Efficient and environmentally friendly biomass heating

Firewood production and use in fireplaces and stoves

Eija Alakangas, Ari Erkkilä & Heikki Oravainen, VTT
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Francisco Puente, Escan
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December 2008
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Preface

This publication is part of the BioHousing Project (BioHousing – Sustainable, comfortable and competitive biomass-based heating of private houses EIE/05/067/ SI2.420197, www.biohousing.eu.com) funded by the European Union’s Intelligent Energy Programme. BioHousing is coordinated by Jyväskylä Innovation Ltd and other partners are VTT, Jyväskylä University of Applied Sciences, ofi, ETA Renewable Energies, Biomasse Normandie and Escan SA.

This publication is also available in Finnish, Italian, Spanish and French. The Finnish version is based on the book “Taloustulisijojen käyttö” (“Using household fireplaces”) published previously by Eija Alakangas, as well as on the latest research on the production of firewood and emissions from burning firewood. The publication also includes a summary of the main regulations, and average figures and examples have been used in the calculations of energy consumption. The drawings have been processed by Pirjo Helke and Oddball Graphics based on the sketches and ideas of Eija Alakangas.

The sources and other literature used for this publication are listed only in the bibliography and are not referenced in the text. Sources are only listed in the text for the photos and tables.

In addition to this publication, other guidelines and reports on the subject have been published in Finnish, French, English and Swedish. A DVD has also been produced for solar energy describing the design and construction of solar collectors. In addition, a guide and reports has been compiled on the correct storage of firewood and the production of firewood.

Jyväskylä, December 2008

Authors
Introduction

This publication provides information about efficient and environmentally friendly fireplace heating. It includes theoretical data, practical guidelines and official regulations concerning fireplace heating in Finland, Austria, France, Italy and Spain. In addition to heating, this publication contains information about storing firewood and purchasing firewood.

The most important aspects of fireplace heating are as follows:

- purchase the right fireplace – invest in efficient and clean technology
- follow the heating instructions of the fireplace or stove manufacturer
- use dry firewood for heating
- learn efficient and environmentally friendly ways of heating your house and take also health issues into account
- maintain your fireplace to ensure its ability to transfer heat and to guarantee fire safety

In recent years environmental issues have also been considered when assessing energy issues related to private houses. These environmental issues include climate change and the environmental load of private houses over their entire lifespan. Energy consumption accounts for 80 to 90 percent of the environmental load of private houses over their entire lifespan. Well-designed houses consume half the energy and create half the environmental loading of ordinary houses. Environmental loading is further reduced when the energy required comes from renewable sources, such as wood, solar and geothermal heating.

Woody biomass contributed 1,334 PJ (370 TWh) in households in the EU27 in 2006, of which more than half was traditional firewood. The biggest consumption of wood fuels in the domestic sector was in France (319 PJ), Germany (222 PJ), Poland (105 PJ) and Romania (108 PJ).

These days fireplaces are seldom the only source of heating in private houses in the Nordic countries, but they often satisfy the entire heat demand in Central and Southern Europe. However, their importance as auxiliary heat sources is all the more important in Nordic countries. Logs or pellets are the primary source of heat if a system based on a boiler or integrated boiler-burner combination is used. Since the 1990s the use of wood pellets in heat production has increased. In Italy approximately 700,000 pellet stoves are used for heating.

Use of wood fuels in households in participating countries and the EU27 (TJ). Source: Eurostat

<table>
<thead>
<tr>
<th>Year</th>
<th>Finland</th>
<th>Austria</th>
<th>France</th>
<th>Italy</th>
<th>Spain</th>
<th>EU27</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>39,200</td>
<td>59,663</td>
<td>336,316</td>
<td>50,998</td>
<td>83,528</td>
<td>1,194,095</td>
</tr>
<tr>
<td>2001</td>
<td>40,800</td>
<td>66,304</td>
<td>324,866</td>
<td>53,078</td>
<td>83,529</td>
<td>1,175,590</td>
</tr>
<tr>
<td>2002</td>
<td>41,400</td>
<td>63,534</td>
<td>297,988</td>
<td>48,223</td>
<td>83,534</td>
<td>1,265,259</td>
</tr>
<tr>
<td>2003</td>
<td>41,290</td>
<td>64,674</td>
<td>323,714</td>
<td>50,414</td>
<td>83,537</td>
<td>1,291,319</td>
</tr>
<tr>
<td>2004</td>
<td>40,980</td>
<td>64,262</td>
<td>328,047</td>
<td>49,557</td>
<td>84,540</td>
<td>1,306,194</td>
</tr>
<tr>
<td>2005</td>
<td>40,620</td>
<td>65,423</td>
<td>327,614</td>
<td>54,000</td>
<td>84,706</td>
<td>1,306,194</td>
</tr>
<tr>
<td>2006</td>
<td>41,240</td>
<td>63,861</td>
<td>318,829</td>
<td>68,400</td>
<td>85,034</td>
<td>1,334,338</td>
</tr>
</tbody>
</table>

1 TJ equals 277,778 kWh
In Finland around 2.9 million stoves are used mainly for auxiliary heat production in private houses. Approximately half of them are heat retaining stoves.

There are almost 24 million one-family houses altogether in Finland, Austria, France and Spain. If owners of private houses would increase their use of solid biomass fuels, the greenhouse gas emissions caused by private houses could be reduced considerably.
2 Fireplaces as a source of heating

Energy consumption of private houses

The energy requirements of private houses vary considerably according to the season and the country. This variation can be described using a load curve, which illustrates the amount of energy used over the course of time. The area of the curve corresponds to the annual amount of energy. Peak output is seldom used. Typically 80 to 90 percent of the energy consumed in private houses is satisfied with an output of 50 percent.

Energy consumption varies according to how the house was built and how it is equipped. Household electricity consumption varies from 3,500 kWh to 7,000 kWh for private houses in Europe. In Finland consumption is higher from 7,000 kWh to 10,000 kWh annually. Most of the household electricity in Finland is consumed for lighting. Approximately 1,000 kWh is consumed each year to heat saunas in Finland. Another 1,000 kWh per person per year is consumed to heat hot water (approximately 50 litres of hot water per person per day).

An ordinary private house conforming to building regulations consumes an average of 90 to 140 kWh/m² heating energy per year in Europe. A low-energy house consumes 40 to 65 kWh/m² and a passive house just 15 to 30 kWh/m² per year for heating and cooling. A passive energy house consumes just 15 to 20 percent of the energy of an ordinary house. Passive energy houses are situated optimally to utilise as much sunlight as possible. Solar and waste energy are also used for heating. Building an energy-efficient house requires sufficient insulation in the roof, walls and floor combined with energy-efficient ventilation. Energy-efficient windows and doors help minimise energy consumption for heating.

The energy regulations for buildings will be tightened in 2010, and the goal is to reduce the energy consumption of new houses.

Example of a load curve showing the energy consumption of a private house heated by electricity in Finland. Source: Tampere University of Technology
## Energy consumption of typical private houses in Finland, Austria, France, Italy and Spain.

<table>
<thead>
<tr>
<th>Country</th>
<th>Energy consumption</th>
<th>Annual heat consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finland</strong></td>
<td>Single family house (heating only) - Electrically heated</td>
<td>9,600 – 14,400 kWh</td>
</tr>
<tr>
<td></td>
<td>Average house size</td>
<td>110 m²</td>
</tr>
<tr>
<td></td>
<td>Average energy consumption</td>
<td>Old houses (pre-1970) 160 – 200 kWh/m²&lt;br&gt;New buildings (2000s) 80 – 120 kWh/m²&lt;br&gt;New houses (2003 standard) 60 – 70 kWh/m²&lt;br&gt;Low energy houses 40 – 60 kWh/m²&lt;br&gt;Passive houses 15 – 30 kWh/m²</td>
</tr>
<tr>
<td></td>
<td>Hot water (heating)</td>
<td>4,000 kWh (1,000 kWh/person)</td>
</tr>
<tr>
<td></td>
<td>Household electricity (not for heating)</td>
<td>7,000 kWh (10,000 kWh for well-equipped houses)&lt;br&gt;Sauna stoves approx. 1,000 kWh</td>
</tr>
<tr>
<td><strong>Austria</strong></td>
<td>Single family house (heating only) (gas)</td>
<td>Common houses (old) 150 – 250 kWh/m²&lt;br&gt;New buildings (1999 standard) 75 – 90 kWh/m²&lt;br&gt;New buildings (energy-saving) 50 – 65 kWh/m²&lt;br&gt;Low energy houses 20 – 50 kWh/m²&lt;br&gt;Passive houses &lt; 15 kWh/m²</td>
</tr>
<tr>
<td></td>
<td>Average house size</td>
<td>97 m²</td>
</tr>
<tr>
<td></td>
<td>Hot water (heating)</td>
<td>10,000 kWh</td>
</tr>
<tr>
<td></td>
<td>Household electricity (not for heating)</td>
<td>3,500 kWh (family)&lt;br&gt;7,000 kWh (family including hot water production, not for heating)</td>
</tr>
<tr>
<td><strong>France</strong></td>
<td>Single family house (heating only) typical heating source gas (37% - natural gas or LPG)</td>
<td>Old houses (pre-1975) 16,700 kWh&lt;br&gt;Newer houses (post-1975) 14,000 kWh&lt;br&gt;(Source: ADEME and CEREN – 2-006)</td>
</tr>
<tr>
<td></td>
<td>Average house size</td>
<td>108 m² (2002) 115 m² (current, source: INSEE).</td>
</tr>
<tr>
<td></td>
<td>Hot water (heating)</td>
<td>2,500 – 3,000 kWh</td>
</tr>
<tr>
<td></td>
<td>Household electricity (not for heating)</td>
<td>3,000 kWh</td>
</tr>
<tr>
<td><strong>Italy</strong></td>
<td>Single family house (heating only)</td>
<td>10,000 – 40,000 kWh</td>
</tr>
<tr>
<td></td>
<td>Average house size (for new houses)</td>
<td>78 m²</td>
</tr>
<tr>
<td></td>
<td>Hot water (heating)</td>
<td>3,000 kWh (Thermal energy)</td>
</tr>
<tr>
<td></td>
<td>Household electricity (not for heating)</td>
<td>3,000 kWh (Electric energy)</td>
</tr>
<tr>
<td><strong>Spain</strong></td>
<td>Single family house (heating only) natural gas heated</td>
<td>14,000 kWh</td>
</tr>
<tr>
<td></td>
<td>Average house size</td>
<td>150 m²</td>
</tr>
<tr>
<td></td>
<td>Average energy consumption</td>
<td>Average 130 – 140 kWh/m²</td>
</tr>
<tr>
<td></td>
<td>Hot water (heating)</td>
<td>2,800 kWh</td>
</tr>
<tr>
<td></td>
<td>Household electricity (not for heating)</td>
<td>4,000 kWh</td>
</tr>
</tbody>
</table>
Heat transfer and the efficiency of fireplaces

In fireplaces the heat energy contained in the fuel is transferred rapidly to the structures of the fireplace during the burning process. When the fuel is being burned, hot combustion gases are formed, the heat of which is transferred to the structures. In heat retaining fireplaces the combustion gases are circulated through the side channels of the fireplace where they cool and transfer heat to the structures. Fireplaces vary considerably in the way they transfer heat. Fireplaces can transfer heat through either radiation or convection. Radiation can be emitted either directly from the flames, as in open fireplaces, or from the surfaces of the fireplace. The ratio between radiation and convection depends on the surface temperature and emissivity of the fireplace. As the surface temperature rises, the proportion of radiated heat increases.

Stoves transfer a lot of energy in a short space of time, whereas storage heating fireplaces transfer heat with less energy over several hours.

The efficiency of fireplaces varies according to the type of fireplace and how they are heated. The recorded efficiency levels are only suggestive, as a European measuring standard for fireplaces has only been developed in recent years. Overall heating efficiency also depends on how the fireplace is heated. The biggest factor affecting efficiency is combustion gas losses, which in turn are affected by the amount of unburnt gases, the amount of combustion air and the temperature of the combustion gases.
The overall efficiency of a fireplace ($\eta$) is (Saastamoinen 1991)

$$\eta = \eta_c \times \eta_h \times \eta_r$$  \hspace{1cm} (1)

- $\eta_c$ = combustion efficiency
- $\eta_h$ = heat transfer efficiency
- $\eta_r$ = heating efficiency

The heating efficiency ($\eta_r$) is

$$\eta_r = \frac{G \times (T_t - T_u)}{G \times (T_h - T_u)} = \frac{T_t - T_u}{T_h - T_u}$$  \hspace{1cm} (2)

$T_t$ = desired room temperature, e.g. 21°C
$T_u$ = outside air temperature, °C
$T_h$ = temperature in room, °C
$G$ = conductance, the ratio between heat transfer and the difference in temperature, W/m$^2$K

In Equation 1 the combustion efficiency ($\eta_c$) depends on unburnt losses in the combustion gases and ashes. High combustion efficiency means low emissions. High combustion efficiency requires a good mixture of secondary air and pyrolysis gases and a high temperature (see Chapter 6). Efficiency is often low when the demand for heat is small, as it is hard to control the heat. Catalytic burning is one way of improving burning when the demand for heat is small.

The heat transfer efficiency of a fireplace ($\eta_h$) can be observed in the lowering temperature of combustion gases, as the corresponding share of heat has been transferred to the structures of the fireplace. Efficiency depends on such factors as the structure of the fireplace (design of the heat surfaces), the materials used and the cleanliness of the heat surfaces. Soot on the heat surfaces reduces heat transfer.

Heating efficiency ($\eta_r$) is often overlooked when calculating the efficiency of fireplaces. This efficiency can be expressed as the ratio between the heat output of the fireplace and the consumption of heat. If the heat output is too high, the excess heat that is produced will dissipate through the walls of the house and through ventilation. For example, if the room temperature is 24°C, the outside air temperature -5°C and the desired temperature 21°C, the heating efficiency = $\frac{|21 - (-5)|}{|24 - (-5)|} = 26/29 = 0.90$ or 90 percent. In other words, 10 percent is excess heat.

The efficiency levels described here are all related to each other. When the amount of air is reduced, heat transfer efficiency improves due to less combustion gas loss but combustion efficiency worsens. Increasing the heating efficiency can lower the combustion efficiency (e.g. smouldering burning) and vice versa. Heating efficiency is also affected by the structure of the house (massive/ light) and how the burning is controlled.

The materials used in the construction of stoves and fireplaces include brick, refractory mass and soapstone. The key properties of the materials used in the construction of storage heating fireplaces include:
- specific temperature capacity, $c_p$ (kJ/kg °C),
- density, $\rho$ (kg/m$^3$)
- heat convection, $\lambda$ (W/m °C)
- workability during the construction phase
- appearance

The specific heat capacities of the different materials are relatively similar to each other. However, the densities of the materials vary considerably. Density, when defined as both the size and total mass of the fireplace, affects heat storage capacity. When selecting the construction material, it is important to consider the desired level of heat transfer. Thin conductive walls heat up and cool down rapidly, whereas thick poorly conductive walls do so slowly.

### Efficiencies of different types of fireplace.
**Source: VTT and fireplace manufacturers.**

<table>
<thead>
<tr>
<th>Fireplace type</th>
<th>Efficiency *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open fireplace</td>
<td>&lt; 30%</td>
</tr>
<tr>
<td>Heat retaining stove</td>
<td>80 – 85%</td>
</tr>
<tr>
<td>Baking oven</td>
<td>80 – 85% **</td>
</tr>
<tr>
<td>Cooker, stove</td>
<td>50 – 70%</td>
</tr>
<tr>
<td>Pellet stove</td>
<td>80 – 90%</td>
</tr>
</tbody>
</table>

* $\eta_c$ and $\eta_h$ (combustion and heat transfer efficiency)

** if only the heat recovered during baking is considered usable heat, the efficiency is 5 – 10%.
Example

The energy amount stored in a heat retaining stove is calculated for a soapstone stove weighing 1,500 kg, when the temperature before heating is 20 °C and after heating it should be 140 °C.

\[ E = c_p \times m \times (T_2 - T_1) \]

where
- \( E \) = energy amount stored in stove, kJ
- \( m \) = mass of the stove, kg
- \( c_p \) = specific heat capacity (kJ/kg°C)
  - for soapstone 0.98
- \( T_2 \) = temperature after heating, °C
- \( T_1 \) = temperature before heating, °C

\[ E = 0.98 \times 1,500 \times (140 - 20) \text{ kJ} = 176,400 \text{ kJ} \]

This energy amount can be produced by burning about 15 kg of firewood (see Chapter 5).

Alternating electric and wood heating in Nordic countries

Electricity differs from fuels in that it cannot be stored. It has to be produced at the same time that it is used. In the Nordic countries electricity consumption varies considerably depending on the season. Adjusting the electricity production according to peak loads increases the price of electricity. In the Nordic countries a lot of private houses and holiday homes are heated by electricity. Alternating the use of electricity and fuels can reduce heating costs.

In alternating heating the energy demand is covered entirely by electricity during the summer. Electricity can be less expensive in summer than in wintertime if a dual-pricing system is used. In wintertime auxiliary heat is produced using a fireplace. When fireplaces are used in wintertime in temperatures below zero, up to 50 percent of the heat output can be replaced with heat produced using a fireplace. In wintertime in temperatures below zero the carbon dioxide emissions of electricity production are also higher than average. The production of a single kilowatt hour of electricity produces an average of 274 g of carbon dioxide emissions in Finland.

Heat properties of different fireplace materials. Source: VTT and fireplace manufacturers.

<table>
<thead>
<tr>
<th>Material</th>
<th>Density, kg/m³</th>
<th>Heat conduction ( \lambda_m ) W/m°C</th>
<th>Specific heat capacity ( c_p ) (kJ/kg°C)</th>
<th>Expansion coefficient ( \alpha, 10^{-5/°C} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick</td>
<td>1,700</td>
<td>0.6</td>
<td>0.92</td>
<td>0.4 – 0.5</td>
</tr>
<tr>
<td>Brick, laid</td>
<td>1,700</td>
<td>0.66 – 0.8</td>
<td>0.82</td>
<td>0.4 – 0.6</td>
</tr>
<tr>
<td>Fire brick</td>
<td>2,000</td>
<td>1.5 – 2.0</td>
<td>0.84</td>
<td>0.3 – 0.8</td>
</tr>
<tr>
<td>Sandlime brick</td>
<td>1,800 – 1,970</td>
<td>0.93</td>
<td>0.84</td>
<td>0.8</td>
</tr>
<tr>
<td>Plaster</td>
<td>1,600 – 2,000</td>
<td>0.7 – 1.2</td>
<td>0.84</td>
<td>0.7 – 1.4</td>
</tr>
<tr>
<td>Concrete</td>
<td>2,200 – 2,500</td>
<td>0.8 – 1.9</td>
<td>0.85 - 1.15</td>
<td></td>
</tr>
<tr>
<td>Natural rock</td>
<td>2,500 – 2,700</td>
<td>1.8 – 3.5</td>
<td>0.7 – 0.9</td>
<td>0.7 – 1.2</td>
</tr>
<tr>
<td>Soapstone</td>
<td>2,980</td>
<td>2 – 6.4*</td>
<td>0.78 – 1.08</td>
<td>0.74 - 1.12</td>
</tr>
<tr>
<td>Cast iron</td>
<td>7,250</td>
<td>50</td>
<td>0.42 – 0.62</td>
<td>0.9</td>
</tr>
<tr>
<td>Steel</td>
<td>7,850</td>
<td>41</td>
<td>0.5</td>
<td>1.2</td>
</tr>
</tbody>
</table>

* Heat conduction varies for soap stones in accordance with the cleavage direction.
Example from Finland

Let us calculate the savings in electricity costs when part of electricity is replaced by fireplace heating. In this example, 0.5 or 6 stacked cubic metres of wood are used per year. The efficiency of the fireplace is 80 percent. Let us calculate the savings when the firewood is purchased and the average price for birch wood is €50/loose cubic metre including delivery. One loose cubic metre of birch saves approximately 1,010 kWh of energy. With an efficiency of 80 percent this creates 800 kWh of usable energy (0.8 * 1,010 kWh). The cost of the heat is €50/loose cubic metre/800 kWh/loose cubic metre, or €0.062/kWh. The average price of firewood is based on the average prices for loose cubic metres on the Mottinetti and Halkoliteri internet portals (www.mottinetti.com, www.halkoliteri.fi). If the firewood is sourced from your own forest or that of an acquaintance, and labour costs are not included, the savings are considerable. An average of 10 to 15 kg of firewood is used for each heating, which represents 33 to 50 kWh/heating with an efficiency of 80 percent (see Chapter 4). A single stacked cubic metre of dried firewood weighs approximately 410 kg. If an average of 12 kg/heating is assumed, the benefit gained from each heating is 4.5 kWh/kg * 0.8 * 12 kg = 39.84 kWh, or almost 40 kWh.

The price of electricity is the cost according to the Finnish Energy Market Authority (www. energiamarkkinavirasto.fi) of direct electric heating in private houses whose rooms are individually heated. The price includes electric energy and distribution, as well as taxes and the basic fee. Accordingly the average price of electricity in the beginning of October 2008 was €0.1002/kWh. Since the price for firewood was €0.062/kWh, the savings amount to €0.0382/kWh. Table below presents the benefit in kilowatt hours and euros per year when firewood is used as a source of auxiliary heat. Furthermore, if a share of the required heat is produced by firewood instead of electricity, fewer carbon dioxide emissions are created. Table also shows the savings in carbon dioxide emissions if heat is produced by electricity in temperatures below zero, when the decrease coefficient is 274 g CO₂/kWh or 0.274 kg CO₂/kWh. If half the private houses (570,000 houses) in Finland that are heated by electricity would use one stacked cubic metre of firewood more per year, especially during the cold winter season, the decrease in carbon dioxide emissions would be as follows:

570,000 * 0.5 * 800 kWh * 0.274 kg CO₂/kWh kg = 62,472 tonnes CO₂ per year.

### Benefit during the heating season when firewood is used as an auxiliary source of energy in addition to electricity, and savings in carbon dioxide emissions.

<table>
<thead>
<tr>
<th>Heat retaining fireplace or stove</th>
<th>100</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of heating times</td>
<td>100</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>Average use of firewood/heating</td>
<td>12 kg/heating</td>
<td>12 kg/heating</td>
<td>12 kg/heating</td>
</tr>
<tr>
<td>Annual use of firewood</td>
<td>3 stacked m³</td>
<td>4.5 stacked m³</td>
<td>6 stacked m³</td>
</tr>
<tr>
<td>Usable energy</td>
<td>4,000 kWh</td>
<td>6,000 kWh</td>
<td>8,000 kWh</td>
</tr>
<tr>
<td>Annual sourcing costs of firewood</td>
<td>€0.062/kWh</td>
<td>€0.062/kWh</td>
<td>€0.062/kWh</td>
</tr>
<tr>
<td></td>
<td>248.00 €</td>
<td>372.00 €</td>
<td>496.00 €</td>
</tr>
<tr>
<td>Reduction in electricity costs</td>
<td>€0.1002/kWh</td>
<td>€0.1002/kWh</td>
<td>€0.1002/kWh</td>
</tr>
<tr>
<td></td>
<td>€401.20 - €372.00</td>
<td>€601.20 - €504.00</td>
<td>€801.60 - €700.00</td>
</tr>
<tr>
<td>Cost savings</td>
<td>€91.68</td>
<td>€229.20</td>
<td>€305.60</td>
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<tr>
<td>Annual savings in carbon dioxide emissions</td>
<td>0.275 kg/kWh x 4,000 kWh = 1,096 kg</td>
<td>0.274 kg/kWh x 6,000 kWh = 1,644 kg</td>
<td>0.274 kg/kWh x 8,000 kWh = 2,192 kg</td>
</tr>
</tbody>
</table>
Combined use of fireplaces and solar energy

The sun is an inexhaustible source of energy and the basis of all life on earth. Solar radiation in Finland is approximately the same as in Central Europe but is characterised by the strong changes between the seasons, from the midnight sun to the polar night. The amount of annual solar radiation in Finland equals 1,000 kWh/m², in Austria 1,150 kWh/m², in France 1,260 kWh/m², in Italy 1,450 kWh/m² and in Spain 1,642 kWh/m². Solar energy can be utilised both actively and passively. Active utilisation involves storing the solar radiation using specially designed equipment. Passive utilisation involves benefiting from the heat through windows or walls, for example. Active solar energy equipment is divided into solar electricity and solar heat.

Solar heat is produced through solar panels. A basic multi-layered solar collector system can store 25 percent of solar radiation. A solar collector can also be connected to a fireplace heating system via a water accumulator. A more common combination of solar heat and biomass is pellet heating. In Central Europe pellet stoves are often connected to solar systems.
Example from Finland:

In the Rannanpelto house in Suomusjärvi, Finland, the floor space of the house is 155 m², the total space (according to external surfaces) is 182 m² and the heated volume 600 m³. Two people live in the house, which serves as the family’s primary home, summer home and place of work. Approximately 50 percent of the energy from firewood can be transferred to the water accumulator. In summertime, which accounts for around one-third of the year, the heat required and all the hot water is produced by the solar collector and stored in the same water accumulator. A 6 kW electric resistor is used in the water accumulator when the occupants are away for longer periods during the wintertime. Solar heat accounts for 10 percent of the total annual energy consumption, which in terms of time is sufficient for over one-third of the year. Annual heating costs have averaged €1,000 to €1,200 in today’s money based on electricity costs of €0.13/kWh and firewood costs of €60/stacked m³.
Example of the energy consumption and costs of the Rannapelto house in Suomusjärvi, Finland during the 2000-2007 heating seasons. Source: Pekka Leppänen.

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
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<th>2004</th>
<th>2005</th>
<th>2006</th>
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<tbody>
<tr>
<td>Energy required to heat the house, kWh</td>
<td>12,660</td>
<td>12,093</td>
<td>14,214</td>
<td>12,138</td>
<td>12,307</td>
<td>12,538</td>
<td>12,129</td>
<td>11,780</td>
</tr>
<tr>
<td>- from firewood</td>
<td>9,813</td>
<td>10,149</td>
<td>11,088</td>
<td>8,703</td>
<td>9,768</td>
<td>10,311</td>
<td>9,967</td>
<td>10,002</td>
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<tr>
<td>- heating electricity for accumulator</td>
<td>322</td>
<td>0</td>
<td>925</td>
<td>1175</td>
<td>446</td>
<td>505</td>
<td>246</td>
<td>0</td>
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<tr>
<td>- electricity for building technology</td>
<td>1,439</td>
<td>1,247</td>
<td>1,260</td>
<td>1,259</td>
<td>1,213</td>
<td>1,153</td>
<td>1,182</td>
<td>1,144</td>
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<tr>
<td>- solar energy used for heating</td>
<td>1,086</td>
<td>697</td>
<td>941</td>
<td>1,001</td>
<td>880</td>
<td>569</td>
<td>734</td>
<td>634</td>
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<td>Energy required to heat household water, kWh</td>
<td>2,040</td>
<td>2,010</td>
<td>1,230</td>
<td>2,040</td>
<td>2,100</td>
<td>2,070</td>
<td>2,010</td>
<td>1,920</td>
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<td>- energy from wood and electricity</td>
<td>1,200</td>
<td>1,200</td>
<td>600</td>
<td>1,200</td>
<td>1,200</td>
<td>1,200</td>
<td>1,200</td>
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<tr>
<td>- solar energy</td>
<td>840</td>
<td>810</td>
<td>630</td>
<td>840</td>
<td>900</td>
<td>870</td>
<td>810</td>
<td>720</td>
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<tr>
<td>Electricity for lighting and household equipment</td>
<td>2,380</td>
<td>2,509</td>
<td>2,562</td>
<td>2,250</td>
<td>2,670</td>
<td>3,248</td>
<td>2,817</td>
<td>2,582</td>
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<tr>
<td>Total energy consumption, kWh</td>
<td>17,080</td>
<td>16,612</td>
<td>18,006</td>
<td>16,428</td>
<td>17,077</td>
<td>17,856</td>
<td>16,956</td>
<td>16,282</td>
</tr>
<tr>
<td>- kWh/living space m²</td>
<td>110</td>
<td>107</td>
<td>116</td>
<td>106</td>
<td>110</td>
<td>115</td>
<td>109</td>
<td>105</td>
</tr>
<tr>
<td>- kWh/total space m²</td>
<td>94</td>
<td>91</td>
<td>99</td>
<td>90</td>
<td>94</td>
<td>98</td>
<td>93</td>
<td>89</td>
</tr>
<tr>
<td>Energy required to heat the house, kWh</td>
<td>12,660</td>
<td>12,093</td>
<td>14,214</td>
<td>12,138</td>
<td>12,307</td>
<td>12,538</td>
<td>12,129</td>
<td>11,780</td>
</tr>
<tr>
<td>- kWh/living space m²</td>
<td>82</td>
<td>78</td>
<td>92</td>
<td>78</td>
<td>79</td>
<td>81</td>
<td>78</td>
<td>76</td>
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<tr>
<td>- kWh/total space m²</td>
<td>70</td>
<td>66</td>
<td>78</td>
<td>67</td>
<td>68</td>
<td>69</td>
<td>67</td>
<td>65</td>
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<tr>
<td>- kWh/living space m³</td>
<td>21.1</td>
<td>20.2</td>
<td>23.7</td>
<td>20.2</td>
<td>20.5</td>
<td>20.9</td>
<td>20.2</td>
<td>19.6</td>
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<td>Purchased energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- firewood, kg</td>
<td>3,671</td>
<td>3,783</td>
<td>3,896</td>
<td>3,301</td>
<td>3,656</td>
<td>3,837</td>
<td>3,322</td>
<td>3,734</td>
</tr>
<tr>
<td>- firewood, stacked m³, birch</td>
<td>9.0</td>
<td>9.2</td>
<td>9.5</td>
<td>8.1</td>
<td>8.9</td>
<td>9.4</td>
<td>8.1</td>
<td>9.1</td>
</tr>
<tr>
<td>- electricity, kWh</td>
<td>4,141</td>
<td>3,758</td>
<td>4,747</td>
<td>4,684</td>
<td>4,329</td>
<td>4,906</td>
<td>4,245</td>
<td>3,726</td>
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<tr>
<td>Solar energy, kWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- heat from water accumulator</td>
<td>2,876</td>
<td>3,047</td>
<td>2,902</td>
<td>2,798</td>
<td>2,832</td>
<td>2,740</td>
<td>3,097</td>
<td>2,586</td>
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<tr>
<td>- solar energy used</td>
<td>1,926</td>
<td>1,507</td>
<td>1,571</td>
<td>1,841</td>
<td>1,780</td>
<td>1,439</td>
<td>1,544</td>
<td>1,354</td>
</tr>
<tr>
<td>- percentage of total, %</td>
<td>67</td>
<td>50</td>
<td>54</td>
<td>66</td>
<td>63</td>
<td>53</td>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td>Total renewable energy, kWh</td>
<td>17,080</td>
<td>16,612</td>
<td>18,006</td>
<td>16,428</td>
<td>17,077</td>
<td>17,856</td>
<td>16,958</td>
<td>16,282</td>
</tr>
</tbody>
</table>
Example from Austria

The Austrian example is a detached single family house in the northwest of Vienna situated close to the Viennese forests. The pellet stove is located in the living room of a single family house which consists of a heated cellar (office rooms), a ground floor and two additional floors. The stove has an overall efficiency (measured on site) of approximately 94%. Approximately 80% of the energy content of the pellets is transferred to a primary water circuit that feeds the energy into a water accumulator (1,000 litres) in the cellar of the building. From this accumulator, the floor heating system is fed to all rooms in the house. Hot water is also provided from the accumulator by a warm water module. Solar radiation supports the heating system. 16 m² thermal solar panels located at the roof of the house feed energy into the accumulator which provide up to 30% of the energy required for heating. The solar system provides the total hot water required for this and the neighbouring house from April to September.

Technical data: pellet central heating stove EVO Aqua from company RIKA, capacity 12 kW

Pellet storage:
The pellet storage room is located in the cellar of the house. It is equipped with a sloped floor and an automatic, pneumatic conveying system. It has a capacity of approximately 4.5 tons pellets, which covers the demand for more than a year.

Building, floor space:
Low energy single family house without controlled living space ventilation, total space of the house is 191 m² and heated volume 515 m³. The heat requirements are calculated according to European regulation: 56.74 kWh/m² a. Annual heating costs for 2008/2009 heating season are expected to be approximately €700 based on the pellet price of €170/ton including delivery and taxes.

Special features of the system:
The system is fully automated. The pellets are transported by a pneumatic system from the storage room in the cellar, which is filled once a year into the stove. The maintenance is reduced to cleaning once a week for approximately one hour. It is planned to change the pellet stove to a dual stove, which can also use also log wood which can be bought for low price.

A water accumulator is situated in the cellar of house.
Photo: Martin Englisch, ofi
Selecting a fireplace/stove

Purchasing a fireplace or stove is usually part of the construction process and should be planned at the start of the project. This makes it easier to take into consideration its space requirements, ideal position, ventilation and flue structures as the construction work progresses.

Care should be taken when selecting a fireplace or stove, as they are fixed structures that dominate the space in which they are. The choice depends on:
- the space available,
- the intended purpose of the fireplace/stove,
- the purchase price, and
- the appearance and suitability with the interior design.

When choosing a fireplace or stove, the habits and comfort of your family should be considered. Each fireplace and stove represents a personal choice, so precise instructions cannot be given.

To make the choice easier, ask yourself the following questions:
1. Will the fireplace/stove be the primary source of heat for the building (e.g. in a holiday cottage)?
2. Will the fireplace/stove be a source of reserve or auxiliary heat?
3. How important is the fireplace/stove as a source of entertainment or atmosphere?
4. How do you get your firewood?
5. How often will you heat the fireplace/stove?

Find out also what is the best place for the fireplace or stove in terms of heat efficiency, functionality and appearance. Once you have selected the type of fireplace or stove you want, you have to find an appropriate flue, make sure there is appropriate ventilation and begin looking at the models and properties offered by different manufacturers. You can also contact a mason or bricklayer if you prefer a tailor-made fireplace or stove.

In holiday homes fireplaces and stoves are usually the primary source of heat. They should heat the cottage rapidly and then maintain an even temperature. Woodburning stoves and fireplaces that circulate the air in the room are ideal for rapid heating. Heavy fireplaces with brickwork are best for maintaining an even temperature. Country baking ovens and cooking stoves are also ideal for cottages.

Room fireplaces are most appropriate as sources of reserve or auxiliary heat. They can be used regardless of the availability of oil or electricity. If affordable firewood is readily available, using the fireplace can reduce heating costs. If the fireplace is seldom used (1-2 times per week) and is mostly a source of auxiliary heat, a model should be chosen that has good heat storage properties and that does not release heat too fast at full power. When selecting a fireplace for an energy-efficient house, it is especially important to pay attention to how to select the fireplace. Since the heating requirements for energy-efficient houses are relatively small, the fireplace should release heat slowly.
Woodburning stoves are also ideal for heating holiday homes or small houses. These stoves can be used to heat up saunas and other rooms, and they can also be used to heat up water. Woodburning stoves circulate the heated air through the gravitational effect so no electricity is required.

For preparing food woodburning baking ovens and cooking stoves are the most versatile options. These can be used to cook food both rapidly and over long periods, depending on the design. Baking ovens are ideal for baking and cooking food slowly. Baking ovens, cooking stoves and fireplaces can also be combined when built by a mason or bricklayer. All of these cooking options also provide a source of auxiliary heat.

If the primary purpose of the fireplace is to create atmosphere, a large open fireplace where you can see the flames is usually desirable. For this purpose a heat retaining fireplace, fireplace insert or open fireplace equipped with glass doors can be chosen. If you plan to use a heat retaining fireplace also in summertime, it can be equipped with a summer flue that directs smoke directly to the chimney without heating the structure of the fireplace (see Chapter 5).

After you have chosen the type of fireplace or stove you want, you must still choose the type of material and construction method – either a tailor-made solution that is built in the house or a factory-built model that simply has to be installed. The price of factory-built models often includes installation. Chapter 2 describes the properties of the construction materials used for fireplaces and stoves and how they release heat.

The most important criteria for selecting a fireplace or stove include a good an appropriate model, nice appearance, heating ability and suitability with the interior design. Storage heating fireplaces and stoves produce 2-4 kW of energy and heat for 2 to 3 hours.
Wood burning cooker. Photo: Courtesy of ofi

A large open fireplace. Photo: Courtesy of ESCAN
Pellet stoves operate automatically and are ideal for homes that have direct electrical heating. The heat output of pellet stoves is controlled by a thermostat in the room. They can also be operated by remote control or even activated from a different location. In this way homes can be preheated by using your mobile phone.

Pellet stoves include a storage compartment for the fuel. The pellets are usually supplied and transported in small sacks. Systems are also available that refill the storage compartment automatically. Some pellet stoves are also designed to heat water. These can be used to heat small houses by adding some radiators or by connecting the flow of hot water to an underfloor heating system. Pellet stoves are particularly popular in Italy and elsewhere in Europe. Pellet stoves also require electricity.

If a fireplace or stove is to be installed in an existing rowhouse or apartment, permission is required from the housing cooperative. An official building permit is also required. Installing a fireplace in an apartment is often not possible due to the lack of a flue. For top-floor apartments flues can be installed through the attic, but relatively light models should be selected and the floor must be inspected to ensure its load-bearing properties.

**Locating the fireplace/stove in the house**

The choice of a stove’s placement is very important because it affects its efficiency. The placement of a radiation stove near a panoramic glass roof or a perimeter wall means dispersal of a good proportion of its radiant heat as it escapes the apartment. Stoves should be located where their heat can be fully exploited.

A design plan of the house can be used to identify the location of the openings, the space dimensions, and the height and thickness of the floors and roof in order to determine the type of chimney required. Ultimately the positioning of the stove depends on the placement of the chimney.
To estimate the output of the stove, it is important to know the degree of the house’s insulation. In this way it is possible to decide if the stove will be the only source of heat for the house or if it will act as a supplement for a particularly cold room.

Stoves can heat via radiation or convection. A radiant stove requires a safe distance from the walls and house furnishings, and especially from the occupants, because of the high surface temperature of the stove. The best position is at the centre of the room in order to take full advantage of its power to radiate.

A convection stove requires only a small safe distance. Heating by hot air flow results in a more uniform temperature, so the stove can be easily located. In addition, the hot air produced can be channelled to other parts of the house. However, care should be taken to avoid the stagnation of hot air in environments with high ceilings.

The fireplace or stove should be situated as centrally as possible to allow the heat to spread evenly through the house. The transfer of the heat produced by the fireplace or stove can be enhanced by ventilation systems that circulate air in the house.

Central heating is possible with a pellet stove. The heating may be by movement of air or water.

In the first case a system for channelling the heated air must be provided. In the second case the stove heats the water that circulates in the radiators.

Fire safety regulations must also be taken into consideration when planning the location of the stove.
fireplace or stove. Sufficient space must be reserved for the size of the fireplace or stove itself, as well as the protective area around it and the space required to use and service it. There are different regulations in different countries.

In Italy the convection stove should be located at least 200 mm away from traditional walls, or 400 mm from walls made of flammable material. The stove can be placed between two walls as long as these distances are respected. Any material that could ignite should be protected from the heat generated by the fire within the stove. Flooring made from wood or other flammable material should be protected with fireproof material of at least 4 mm between the floor and the stove. This protective layer must cover the entire area under the stove, in front of the stove of a measure equal to the floor mouth + 30 cm, and no less than 60 cm, while on the sides of the stove the projection should be equal to + 20 cm. Also, if any wood is located above the stove, it must be protected with fireproof material. Shelves should be located no closer than 500 mm above the stove.

Care must be taken to ensure that the stove is level by using a spirit level and adjusting the stove feet if necessary. If the stove uses electricity, the stove cable must reach the nearest electrical outlet. Ideally, the electrical outlet should be located behind the stove to prevent people from tripping over the cable and children from playing with the outlet. Adapters, extension cords or multiple outlet devices of any kind should not be used.

If the stove is equipped with an external temperature detector, it should be connected to the back of the stove by up to a 5-metre cable to allow flexibility in location. In placing the stove, space for manoeuvring in the event of maintenance must be considered.

At least one metre must be kept free in front of fireplaces.

At least one metre must be kept free in front of the fireplace or stove, as well as one metre on either side. For baking ovens at least two metres should be kept free in front and sufficient space on either side. For chimney sweeping purposes, at least 60 cm should be kept free in front of any hatches.

These days fireplaces and stoves are tested in order to define the required protective distances around them. These tests measure the increase in
Classification and protective distances for fireplaces and stoves that are built from bricks in Finland. RakMk E8.

<table>
<thead>
<tr>
<th>Surface temperature classification</th>
<th>Protective distance, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Classification of all or part of the fireplace or stove</td>
</tr>
<tr>
<td>Warm surface</td>
<td>less than 80</td>
</tr>
<tr>
<td>Hot surface</td>
<td>80 – 140</td>
</tr>
<tr>
<td>Burning surface</td>
<td>140 – 350</td>
</tr>
<tr>
<td>Glowing surface</td>
<td>350 – 600</td>
</tr>
</tbody>
</table>

1 The separate brickwork cover around a fireplace is considered part of the protective distance. An expansion joint of at least 5 – 15 mm must be left between the hearth and the cover.
2 The protective distance is reduced by 50% using simple and 75% using double protection.
3 The protective distance is reduced by 25% using simple and 50% using double protection.
4 The protective distance for cast iron stove surfaces is 1,000 mm.
Firewood quality

All tree species can be used as firewood. Naturally, however, different tree species have different properties. It is useful to note the differences in terms of quality. Softwood (coniferous) trees, such as spruce, fir and pine, can spark a lot when burnt, so they are not ideal for use in open fireplaces. Of course, this does not prevent them from being used in enclosed fireplaces or continuously heated sauna stoves. Robinia, beech and oak in Central Europe and birch in the Nordic countries have high energy content thanks to the density of the wood. Robinia, oak, beech and birch are therefore ideal for heating ovens, heat retaining fireplaces and open fireplaces. Alder is particularly suitable for continuously heated saunas and smoke saunas.

The most important factor affecting the quality of firewood is moisture content, which determines how much of the energy content can be utilised. The ideal moisture content for firewood is less than 20 percent. The moisture content of fresh wood is generally 45 to 55 percent. After 1 to 2 years of storage time it is in an “air dried” condition with moisture content of 15 to 20 percent. Hardwood dries more slowly than softwood, and the drying time for oak is especially long. Ideally firewood should be stored for at least two years in a sunny, well aerated place. The combustion of fresh cut or moist wood in a stove provides little energy and can harm the furnace.

Dry wood that has been split into suitable sizes is easier to ignite than moist wood. Dry wood also burns more efficiently, produces less emissions and provides more heat than moist wood. The drier the wood, the greater its energy content (=net calorific value). If you burn 10 kilos of birch with a moisture content of 20 percent, two kilos of water has to be effectively evaporated, compared...
to four kilos if the moisture content is 40 percent. The energy content of 10 kilos of moist wood is 31 kWh, whereas that of dry wood is 41 kWh.

Tools that rely on human muscle power eliminate the need for environmentally unfriendly energy production and are ideal for chopping small amounts of wood. Special splitting axes are available for splitting logs, and a number of other products can also be used, such as the Smart Splitter, the Logmatic Wedge Axe and the Vipukirves Lever Axe. These products are designed to be safer, more ergonomic and more effective than traditional axes.
There is not much difference in the energy content of different tree species on a similar weight basis. In terms of volume, robinia, beech and birch have the highest energy content due to its density. All wood species contain approximately equal amounts of energy – 4 kWh/kg with a moisture content of 20 percent.

Firewood amounts are given in cubic metres. A cubic metre of stacked wood means a stack of wood that occupies a space of one cubic metre. A cubic metre of loose wood is equal to a box one cubic metre in size into which the split logs are “thrown”. This is also referred to as an “unstacked cubic metre”. Naturally, the conversion rates between the volumes in the table below will be affected by the size of the logs and how they are arranged. Firewood is usually sold in by either loose cubic metre or stacked cubic metre.

**Comparison of volumes. Drawing: VTT**

<table>
<thead>
<tr>
<th>Wood species</th>
<th>Net calorific for fuel in typical moisture content, kWh/stacked m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poplar</td>
<td>1,110</td>
</tr>
<tr>
<td>Spruce</td>
<td>1,300 – 1,320</td>
</tr>
<tr>
<td>Aspen</td>
<td>1,330</td>
</tr>
<tr>
<td>Fir</td>
<td>1,350 – 1,370</td>
</tr>
<tr>
<td>Pine</td>
<td>1,360 – 1,570</td>
</tr>
<tr>
<td>Alder</td>
<td>1,230 – 1,400</td>
</tr>
<tr>
<td>Willow</td>
<td>1,440</td>
</tr>
<tr>
<td>Larch</td>
<td>1,780</td>
</tr>
<tr>
<td>Maple</td>
<td>1,675 – 1,780</td>
</tr>
<tr>
<td>Birch</td>
<td>1,700 – 1,810</td>
</tr>
<tr>
<td>Ash</td>
<td>1,870</td>
</tr>
<tr>
<td>Beech</td>
<td>1,850 – 1,930</td>
</tr>
<tr>
<td>Oak</td>
<td>1,890 – 2,030</td>
</tr>
<tr>
<td>Robinia</td>
<td>2,040 – 2,200</td>
</tr>
</tbody>
</table>

**There is not much difference in the energy content of different tree species on a similar weight basis.**

Typical properties of firewood (moisture < 20 w-%).

In Austria one stacked cubic is equivalent to 0.7 solid cubic meters and 1.4 loose cubic meters. One stacked cubic meter of air-dried hardwood weights 410 to 550 kg, depending on the type of wood. The weight of air-dried softwood ranges from 350 to 450 kg. An important quality characteristic in addition to size and type of wood is the moisture. Fresh cut wood is usually stacked and dried in pieces of one meter with good aeration.

**Amount of firewood needed**

The amount of firewood needed each year depends on how it is used. In private houses firewood is typically burnt in fireplaces for comfort and heat, as well as to heat saunas in the Nordic countries. The amount of firewood thus depends on how frequently it is burnt. If firewood provides the only source of heating, the amount of firewood needed

**Comparison of volumes of firewood in Finland. Conversion rates according to the TTS Institute**

<table>
<thead>
<tr>
<th>Measuring unit</th>
<th>Loose m³</th>
<th>Stacked m³</th>
<th>Solid m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose m³, 33-cm split logs</td>
<td>1</td>
<td>0.60</td>
<td>0.40</td>
</tr>
<tr>
<td>Stacked m³, 33-cm split logs</td>
<td>1.68</td>
<td>1</td>
<td>0.67</td>
</tr>
<tr>
<td>Stacked m³, 100-cm unsplit logs</td>
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<td>1</td>
<td>0.62</td>
</tr>
<tr>
<td>Solid m³</td>
<td>2.50</td>
<td>1.50</td>
<td>1</td>
</tr>
</tbody>
</table>
each year depends on several factors, such as the amount of space being heated, weather conditions and the level of heat insulation. The efficiency of the fireplace or stove also affects the amount of firewood needed. The efficiency ratio of the newest storage heating fireplaces is as high as 80 to 85 percent.

If firewood provides the only source of heating, the annual consumption of heating energy is 20,000 kWh and the efficiency of the storage heating fireplace is 80 percent, 25 loose cubic metres or 15 stacked cubic metres of dried birch or beech logs will be needed to produce the required heating energy. If the fireplace is used as an additional source of heat, or if the sauna stove is heated on average twice a week around the year, and the efficiency ratio is 75 percent, around 7 loose cubic metres or 4 stacked cubic metres of dried birch or beech logs are required. If alder is burnt instead of birch, then the demand for firewood is 1.4 times greater.

Fireplace or stove manufacturer specify in their heating instructions the right amount of firewood to be used. The right amount of firewood for each heating is generally one kilo per hundred fireplace kilos. A typical fireplace in the Nordic countries weighs 1,500 kg, so the right amount of firewood is approximately 15 kg. The amount of firewood required is divided into several loads (3 to 5 kg/load).

In Italy a typical house uses about 12 stacked cubic metres of wood (18,800 kWh). In Spain weekend houses need annually about 3.2 stacked cubic metres (5,000 kWh). In Finland consumption varies a lot. The holiday homes in Finland use annually 2.7 stacked cubic metres per house. Private houses use on average 5.7 stacked cubic metres per house (9,700 kWh), and farmhouses use annually 21.6 stacked cubic metres per house (29,900 kWh) in Finland. In France a typical house uses about 5.3 stacked cubic metres per house (12,250 kWh) annually.

Example

The net calorific value of firewood as received (the moist fuel) can be calculated by the net calorific value of the dry basis according to the equation (EN 14961-1) (4).

$$q_{\text{net, ar}} = q_{\text{net, d}} \times \frac{100 - M_{\text{ar}}}{100} - 0.02443 \times M_{\text{ar}}$$  \hspace{1cm} (4)

where

- \(q_{\text{net, ar}}\) is the net calorific value (at constant pressure) as received (MJ/kg);
- \(q_{\text{net, d}}\) is the net calorific value (at constant pressure) in dry matter (MJ/kg);
- \(M_{\text{ar}}\) is the moisture content as received [w-%];
- 0.02443 is the correction factor of the enthalpy of vaporization (constant pressure) for water (moisture) at 25 °C [MJ/kg per 1 w-% of moisture].

In this example net calorific value in dry basis \(q_{\text{net, d}}\) is 19 MJ/kg.

The net calorific value for moist fuel (20 w-%) is

$$q_{\text{net, ar}} = 19 \times (100 - 20/100) - 0.02443 \times 20 = 14.71 \text{ MJ/kg}$$

If the efficiency of the stove is 80%, the net energy stored in the stove is

\(0.8 \times 4.09 \text{ kWh} = 2.6 \text{ kWh}\).

Note:

1 MJ/kg = 1/3.6 kWh/kg = 0.2778 kWh/kg
**Storage**

The moisture content of even dry wood varies according to the temperature and humidity of the surrounding air. The equilibrium moisture content of wood in a covered outdoor woodshed can vary between 15 and 25 percent depending on the season in Nordic conditions. Storing firewood correctly helps prevent the accumulation of rot and funguses. For this reason it is important to keep dried wood dry.

**Drying and storing semi-dried logs**

The ideal woodshed is spacious, well ventilated and protected from dampness and rain. If you plan to continue drying the logs in an outdoor woodshed, the storage area should be ventilated from the walls and floor. The less air and open space there is within the woodshed, the drier the logs should be before storing them there. Air should flow freely under, around and between the logs. The flow of air beneath the woodpile can also be ensured with the appropriate floor structures or supporting logs. On flat concrete floors less space is required beneath the logs, and thin trunks or empty pallets can be used to support them. If the wall surface is flat, the flow of air can be ensured by placing thin trunks or planks between the wall and the stack. In outdoor shelters without floors, the airflow should be ensured in the same way as with outdoor stacks.

Space should be left between the stacks whenever possible. The more even the sides of the stacks are, the better the airflow. There should be sufficient ventilation between the woodshed and open air to prevent mould.

The woodshed should be large enough to store enough firewood for one year or half a year at a time. In most of the houses an average of around 6 cubic metres of stacked firewood is consumed a year. This amount of firewood will fill an area of approximately five square metres. The storage area should be made big enough to allow sufficient space around the woodpiles for safe and unimpeded access to the wood.

A good woodshed will have large door openings and low thresholds to facilitate access. Low thresholds make it easier to fill the woodshed.
Ideally the door opening should be wide enough to allow logs to be brought in on a pallet. The door of the woodshed should face the building into which the logs will be carried.

The correct location of the woodshed will help make it convenient to use. The woodshed should be situated as close to a road or path as possible, and there should be sufficient space around the woodshed for the logs to be unloaded before being stacked. There must be sufficient room to operate a truck, loader or trailer, and the road or path must be able to carry the weight. The distance between the woodshed and the building in which the logs will be burnt should be as short as possible. Firewood is often needed most in the dark wintertime. The woodshed and paths should be sufficiently well lit to ensure safe passage.

**Storing dry logs**

Dried logs can also be stored indoors. However, close attention must be paid to fire safety regulations, occupational safety aspects and convenience when planning the storage of firewood.

To make using your fireplace as convenient and easy as possible, firewood should be brought inside into the warmth one day before it is burnt. Humidity in the room will condense on the surface of cold wood, making it harder to light. Firewood should be stored near the fireplace in such a way that any risk of accidentally combusting is eliminated. Different safety distances are recommended for different fireplaces, and these must be adhered to.

It is recommended that a maximum of 0.5 cubic metres of firewood is stored inside unless stored in a separate compartmentalised storage area.
Compartmentalised storage areas inside houses include boiler rooms, car garages and fuel storage areas. Even if a car garage or other motor vehicle shelter is compartmentalised, motor vehicles and firewood must not be stored together in the same area at the same time.

In Finland there is a regulation that fuel storage areas must be compartmentalised into a separate fire compartment. The fire resistance rating for compartmentalised areas in houses usually must be able to resist fire for 30 or 60 minutes before spreading. The surface materials of inner walls and ceilings have their own requirements that must be adhered to. Floor materials do not have their own fire safety requirements. If a fuel storage area is situated in the basement of the building, the building material requirements are more stringent.

In Italy, Spain, France and Austria there are no special regulations on the storage of fuel for heating systems with an output less than 5 kW. The only recommendation is to keep the fuel in a dry place so as not to affect its quality. In Italy heating systems with an output of more than 35 kW have to abide by the ministerial decree of 28 April 2005.

Outdoor woodsheds also have their own fire safety requirements in Finland. These vary according to the distance from the woodshed to other buildings. If the distance between the structures is more than eight metres, no additional fire protection is needed to protect one from the other. If the distance is less than eight metres, structural protection is required to limit the spread of any fire as much as possible, usually by compartmentalising. There are also restrictions based on the distance from the woodshed to the border of the property on which it stands. These restrictions may vary according to municipality and address.

Attention must be paid to fire safety risks also when temporarily storing firewood. Firewood should not be stacked against the outer walls of buildings. If the woodpile catches fire or is lit on fire, the entire building could burn down. Woodpiles can also cause structural damage if stacked against outer walls.

Local fire and building inspection officials can provide advice about fire safety, including how to compartmentalise and where to locate woodsheds.
Purchasing firewood

Products, characteristics, quality and packaging

In addition to harvesting firewood yourself, it is also possible to purchase ready-to-use wood-based fuels. The most common of these include firewood, wood pellets and briquettes.

Firewood is sold in the form of chopped wood in various quantities and made from different wood species. Professional suppliers of chopped wood prepare their products in accordance with quality guidelines, as a result of which the quality of the chopped wood is generally better than firewood that has been harvested yourself. The common lengths of firewood in Europe are 25 cm, 33 cm and 50 cm and diameters 8 to 15 cm. The CEN standard EN 14961 for firewood quality is currently being developed and will be published in 2009.

In Austria logwood is defined by the standards ÖNORM M 7104 and M 7132. Logwood is mainly supplied by small-scale agriculture and forestry or by self-supply. It can be differentiated between hardwood and softwood. Logwood is also classified according to the size. Logwood is ready to use firewood that has been cut into the appropriate length. The most common lengths are 25 cm, 33 cm, 50 cm and 100 cm.
When purchasing firewood, it is helpful to consider how it will be used. When used as a source of heat, the most important characteristic of logs is sufficient dryness. The right size of the logs for their intended use is also important. Possible funguses and mould on the logs will not affect how they burn, but they may cause various symptoms, especially to the eyes and respiratory systems, to the user when handling the logs. The evenness of the cut ends of the logs and other esthetic qualities do not play a major role in how the wood burns, but they can affect how easy they are to handle.

Logs are sold either loose or in packages. Loose logs are usually delivered to the customer in a trailer. After the logs have been unloaded, it is then up to the customer to move them into storage so they do not get wet.

Logs are also sold in various forms of packaging, the most common of which include mesh sacks, mesh bags, plastic bags with ventilation holes, plastic wrapping and cardboard boxes. The most common packaging size is one cubic metre packed on a pallet or in a mesh sack. The size of mesh bags, plastics bags with ventilation holes, plastic wrapping and cardboard boxes is usually 30 or 40 litres, which holds 10 to 15 kg of chopped wood. The most convenient packages contain enough firewood and kindling for a single burning. Packaged firewood is often sold at gas stations and at hardware and farm shops, as well as directly from suppliers.

In some places a firewood service is available in which the supplier carries the ready-to-use logs into the customer’s house, for example on a castor pallet. This service is ideal if you do not have your own storage areas for dry wood, but it requires that the delivery truck is able to get close to the house.

Wood pellets are a dry, compressed and uniform biomass fuel that is made from the residues and by-products of the mechanical wood-processing industry. The raw material is mostly dry sawdust, grinding dust and cutter shavings. Pellets are cylindrical in shape and usually have a diameter of 6 or 8 mm. Their length can vary from 5 to 40 mm. The energy content of wood pellets is 4.8 kWh/kg and the moisture content less than 10 percent. Wood pellets are used in special pellet boilers equipped with a pellet burner, as well as in pellet stove. A specially designed pellet accessory must be used for burning pellets in ordinary fireplaces.
Wood pellets are sold either as bulk goods in 500 to 1,000 kg large sacks or in small 15 to 20 kg sacks. Loose pellets can be ordered directly from the manufacturer. Sacks can also be purchased from hardware and farm shops.

Wood briquettes are also made from the residues and by-products of the mechanical wood processing industry. The size of briquettes is larger than that of pellets, the smallest generally having a diameter of 50 to 75 mm. Briquettes are compressed into cylinders or bricks. The energy content of briquettes by weight is the same as for wood pellets. Briquettes are also supplied in bulk and packaged. When used for heating it is important to note that briquettes contain more than two times the energy per volume of chopped logs.

**E-trading**

Buying and selling over the internet is increasingly popular, also in terms of firewood, pellets and briquettes. Websites for both individual firewood suppliers and firewood services in general can be found on the internet. Several services are available in Europe (see www.eufirewood.info).

These websites offer search engines that make it possible to find the details of firewood suppliers by location and product. The prices and quality of firewood can be easily compared and orders made by filling in the order form or by e-mail, letter or phone. Online retailers have delivery and sale conditions that suppliers must adhere to. The seller must ensure that his wood meets the quality criteria set out in the terms and conditions. Payment takes place directly between the buyer and seller. Home delivery, delivery times and other related services are also agreed directly between the parties involved.
Why combustion air is needed

Theoretically wood requires approximately 3.7 m³ of air per kilo when burning. In practice the air coefficient for burning (λ) in fireplaces or stoves with doors is 2 to 2.5, meaning that 7.5 to 10 m³ of air is used per kilo of wood. In newer models the air coefficient is slighter lower, 2.0 to 2.2. In open fireplaces the air coefficient is 10 to 30, meaning that 40 to 110 m³ of air is used per kilo of wood.

Combustion air is usually divided into at least two parts: primary air and secondary air. In fireplaces and stoves equipped with a traditional fire grate, primary air is fed to the fire through the ash door beneath the fire grate. Secondary air is fed through air inlets or hatches built into the fireplace or stove and is also used to help keep the glass door clean from the inside.

In fireplaces and stoves equipped with modern fire grates, secondary air is fed much more efficiently. At the same time the amount of primary air is limited during powerful burning to help ensure that the gasification of the wood does not occur too rapidly. In new models primary air is usually fed to the fire from below the fire grate, while secondary air is focused on two areas: on top of the fire and to the front of the fireplace or oven. The purpose is to create an optimal mixture of combustion air and combustion gases, as well as to help keep the flue gases in the fireplace or oven long enough to achieve a clean burn. As a result, emissions have been significantly reduced.

In stoves without fire grates, such as baking ovens and traditional tiled stoves, primary air is fed through the ash door to the front of the fire. Secondary air is adjusted by air inlets or hatches, or it can be fed in through a separate pipe at the rear of the stove.

The amount of combustion air needed depends on the burning phase. The need for combustion air is greatest when the wood’s pyrolysis products (gases) are burning. Combining air with the gases that are formed during the burning process is important. The need for secondary air is greatest when the gaseous substances burn. When only embers remain, hardly any secondary air is required, as only the embers are burning and no more pyrolysis gases are being formed at this stage.

New stove models come with precise instructions for feeding combustion air to the fire. It is hard to regulate the optimal amount of combustion air inside the traditional fireplace of stove. To achieve a good burn and clean flue gases, the amount of air should be adjusted continuously. If dark smoke comes out of the chimney during burning, this is a sign of non-optimal burning. Usually this occurs if the wood is gasifying too rapidly and there is insufficient combustion air to burn all the gases. If the flames reach up into the flue, there is too much combustion air.
Importance of the smoke flue and chimney

The purpose of smoke flues and chimneys is to remove the flue gases from the fireplace or oven into the outside air. The amount of draught in the chimney depends on the difference in densities between the flue gases and the outside air (kg/m³), as well as on the height of the chimney. The hotter the gases flowing through the chimney are, the bigger the difference in densities between the flue gases and the outside air. The temperature should be at least 120°C to ensure sufficient draught. This also prevents water from condensing on the flue surfaces.

Chimneys are designed and specified according to the fireplace or stove and the fuel used to ensure sufficient draught, fire safety, long life and solidity. EN standards have been created for testing fireplaces and stoves. These tests provide the data required for selecting and specifying the right chimney. The design of the fireplace or stove also determines whether good draught is created. The flow of smoke through channels should be made as smooth as possible, and tight corners and vertical surfaces should be avoided. To improve draught the chimney should be located on top of the roof. Chimneys should be made as vertical as possible. The top of the chimney should be protected from the rain and snow. When designing covers for chimneys, the effects of snow and need for chimney sweeping are taken into consideration. The additional height created by the cover is not counted when determining the length of the chimney. Chimneys and chimney covers are manufactured from A1-class non-combustible materials.

In addition to the design of the flue, terrain and weather conditions can also affect draught. If the house is situated beside tall forest, the chimney should be tall. Creating good draught is harder in low pressure conditions, as the difference in densities is small. Finland’s construction regulation manuals (RakMk E3 and E8) include guidelines and regulations concerning the fire safety of flues and chimneys, as well as fireplaces and stoves. These manuals also include information about specifying flues and chimneys. Manufacturers and importers of factory-built fireplaces and stoves must provide data about the amount and temperature of flue gases according to European fireplace and stove standards.

The size of smoke flues that are built onsite usually varies between full-size (approximately 140 x 270 mm³) or half-size (approximately 140 x 140 mm³) flues. Open fireplaces require full-size or larger flues (300 cm³). Full-size flues are suitable for fireplace stoves and larger heating stoves and baking ovens. Half-size flues are generally sufficient for smaller heating stoves, baking ovens and cooking stoves. Smoke flues are made from bricks or stainless steel (Finnish construction regulation manual E3 and RIL 245-2008 Small flues).

Various factory-built flues have become more popular recently. These are installed on saunas, pellet stoves and light fireplaces, for example. Factory-built flues and chimneys have their own EN standards and CE requirements.

When a fireplace or stove is not in use, excessive drafts are prevented by using a chimney damper. Dampers are not permitted in all countries. These are designed to be easy to use and effective, and the materials used for them comply with the construction material of the flue. The damper is located inside the flue or where the fireplace and flue meet. Drafts can also be prevented by a gas-proof door in front of the fireplace or stove. The damper should be located as close as possible to the border between hot and cold areas. Sliding and rotating dampers are installed in such a way that they are easy to clean. Modern dampers must include a small gap (3 percent of surface area) to allow carbon monoxide from embers to escape through the chimney.

When escaping the fireplace or stove, the smoke begins to cool immediately. If the flue is the right size, the temperature of flue gases should decrease by 10°C every one metre. The temperature of flue gases should not decrease too much to prevent water vapour, acids, pitch and tar from collecting on the surfaces (the dew point). Cooling and the concentration of smoke that occurs as a result depend on such factors as the design and specifications of the smoke flue and the temperature of the outside air.

EN standards have also been introduced for small flues. Flues are categorised according to temperature, the highest category being T600 (temperature of flue gases 700°C). Manufacturers of fireplaces and stoves must specify flues complying with the right heat category. In addition, the manufacturer or importer must state the amount of flue gases that are created by the fireplace or stove.
Diagrams of half-size and full-size flues.

Flues in one row

Flues in two rows

The minimum height of chimneys for fire safety in Finland.

The tops of brick chimneys can be protected with a cover. Photo: Kauhabisnes Oy

Sliding damper and summer flue damper. Photos. Polar Metalli Oy
<table>
<thead>
<tr>
<th>Requirements</th>
<th>System</th>
<th>Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>stable</td>
<td>moisture resistant chimney</td>
<td>universally useable</td>
</tr>
<tr>
<td>fire-resistant</td>
<td></td>
<td>intensive to moisture</td>
</tr>
<tr>
<td>flue gas leakproof</td>
<td></td>
<td></td>
</tr>
<tr>
<td>acid-resistant</td>
<td></td>
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<td>heat-insulated</td>
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<td>moisture resistant</td>
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<td>countercurrent operation</td>
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<tr>
<td>stable</td>
<td>triple-wall (mass-) insulated chimney</td>
<td>large area of application</td>
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<tr>
<td>fire-resistant</td>
<td></td>
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<tr>
<td>flue gas leakproof</td>
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<td>acid-resistant</td>
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<tr>
<td>heat insulated</td>
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<td>stable</td>
<td>double-wall (mass-) insulated chimney</td>
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<td>fire-resistant</td>
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<td>small resistance of friction</td>
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<td>flue gas leakproof</td>
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<td>freely movable inside pipa</td>
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<td>flue gas leakproof</td>
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</tbody>
</table>

Different type of chimneys in Austria. Source: ÖNORM EN 13384-1
If the water vapour in the smoke condenses on the surfaces of the flue, brick chimneys can begin to crumble. The bricks absorb the moisture, and when the moisture freezes it expands and breaks the bricks. This phenomenon causes chimneys to crumble. Dampness can also be created by the chimney’s own heat losses and excessive size. Heat losses are created in older houses, for example, where non-insulated chimneys pass through cold attics. This causes the flue gases to cool excessively. The same occurs if the flue is too big, causing cold air to flow down the sides of the flue. This cools down the upper part of the chimney. In addition, flue gases have more time to cool inside large flues due to the slower flow.

The tops of brick chimneys are protected from the weather using a reinforced concrete slab that directs the smoke outwards or with a special chimney covers. Chimney covers must be fitted in such a way that they allow access for chimney sweeping.

In the Nordic countries, if a brick chimney extends beyond 0.8 metres above the top of the roof, and if the fireplace or flue become covered in pitch, the smoke flue should be insulated and covered.

In Austria chimneys are planned according to the EN standard 8- (see References).

In France the chimney exit has to be 40 cm higher than any ridge in an 8 m radius without obstruction. The flue has to be at least 5 cm lower than the ceiling of the room where the heating device is located. In order to prevent condensation and to facilitate draught, an insulated flue is preferred. Moreover, the outside temperature of walls in an inhabitable room should not rise above 50°C. In non-inhabitable rooms, this temperature should not rise above 80°C.

The smoke flue has to be as straight as possible. According to the regulation, one direction change is authorized, meaning two 45° elbows.

The distance between the outside wall of the flue and all inflammable depends on the temperature class of the flue used.

The implementation of a draft regulator on the connection duct or the smoke duct is necessary to preserve a constant value for the draft of the device nozzle and thus constant efficiency.

The connecting flue:
- has to be visible and removable along its whole length;
- has to be able to expand freely;
- is jointed with the female part in the direction of the smoke duct;
- must have a section at less equal to the device nozzle – no reducer should be placed on the device nozzle;
- can contain a reducer on the connecting part to the chimney flue; and should be as short as possible.

In Italy the rule UNI 10683 - September 2005 – “Heat generators fired by wood or other solid fuels. Installation requirements” is applied to chimneys and flue. This standard establishes requirements for the design of the chimney, flue and channels. The standard “UNI 7 9 December 2001 Plant for household gas-powered distribution network. Design, installation and maintenance” provides advice on the exit of the chimney to gas plans and, without a specific rule for biomass plants, reference is made to this rule.

**Flue requirements in France. Source: Biomasse Normandie**

If the roof rake is lower than 15° and for flat roofs, the chimney exit has to be at least 1.20 m higher than the exit point of the roof and at least one meter higher than the acroterion if this is higher than 20 cm. The chimney has to be waterproof, with a diameter adapted to the device connected and without any diameter reduction. Only one device can be connected to the flue.

The dimension of the flue has to be linked to the power of the device. In any case, the minimum diameter is 18 cm.
For natural drafts, the combustion air should be sufficient to avoid the possible reversal of the draft.

Air is drawn into the stove from the external environment during regular operation. A 50 mm diameter intake hole of the stove is located at the back of the stove. If an external wall is located behind the stove, a hole with a diameter of 8 to 10 cm (with a section free of at least half the free section of the chimney, but no less than 200 cm² for the open appliances, and 80 cm² for closed appliances) must be made for the air intake at a height of 20 to 30 cm from the floor. An aeration grid must be installed externally; particularly for windy and weather-beaten locations, additional anti-rain and anti-wind protection may be needed. Any possible obstruction from the inside or outside of the hole should be avoided.

If there is no external air intake from the back wall, another location should be found for the air intake close to the stove, as long as the room is not used as a bedroom or bathroom and is not at high risk for fires.

- If it is not possible to make a hole from the exterior, the air intake must be realised in some other fashion (a grate in the wall, an outlet through a curtain box, a rolling window shutter).
- The UNI 10683 standard forbids the withdrawal of combustion air from garages, or from storage rooms with combustible materials or activities that could be subject to fire danger.
- The air intake must not be connected to the stove with a tube.
- Whenever the stove is in the same location with other heating systems, the amount of air intake available must be sufficient for all apparatuses. Simultaneous use with gas type B (natural draft), heat pumps or ventilation ducts of a collective agreement is forbidden.
- The flow of air can also be obtained from an adjacent room, provided that the flow is free through permanent openings. In the adjacent room there must not be additional generating heat equipment or other ventilation intakes.

In Spain chimneys must be situated on the roof of the house or building in all houses, both in new buildings or old buildings with renovated heating systems.

In Spain chimney dimensioning will follow UNE norms for chimneys indicated in the Thermal Installations Spanish Code. The chimney should be as vertical as possible to avoid dust accumulation (maximum 45° is allowed in Spain and in France and 30° in Finland).
Chimneys should have a length of at least one metre above the top peak of the house.

Flue gases from chimneys should not affect surrounding buildings.

The stack should be as vertical as possible. Source: ESCAN.

Indoor walls should have no obstacles for the smoke.

Chimney ends should have enough room for flue gases to expand easily. The same length as the diameter of the chimney is the minimum requirement.
**Replacement air and mechanical ventilation**

If the house is equipped with mechanical air conditioning, replacement air must usually be supplied separately to ensure draught. Air conditioning creates slightly lower pressure indoors, which is less ideal for fireplaces and stoves. The air conditioning should be designed so that one replacement air valve is situated close to the fireplace or stove. Fireplaces and stoves can also be equipped with a fresh air channel with a diameter of approximately 10 – 15 cm that runs beneath the floor. The fresh air is fed to the bottom of the fireplace or stove, but care must be taken that this supply of fresh air can be closed when the fireplace or stove is not in use.

Kitchens usually have effective outward ventilation, which can make it hard to light the fire. If the stove or fireplace is located in the kitchen, there should be a window that can be opened to supply replacement air if necessary. While heating the fireplace or stove, the air conditioning should be set to remove as little air as possible or turned off altogether. The air-conditioning system can be designed so that it can be turned off for a few hours at the press of a button.

Open fireplaces use 40 to 110 m³ of air for the combustion of one kilo of wood. Photo: Courtesy of ofi
Clean and efficient combustion

The theory of combustion

Wood is composed primarily of carbon (C) (47-52% by weight), oxygen (O$_2$) (38-45%) and hydrogen (H$_2$) (6.1-6.3%). Structurally wood is composed of cellulose (40-45%), hemicellulose (20-35%) and lignin (15-30%). These proportions are based on the weight of the dry matter. The nitrogen content (N) is low (less than 0.5%) and the sulphur content is less than 0.05%. Generally the mineral content is less than 1%. The key minerals are: potassium (K), magnesium (Mg), manganese (Mn), sulphur (S), calcium (Ca), chlorine (Cl), phosphorous (P), iron (Fe), aluminium (Al) and zinc (Zn).

Combustion refers to the chemical reaction of the material with oxygen, during which energy is released in the form of heat.

When solid fuels are burnt, the following phases occur:
- initial heating to approximately 100°C
- evaporation of moisture
- pyrolysis and the ignition and burning of pyrolysis gases
- burning of residual charcoal.

In terms of individual pieces of fuel (logs), these phases are usually consecutive. In fireplaces and ovens where the size of fuel pieces is large, the surface layer may dry and undergo pyrolysis and thus also ignite, even if there is moisture and fuel that has not undergone pyrolysis inside the wood. In fireplaces and ovens where the fuel is added by batches, each batch is usually burnt down to embers before a new batch is added.

The combustion of solid fuel pieces depends on their:
- chemical properties (reactivity, pyrolysis temperature, calorific value),
- structural properties (size, density and porosity), and
- physical properties (heat capacity, heat convection).

The combustion of the fuel depends on heat transfer, substance transfer and the speed of the chemical reaction. Usually one of these three phenomena limits the combustion speed. Normally when burning small fires (with large pieces) the combustion process is limited by heat and substance transfer.

The composition of firewood. Source: Eija Alakangas, VTT
Of the combustion phases, the evaporation of moisture, ignition and pyrolysis are processes that expend heat. The burning of pyrolysis gases and residual charcoal in turn are processes that release heat.

The ignition phase consists of the heating and drying of the fuel and the initial phases of pyrolysis. During the ignition phase large amounts of vapour, evaporating hydrocarbons and pyrolysis gases that form at low temperatures are released from the wood. Once the temperature and content of the pyrolysis gases reach a high enough level, they ignite, which can be observed in the form of flames. During the combustion phase the temperature of the fuel pieces increases with the flames, resulting in a powerful combustion phase and a decay (cooling) phase. The speed of pyrolysis is at its highest during the combustion phase, while the formation of pyrolysis byproducts slows down during the decay phase. In the final so-called char burning phase pyrolysis byproducts are by and large no longer formed, and the fuel burns slowly without flames.

**Evaporation of moisture**

Moisture begins to evaporate at temperatures of 100-105°C. The surface of the wood begins to dry at temperatures below 100°C, as the temperature inside the wood can exceed 100°C due to the high pressure. Source: Eija Alakangas, VTT

The moisture content of the fuel has a direct effect on pyrolysis and combustion. The more moisture there is, the slower the pyrolysis and combustion processes are. The moisture content also has an effect on the amount of pyrolysis byproducts and residual charcoal.

Moisture is removed from the fuel in different ways depending on the speed of heating and the amount of moisture. Moisture can move within fuel particles in either liquid or gaseous form. The movement of moisture within the fuel usually inhibits the combustion. The heat from the fire usually transfers to the surface of particles (hot flue gas, radiation) so rapidly that there is not enough time for the moisture to transfer from the inside to the surface as fast as it is evaporating. The evaporation of moisture requires heat, just like pyrolysis. At first the moist fuel piece reaches its drying temperature, after which most of its water content vaporises. As the fuel dries the temperature of the fuel increases, and the pyrolysis phase begins. During the pyrolysis phase the large molecules in the fuel (such as cellulose, hemicellulose and lignin) are broken down, creating large amounts of combustible gases, liquid tars and certain inert gases.

**Pyrolysis**

Pyrolysis begins at temperatures of 100-105°C. The molecules begin to break down at 200°C. Source: Eija Alakangas, VTT
The pyrolysis of wood fuels consists primarily of degradation reactions under the influence of heat. Typically pyrolysis byproducts burn as flames around the fuel piece, which releases more heat promoting more pyrolysis reactions.

During pyrolysis the substances contained in the wood are broken down into other compounds. Hemicellulose degrades at approximately 200-350°C, cellulose at 250-450°C and lignin, which is the least reactive, at 200-500°C. At a temperature of 400°C all substances that evaporate have been removed and the gasification slows down. Pyrolysis byproducts can be divided roughly into light hydrocarbons and tars (heavy hydrocarbons), as well as into combustion byproducts (water and carbon dioxide) and unburnt gases (carbon monoxide and hydrogen). The pyrolysis byproducts that are formed and the speed of pyrolysis depend largely on the temperature. When wood is heated slowly to 800-900°C, the amount that undergoes is approximately 80 percent of its mass, which represents approximately 50 percent of the wood’s heating value. During slow pyrolysis the fuel is heated gradually (under 10°C/second) and to a low temperature (less than 500°C), creating large amounts of tars and residual charcoal. When the temperature is increased faster and higher, more light hydrocarbons and less residual charcoal are formed.

Ignition and gas burning

When the temperature rises above 180°C, gases are ignited momentarily. At temperatures above 225°C the gases that are formed continue to burn after ignition.

Source: Eija Alakangas, VTT

Wood ignites as a result of the pyrolysis gases that are formed around it. Ignition occurs when the heat output of the reactions exceeds the heat losses (approximately 270°C). Ignition depends on the surrounding temperature, the ratio of gases to oxygen, and whether there is an external source of energy nearby. The ignition of wood depends on the moisture content of the fuel, the size of the fuel piece and the surrounding temperature. Moisture inhibits ignition, as the vaporisation of the water consumes energy and the vapour that is released from inside the wood cools its surface. Large fuel pieces take longer to ignite due to the slower pace of heating and drying. Dry wood ignites at 200-300°C. The mixture of gases ignites without flames at 330°C. Ignition occurs immediately with dry kindling, as the pyrolysis gases that are required for combustion begin to form at once. The surface temperatures of particles during ignition are 380-600°C. The flame extinguishes when the internal temperature of the particles is 400°C.

In the pyrolysis phase the pressure change in the wood is fast compared to the burning phase of the residual charcoal.
Combustion of residual char

As pyrolysis progresses the C/H ratio of the fuel increases, creating so-called residual char. The combustion of residual char is a flameless combustion phase in which combustion (the oxidation of the fuel) occurs on the surface of the fuel piece. Although residual char generally accounts for just 10-30 percent of the dry mass of biomass fuels, it provides 25-50 percent of the total energy released during its combustion. This is due to the high heating value of the residual char. The combustion of residual char is the slowest phase.

In residual char with high carbon content, there is little gasification and the fuel oxidises on the surface or inside cracks.

Clean combustion

The combustion of logs is a batch-burning process. Fuel is added to the fireplace or stove in relatively large batches and topped up at intervals. In a continuous combustion process, fuel is added by a constant flow of small amounts. For example, pellet stoves operate on this principle.

Combustion efficiency and emissions vary according to

- the temperature of gases in the fireplace or stove,
- the amount of oxygen (combustion air) and mixture of the combustion air,
- the temperature of the inner walls (size and materials of the fireplace or stove) and
- the fuel properties (size, moisture content, position within the fireplace or stove and amount).

In order for the combustion to be as clean as possible in the batch-burning process, the fuel must be dry, there must be the right amount of combustion air for each phase, and the combustion air must mix well with the gases released from the wood. In addition, additional batches must be added at the right time and the fuel positioned correctly. The design of the fireplace or stove is only one factor that can help ensure clean combustion. The user can also play a big role in the formation of emissions.

Small pieces of kindling should be used when lighting a fire. Only a small amount of logs and kindling should be used. When the fuel pieces are small, the surface area is relatively large, which allows rapid ignition.

Following ignition more wood can be added, but the fireplace or stove should not be filled. To facilitate clean combustion, fuel should be added in small batches to prevent sudden variations in the combustion process. Adding too much fuel at a time causes too many gases to be formed, creating imperfect combustion. The oxygen in the combustion air is insufficient for perfect combustion, and not enough mixing occurs. In addition, some of the pyrolysis gases that are released from the wood are not burnt. This creates flue gas emissions that are detrimental to your health. They also lower the efficiency.
Fireplace and stove emissions

The formation of emissions

The combustion of all fuels is based on a chemical reaction in which fuel reacts with the available oxygen and produces heat energy. The ideal combustion of hydrocarbons in fuel produces only carbon dioxide and water. The formation of emissions depends on the properties of the fuel (chemical composition, moisture content, size), the amount of fuel per unit of time (kg/hour), the amount and mixing of combustion air, the design of the fireplace or stove, and how the combustion is managed. Efficient combustion produces low emissions.

Each combustion process creates water (H₂O) and carbon dioxide (CO₂). If the fuel contains sulphur, sulphur dioxide (SO₂) is also created. Since the sulphur content of wood fuels is low, generally less than 0.05% of the weight of the dry matter, the amount of sulphur dioxide in the flue gas is small. Usually combustion is imperfect and carbon monoxide (CO) and other harmful emissions, such as particle emissions and hydrocarbons (CxHy or OGC), are formed when the carbon is burnt. The formation of nitrogen oxide (NOx) depends on the temperature of the fireplace or stove and the nitrogen content of the fuel. The nitrogen content of wood is less than 0.5% of the dry weight. If the temperature exceeds 1400°C, so-called terminal NOx is formed. However, such temperatures are seldom reached in ordinary fireplaces or stoves. If the fuel contains chloride (Cl), extremely toxic furans and dioxins can be formed in poor or poorly managed combustion conditions. These are generally formed when burning waste.

The emissions from small fires are referred to as local emissions. They are released from low heights and affect in particular the surrounding air quality. The emissions from small wood fires cannot be controlled as well as those from large furnaces that utilise particle separators and more advanced control technology.

The emissions of fireplaces and small stoves depend on many factors, including:

- the quality of the fuel (moisture content, size),
- the composition of the fuel (potassium, sodium and chloride content),
- the combustion method (by batches or continuous)
- the technology and maintenance of fireplace or stove
- how they are managed (settings, ignition and refills), and
- the heating method (storage heating or direct heating).

The quality of the fuel and how it is used have the biggest effect on emissions. They have a big impact on the creation of soot and condensating hydrocarbons, which play a vital role in the formation of particulates. In batch combustion, such as when heating fireplaces, hydrocarbons are created mostly at the start of the combustion process and during the most active pyrolysis phase. Inorganic elements, such as potassium (K), sodium (Na) and chloride (Cl), are easily vaporised and create inorganic compounds in the form of particulates smaller than 1 μm, some of which are transported with the flue gas. A significant share of the particle emissions are created during the pyrolysis phase. Most hydrocarbon emissions are also created during the pyrolysis phase. Carbon monoxide emissions are also created during the char burning phase.

Wood contains large quantities of potassium (K), which is vaporised during combustion and creates fine particles. In other words, fine particles cannot be totally eliminated even with the most efficient combustion due to the properties of the fuel. However, most of the fine particles from burning logs are the result of incomplete combustion.

Carbon dioxide emissions

Fossil fuels cause the greenhouse phenomenon, and wood does not cause net carbon dioxide emissions since trees trap the carbon dioxide released when wood is burnt.
### Typical carbon dioxide emissions of different fuels

<table>
<thead>
<tr>
<th></th>
<th>gCO₂/MJ</th>
<th>gCO₂/kWh</th>
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</thead>
<tbody>
<tr>
<td>Milled peat</td>
<td>105.9</td>
<td>381.2</td>
</tr>
<tr>
<td>Sod peat</td>
<td>102.0</td>
<td>367.2</td>
</tr>
<tr>
<td>Peat pellets</td>
<td>97.0</td>
<td>349.2</td>
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<tr>
<td>Wood</td>
<td>109.6*</td>
<td>394.6*</td>
</tr>
<tr>
<td>Heavy fuel oil</td>
<td>78.8</td>
<td>283.7</td>
</tr>
<tr>
<td>Light fuel oil</td>
<td>74.1 - 76.7**</td>
<td>266.8 - 276.2**</td>
</tr>
<tr>
<td>Natural gas</td>
<td>55.0</td>
<td>198.0</td>
</tr>
<tr>
<td>LPG</td>
<td>62.5</td>
<td>225.1</td>
</tr>
<tr>
<td>Coal</td>
<td>94.6 - 96.5**</td>
<td>340.6 - 347.3**</td>
</tr>
</tbody>
</table>

* Carbon dioxide emissions from wood are not included in carbon dioxide emissions, and the net emissions of wood fuels are 0.
** National difference

### Particles and fine particles

Since the parameters of particles – mass, number, size, form and composition – are interrelated, particle emissions should be analysed in terms of all of these.

Particle content refers to the mass of particles in dry flue gas (mg/Nm³) reduced to the desired oxygen content, which is usually 13 percent in fireplaces and 10 percent in small boilers.

Specific emissions refer to the mass of particles per amount of energy burnt (1 mg/MJ = 3.6 mg/kWh).

Fine particles refer to particles with a diameter of less than 2.5 μm (PM2.5). One μm equals 0.001 mm. Fine particles can be categorised according to size (D = diameter) as follows:

- ultrafine particles 0.001 < D < 0.1 μm,
- accumulated particles 0.1 < D < 1 μm, and
- coarse particles D > 2.5 μm.

The share of fine particles of total suspended particle mass varies according to combustion method and conditions. In addition to mass, fine particles are also described by their number (per cm³) or by specific emissions (mg/MJ or mg/kg burnt wood).

Fine particles come from remote sources, from transportation, from light dust and sea salt, and from burning and other sources. Amount of these estimates vary according to different sources.

The smallest particles can be carried deep into respiratory systems, causing an increase in asthma symptoms and respiratory and heart diseases. With the exception of soot particles, fine particles generally have a cooling affect on the atmosphere in terms of climate change.

Batch combustion and continuous combustion create different levels of emissions. There are also considerable variations in the amount of emissions produced by each type of burning. Small stoves create total particle emissions (TPS) of less than

![Comparison of the net carbon dioxide emissions of a cubic metre of birch wood and light oil containing the same amount of energy](image)

**How fine particles enter your lungs.**
200 mg/MJ on average. The carbon monoxide, hydrocarbon and particle emissions from batch burning are higher than those from continuous combustion.

Continuous combustion (for example in pellet stoves) creates approximately 20 mg/MJ of fine particles and as little as 5 – 10 mg/MJ. Particulate emissions from fireplaces and stoves vary considerably depending on the quality of the fuel and how the fireplace or stove is used. The hydrocarbon and carbon monoxide emissions from the newest heat retaining fireplaces and stoves are a tenth those of traditional fireplaces and stoves.

The particle content depends on what measuring system is employed. As many different systems are used, their results cannot be compared directly. For all results to be comparable, standardised particle measuring systems should be employed.

**Emission testing for fireplaces and stoves**

In Finland emissions testing for fireplaces and stoves is not yet required, but in Austria, France and Italy they are required. Finnish fireplace and stove manufacturers have traditionally tested the emissions of their products in order to obtain qualification approval in Austria, Sweden, Germany and the USA. In many countries qualification approval for fireplaces and stoves has required emissions testing. The Finnish Ministry of Environment has proposed a new legislation (D8: Emission regulations and efficiency requirements for wood burning appliances, Ministry of Environment, Regulations and guidelines 2008). This decree proposal is at present being circulated for commenting. The proposed limit values for fireplaces and stoves are following: CO 0.17 % calculated in 13% oxygen (3,000 mg/Nm3, calculated in 10% of oxygen content) and efficiency at least 70%.

In the near future, all fireplaces and stoves will have to have CE markings and fulfil new emissions and efficiency requirements. CE markings alone will not ensure that these requirements are met.

The key types of emissions that are measured are particle, carbon monoxide, hydrocarbons and NOx emissions. Research has also been carried out on the formation and quantities of other compounds.

New EN standards have been created for testing fireplaces, heat retaining fireplaces and stoves, fireplace inserts, cooking stoves, pellet stoves and pellet burners (see References). Several other equipment standards are under preparation, such as for multifired sauna stoves. Harmonised product standards are being created for CE marking purposes. Since the requirements for CE marking

### Efficiency limits for small scale combustion systems in Austria. Source: ofi

<table>
<thead>
<tr>
<th>Small scale combustion systems for solid fuels; central heating systems</th>
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<tbody>
<tr>
<td><strong>Manually fed</strong></td>
</tr>
<tr>
<td>Up to 10 kW</td>
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<tr>
<td>10 to 200 kW</td>
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<tr>
<td>More than 200 kW</td>
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<tr>
<td><strong>Automatically fed</strong></td>
</tr>
<tr>
<td>Up to 10 kW</td>
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<tr>
<td>10 to 200 kW</td>
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<tr>
<td>More than 200 kW</td>
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### Emissions limits for small-scale combustion systems in Austria. Source: ofi

<table>
<thead>
<tr>
<th>Systems for solid fuels</th>
<th>Emissions limits [mg/MJ]</th>
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<tbody>
<tr>
<td></td>
<td>CO</td>
</tr>
<tr>
<td><strong>Manually fed</strong></td>
<td></td>
</tr>
<tr>
<td>Biomass fuels</td>
<td>1,100</td>
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<tr>
<td>Fossil fuels</td>
<td>1,100</td>
</tr>
<tr>
<td><strong>Automatically fed</strong></td>
<td></td>
</tr>
<tr>
<td>Biomass fuels</td>
<td>500(2)</td>
</tr>
<tr>
<td>Fossil fuels</td>
<td>500</td>
</tr>
</tbody>
</table>

1) valid only for wood combustion units
2) exceeding a limit by 50% is allowed in case of 30% part load
are currently not particularly demanding, many countries have national requirements for different emissions.

In 1992 the Federal Ministry of Environment, Youth and Family of Austria started to regulate the release of small scale combustion systems by law. The regulations are valid for all combustion systems for solid fuels (fossil and biomass).

To prove that a stove or boiler complies with the Austrian limits, it is not necessary to test each boiler or stove. The manufacturer is responsible for performing a wide range of tests to obtain the certificate, which is the requirement for selling.

Under the Italian legislation (March 8, 2002 DPCM), each biomass boiler in private houses should respect the values of CO (< 200 mg/m³) and particles (< 150 mg/m³) even if it refers to plants for private use above 150 kW of output.

In Spain, the limits for small-scale biomass heating systems are provided usually at the regional level. If there are no specific limits, the following general restrictions are predominant: CO < 200 mg/Nm³ and particles < 150 mg/Nm³.

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**Effect of heating method on emissions**

In terms of emissions, the most detrimental form of combustion is “slow” burning in which the fireplace or stove is generally filled to the limit with wood or combustion is prolonged by restricting the amount of air. With this method of burning a high temperature is achieved too slowly, and the amount of air is insufficient to burn all the gases. Due to the low temperature, high quantities of soot and tar are formed and stick to the surfaces of flues and chimneys. Soot that has accumulated along the surfaces of smoke channels reduces heat transfer and increases the risk of soot fires.

Most of the fireplaces and stoves in Finland and Sweden are heat retaining models that create heat fast and efficiently. At least 5 kg/hour of fuel is consumed. Thus smouldering burning is mainly applied for light stoves.

A typical characteristic of batch combustion is sequential combustion. After the fuel is ignited the CO₂ content increases rapidly to as high as 15 percent. As combustion progresses, the CO₂ content decreases. A low CO₂ content indicates excessive amounts of combustion air. Additional loads of fuel are indicated by spikes in carbon monoxide along the combustion curve.

![CO and hydrocarbon formation in a conventional fireplace using 3 kg of firewood. Source: Heikki Oravainen, VTT](image-url)
The University of Kuopio conducted an experiment in which it compared the results of good combustion and poor combustion in a small traditional heat retaining stove. Good combustion involved the right amount of air, logs weighing approximately 0.5 kg each and loads of approximately 2.5 kg. Poor combustion involved restricted combustion air, logs that were around one third smaller than ordinary firewood logs, and loads of approximately 3.5 kg. The resulting emissions of gaseous compounds and particles were many times higher than those of ordinary fires:

- carbon monoxide emissions were 3 times higher,
- total hydrocarbon (OGC) emissions were 9 times higher,
- PM1 (< 1 μm particles) emissions were 6 times higher, and
- methane emissions (CH4) were 12 times higher.

Poor combustion created 4 times more cellulose and hemicellulose pyrolysis byproducts (levoglucosan). The amount of PAH compounds, which cause cell-based changes, were 5 times higher. Since levoglucosan is produced only by burning biomass, it can be used to estimate what proportion of particulates in the air are created by small fires.

Fine particles are produced by both good and poor combustion. In good combustion conditions the particle emissions consist of primarily inorganic fly ash. In poor combustion conditions, however, the share of fly ash is smaller due to the higher quantities of soot and hydrocarbons. The more efficient combustion is, the higher the proportion of fine particles. The quantities do not necessarily correlate directly with the quality of combustion. The size of particles, however, is smaller as a result of good combustion.

The amount of particulates (PM10) that can be inhaled must not exceed 50 μg/m³ over a period of 12 days in Europe. In addition, the level of PAH compounds from PM10 particulates cannot exceed 1 ng/m³ in the open air. In the near future this will be increased to PM 2.5 particles.
Using fireplaces and stoves

Heat retaining fireplaces and stoves

The manufacturer or builder of your fireplace or stove should provide instructions for how to use that specific model. Care should be taken when lighting new fireplaces and stoves for the first time.

The following guidelines have been drawn up for using traditional fireplaces and stoves. Many different types of fireplaces and stoves are offered to serve different needs and preferences. The more you use your fireplace or stove, the better it will serve you.

Use kindling and dry firewood
Use kindling and dry firewood. The ideal moisture content of firewood is 15 to 20%. Dry wood should making a clinking sound when hit together. Wood shavings, newspaper, bark and small wood chips are ideal for kindling. Roughly an armful of dry firewood is required for a single heating. The firewood should be carried indoors well in advance to allow it to warm up to room temperature. If you store firewood outdoors, the logs should be carried indoors two days before it is burnt. Each batch should weigh 3 to 5 kg. For the first batch use kindling and smaller logs weighing approximately 0.5 kg each and around 5 cm in diameter. The length of the logs depends on the design of the fireplace or stove. The ideal length is approximately 5 cm shorter than the length or width of the fire box. For the second batch use larger logs weighing approximately 1 kg each and 8 to 10 cm in diameter. A log of this size will weigh about the same as a litre of milk in a carton. For baking ovens and cooking stoves, smaller logs with a diameter of less than 5 cm should be used.

Never use demolition wood that has been painted or impregnated wood. Impregnated wood is hazardous waste. Pre-painted wood that are used for house building can contain chemicals used to prevent rot, mould or discolouring. These chemicals may contain hazardous organic halogenated compounds.

Careful preparation is important
Open the damper and check the amount of ash. The level of ash must not reach the fire grate, and the flow of combustion air should be unimpeded. Remove the ash with a container that is made of a fireproof material and that has a cover and legs.

If the fireplace or stove has not been used for a longer period of time, the draught may be poor. If the air inside the flue is damp or colder than the outside air, there will be no draught. The air inside
the flue must be heated in order to get it moving. Check the draught by burning a match by the mouth of the main hatch. If the flame does not bend towards the fire grate, preheat the flue. Remove the service hatch from below and burn a crumpled up piece of newspaper inside. Alternatively, you can use a heat blower or hairdryer.

If your heat storage fireplace or stove is equipped with a so called summer damper, it should be opened when lighting the fire to allow the flue gases to flow directly out the chimney instead of circulating through side channels. Once the temperature of the flue rises and proper draught is created, carefully close the summer damper.

In summertime, when fireplaces and stoves are used less frequently, the dampers should be kept open. The flow of air will keep the channels and flue at room temperature, preventing moisture in the air from condensing on the surfaces. The dampers should also be kept open in cottages that are kept cold over the wintertime in order to ventilate the flue.

**Use small amounts to light the fire**

Use a small amount (0.5 to 1 kg) of logs with a diameter of around 5 cm for the first batch. If you have heated the fireplace or stove the previous day, you can use larger logs. Stack them loosely and place kindling on top or underneath depending on the type of fire grate. Stack the logs horizontally or in a crisscross pattern and fill the firebox halfway to the top, unless instructed otherwise by the manufacturer. The hatches can be closed once the logs are burning well.

In baking ovens a small log can be placed crossways at the rear of the oven in order to improve air circulation and combustion. Usually baking ovens should be heated the previous day when baking pastries that require a high temperature, such as rye bread and pizza.

The manufacturer of your fireplace or oven will also provide instructions on how to light a fire. During the ignition phase high temperatures should reach the upper levels of the fuel as fast as possible. This can be achieved best by placing kindling on top of the batch. However, this method does not apply to all fireplace or stove models. The advantage of lighting from the top is that the gases that are released from the lower level of the fuel batch due to the effects of heat are forced to pass through the hot fire zone. This ensures that the gases ignite and burn.

**Gradually add more wood**

Ideally, firewood should be added gradually and in small amounts. Logs should only be added once the previous batch has burnt almost to embers and the flames have died down. Place the logs preferably with the bark side down and stack the logs tightly together to allow slower gasification. Avoid stirring up the fire too much so that the combustion process is not disturbed. Lots of combustion air is needed to
feed the flames.

Do not fill the firebox to the top. At least one-third of the height of the firebox should be left free. Baking ovens and cooking stoves should never be filled more than half way.

**Energy from the glow of the embers**

Embers that are glowing red release a lot of heat, 25 to 50 percent of the energy content of the wood. Reduce the amount of air flowing through the hatch and stir up embers that have lost their glow. The damper can be closed somewhat when no more blue flames can be seen. Once the embers have died down, the damper can be closed entirely. These days dampers must have a small hole in them even when closed.

In baking ovens, once the combustion has progressed to the final stage, the embers can be spread out and stirred up. In cooking stoves the embers can then be dragged to the front or pushed to the back of the oven to burn out, and the final embers are extinguished under the fire grate. Once the embers have burnt out, the damper can be closed. Before baking the oven should be cleaned with a scraper or brush. Keep the damper open when sweeping. Before placing pastries in the oven, let the temperature level out for 15 to 30 minutes. When cooking, an even heat is not so important.

The combustion has been good if the fire surfaces are white and there is no soot.
A few important tips

• Never burn waste in fireplaces or stoves!

• Make sure that the fuel has burnt completely before closing the dampers.

• Never leave a stove unwatched while heating!

• Never add ash to compost! Ash is an alkaline, so it can be used as a fertiliser.

• Remember to have your chimney swept! The owner of the property is legally responsible for chimney sweeping. Use a professional chimney sweeper.

• Officials recommend using a carbon monoxide alarm in properties where there is a fireplace or stove.

• Always follow the manufacturer’s instructions. This is particularly important with new stoves equipped with more advanced fireboxes and fire grates. The usage of these differs from that of traditional stoves.
Sauna stoves

Logs are the best fuel for sauna stoves. Fuels with a high heating value, such as plastic and charcoal must never be used to heat sauna stoves. If you use wood briquettes note that the heating value is more than double compared to wood logs. The draught can be controlled by adjusting the amount of air entering through the ash box. Too much draught can cause the sauna stove to glow red, which significantly decreases their lifespan. Moderate draught should be maintained, however, to allow the sauna stove to heat up sufficiently. Occasionally, sauna stoves can be heated up aggressively in order to burn any soot that has accumulated in the flue and thus improve the heating properties of the stove.

In the early stage of heating the sauna stove, the ash box can be kept slightly open to create strong draught. When taking a sauna the hot ash box can be closed completely or partially in order to slow down the burning process and control the use of wood.

How quick the heating of sauna room is carried out depends on the volume of the room, the output of the stove and the materials used in the walls and ceiling of the sauna. A correctly specified sauna stove should heat up a sauna room in 30 minutes to one hour.

When heating sauna stoves it is very important that good quality wood is used. Birch and beech burn efficiently, and logs do not have to be added so often as with other types of wood since these are heavy wood. It has a higher heating value per volume than softwoods, for example. Smaller logs should be used for the first batch to create heat rapidly. Larger logs, and even lower quality wood, can be used for the next batches.

Heating sauna stoves differs from heating other types of stoves or fireplaces in that the wood should be burnt aggressively to heat up the sauna stoves quickly. This creates higher flue gas temperatures, which should be taken into consideration when constructing the chimney. The design of woodburning stoves is simple, as a result of which combustion produces more emissions than other stoves or fireplaces. For this reason the quality of the wood is particularly important. If the firebox is filled to the top, there will be insufficient combustion air as all air enters via the ash box. So-called low-emission sauna stoves are being developed in which combustion air is fed into the firebox. These stoves will be on the market in 2009.
Pellets to be burned in a separate pellet unit are ignited by lighter fluid. This kind of device can burn up to 12 kg of pellets in one batch. Photo: Heikki Oravainen, VTT

A separate pellet unit manufactured by Tulipiippu Ay fitted in the firebox of a fireplace-baking oven. Photo: Tulipiippu Ay

Using pellet baskets and separate pellet burning units in fireplace or stove
Pellet baskets or separate pellet burning units have also been introduced that can be used to heat up mainly heat retaining fireplaces and stoves. Smaller pellet baskets can be used in other stoves and fireplace inserts. They are not suitable for open fireplaces, however, as the combustion air cannot be fed to the separate pellet unit as efficiently, and flue gases can escape into the room. Pellet baskets are also generally not suitable for use in baking ovens due to the low height of their fireboxes. Pellet units are sold in hardware stores and over the internet (see References).

The photos above show two different types of separate pellet units fitted in a heat retaining stove. The instructions of the manufacturer should be carefully followed, when using these units. With pellet units only one batch can be burnt at a time. The amount of pellets varies from 2 to 12 kg. The combustion time of the residual char, especially in vertical model, is long and lasts several hours. Fresh
pellets cannot be placed on top of the embers, as they can gasify rapidly and even cause a danger of explosion.

**Pellet stove**

After the installation of a pellet stove, the pellets are stored in a silo, which must always contain a quantity of fuel to enable a regular supply to the stove. The door of the firebox and the ash tray have to be properly closed during operation to prevent the escape of flue gases and the infiltration of air, which increases the filth of the firebox and glass.

Usually pellet stoves are equipped with a control panel that allows manual ignition and manual shutdown of the stove, as well as adjustment of the operation and a range of programs for management and maintenance. The panel can be adjusted by remote control.

The stove’s ignition can be either manual or automatic.

Manual ignition through the control panel:
- After pressing the ON/OFF button, the LED lights indicate the stove’s ignition. After about 4-5 minutes the stove is turned on;
- The desired level of power can be selected;
- The desired speed of hot air ventilation can be selected;
- For the total shutdown of the stove the ON/OFF button has to be used, the stove will remain in operation for about 20 minutes until the cooling of all its internal parts.

Automatic ignition:
- The daily/weekly ignition is set by a timer;
- Some stoves allow the ability to select the ideal temperature with a thermostat environment or by connecting a remote telephone modem.
**9 Maintaining fireplaces and stoves**

**Routine maintenance**

The most important maintenance that you must perform routinely is to remove the ash. The ash should be collected in a container that is made of a fireproof material and that has a cover and legs. A metal bucket with a lid can be used for this purpose.

The amount of ash should be checked before lighting the fire. The level of ash must not reach the fire grate, as this impedes the flow of primary air through the fire grate, which can also heat up excessively.

Sauna stoves usually have small ash boxes. The ash box should be emptied each time before lighting the fire.

Many saunas at summer cottages still have large cauldrons for heating water. Because the base and walls of the cauldron are usually relatively cold (hardly ever above 100°C), soot and tar can accumulate easily. The base of the cauldron should be swept on a regular basis. If the water holder can be lifted out separately, the surfaces of the walls can also be cleaned. Steel brushes are ideal for this purpose.

Ash from wood is an alkaline, so it can be used as a fertiliser if no waste has been burnt in the same stove. Ash must not be added to compost, as the alkaline prevents the microorganisms from functioning. Ash should also not be added to potato fields, as it disfigures the potatoes. You can clean door glasses with moist paper towel with the ash.

**Professional chimney sweeping**

The Finnish Ministry of the Interior has defined rules for chimney sweeping based on Article 22 of the Finnish Rescue Act (468/2003). Regional rescue services are in charge of arranging chimney sweeping services in their region. They can take care of chimney sweeping themselves or obtain these services from a private contractor.

Building owners and occupants are responsible for ordering chimney sweeping services for the building regularly in Finland. Fireplaces and smoke flues in year-round dwellings must be swept once a year. Fireplaces and flues in private holiday homes and their saunas must be swept at least once every three years. Fireplaces and flues in holiday homes and their saunas that are rented out and in regular use must be swept every year. The chimney sweeping must be performed in the same season when the holiday home is usually occupied. The chimney sweeper inspects the safe distances and clearances of the fireplaces and flues, as well as the condition of the ladders and cleaning frames. Any faults or shortcomings must be notified to the owner or occupant of the property.

The number of visits specified by the Ministry of the Interior are minimal requirements in Finland. Fireplaces, flues and ventilation must be ready to use after the work is completed.

The chimney sweeper removes any waste collected
during the cleaning. If the chimney sweeper identifies any faults or shortcomings, he reports them to the fire safety authorities and to the owner of the property. The chimney sweeper also takes care of burning any soot, tar and other residues that have accumulated in the fireplace and flue and that may cause an accidental fire.

In Austria each house or flat occupant has to by law arrange an inspection of his or her chimney once a year. Usually for each house there are three fixed dates per year when the chimney sweeper plans to look after the chimneys, one of which has to be chosen. Chimney sweepers do not compete with each other because they have territorial protection. Chimney sweepers do not look after the functionality of the boiler or stove, as he is only responsible for functionality of the chimney.

In France the maintenance rules for the smoke ducts are defined by the Réglements Sanitaires Départementaux (Departements Sanitary Regulations). Even if some differences can exist from one Department (French council) to another, all contain these major following points:

- Flues have to be maintained in a good state of operation and maintenance (sweeping 2 or 3 times per year depending of the Department).
- Heating devices can be connected to the flue only after having been examined by an installer. The installer has to deliver a certificate establishing the tightness of the duct, its regularity, its sufficient section, its continuity and its sweeping.
- Heating devices have to be cleaned and verified at least once per year (depending on Department).

In Italy there are no national laws about the role of chimney sweepers, but some provinces have issued ordinances. For example, the province of Bolzano has regulated the obligations of the chimney sweeper (DPP 13/11/2006 N.62). This decree stipulates that every chimney should be certified by the chimney sweeper before being put into function properly and that only the certification of the chimney sweeper will allow the company to deliver to their clients and put it into operation permanently. The security and accountability, according to the decree of 22 January 2008 N. 37, remains with the company who performed the installation. The chimney sweepers perform the inspections.

The chimney sweeper cleans different parts of the fireplace. Photo: Central Association of Chimney Sweeps, Finland

Tasks of the chimney sweeper:
- preparation work
- sweeping of fireplaces, smoke flues and connected equipment and connecting flues
- opening of fireplaces and smoke flues
- cleaning of dampers (unless damper is within the structure) and inspecting their condition and functioning
- removal of ash and other waste collected during sweeping and disposal according to fire safety regulations
All the documents for certification of an installation in Italy:

- Test leak of the tube inside the flue;
- Video of the entire route of the chimney;
- Minimum heights and distances of the chimney;
- Positions, documents and mounting accessories required and useful;
- Security throughout the chimney.

The inspection and cleaning of the chimney must be performed by a chimney sweeper once a year or every 2,000 kg of wood burned. After a fire a technical chimney sweeper must inspect the chimney and issue a certificate of fitness.

In Italy it is advisable to clean the chimney at the beginning of each winter season.

In Italy the regulation DPR /9 “Regulation on the design, installation and maintenance of thermal systems of buildings, in order to control consumption of energy, in implementation of article 4, paragraph 4 of Law 9 January 1991, No. 10” requires the implementation of mandatory annual maintenance to the heating device, including the chimney.

The standard CTI UNI 8364-February 1984 provides instructions for monitoring and maintenance of devices with a thermal output of no less than 35 kW intended for private use, particularly for household heating and the production of hot water.

At the end of each period of activity, the owner is responsible for cleaning the combustion chambers. When cleaning it is essential to monitor and, where necessary, restore any fractures in the chimney. At least once a year you must ensure the water tightness of the combustion chambers of heat stoves (natural draft) with the sealing of cracks eventually found between the generator and the basement and between the elements (in the case of separable stove -element) in order to prevent the infiltration of air.

Every three years the soot from the flue gas pipes, fittings from the generator, any flue gas channels, the chimney and the tank collection at the base of the chimney have to be cleaned.

When cleaning smoke flues, it is necessary to monitor the water tightness, checking the difference between the content of CO at the exit of the stove and at the base and top of the chimney. Any slits from which air enters must be sealed.

At least at the beginning of each period of activity the draught to the entry of furnace and at the base of the chimney should be measured, checking their possible deviations from the test values.

In Spain it is recommended to have one inspection and cleaning per year, regardless of the frequency of use.
The main hazards when using fireplaces and stoves are fire and carbon monoxide poisoning.

Fireplaces and smoke flues are responsible for a considerable share of fires in buildings. In Finland, some of the fires and soot fires caused by smoke flues are started by heating sauna stoves. Consequently, saunas are responsible for around half of all fires caused by fireplaces and stoves in Finland.

Usually fires are caused by improper usage. Fire safety rules and regulations, such as those concerning safe distances or clearances, must be taken into account when planning a fireplace. Fireplaces must also be used correctly and maintained by removing ash. Chimney sweepers can be ordered more than requested by authorities if necessary.

Firewood should be stored indoors in such a way that any risk of accidentally combusting is eliminated. Firewood must never be stored on top of fireplaces.

The most dangerous kind of fire are soot fires, which can occur when soot and tar that have accumulated on the surfaces of smoke flues and chimneys are accidentally ignited. Soot consists of fine carbon particles that are created as a result of bad combustion. Soot may also contain tar, water, acids and other substances. Soot accumulates on the surfaces of smoke flues and chimneys and can be ignited accidentally, causing a so-called soot fire. These are extremely dangerous, as the flames can extend high up into the flue. Since soot contains carbon, it has a very high heating value. The danger with soot fires is that they can spread to other parts of the property and the chimney can crack.

In case of fire, the emergency services (telephone number in Europe 112) must be contacted immediately.

Fire blankets and fire extinguishers are effective tools for extinguishing fires before they spread. Traditional water-filled fire extinguishers are effective on wood fires, but they must never be used for grease or electrical fires. Whenever you are dealing with fire, keep extinguishing equipment close by. First-aid kits are also recommended. It is important to plan in advance what to do if an emergency situation arises. Inform all family members and guests how to exit the building and where to gather if a fire breaks out. It is also good to practice extinguishing fires in advance.

In addition to fire detectors, carbon monoxide detectors are also highly recommended. Fire detectors function in different ways. Optical fire detectors respond rapidly to the smoke with big particles. Ionic detectors react faster to smoke with small particles, which all fires produce. However, if you install just one fire detector, an ionic fire detector is preferable. Optical fire detectors can be placed near kitchens and bathrooms, as cooking steam and light humidity do not cause false alarms as easily. To enhance fire safety in your home, install additional fire detectors in the...
Fire blankets and fire extinguishers are effective tools for extinguishing fires before they spread. Photos: SPEK

Fire and carbon monoxide detectors should be installed on the ceiling. Photos: Kidde and SPEK

front hallway and bedrooms.
If a room has a fireplace or stove, a combination carbon monoxide and fire detector provides the best protection. Carbon monoxide detectors react only to carbon monoxide. The newest models operate electrochemically and display the amount of carbon monoxide in real time. Carbon monoxide and fire detectors are usually installed in the middle of the ceiling. Warm smoke will climb first to the ceiling. Carbon monoxide is also slightly lighter than air, and it is usually contains heat. For precise installation instructions, refer to the manufacturer’s recommendations. Detectors that are connected to the mains current are more reliable.

According to the Finnish Ministry of the Environment’s decree, all new buildings with electricity from 1 March 2009 onwards must be equipped with fire detectors connected to the mains current.

Fire detectors must be maintained properly:
• Test fire detectors once a month by pressing the test button, which checks batteries and noise.
• Change the batteries as required. Batteries last around one year. Fire detectors last around ten years and carbon monoxide detectors around five years.
• Do not leave detectors in cold or damp places, for example in unheated summer cottages over winter.
• Disused fire detectors must not be thrown away with regular waste but must be disposed of properly as with other waste electrical and electronic equipment.
One in seven fires in Finnish holiday homes are caused by fireplaces or smoke flues. Fires often cause flues or stoves to crack. Cracked flues are hard to detect without the help of a professional chimney sweeper, who will inspect the condition of fireplaces, flues and chimneys. It is also important to remember that the first time a fireplace or stove is heated after the winter only a small fire should be made. The flue can be preheated by burning an outdoor candle in the firebox, for example. Heating too rapidly can damage the fireplace and flue, as well as the connection between the two.

In Finland fire detectors are also mandatory in all buildings at summer cottages where people sleep. The batteries should be changed after each winter and tested by pressing the test button.

Carbon monoxide is extremely hazardous to humans. It is hard to detect, as it is a colourless, odourless and tasteless gas. Carbon monoxide compromises haemoglobin in the blood, which absorbs it faster than oxygen. Closing the damper too early can easily cause carbon monoxide to build up. Finnish authorities have decided to prevent this from happening; modern dampers must have a hole in them that is 3 percent of the surface area in size when the damper is closed. If a house is designed with only mechanical ventilation, care must be taken to ensure that the flue is not used to bring fresh air into the house (Finnish building code, RakMk E3).

If smoke enters the room from the fireplace or stove, there could be a leak or insufficient draught.

Both carbon monoxide poisoning and soot fires are connected with bad combustion, which is why it is important to learn the correct ways of heating fireplaces and stoves.
Definitions

Air coefficient, $\lambda$
The ratio of the actual amount of combustion air to the theoretical amount.

Ash
The solid inorganic residue created when a substance burns. The ash content (%) is the weight of ash in relation to the dry matter of the fuel, which also contains ash. The ash content of solid biofuels is calculated using the CEN/TS 14775 method.

Baking oven
A stove that is designed for baking pastries and slow cooking. Baking ovens are often also used for heating purposes.

Brick fireplace
A handmade fireplace that is built onsite out of bricks and mortar and is a permanent part of the structure. Brick fireplaces can also include features made out of metal and other fireproof materials.

Carcinogenicity
A measure of the ability to cause cancer. Extremely carcinogenic PAH compounds include benz[a]pyrene (BaP), dibenzo[a,h]anthracene, 7,12-DMBA and 3-methylcholanthrene.

Central heating wood stove
A stove that combines a central heating boiler with a woodburning stove. The firebox can either be separate or combined.

Chimney
Usually a vertical section of a building that contains at least one flue.

Chimney cover
A plate above the top of the chimney to protect against the effects of weather.

Cooking stove
A stove that is designed for boiling and frying food. Cooking stoves often include a small oven and water heater.

Density, $\rho$ (kg/m$^3$)
The mass of a fuel per volume. Density depends on the amount of both dry matter and moisture in the fuel.

Dew point, °C
The temperature at which the vapour, acids, soot and tar in the flue gases begin to condense onto the linings of the smoke flue. The higher the dew point temperature, the more moisture there is in the fuel and the higher the CO$_2$ content in the flue gases. The CO$_2$ content of flue gases from fireplaces is generally 6 to 12 percent, giving a dew point of 35 to 50 °C. The acid dew point is the temperature at which corrosive acid begins to condense from the flue gases onto the inner linings of the smoke flue.

Damper
A device for cutting off the flow of flue gases or air through the flue.

Draught
The upwards draught inside chimneys by which flue gases are evacuated. The amount of draught depends on the height of the chimney, the flow resistance inside the smoke flue, the technical flow characteristics and position of the mouth of the chimney, and the prevailing heat differences and wind conditions.

Dust emissions, particle emissions (mg/Nm$^3$, mg/MJ)
The mass of impurities in flue gases per normal cubic metre or fuel energy (MJ). Fuel energy is calculated by multiplying the mass of the fuel and the lower heating value. Dust emissions are expressed as a ratio to the volume of dry gas in normal conditions (0°C, 101.3 kPa) and with a 13% oxygen content in the fireplace. Particles can also be measured in different fractions, PM10 (< 10 μm) and fine particles P2.5 (< 2.5 μm) and PM1(< 1 μm).

Efficiency ($\eta$, %)
The ratio of usable energy obtained in a process (net energy) to the energy expended in the process (gross energy).

Elemental analysis of fuel (%)
A process of determining the elemental composition of fuel, including carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sulphur. The oxygen content is measured on the basis of other elements. For solid biofuels the measurement is made using the CEN/TS 15104 method for carbon, hydrogen and nitrogen and method CEN/TS 15289 for sulphur content.

Emissions
Hazardous compounds and impurities in flue gases that are created during combustion. Emissions include particles, carbon monoxide, sulphur dioxide, total hydrocarbons (C$_x$H$_y$ or OGC), nitrogen oxide and polycyclic aromatic hydrocarbons. Emissions are usually expressed in mg per normal cubic metre (mg/Nm$^3$) at 13% oxygen content. Emissions can
also be expressed in units (mg/MJ) per fuel energy entering the fireplace.

**Emissivity (ε)**
The ratio of radiated energy to the theoretical maximum radiated energy, i.e. the radiated energy of a black body. The degree of emissivity depends on the surface properties of material, such as colour and temperature.

**Fireplace**
A device inside a building used for burning solid, liquid or gaseous substances and whose combustion byproducts are evacuated through a chimney. Fireplaces are connected to smoke flues.

**Fireplace stove**
A small fireplace made of metal and usually with a large front hatch. The surface of fireplace stoves heats up and releases a lot of heat. Fireplaces are best suited for rapidly heating holiday homes.

**Fuel dry matter (d)**
The mass of dry matter (kg) is the total amount of the fuel without water and is used to compare the percentages of dry matter. The dry matter of fuel includes both combustible and non-combustible elements. The combustible elements are mainly carbon, hydrogen, oxygen, nitrogen and sulphur, and the non-combustible elements are non-organic substances such as minerals (ash).

**Fuel moisture content (M, weight %)**
The amount of water contained in a fuel expressed as a ratio to saturated fuel. The moisture content (M) is the percentage of water of the total mass of the fuel. Moisture is defined according to the CEN/TS 14774 standard. A sample of the fuel is dried for a maximum of 24 hours at a temperature of 105°C (precision ±2°C).

**Fuel moisture ratio (u, dry weight %)**
The amount of water contained in a fuel expressed as a ratio to dry matter.

**Greenhouse phenomenon**
The effect by which the atmosphere absorbs visible light but retains infrared radiation emitted from the Earth. This phenomenon is due to greenhouse gases, primarily carbon dioxide (CO₂) and water vapour. However, water vapour is not considered a greenhouse gas that is caused by human activities. Other greenhouse gases include methane (CH₄) and nitrous oxide (N₂O). Methane is multiplied by 21 and nitrous oxide by 310 to correspond with carbon dioxide.

**Halogenated organic compounds**
Compounds that contain fluorine (F), chlorine (Cl), bromine (Br) or iodine (I), for example, PVC compounds (PVC – polyvinyl chloride; found in plastics) and PCB compounds (PCB – polychlorinated biphenyls; used before 1970 as an additive in PVC plastic, for example). Furans (PCDF – polychlorinated dibenzofurans) and dioxins (PCDD – polychlorinated dibenzodioxins) can form when organic chlorine compounds are burnt in poor combustion conditions.

**Handmade brick chimney**
A handmade chimney that is built onsite out of bricks and mortar.

**Handmade steel chimney**
A handmade chimney that is built onsite out of steel piping and heat insulation.

**Heat output and net energy**
Heat output is the amount of fuel used per unit of time in the fireplace (kg/s) multiplied by the net calorific heating value (kJ/kg) of the fuel minus losses. Net energy of the appliance (kWh) is heat output (kW) multiplied by time (h).

**Heat retaining fireplace**
A fireplace that can store heat. Storage heating fireplaces are heavy and may feature an additional outer layer.

**Heating value (MJ/kg, kWh/kg)**
Heating value refers to the amount of heat generated in perfect combustion as a proportion of fuel mass. Heating value is often expressed as a proportion of volume (MJ/m³ or MWh/m³). The gross calorific value of the dry matter of solid biofuels is defined according to the CEN/TS 14918 standard, and the net calorific heating value is calculated according to these results. The net calorific heating value of wet fuel (=as received) is calculated according to the EN 14961-1 standard (Appendix E).

**Household fireplace**
A fireplace that is not intended for heating an entire building continuously and in which solid biofuels are usually burnt. Household fireplaces include ovens, baking ovens, cooking stoves, cooking stove/baking oven combinations, open fireplaces, fireplace stoves, sauna stoves and other stoves.

**Kindling, tinder**
Ignition material to starting a fire, especially small pieces of dry wood.
Load duration curve
Illustrates the changes in energy demand (power) over a period of time. The area within the curve illustrates energy consumption.

Log
Wood that has been cut into lengths of 25 to 100 cm and split for use in central heating boilers and fireplaces in houses and on farms.

Mutagenity
A mutagen is an agent that changes the genetic information of an organism. Mutagenity is used to measure the harmfulness of various emissions.

Open fireplace
A fireplace without doors that is connected to the smoke flue from the top.

Oven
A heating device that is either handmade out of bricks and mortar or factory-built and that features a front hatch.

Polycyclic aromatic hydrocarbons (PAH compounds)
Compounds formed by two or more fused aromatic rings and that consist of only carbon and hydrogen. There are very many PAH compounds, including 7 to 32 that have been defined in fireplace research. Some PAH compounds are mutagenic and/or carcinogenic (see mutagenicity, carcinogenicity).

Pyrolysis
The chemical decomposition of a solid fuel into gases and/or liquids due to the effect of heat.

Sauna stove
A stove lined with fireproof mass that is used as a heating source for free-flowing air. The stove is installed inside a sauna where the hot air is released through the effects of gravity. Some sauna stoves also heat water for washing purposes.

Small chimney
A chimney that is made from one or more smoke flues and is connected to a fireplace whose total heat output does not exceed 120 kW.

Smoke flue
A lined channel for removing smoke from fireplaces along which combustion byproducts are transported to the open air. The fireplace can be connected to the smoke flue with various types of connecting flue pipe.

Soot fire resistance G (mm)
A classification based on a soot fire test conforming with the standard for CE marking. G=soot fire resistance, (mm)=distance to combustible material. The soot fire test is performed by feeding 1,000°C gas through a pipe for 30 minutes.

Specific energy consumption (kWh/building m³,a or kWh/m²,a)
The annual energy consumption of a building per volume or floor space.

Stove
A small metal heating unit that produces a lot of heat over a short period of time due its high surface temperature.

Wood briquette
A compressed solid biofuel made from ground up wood biomass with or without binding agents into cubes or cylindrical pieces. Briquettes are usually manufactured using a piston press. The total moisture content of briquettes is generally less than 15 percent by weight.

Wood pellet
A compressed solid biofuel made from ground up wood biomass with or without binding agents into cylindrical pieces ranging from 5 to 30 mm in length and featuring rough ends. Wood pellets are usually manufactured using a press and die. The total moisture content of briquettes is generally less than 10 percent by weight.

Volatile substances (%) The organic substances and degradation products found in solid biofuels that are released as gases when the fuel is heated to 900°C in anaerobic conditions. The volatile substances found in solid biofuels are defined according to their dry weight percentage using the CEN/TS 15148 method.
### Units and abbreviations

#### Conversion table for energy units

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<th>kWh</th>
<th>MJ</th>
<th>Mcal</th>
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<tr>
<td>kWh</td>
<td>1</td>
<td>3.6</td>
<td>0.86</td>
</tr>
<tr>
<td>MJ</td>
<td>0.2778</td>
<td>1</td>
<td>0.2388</td>
</tr>
<tr>
<td>Mcal</td>
<td>1.1630</td>
<td>4.1868</td>
<td>1</td>
</tr>
</tbody>
</table>

Example: 1 MJ = 1 000 kJ = 0.2778 kWh

100 ppm = 0.01 %

#### Abbreviations

<table>
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<tr>
<th>Abbreviation</th>
<th>Unit</th>
<th>Symbol</th>
<th>Value</th>
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<tr>
<td>μ = micro</td>
<td>micro</td>
<td>μ</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>k = kilo</td>
<td>kilo</td>
<td>k</td>
<td>$10^3$</td>
</tr>
<tr>
<td>M = mega</td>
<td>mega</td>
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<td>G = giga</td>
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<tr>
<td>T = tera</td>
<td>tera</td>
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<td>$10^{12}$</td>
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<tr>
<td>P = peta</td>
<td>peta</td>
<td>P</td>
<td>$10^{15}$</td>
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</tbody>
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References

Standards

Solid biofuels – general classification

Product standards for wood fuels to be used in non-industrial applications
prEN 14961-2, Solid biofuels – Fuel specification and classes, Part 2 – Non-industrial wood pellets (under preparation).

Fireplaces and stoves
SFS-EN 13229, Inset appliances including open fires fired by solid fuels – Requirements and test methods
EN 12815, Residential cookers fired by solid fuel – Requirements and test methods.
SFS-EN 13240, Room heaters fired by solid fuels – Requirements and test methods.
EN 12815, Residential cookers fired by solid fuel – Requirements and test methods.
EN15250, Slow heat release appliances fired by solid fuel – Requirements and test methods.

Chimneys
SFS-EN 1856-1, Chimneys. Requirements for metal chimneys. Part 1: System chimney products
SFS-EN 1856-2, Chimneys. Requirements for metal chimneys. Part 2: Metal liners and connecting flue pipes
SFS-EN 1857, Chimneys. Components. Concrete flue liners
SFS-EN 1858, Chimneys. Components. Concrete flue blocks
SFS-EN 12446, Chimneys. Components. Concrete outer wall elements
SFS-EN 13502, Chimneys. Requirements and test methods for clay/ceramic flue terminals
van Loo, S & Koppejan, J. The handbook of biomass combustion and co-firing. IEA Bioenergy, Earthscan. 2008 (www.earthscan.co.uk)


Finland


Stoves at www.biohousing.eu.com/catalogue
**Italy**

In the following paragraphs a complete list of reference norms of the National Italian Standards Institution, UNI, is reported:

**Solid Wood fuels**

- **UNI 3517:1954 - 31/03/1954** - Nomenclatura dimensionale degli assortimenti legnosi di produzione nazionale. (Dimensional definitions of the wood stocks in the national production)
- **UNI 3917:1983 - 30/04/1983** - Nomenclatura commerciale dei legnami esotici d'importazione. (Commercial definitions of the imported exotic timber)
- **UNI 676:970 - 01/07/970** - Gassogeni per combustibili solidi a marcia continua ed intermittente. Classificazione e prove di collaudo. (Classification and trial test of gas producer for solid fuels)
- **UNI 70:97 - 01/06/97** - Analisi dei combustibili minerali solidi e derivati. Determinazione dell' umidità. Metodo gravimetrico diretto in corrente di azoto (Moisture content determination - Nitrogen flow Method)
- **UNI 9025:1987 - 31/07/1987** - Classificazione e requisiti dei combustibili solidi minerali per usi termici civili. (Mineral Solid fuels requirements & classifications for civil thermal usage)

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**Austria**

15 a B-VG über die Einsparung von Energie [Regulations regarding energy saving (insulation, heating efficiency and hot water supply) for systems below 350 kW]

15 a B-VG über die Schutzmaßnahmen betreffend Kleinfeuerungen [Regulations regarding the release of small scale combustion systems below 400 kW]


Nussbaumer T., Klippel N. & Oser M.: Health relevance of aerosols from biomass combustion in comparison to diesel soot indicated by cytotoxicity tests, 14th European Biomass Conference, Paris (2005)

**France**

Claude AUBERT in collaboration with Ageden, 2006, "Poêles, inserts et autres chauffages au bois », ed. « terre vivante ».


UNI 8857:1986 - 31/10/1986 - Generatori di calore ad acqua calda con potenza termica fino a 1,2 MW funzionanti con combustibili solidi. Prova termica. (Thermal test of heat generator up to 1.2 MW)

UNI 9026:1987 - 30/06/1987 - Termocucine alimentate con combustibili solidi. Prova termica e limiti di accettazione. (Thermo cooker fed by solid fuels: thermal test and limits)


UNI 10474:1995 - 30/09/1995 - Forni di cottura alimentati con combustibili solidi. Classificazione, caratteristiche e prova termica. (Oven fed by solid fuels: classification, characteristics and thermal test)


Spain

Royal Decree 1027/2007, 20th July, with the approval of the National Regulation of Thermal Installations in Buildings. 2007.


Automatic Heating Systems for Houses and Buildings, ESCAN, 2006

This publication provides information about efficient and environmentally friendly fireplace and stove heating. It includes theoretical data, practical guidelines and official regulations concerning fireplace heating in Finland, Austria, France, Italy and Spain. In addition to heating, this publication contains information about storing and purchasing firewood.

www.biohousing.eu.com/stoveheating