

# 7. Small Boilers

The present number of small boilers for solid fuel in Denmark is approx. 80,000 of which approx. 70,000 are fired with firewood, wood chips, or wood pellets. In addition to that, there are approx. 300,000 wood stoves. Since the introduction of the state-subsidised scheme for approved boilers for solid fuels in 1995, more than 8,000 subsidised systems have been installed. In addition to that, 3,000-4,000 systems have been installed without subsidies. Approx. 30% of the new installations are manually fired boilers for fuelwood with storage tank. The efficiency of many of the old boilers is insufficient and emissions too high. Thus it would be advantageous to replace them by new approved boilers.

Distinctions should be made between manually fired boilers for fuelwood and automatically fired boilers for wood chips and wood pellets. Manually fired boilers should be installed with storage tank so as to accumulate the heat energy from one infeed of fuel (a full magazine). Automatic boilers are equipped with a silo containing wood pellets or wood chips. A screw feeder feeds the fuel simulta-

neously with the output demand of the dwelling.

Great advances have been made over the recent 10 years for both boiler types in respect of higher efficiency and reduced emission from the chimney (dust and carbon monoxide (CO)). Improvements have been achieved particularly in respect of the design of combustion chamber, combustion air supply, and the automatics controlling the process of combustion. In the field of manually fired boilers, an increase in the efficiency has been achieved from below 50% to 75-90%. For the automatically fired boilers, an increase in the efficiency from 60% to 85-92% has been achieved.

## Nominal output

The boiler nominal output (at full load) can be calculated on the basis of the known annual consumption of oil or the floor space and age of the dwelling (and insulation).

## Manually Fired Boilers

The principal rule is that manually fired boilers for fuelwood only have an accept-

able combustion at the boiler rated output (at full load). At individual plants with oxygen control, the load can, however, be reduced to approx. 50% of the nominal output without thereby influencing neither the efficiency nor emissions to any appreciable extent. By oxygen control, a lambda probe measures the oxygen content in the flue gas, and the automatic boiler control varies the combustion air inlet. The same system is used in cars. In order for the boiler not to need feeding at intervals of 2-4 hours a day, during the coldest periods of the year, the fuelwood boiler nominal output is selected so as to be up to 2-3 times the output demand of the dwelling. This means that the boiler efficiency figures shown in Figure 15 and 16 should be multiplied by 2 or 3 in the case of manually fired boilers.

Boilers designed for fuelwood should always be equipped with storage tank. This ensures both the greatest comfort for the user and the least financial and environmental strain. In case of no storage tank, an increased corrosion of the boiler is often seen due to variations in water and flue gas temperatures, and in addition to that, the manufacturer

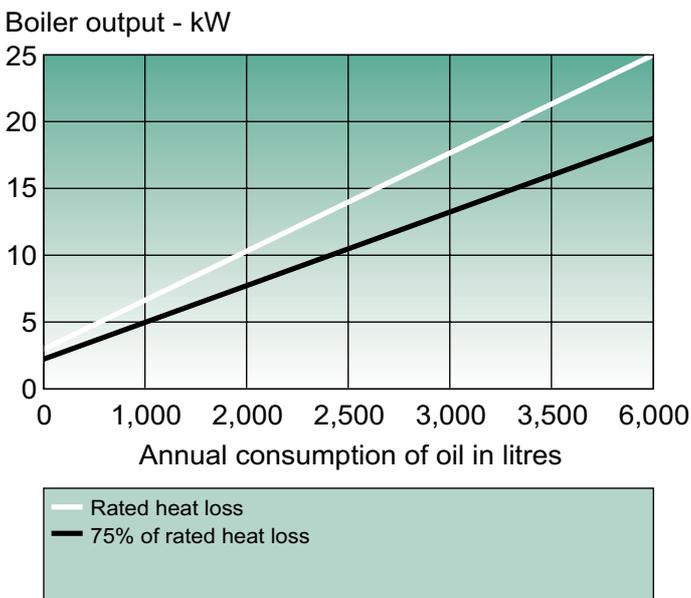


Figure 15: Boiler nominal output based on an annual consumption of oil in a relatively new, well-insulated dwelling. Output for hot water and loss (2 kW) included. If an oil-fired furnace is also installed, it will be sufficient to, install a boiler for 75% of the output demand in the case of automatic boilers. Thereby a more stable operation is achieved during the summer /ref.52/.

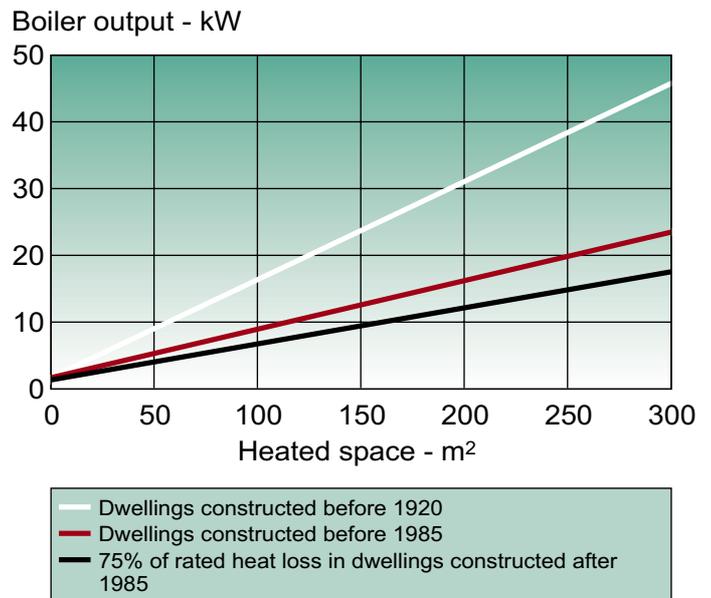


Figure 16: Boiler nominal output based on the age of the dwelling and floor space to be heated. If a relatively old dwelling is re-insulated, an estimated reduction in the boiler nominal output should be made. As shown in Figure 15, an oil-fired furnace may be installed /ref. 52/.

warranty may also lapse. The size of the storage tank can be determined on the basis of Figure 18.

### Automatically Fired Boilers

Despite an often simple construction, most of the automatically fired boilers can achieve an efficiency of 80-90% and a CO emission of approx. 100 ppm (100 ppm = 0.01 volume %) . For some boilers, the figures are 92% and 20 ppm, respectively. An important condition for achieving these good results is that the boiler efficiency during day-to-day operation is close to full load.

For automatic boilers, it is of great importance that the boiler nominal output (at full load) does not exceed the max. output demand in winter periods. In the transition periods (3-5 months) spring and autumn, the output demand of the dwelling will typically be approx. 20-40% of the boiler nominal output, which means a deteriorated operating result. During the summer period, the output demand of the dwelling will often be in the range of 1-3 kW, since only the hot water supply will be maintained. This equals 5 -10% of the boiler nominal output. This operating method reduces the efficiency - typically 20-30% lower than that of the nominal output - and an increased negative effect on the environment. The alternative to the deteriorated summer operating is to combine the installation with a storage tank, oil-fired furnace, electrical power heated hot water supply or solar heat.

### Type Testing of Small Biofuel Boilers

So far, there has been no tradition in Denmark for systematic type testing of heating systems for solid fuels - apart from boilers for straw that have been type tested at Research Centre Bygholm, Horsens, in connection with previous subsidy schemes. The market for small heating systems has been uncontrolled, i.e. so far there have been no statutory requirements in respect of type testing of energy, environmental, or safety properties. The only statutory requirements are safety requirements laid down in the Directory of Labour Inspection Publication No. 42 /ref. 53/, dealing with safety systems for fired hot-water systems, and in Brandteknisk vejledning nr. 32 /ref. 54/,



Figure 17: "X-ray" of manually fired boiler. The magazine is almost half full of fuelwood, and the combustion is in the form of downdraft combustion, i.e., the burning gases pass down through a lined chamber, where the combustion is completed. The combustion air is introduced through inlets in the gate and is pre-heated. The flue gases move backwards and pass the tubes (the convection unit). The tubes are equipped with spirals so as to increase the amount of heat being given off to the boiler water. An exhaust fan at the back of the boiler ensures a correct negative pressure in the combustion chamber.

graphics: hs boilers - tarm a/s

dealing with fire protection of equipment and boiler room.

With the introduction of the subsidy schemes for small biofuel boilers in 1995, type testing immediately became of great interest to the manufacturers. This is due to the Danish Energy Agency requiring as a precondition for granting subsidies a type approval of the boiler in order for it to comply with a wide range of requirements in respect of low emissions and high energy utilisation. The type testing was carried out at the Test Laboratory for Small Biofuel Boilers in accordance with test directions setting out in detail the guidelines for testing, and the requirements to be met in order to achieve a type approval. The directions are drafted on the basis of recommendations for a

joint European standard for solid fuel systems. However, the requirements in respect of efficiency and emissions have been made more rigorous and grouped according to firing technology (manual or automatic) and fuel type (straw or wood). The requirements are established in a joint collaboration between the manufacturers of biofuel boilers, the Test Laboratory for Small Biofuel Boilers, the Danish Energy Agency, and the Danish Environmental Protection Agency /ref. 55/.

The type testing can be carried out on the basis of various fuels, e.g.: Fuelwood, straw, wood pellets, wood chips, cereals, or sawdust/shavings. The type approval only applies to the fuel that was used during the testing. The scheme applies to automatic boilers up to 250 kW

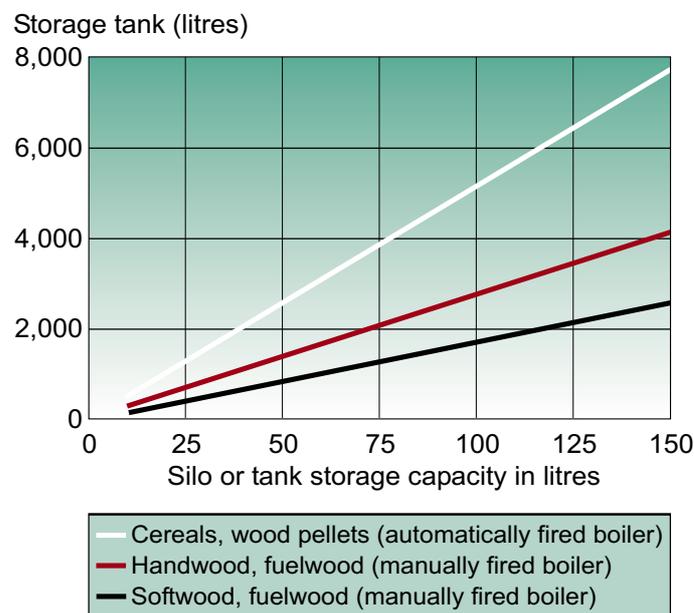
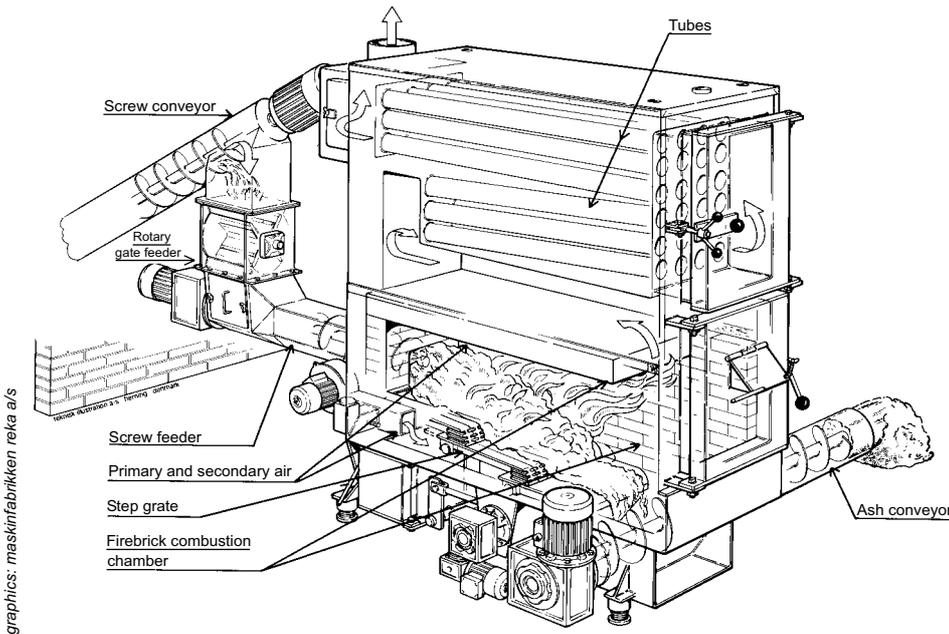


Figure 18: When knowing the boiler magazine size (i.e. the unit of the boiler that is filled with fuelwood), the necessary size of the storage tank can be determined /ref. 52/.



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*Figure 19: Automatic chip-fired system. The chips are loaded onto a conveyor and screw feeder from the silo, then pass onto the grate, where the combustion takes place. The movements of the grate push the ash towards the ash chute and further out with the ash conveyor. The flue gases are cooled by passing through the tubes that are surrounded by boiler water.*

and for manually fired (batch-fired) boilers up to 400 kW. By raising the level to 400 kW, a reasonable combustion time is achieved for big bales for boiler systems for farms. A list of type-approved systems is published approx. 5 times per year /ref. 56/.

The values for CO emission, dust emission, and efficiency are determined during the type testing as the mean value over 2 x 6 hours at nominal output. The nominal output should be stated by the manufacturer and is an expression of the boiler optimal output with the efficiency being high and emissions low.

In addition to testing at nominal output, type testing also includes testing at low load, which is max. 30% of the nominal output. The requirements in respect of dust emissions and CO-emission are listed in Table 13, while the efficiency should at least be such as listed in Figure 20.

Other important requirements are:

- Securing against backfire/burn-back in magazine (e.g. mechanical damper or by sprinkling with water).

- Max. allowable surface temperatures.
- Leakage tightness so as to prevent flue gas penetrating into the room.
- Documentation, e.g. technical information, operating and installation manual etc.

The subsidy scheme applies to biofuel boilers that are installed in areas without district heating supply. The subsidy percentage is calculated on the basis of the testing result, and the amount of money is calculated in proportion to the consumer's expenses for boiler plant and installations. The subsidy scheme is administered by the Danish Energy Agency.

### Experiences and Future Developmental Requirements

Since the introduction and implementation of systematic type testing in 1995, a wide range of experiences has been acquired from small heating systems. It was obvious at the beginning that many manufacturers were marketing heating systems, whose output exceeded by far the

heat demand of ordinary dwellings. This resulted in an obvious disparity between the actual demand of the consumers and the supply of heat by the heating systems with an output of less than 20 kW. The situation has changed since then, and the greater number of manufacturers by far now offer systems with outputs in the range of 10-20 kW, or are developing new systems. The small systems are often designed for wood pellets or perhaps for cereals.

There is still a need for improvements of boiler efficiencies. Several concepts are being developed at present, e.g.:

- Improvements of the boiler convection unit so as to reduce the flue gas temperature from the present 250-300 °C to 150-200 °C.
- Improvements of the lining (for wet fuels) and the design of air nozzles so as to keep constant the excess air and CO<sub>2</sub>, contained in the flue gas thus at the same time contributing to reduce dust emissions. Note that dust emis-

Fuel	Feeding	CO emission at 10% O <sub>2</sub> , 30% load	CO emission at 10% O <sub>2</sub> nominal output	Dust emission at 10% O <sub>2</sub> (mg/nm <sup>3</sup> )
Fuelwood, pellets, shavings/powder, chips, cereals	Manual	0.50 %	0.50 %	300
Fuelwood, pellets, shavings/powder, chips, cereals	Automatic	0.15 %	0.10 %	300
Straw	Manual	0.80 %	0.80 %	600
Straw	Automatic	0.40 %	0.30 %	600

Table 13: Max. allowable CO emission and dust emission at nominal output and low load during type testing.

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sions do not always depend on the combustion. Variations in fuel quality may result in variations in emissions.

- Improvements of the boiler control equipment so as to ensure an environmentally desirable and energy efficient optimal operation at the same time as being highly user-friendly requiring only minimal weekly attendance. Note that several boilers have advanced controls with several output options, and sometimes also oxygen control which to a high extent can handle the variations in consumption in a typical central heating installation. The Danish Energy Agency is funding a research and development project aiming at developing an inexpensive, universal oxygen control unit that can be adapted to the majority of small boilers on the market.
- Improvements of the low-load properties so as to maintain an acceptable operation during the summer period.

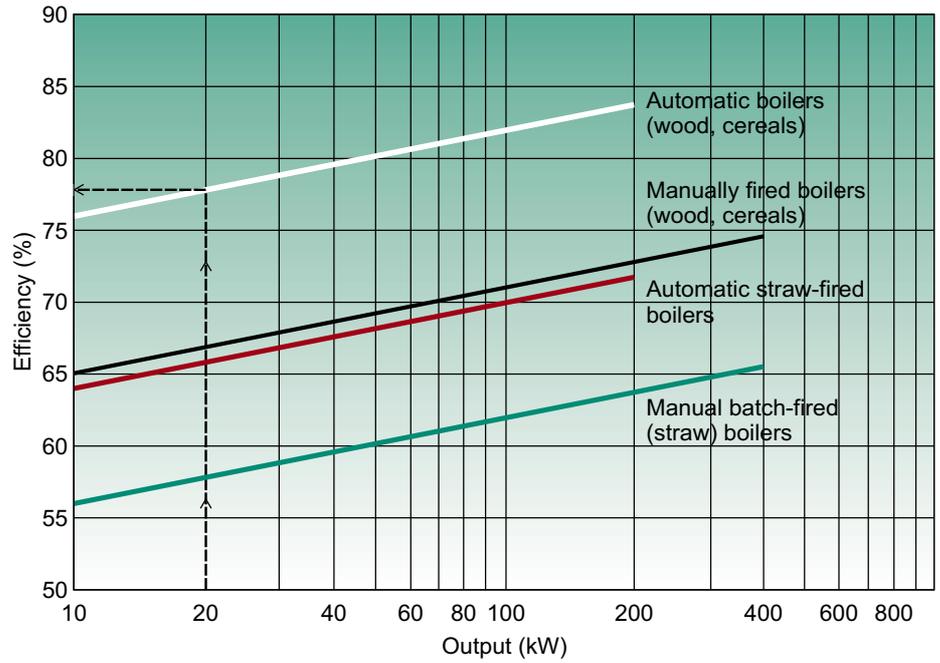


Figure 20: Minimum efficiencies depending on the type of system. An automatic 20 kW system for wood should have an efficiency of at least 77.5% in order to be type approved.