pellet-fired boilers have an efficiency exceeding 90 per cent and CO-emissions of approx. 0.002 per cent. Technically, this is about as good as it gets, unless the plants are fitted with flue gas condensation equipment.

increased dramatically in the beginning of the 1980's. Then the increase levelled out, until the subsidy scheme of the Danish Energy Agency was introduced in 1995. Since then the efficiency has gone up from approx. 70 per cent to more than 80 per cent. Two of the manually fed boilers have reached 83 per cent efficiency, which is better than that of several types of automatic straw-fired boilers.

The efficiency of the automatic systems has increased steadily from 1980 to 1999, and the increase has been slightly stronger for the last couple of years.

Cleaner environment

The carbon monoxide (CO) content of the smoke is a good indication of boiler efficiency. Low CO-emissions indicate efficient combustion, which is characterized by the absence of smell, invisible smoke and a very low risk of chimney fires.

From 1984 to 1990 CO-emissions tended to drop for manually fed as well as automatic systems, but the values fluctuated considerably. Since 1995, however, CO-emissions from manually fed boilers have dropped significantly, typically from 0.5 per cent in 1995 to 0.1 per cent in 1999. This progress is mainly attributed to the introduction of electronic systems that control the combustion air supply on the basis of the oxygen content of the smoke. In addition, an increasing area of the heating surface in the combustion chamber is fitted with a refractory lining in order to increase the combustion temperature.

Still, the automatic straw-fired plants with oxygen supply control are in the lead with typical CO-emissions of 0.02 per cent.

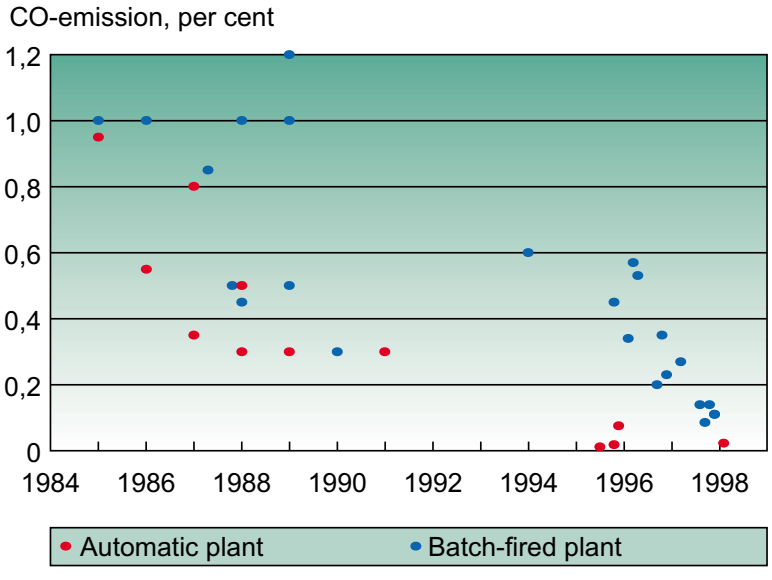

Figure 5: CO-emission from automatic and batch-fired Danish straw fired boilers from 1984 to 1998.

Cross-section of a manually fed wood-fired boiler from BAXI. The process involved is downdraft combustion, which means that the fire burns downward through a lined chamber at a very high temperature. This ensures eco-friendly combustion and high efficiency.

But under all circumstances, CO-emissions of 0.1 per cent from a manually fed straw-fired boiler is a very fine result which by far exceeds what anyone would have expected just a few years ago.

In the years to come we will undoubtedly see further progress in efficiency as well as CO-emissions from the manually fed straw-fired boilers, which are the most common straw-fired boilers installed these years. Apart from increasing the use of straw-fired boilers, the subsidy scheme of the Danish Energy Agency has been a much needed catalyst in the development of high-efficiency straw-fired boilers with low CO-emission values.

Minor plants

This strong trend of increasing efficiency and declining CO-emissions cannot be found among the small-scale automatic wood pellet-fired plants. Despite their rather simple design, most wood pellet-fired boilers achieved 80-90 per cent efficiency and CO-emissions of about 0.01 per cent from the start.

The efficiency of the manually fed straw-fired boilers has increased from 30-40 per cent in the 1970's to more than 80 per cent today. This means that manually fed plants are as efficient as automatic ones. On the other hand, the automatic plants generally require less service, and the carbon monoxide emission is lower. This favours the environment and reduces the amount of obnoxious smells, which is particularly important if the plant is located close to residential areas.

Today, many wood pellet-fired boilers have efficiency ratings exceeding 90 per cent and CO-emissions of approx. 0.002 per cent. Technically, this is about as good as it gets, unless the plants are fitted with flue gas condensation equipment, allowing the water content of the fuel to be exploited.

In the development of wood pellet-fired boilers, activities have mainly been focused on automatic boilers with relatively low output, which are better adapted to the demand in small houses.

Back in 1995 most biofuel plants had an output of 40-60 kW, whereas the demand is typically 10-20 kW. Today, most of the systems marketed have an output of 15-30 kW, while a smaller number of automatic plants with a nominal output of 10-15 kW have been developed. However, the number of plants with a nominal output of approx. 10 kW is still limited.

Adapting the output

In recent years the control systems for the automatic plants have seen some improvement.

The effective capacity control range of the plants is normally between 30 and 100 per cent of the nominal output, i.e. the output at optimum boiler combustion. The required output is rarely close to the nominal output of the plant, as the heat demand varies through the year and in the course of a single day.

Previously, most biofuel boilers were controlled in a similar way as an oil-fired boiler, with a thermostat connecting and disconnecting the fuel and air supply. This control method typically results in considerably lower efficiency and a significantly higher environmental impact at partial load compared to boiler operation at nominal output.

Nowadays, an increasing number of plants have more sophisticated control equipment that ensures more energy-efficient and eco-friendly operation. For instance, two- or three-stage control systems are used, where each stage corresponds to a predefined output. In some cases the plant can automatically switch between stages, and in other cases a manual switch is required.

Some manufacturers have developed control systems, in which the fuel and combustion air supply is modulated and adapted to the actual heat demand. These control systems are normally referred to as oxygen control systems.

1999 saw the development of a universal control system based on oxygen control. This project received support from the Danish Energy Agency. The system, which can be adapted to the majority of proven combustion plants in the Danish market, is expected to become the market standard within a relatively short time.

Safety First

The more widespread use of biofuel-fired central heating boilers has created a need for common guidelines as to how you build and install such plants safely with a view to preventing fires.

In September 1998 the Danish Institute of Fire Technology prepared a special set of instructions for biofuel-fired central heating plants. These instructions cover boiler plants as well as any installations used to transport the fuel from the storage area to the boiler. Specific requirements are made concerning the prevention of fires in the fuel feeding system, the connection of stokers and boilers, door contacts, etc. This has ensured more uniform plant safety, especially as regards safeguarding the plants against fires.

Chemical process engineer Sigrid Laursen is employed with the Test Laboratory for small Biofuel Boilers at the Danish Technological Institute in Århus.

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dk-TEKNIK ENERGY & ENVIRONMENT
Gladsaxe Moellevej 15 • DK-2860 Soeborg • Denmark
Phone: +45 39 555 999 • Fax: +45 39 696 002
www.dk-teknik.dk • e-mail: dk-teknik@dk-teknik.dk