Instruction Manual

for the Calculation of Wood Fuel Parameters

Version 1.6-ENG

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1 Introduction

Due to a rising demand in wood fuel, the knowledge of the energy content of customary wood fuel assortments has been gaining in importance in wood fuel trade. In order to facilitate the conversion from prices per volume or weight unit commonly used in forestry and the timber industry to energy prices relevant in the context of energy production, the Austrian Energy Agency has compiled an easy-to-use calculation tool. With only a few required variables the program can quickly calculate the most important parameters for a variety of wood fuel assortments.

The basic parameters you have to enter into the spreadsheet are wood species, assortment, moisture content and price in one of the customary units. The energy content as well as the assortment price per volume unit and per weight unit are calculated in consideration of the average species-specific oven-dry density and shrinkage.

Furthermore, the estimated annual fuel demand of the biomass heating installation serves as a basis for the calculation of the quantities (in weight and volume) of the considered wood fuel assortments needed per year as well as for the calculation of the annual fuel costs.

For price comparisons, it is essential to consider the potentially different points of sale and trading units. Transportation and manipulation costs from the place of origin (forest or industrial plant) to the point of use can account for a significant part of the overall costs of the various wood fuel assortments and should not be underestimated.

The calculations are based on the Austrian standards ÖNORM M 7132, ÖNORM M 7133, ÖNORM M 7135 and ÖNORM B 3012, data provided by the Provincial Chamber of Agriculture of Upper Austria (G. Danninger) and the Provincial Chamber of Agriculture of Lower Austria (A. Jonas & H. Haneder), and on generally acknowledged empirical values. These data have been compiled to the best of the author's knowledge and experience. However, the author accepts no liability whatsoever for errors or omissions.

If you have any corrections, comments or questions regarding the calculation, please send an e-mail to "energieholz@klimaaktiv.at".

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2 Checking the settings

2.1 Open Excel

The calculation program is based on the spreadsheet application "Excel". For all functions of the spreadsheet "Calculation of Wood Fuel Parameters" to work as intended, macros must be activated. Please open "Excel" and check the security settings for macros.

2.2 Change security settings for macros

This calculation uses macros[1], please check the security settings in Excel and change them if necessary.

Open the drop-down menu *"Tools"*, select *"Macro"* and then *"Security"* (see Figure 1: Step 2.1). A new window (*"Security"*) appears (see Figure 2: Step 2.2).
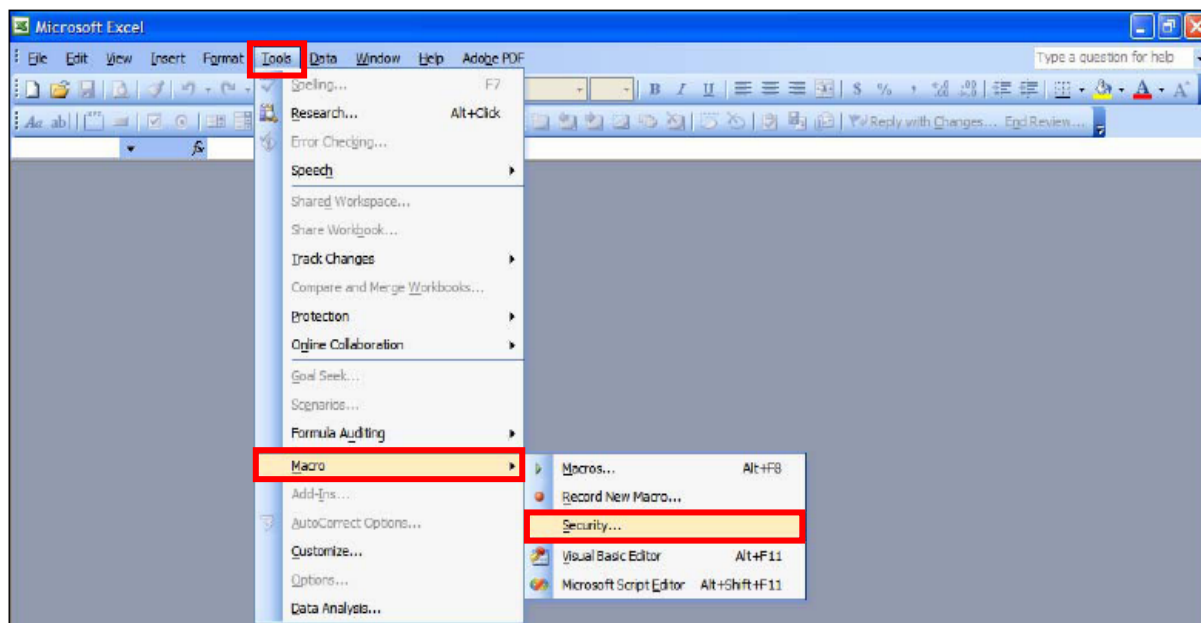
Figure 1: Step 2.1 – Open the Security window to change the Security settings for macros (Tools | Macros | Security)

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[1] A macro is a small script that automates certain actions in an application.

In the *"Security"* window, choose the *"Security level"* tab and select *"Medium. You can choose whether or not to run potentially unsafe macros."* (see Figure 2: Step 2.2). Confirm your selection by clicking *"OK"*.

Figure 2: Step 2.2 – Select medium security level for macros

3 Opening the spreadsheet „Calculation of Wood Fuel Parameters"

Please open the file "Calculation of Wood Fuel Parameters". The *"Security Warning"* window appears. You are asked if you want to activate the macros contained in the "Calculation of Wood Fuel Parameters" spreadsheet[2]. For all functions of the sp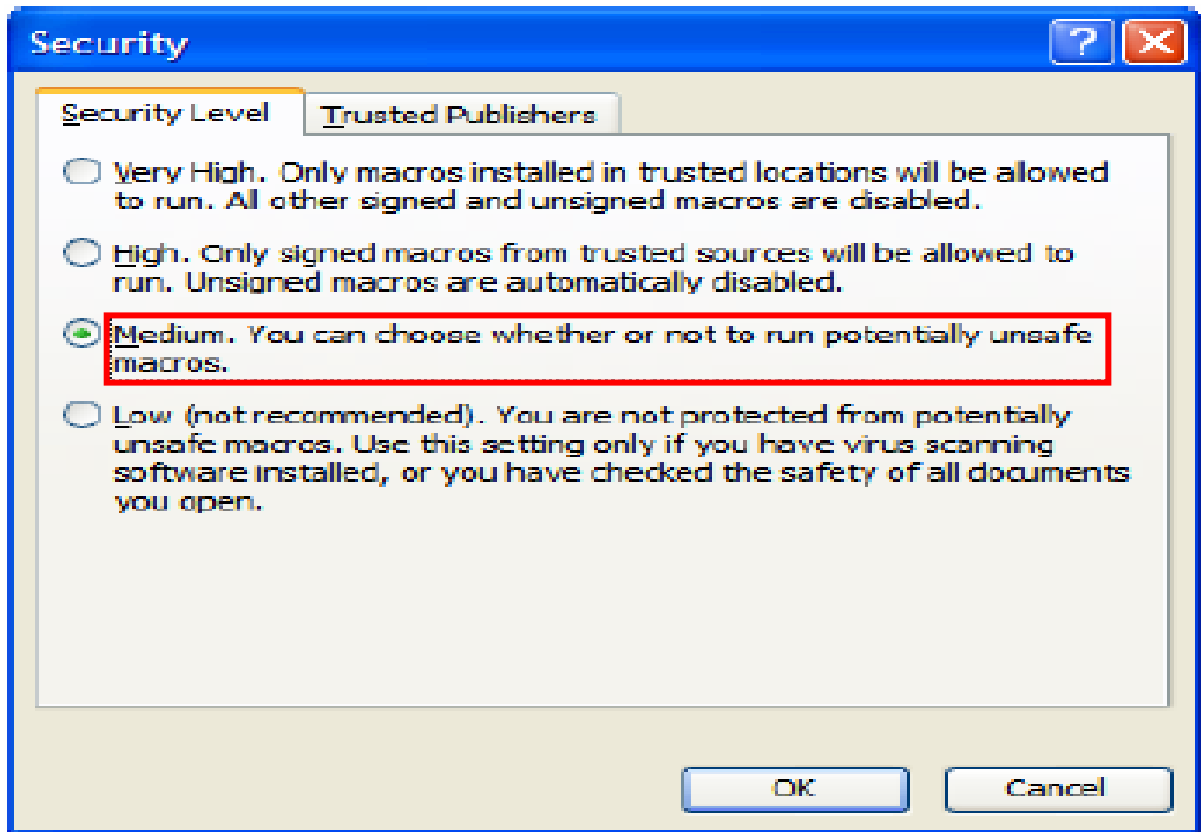readsheet to work properly, please click on "**Enable Macros**" (see Figure 3: Step 3.1). The file "Calculation of Wood Fuel Parameters" is opened and all functionalities are available.
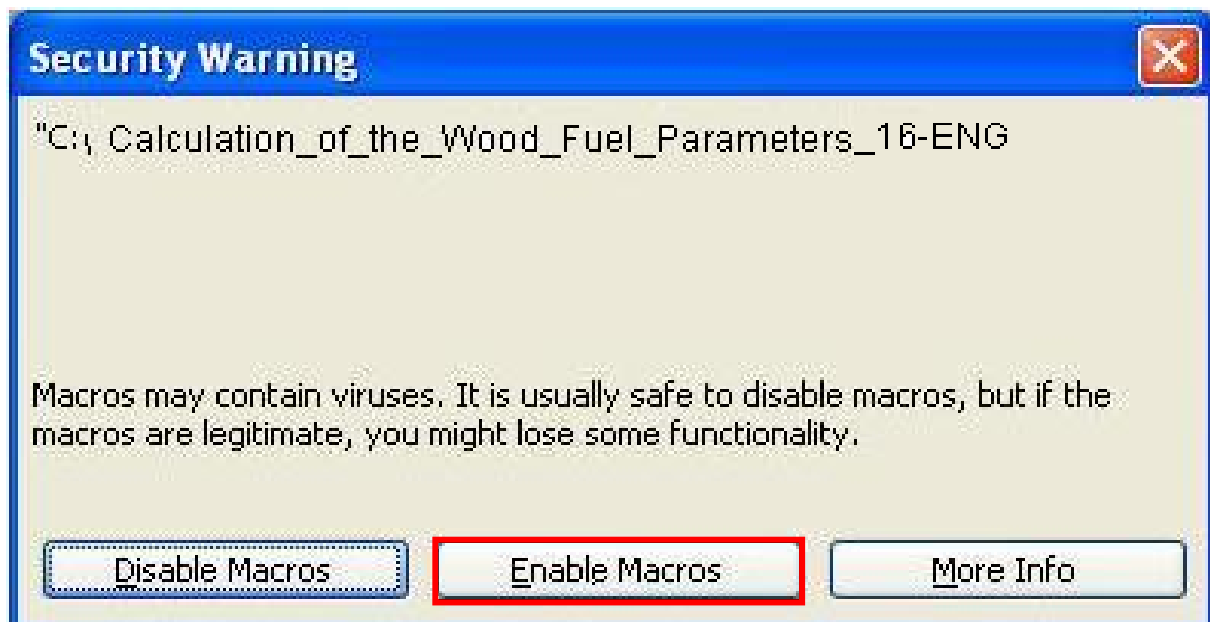
Figure 3: Step 3.1 – Activate macros for the calculation of parameters when you open the file

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[2] Note: The security warning preceding the activation of macros aims to protect your system from viruses. When you download the spreadsheet "Calculation of Wood Fuel Parameters" from our **klima:**aktiv website (www.energieholz.klimaaktiv.at), you can assume that the file does not contain any viruses. However, in theory every file or macro can contain a virus. Therefore, please make sure that you have anti-virus software installed and updated on your computer, and run your anti-virus programme before you use the file in case of unclear origin.

4 Using the spreadsheet „Calculation of Wood Fuel Parameters"

The spreadsheet "Calculation of Wood Fuel Parameters" consists of two worksheets. In the "Calculation" worksheet, the calculations are carried out, while the worksheet "Data sheet" contains the data the calculation is based on.

			firewood (stacked)	solid wood mass	s
	Assortment	Selection in the drop-down menu			
	Conversion factor	1 m³(solid) = x m³(stacked) or x m³(loose)	1.18	1.00	
	Unit	**Customary unit**	**m³(stacked)**	**m³(solid)**	
Moisture	Moisture content (H₂O)	% (by weight, FS)	40.0	40.0	
	Hydrogen content (H)	% (by weight, DM)	6.2	6.2	
Higher heating value (HHV)	HHV of dry matter (DM)	MJ/kg DM	20.4	20.4	
	HHV of DM	kWh/kg DM	5.66	5.66	
Lower heating value (LHV)	LHV of dry matter (DM)	MJ/kg DM	19.0	19.0	
	LHV of DM	**kWh/kg DM**	**5.28**	**5.28**	
	LHV of fresh substance (FS)	MJ/kg FS	10.4	10.4	
	LHV of FS	**kWh/kg FS**	**2.89**	**2.89**	
	LHV of FS	MJ/m³ FS	5,003	6,595	
	LHV of FS	**kWh/m³ FS**	**1,390**	**1,832**	
Density	Mean oven-dry density	kg/m³ (at 0 % H₂O)	370	430	
	Mean shrinkage	%	8.4	11.7	
	Bulk density	**kg/m³ (at x ‰ H₂O)**	**480**	**633**	
	- Proportion of wood substance	kg/m³ (proportion of DM at x % H₂O)	288	380	
	- Proportion of water	kg/m³ (proportion of H₂O at x % H₂O)	192	253	
	Ratio m³ per t FS	m³/t FS	2.1	1.6	
Ash	Ash content (estimate)	% (by weight, DM)	1.00	1.50	
	Ash density (estimate)	kg/m³	700	700	
Price per unit		**Euro/t DM**	**72.37**	**79.01**	
Activate macros !	Enter the fuel price in one of the input fields, the price will immediately be converted into the other price units!	**Euro/t FS**	**43.42**	**47.41**	
		Euro/m³ FS	**20.85**	**30.00**	
		Euro/MWh	**15.00**	**16.38**	
		Euro/GJ	4.17	4.55	

Calculation / Data sheet

Figure 4: Selection of the worksheets "Calculation" or "Data sheet"

4.1 Overview of the calculation of parameters (worksheet „Calculation")

4.1.1 Colour code

Dark green main sections:
These are the main sections of the spreadsheet ("Parameters", "Wood species", "Bark", "Compressed wood" and "Other").

Light red cells are input fields.

Light green cells and bold text mark the most important and most commonly used data and values.

4.1.2 Description of the individual sections

The spreadsheet is divided into five main sections (see Figure 5: Overview of the main sections).

Figure 5: Overview of the main sections

- **Main section „Parameters"**

In this section, the individual parameters are listed with the respective units (e.g. lower heating value in kWh per kg fresh substance), with each parameter applying to all fields in the same row.

Move the cursor over the red triangle in the respective cell to show hidden comments containing detailed information on the individual parameters (see

Figure 6: Show comments on the individual parameters).

Figure 6: Show comments on the individual parameters

The main section "Parameters" is divided into 7 groups:

- *Basic parameters*

In this section, you can select or enter the wood species/fuel type and the wood fuel assortment. The selected wood species/fuel type is assigned to a fuel group, and the conversion factor from m³(solid) to m³(stacked) or m³(loose) is determined.

- *Moisture content parameters*

Enter the moisture content of the respective assortment in percent by weight of fresh substance in this section. Furthermore, the mean hydrogen content of wood (around 6 %) is shown or can be entered in the "Other" section.

- *Higher and lower heating values*

In this section, the higher heating value (HHV) and the lower heating value (LHV) are shown. These values are calculated based on the data selected or entered in the above sections "Basic parameters" and "Moisture content", i.e. they are either taken from the data sheet or are calculated from the manually entered values. Both values are shown in several different units. In this section, no input is necessary (except in the "Other" section).

- *Density parameters*

This section shows the mean oven-dry density, the mean shrinkage rate and the bulk density. In this section, no input is necessary either (except in the "Other" section). The oven-dry density and shrinkage values are taken from the data sheet according to the selected wood species/fuel type; the other values are calculated based on the previously entered data.

- *Ash parameters*

This section shows an estimate of the amount of ash and the ash density for the selected wood species/fuel type. These values are taken from the data sheet. In this section, no input is necessary (except in the "Other" section).

- *Price per unit*

In this section, the wood fuel prices are converted into several different units. Select one of the input fields and enter the fuel price per unit specified in the selected field. The price is immediately converted into the other price units.

- *Installation parameters*

In this section, you can enter the annual fuel demand of your installation and the fuel ratio of the assortments you use.

Thus, you can assemble the total fuel demand of your installation by varying the proportion of the individual wood fuel assortments. This section shows the calculated fuel weight and fuel volume, the ash weight and ash volume and the annual fuel costs of an installation. These values are given individually for each assortment and as total values for the selected fuel mix. In addition, the composite fuel price is shown in Euro/MWh.

- **Main section „Wood species"**

In this section, various wood species and wood fuel assortments can be selected. Three columns are available, allowing you to directly compare different wood species and wood fuel assortments.

- **Main section „Bark"**

In this section, the parameters of bark assortments are calculated. It is important to bear in mind that the bulk density of bark can vary greatly depending on wood species, season and processing (debarker, chipping, etc.) and that the factor used for the conversion from cubic metre solid to cubic metre loose can deviate considerably from the mean value defined by the standard.

- **Main section „Compressed wood"**

In this section, the parameters of compressed wood (pellets and briquettes) are shown.

- **Main section „Other"**

In this section, you can enter all parameters manually. This allows you to make calculations for special fuels or fossil fuels. Furthermore, you can enter your own empirical values for the fuels and compare them with the given values.

4.2 Description of the input fields

4.2.1 Selection of the wood species

For the selection of the wood species, move your cursor to the light red field for the wood species and click once with the left button of your mouse (currently selected wood species: spruce). To the right of the cell, a small grey box with an arrow in it appears (see Figure 7: Step 4.1 – Selection field wood species).

Figure 7: Step 4.1 – Selection field wood species

When you click on the grey box, a drop-down menu listing the various wood species appears. You can select one of them by clicking on the wood species of your choice, e.g. fir (see Figure 8: Step 4.2 – Selection of a wood species). You can move through the whole drop-down menu via the scroll bar on the right.

Figure 8: Step 4.2 – Selection of a wood species

4.2.2 Selection of the assortment

For the selection of the wood fuel assortment (e.g. wood chips G50 or sawdust), move your cursor to the light red field for the assortment and click once with the left button of your mouse (currently selected assortment: wood chips G50). To the right of the cell, a small grey box with an arrow in it appears (see Figure 9: Step 4.3 – Selection field assortment).

Figure 9: Step 4.3 – Selection field assortment

When you click on the grey box, a drop-down menu listing the various assortments appears. You can select one of them by clicking on the assortment of your choice, e.g. sawdust (see Figure 10: Step 4.4 – Selection of an assortment). Together with the selection of the assortment, the conversion factor from m³(solid) to m³(loose) or m³(stacked) is determined.

Figure 10: Step 4.4 – Selection of an assortment

4.2.3 Input of the moisture content

Another important parameter you have to enter is the moisture content of the wood fuel assortment. Enter the moisture content in %[3] in the field. You can enter several decimal places; although only the first decimal place will be shown, all entered decimal places are considered in the calculation (see Figure 11: Step 4.5 – Input of the moisture content).

Figure 11: Step 4.5 – Input of the moisture content

4.2.4 Input of the price per unit

You can enter the wood fuel price per unit in four different input fields:

- input in Euro/t dry matter (DM)

- input in Euro/t fresh substance (FS)

- input in Euro/m³ fresh substance (FS)

  The price per volume unit in m³ corresponds to the unit commonly used for the assortment selected in Figure 10: Step 4.4 – Selection of an assortment (m³(solid), m³(stacked) or m³(loose)).

- input in Euro/MWh

"DM" stands for "dry matter" (0 % moisture content), "FS" stands for "fresh substance" (variable moisture content).

Enter the price in only **one** of the 4 fields – the price will **immediately** be converted into the other price units (see Figure 12: Step 4.6 – Conversion price per unit).

Note: The conversion only works if you have activated the macros, see chapter 3.

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[3] For the main sections "Wood species", "Bark" and "Other", the maximum moisture content you can enter is 80 %; for the main section "Compressed wood", the maximum value is 18 %.

Figure 12: Step 4.6 – Conversion price per unit

4.2.5 Input of installation parameters (fuel demand and fuel mix)

Enter the estimated fuel demand in MWh per year and the fuel mix of your choice in % for the calculation of various installation-specific parameters (such as the amount of fuel needed and the annual fuel costs) (see Figure 13: Step 4.7 – Input of installation parameters).

- Input of the annual fuel demand in MWh

Enter the fuel demand of a specific installation in MWh per year.

- Input of the desired fuel ratio

If you are using more than one wood fuel assortment to fuel your installation, please enter the fuel ratio in % of the total fuel demand for each of your chosen fuel types (values must be integers and must always add up to 100 %).

Figure 13: Step 4.7 – Input of installation parameters

4.3 Details regarding the calculations

- Calculation of the lower heating value based on the higher heating value

The lower heating value (LHV) of fuels can be derived from the higher heating value (HHV), the moisture content and the hydrogen content with the following formula[4]:

$$LHV = HHV * \left(1 - \frac{mc}{100}\right) - 2{,}447 * \frac{mc}{100} - \frac{h}{100*2} * 18{,}02 * 2{,}447 * \left(1 - \frac{mc}{100}\right) \qquad [MJ \, / \, kg \, FS]$$

> *LHV …lower heating value in MJ / kg FS*
> *HHV …higher heating value in MJ / kg DM*
> *mc …moisture content in % by weight FS*
> *h …hydrogen content in % by weight DM*

Formula 1: Calculation of the lower heating value (LHV) based on the higher heating value (HHV), the moisture content and the hydrogen content of a fuel

- Calculation of the bulk density of fresh substance

The calculation of the bulk density is based on the oven-dry density, the moisture content, the shrinkage rate and a conversion factor for the unit (

Formula 2: Calculation of the bulk density of fresh substance).

Tables and standards usually list only the species-specific mean oven-dry weight[5] of water-free wood substance (0 % moisture content). For the calculation of wood fuel parameters per volume unit of fresh substance, the spreadsheet uses the formulas below to calculate the approximate bulk density at the manually entered moisture content.

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[4] Obernberger, I. et al (1999): Planerseminarzyklus für Biomasseheizwerke und Biomasse-Kraft-Wärme-Kopplungsanlagen

[5] Sometimes, the bulk density at a moisture content (on a dry weight basis) of 12-15 % - a value which is relevant for interior work – is also specified. It is important not to confuse the moisture content on a dry weight basis (given in % by weight of dry matter) with the moisture content on a wet weight basis (given in % by weight of fresh substance).

$mc > 23\,\%:$

$$\rho = \left[\rho_0 * \left(1 - \frac{\beta}{100}\right) \middle/ \left(1 - \frac{mc}{100}\right)\right] * \frac{1}{f_1} \qquad \left[kg/m^3\right]$$

$mc \le 23\,\%:$

$$\rho = \left[\rho_0 * \left(1 - \frac{\dfrac{mc}{23} * \beta}{100}\right) \middle/ \left(1 - \frac{mc}{100}\right)\right] * \frac{1}{f_1} \qquad \left[kg/m^3\right]$$

$\rho \ldots bulk\ density\ in\ kg/m^3$

$\rho_0 \ldots oven - dry\ density\ in\ kg/m^3$

$mc \ldots moisture\ content\ in\ \%\ by\ weight\ FS$

$\beta \ldots shrinkage\ in\ \%$

$f_1 \ldots conversion\ factor\ (m^3(solid) - m^3(stacked) - m^3(loose))$

Formula 2: Calculation of the bulk density of fresh substance at a moisture content above the fibre saturation point (mc > 23 %) and below the fibre saturation point (mc ≤ 23 %)

During the drying process, wood shrinks when the moisture content drops below the fibre saturation point (around 23 % moisture content) until the oven-dry weight (0 % moisture content) is reached; the shrinkage rate depends on wood species, density and fibre orientation. The shrinkage is smallest along the grain (longitudinally) (0.1 -1 %), higher across the rings (radially) (5 %), and highest in the direction of the annual rings (tangentially) (10 -17 %).

The total volumetric shrinkage value used for the calculation of the bulk density in the spreadsheet is the sum of longitudinal, radial and tangential shrinkage of the respective wood species. An overview of the total shrinkage rates of the different wood species used for the calculation and the respective data sources are given in the data sheet.

- Oven-dry density and bulk density

The calculation of parameters for all wood species is based on mean oven-dry density values in kg/m³. For the sake of simplicity, the oven-dry density values for bark used for this calculation are the same as the values for non-coniferous wood or coniferous wood. The Austrian Energy Agency consulted the following sources for the compilation of the list of species-specific mean oven-dry density values:

- ÖNORM B 3012 Holzarten – Kennwerte zu den Benennungen und Kurzzeichen der ÖNORM EN 13556

- Kollmann, F. (1951): Technologie des Holzes und der Holzwerkstoffe, Springer Verlag

- Wagenführ, R. und Scheiber, C. (1985): Holzatlas, 2. Auflage. VEB Fachbuchverlag Leipzig.ll
  Wagenführ, R. (2004): Bildlexikon Holz, 2. verb. u. erw. Auflage, Fachbuchverlag Leipzig

- Jonas, A. et al (2005): Energie aus Holz, Informationsbroschüre der Landwirtschaftskammer, 9. überarbeitete Auflage, Landeslandwirtschaftskammer NÖ

- Estimations of the Austrian Energy Agency

An overview of the used mean oven-dry density values and the respective data sources are given in the data sheet. Please note that the actual oven-dry density of individual wood fuel shipments can differ considerably from the mean value even within one wood species, as illustrated by the following example.

Slow-growing spruce, nutrient-poor high altitude site:	600 kg/m³
Mean oven-dry density of spruce:	**430 kg/m³**
Fast-growing spruce, nutrient-rich low altitude site:	350 kg/m³

Especially in the case of mixed assortments (e.g. coniferous wood and non-coniferous wood mixed), the oven-dry density of shipments can vary greatly depending on wood species ratio, origin and quality, and can therefore deviate considerably from the values given in the data sheet. It is therefore recommended to set up contracts with wood fuel suppliers based on the delivered energy content [Euro/MWh] or the delivered weight [Euro/t DM].

For the bulk density of pellets in a water-free state, a customary value of 600 kg/m³ was used.

Since wood and bark briquettes are produced in so many different forms, no universally valid bulk density values can be provided for briquettes in a water-free state. Therefore, the calculation uses an estimated bulk density value in kg/m³ based on the value of a very common briquette type (round briquette with a hole in the centre, around 10 cm in diameter and roughly 30 cm in length).

Please note that the oven-dry density value of 700 kg/m³ is only an estimate for a certain briquette type and way of stacking, and that this value can vary considerably for other briquette types and ways of stacking!

- Shrinkage

The calculation of values per volume unit takes shrinkage rates into account. The Austrian Energy Agency consulted the following sources for the compilation of the list of species-specific mean (volumetric) shrinkage rates:

- ÖNORM B 3012 Holzarten – Kennwerte zu den Benennungen und Kurzzeichen der ÖNORM EN 13556

- Kollmann, F. (1951): Technologie des Holzes und der Holzwerkstoffe, Springer Verlag

- Wagenführ, R. und Scheiber, C. (1985): Holzatlas, 2. Auflage. VEB Fachbuchverlag Leipzig.ll
  Wagenführ, R. (2004): Bildlexikon Holz, 2. verb. u. erw. Auflage, Fachbuchverlag Leipzig

- Jonas, A. et al (2005): Energie aus Holz, Informationsbroschüre der Landwirtschaftskammer, 9. überarbeitete Auflage, Landeslandwirtschaftskammer NÖ

- Estimations of the Austrian Energy Agency

The mean total shrinkage rate of mixed assortments (e.g. non-coniferous wood mixed) can vary greatly depending on the ratio of wood species and their origin, and can therefore deviate considerably from the values given in the data sheet.

In the case of compressed wood, no shrinkage adjustment is calculated, since the moisture content of these fuel types usually does not exceed the value range specified by the standards. Deviations from the standards are not taken into account in the calculations in the spreadsheet. Unintended contact of compressed wood products with water due to improper storage or an ingress of water can lead to extreme swelling and the pellets/briquettes disintegrating into sawdust.

4.4 Information on the spreadsheet and the individual parameters

4.4.1 General notes on the use of the spreadsheet

Since the calculation uses macros, please set the security level for macros to "Medium" so that all functions will work properly (drop down menu "Tools" --> "Macro" --> "Security" --> select "Medium" on the "Security level" tab).

The calculations are based on the Austrian standards ÖNORM M 7132, ÖNORM M 7133, ÖNORM M 7135 and ÖNORM B 3012, data provided by the Provincial Chamber of Agriculture of Upper Austria (G. Danninger) and the Provincial Chamber of Agriculture of Lower Austria, and on empirical values.

When using the spreadsheet, please note the following:

- In the first 5 columns of the spreadsheet (columns: "Wood species", "Bark", "Compressed wood"), the mean values from the data sheet are used for the calculations.

- In the last column of the spreadsheet (column "Other"), you can manually enter values based on your own sources or data.

- According to the Austrian standard ÖNORM M 7132, the lower heating value is 18 MJ/kg DM (dry matter) for non-coniferous wood and 19 MJ/kg DM for coniferous wood.

- The oven-dry density of wood containing no water is between roughly 400 and 750 kg/m³ DM and depends on the wood species, the growth conditions (e.g. nutrient-rich low altitude site or nutrient-poor high altitude site) and various other properties of the wood (branchiness, reaction wood, rot and decay, etc.). **The oven-dry density can also vary considerably within a wood species in different wood shipments!**

- Depending on wood species and chip size, the bulk density of forest chips varies between 150 and 230 kg/m³ DM (dry matter).

- For the calculation of the bulk density at a specific moisture content, the mean shrinkage rate of the various wood species (depending on species 8-20 %, see "Data sheet") is taken into consideration.

- The bulk weight of pellets is around 600 kg/m³ DM (dry matter) or around 650 kg/m³ FS (fresh substance). The specified bulk density of pellets - 650 kg/m³(loose) - is consistent with the commonly available product in Austria (spruce sawdust, 6 mm in diameter and 8 % moisture content, tank truck delivery).

- The specified bulk density of roughly 760 kg/m³(stacked) for briquettes (10 kg shrink-wrapped packages stacked on pallets) is only a rough estimation and varies depending on the form of the briquettes and the type of packaging.

- The estimated values of ash weight or ash volume for the calculation of the amount of ash produced can vary depending on wood fuel quality, level of impurities, combustion technology and ash handling.

- It is recommended to set up contracts with wood fuel suppliers based on the delivered energy content in Euro/MWh or based on the weight of the delivered dry matter in Euro/t DM.

- For increased price transparency and easier cost calculation, the fuel costs are given per MWh as well as per volume unit.

The spreadsheet and the data contained therein have been compiled to the best of the author's knowledge and experience. However, the author accepts no liability whatsoever for errors or omissions!

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4.4.2 Detailed information regarding basic parameters

Move the cursor over the red triangle in the respective cell to show the hidden comments in the spreadsheet.

- **Wood species/fuel type**

Choose a wood species/fuel type from the drop-down menu or enter a fuel type of your choice in the "Other" column.

The possible choices in the drop-down menu are also listed in the first column ("Wood species/fuel type") of the data sheet.

- **Fuel group**

The wood species/fuel type is automatically assigned to one of the fuel groups listed in the data sheet (coniferous wood, non-coniferous wood, coniferous wood (mixed), non-coniferous wood (mixed), non-coniferous wood and coniferous wood (mixed), bark (coniferous wood), bark (non-coniferous wood), compressed wood).

In the "Other" column, the fuel group can be entered manually.

- **Assortment**

Choose the assortment from the drop-down menu. The list of selectable wood fuel assortments in the drop-down menu is based on the Austrian standards ÖNORM M 7132, ÖNORM M 7133, ÖNORM M 7135.

In the "Other" column, you can enter the assortment of your choice based on your own data or sources.

- **Conversion factor**

The following factors for the conversion from m³(solid) to m³(stacked) or m³(loose) have been used for the customary assortments:

split firewood (1 m):   1 m³(solid) = 1.4286 m³(stacked)
firewood (stacked):   1 m³(solid) = 1.1765 m³(stacked)
firewood (loose):   1 m³(solid) = 2.0000 m³(loose)
wood chips G30:   1 m³(solid) = 2.5000 m³(loose)
wood chips G50:   1 m³(solid) = 3.0303 m³(loose)
sawdust: 1 m³(solid) = 3.0303 m³(loose)
wood shavings: 1 m³(solid) = 5.0000 m³(loose)
bark chippings (loose):   1 m³(solid) = 3.3333 m³(loose)
Source: ÖNORM M 7132, Papierholz Austria

In the "Other" column, you can manually enter a conversion factor based on your own data or sources.

- **Unit**

m³(solid): unit used in wood fuel trade for roundwood, equals 1 m³ solid wood mass. A further distinction is made in roundwood trade between m³ solid over bark (SOB) and m³

solid under bark (SUB). When comparing prices, it is necessary to consider the point of sale (usually at forest roadside) and possible deductions of bark weight in case of SOB.

m³(stacked): unit used in wood fuel trade equalling 1*1*1 m or 1 m³ stacked wood with air space between the pieces of wood. Firewood is often sold as split firewood (1 m in length) at forest roadside or as oven-ready firewood at heating plant or delivered to the end user. Therefore, it is essential to consider the point of sale and the fuel quality (especially size, wood species, moisture content and storage time) when comparing prices.

m³(loose): unit used in wood fuel trade equalling 1*1*1 m or 1 m³ loosely heaped wood in the form of sawdust, wood chips or oven-ready firewood with air space between the pieces of wood. The solid wood mass contained in one cubic metre loose can vary significantly depending on bulk density and the size of the pieces.

The volume units in m³ that are used with the values below refer to the respective unit used in the wood fuel industry for the selected assortment (e.g. wood chips G30 => unit m³(loose) => bulk density of fresh substance in kg/m³ FS = bulk density of fresh substance in kg/m³(loose) FS).

In the "Other" column, you must also enter the unit corresponding to the chosen conversion factor.

4.4.3 Detailed information regarding moisture content parameters

Move the cursor over the red triangle in the respective cell to show the hidden comments in the spreadsheet.

▪ <u>Moisture content [%]</u>

Enter the moisture content of the chosen wood fuel assortment in this field. Usual levels of moisture content of available wood fuel assortments are:

firewood (oven-ready), one-year seasoned:	25 – 35 %
firewood (oven-ready), two-year seasoned:	15 – 25 %
wood chips (seasoned for at least one summer):	< 35 %
sawing residue chips (green):	45 – 55 %
sawdust (depending on source):	0 – 55 %
bark (green):	45 – 55 %
compressed wood:	8 - 10 % (ÖNORM M 7135: ≤ 10 %)
compressed bark:	usually 8 - 10 % (ÖNORM M 7135 ≤ 18 %)

Source: Empirical values, ÖNORM M 7135

Note: In the wood fuel business, moisture content is defined on a wet weight basis and is expressed as a percentage by weight of the total weight of the wood containing water. For example, a shipment of 1 tonne of wood chips with a moisture content of 40 % consists of 400 kg water and 600 kg water-free wood substance (dry matter). It is important not to confuse the moisture content on a wet weight basis with the moisture content on a dry weight basis.

The maximum moisture content you can enter is 80 % (18 % for compressed wood)!

▪ <u>Hydrogen content [%]</u>

The hydrogen content of wood is around 6.0 - 6.2 % (% by weight of DM).

Source: ÖNORM M 7132

In the "Other" column, you need to enter the hydrogen content of the selected fuel as specified in your own data sources.

4.4.4   Detailed information regarding higher and lower heating values

Move the cursor over the red triangle in the respective cell to show the hidden comments in the spreadsheet.

- Higher heating value (HHV) of dry matter (DM) [MJ/kg]

The higher heating value (HHV) of coniferous wood is around 20.4 MJ/kg DM. Due to a lower resin and lignin content, the higher heating value of non-coniferous wood is somewhat lower than the HHV of coniferous wood and is around 19.3 MJ/kg DM.

For the calculation of the higher heating value of bark (coniferous wood, non-coniferous wood), the spreadsheet uses the same values as for coniferous wood and non-coniferous wood. However, in case of a high content of resin or other extractive compounds the higher heating value of bark can be up to 2.5 MJ/kg higher than that of the wood.

Source: ÖNORM M 7132. For the conversion between MJ/kg and kWh/kg, a factor of 3.6 (1 kWh = 3.6 MJ) is used.

In the "Other" column, you need to enter the higher heating value (HHV) of the selected fuel as specified in your own data sources.

- Higher heating value (HHV) of dry matter (DM) [kWh/kg]

The higher heating value (HHV) of coniferous wood is around 5.6 kWh/kg DM. Due to a lower resin and lignin content, the higher heating value of non-coniferous wood is somewhat lower than the HHV of coniferous wood and is around 5.4 kWh/kg DM.

For the calculation of the higher heating value of bark (coniferous wood, non-coniferous wood), the spreadsheet uses the same values as for coniferous wood and non-coniferous wood. However, in case of a high content of resin or other extractive compounds the higher heating value of bark can be up to 0.7 kWh/kg higher than that of the wood.

Source: ÖNORM M 7132. For the conversion between MJ/kg and kWh/kg, a factor of 3.6 (1 kWh = 3.6 MJ) is used.

- Lower heating value (LHV) of dry matter (DM) [MJ/kg]

The lower heating value (LHV) of a fuel can be derived from the higher heating value (HHV) via an approximation depending on moisture and hydrogen content. Details of the conversion from HHV to LHV are explained in the manual.

According to the Austrian standard ÖNORM, the lower heating value of coniferous wood is 19.0 MJ/kg DM. Due to a lower resin and lignin content, the lower heating value of non-coniferous wood is somewhat lower than the LHV of coniferous wood and is 18.0 MJ/kg DM according to ÖNORM.

For the calculation of the lower heating value of bark (coniferous wood, non-coniferous wood), the spreadsheet uses the same values as for coniferous wood and non-coniferous wood. However, in case of a high content of resin or other extractive compounds the lower heating value of bark can be up to 2.5 MJ/kg higher than that of the wood.

Source: ÖNORM M 7132. For the conversion between MJ/kg and kWh/kg, a factor of 3.6 (1 kWh = 3.6 MJ) is used.

- **Lower heating value (LHV) of dry matter (DM) [kWh/kg]**

The lower heating value (LHV) of a fuel can be derived from the higher heating value (HHV) via an approximation depending on moisture and hydrogen content. Details of the conversion from HHV to LHV are explained in the manual.

According to the Austrian standard ÖNORM, the lower heating value of coniferous wood is around 5.3 kWh/kg DM. Due to a lower resin and lignin content, the lower heating value of non-coniferous wood is somewhat lower than the LHV of coniferous wood and is around 5.0 kWh/kg DM.

For the calculation of the lower heating value of bark (coniferous wood, non-coniferous wood), the spreadsheet uses the same values as for coniferous wood and non-coniferous wood. However, in case of a high content of resin or other extractive compounds the lower heating value of bark can be up to 0.7 kWh/kg higher than that of the wood.

Source: ÖNORM M 7132. For the conversion between MJ/kg and kWh/kg, a factor of 3.6 (1 kWh = 3.6 MJ) is used.

- **Lower heating value (LHV) of fresh substance (FS) at x % H_2O [MJ/kg]**

The lower heating value (LHV) of wood – per weight unit – mainly depends on the moisture content: A 5 % reduction of the moisture content results in an increase of the energy content by roughly 1 MJ/kg.

Freshly felled wood with a moisture content of roughly 55 % has an energy content of around 7 MJ/kg; the moisture content of split firewood can be reduced to around 20 % if it is seasoned for 2 to 3 years, doubling its energy content to around 14 MJ/kg.

- **Lower heating value (LHV) of fresh substance (FS) at x % H_2O [kWh/kg]**

The lower heating value (LHV) of wood – per weight unit – mainly depends on the moisture content: A 5 % reduction of the moisture content results in an increase of the energy content by roughly 0.3 kWh/kg.

Freshly felled wood with a moisture content of roughly 55 % has an energy content of around 2 kWh/kg; the moisture content of split firewood can be reduced to around 20 % if it is seasoned for 2 to 3 years, doubling its energy content to around 4 kWh/kg.

- **Lower heating value (LHV) of fresh substance (FS) at x % H_2O [MJ/m³]**

The m³ unit refers to the unit (m³(solid), m³(stacked) or m³(loose)) of the selected assortment (e.g. larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with an energy content of roughly 3,500 MJ).

The lower heating value (LHV) of wood – per volume unit – depends on a variety of factors. Depending on wood species or mixture of wood species, growth site (nutrient-poor high altitude site versus nutrient-rich low altitude site), assortment (sawdust, coarse wood chips, fine wood chips, firewood, roundwood, compressed wood, etc.) and quality (moisture content, rot and decay, contamination, etc.), the energy content of a wood fuel shipment can vary greatly. The values per volume unit calculated in the spreadsheet are only approximate values for average wood quality and customary assortments.

In order to reduce the risks associated with wood fuel transactions, it is recommended to set up contracts (in Euro per tonne dry matter (DM) or Euro per MWh) that take the bulk weight and the moisture content into account.

- <u>Lower heating value (LHV) of fresh substance (FS) at x % H_2O [kWh/m³]</u>

The m³ unit refers to the unit (m³(solid), m³(stacked) or m³(loose)) of the selected assortment (e.g. larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with an energy content of roughly 970 kWh).

The lower heating value (LHV) of wood – per volume unit – depends on a variety of factors. Depending on wood species or mixture of wood species, growth site (nutrient-poor high altitude site, nutrient-rich low altitude site), assortment (sawdust, coarse wood chips, fine wood chips, firewood, roundwood, compressed wood, etc.) and quality (moisture content, rot and decay, contamination, etc.), the energy content per volume unit of a wood fuel shipment can vary greatly. The values per volume unit calculated in the spreadsheet are only approximate values for average wood quality and customary assortments.

In order to reduce the risks associated with wood fuel transactions, it is recommended to set up contracts (in Euro per tonne dry matter (DM) or Euro per MWh) that take the bulk weight and the moisture content into account.

4.4.5 Detailed information regarding density parameters

Move the cursor over the red triangle in the respective cell to show the hidden comments in the spreadsheet.

- Mean oven-dry density [kg/m³] (at 0 % H_2O)

The specified mean oven-dry densities refer to 1 m³ oven-dried solid wood mass. The oven-dry density values used for the calculation and the respective data sources can be found in the data sheet.

In the "Other" column, you need to enter the oven-dry weight of the selected fuel as specified in your own data sources.

- Mean shrinkage [%]

During the drying process, wood shrinks when the moisture content drops below the fibre saturation point until the oven-dry weight is reached; the shrinkage rate depends on wood species, density and fibre orientation. The shrinkage is smallest along the grain (longitudinally) (0.1 - 1 %), higher across the rings (radially) (5 %), and highest in the direction of the annual rings (tangentially) (10 - 17 %).

The total shrinkage value (for the volume) used for the calculations in the spreadsheet is the sum of longitudinal, radial and tangential shrinkage of the respective wood species. An overview of the total shrinkage rates used for the calculation and the respective data sources are given in the data sheet.

In the case of compressed wood, no shrinkage adjustment is calculated, since the moisture content of these fuel types usually does not exceed the value range specified by the standards. Deviations from the standards are not taken into account in the calculations in the spreadsheet. Unintended contact of compressed wood products with water due to improper storage or an ingress of water can lead to extreme swelling and the pellets disintegrating into sawdust.

In the "Other" column, you need to enter the shrinkage of the selected fuel as specified in your own data sources.

- Bulk density [kg/m³] (at 0 % H_2O)

The estimated bulk density of the selected wood fuel assortment is calculated based on the mean oven-dry density and in consideration of the selected assortment, the specified moisture content and mean shrinkage values. The m³ unit refers to the unit (m³(solid), m³(stacked) or m³(loose)) of the selected assortment (e.g. larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with a bulk density of roughly 278 kg/m³(loose)).

The bulk density of a specific shipment can deviate significantly from the calculated approximate value since the density of wood can differ considerably from the mean values even within one wood species depending on the growth site (nutrient-poor high altitude site, nutrient-rich low altitude site), and furthermore due to the fact that the chip size and the bulk density of wood chips or bark chippings can vary considerably depending on the wood chipper and the transportation distance.

In order to reduce the risks associated with wood fuel transactions, it is recommended to set up contracts (in Euro per tonne dry matter (DM) or Euro per MWh) that take the bulk weight and the moisture content into account.

- <u>Proportion of wood substance [kg/m³] (proportion of DM at x % H_2O)</u>

The estimated proportion of wood substance of the selected wood fuel assortment is calculated based on the mean oven-dry density and in consideration of the selected assortment, the specified moisture content and mean shrinkage values. The m³ unit refers to the unit (m³(solid), m³(stacked) or m³(loose)) of the selected assortment (e.g. larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with a bulk density of roughly 278 kg/m³(loose) => a moisture content of 30 % corresponds to 84 kg H_2O per m³(loose), 70 % wood substance (DM) correspond to 195 kg DM per m³(loose) (rounded)).

The bulk density of a specific shipment can deviate significantly from the calculated approximate value since the density of wood can differ considerably from the mean values even within one wood species depending on the growth site (nutrient-poor high altitude site, nutrient-rich low altitude site), and furthermore due to the fact that the chip size and the bulk density of wood chips or bark chippings can vary considerably depending on the wood chipper and the transportation distance.

In order to reduce the risks associated with wood fuel transactions, it is recommended to set up contracts (in Euro per tonne dry matter (DM) or Euro per MWh) that take the bulk weight and the moisture content into account.

- <u>Proportion of water [kg/m³] (proportion of H_2O at x % H_2O)</u>

The estimated proportion of water of the selected wood fuel assortment is calculated based on the specified moisture content and in consideration of the selected assortment, the mean oven-dry density and mean shrinkage values. The m³ unit refers to the (m³(solid), m³(stacked) or m³(loose)) of the selected assortment (e.g. larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with a bulk density of roughly 278 kg/m³(loose) => a moisture content of 30 % corresponds to 84 kg H_2O per m³(loose), 70 % wood substance (DM) correspond to 195 kg DM per m³(loose) (rounded)).

The bulk density of a specific shipment can deviate significantly from the calculated approximate value since the density of wood can differ considerably from the mean values even within one wood species depending on the growth site (nutrient-poor high altitude site, nutrient-rich low altitude site), and furthermore due to the fact that the chip size and the bulk density of wood chips or bark chippings can vary considerably depending on the wood chipper and the transportation distance.

In order to reduce the risks associated with wood fuel transactions, it is recommended to set up contracts (in Euro per tonne dry matter (DM) or Euro per MWh) that take the bulk weight and the moisture content into account.

- <u>Ratio m³ per tonne fresh substance (FS) [m³/t]</u>

Provides an estimate of the required storage and transport volume per tonne fresh substance (FS) of the selected wood fuel assortment.

The estimated bulk density of the selected wood fuel assortment is calculated based on the mean oven-dry density and in consideration of the selected assortment, the specified moisture content and mean shrinkage values. The m³ unit refers to the unit (m³(solid), m³(stacked) or m³(loose)) of the selected assortment (e.g. larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with a bulk density of roughly 278 kg/m³(loose) => 1,000/278 = around 3.6 m³(loose) of wood chips per tonne fresh substance.

The bulk density of a specific shipment can deviate significantly from the calculated approximate value since the density of wood can differ considerably from the mean values even within one wood species depending on the growth site (nutrient-poor high altitude site, nutrient-rich low altitude site), and furthermore due to the fact that the chip size and the bulk density of wood chips or bark chippings can vary considerably depending on the wood chipper and the transportation distance.

In order to reduce the risks associated with wood fuel transactions, it is recommended to set up contracts (in Euro per tonne dry matter (DM) or Euro per MWh) that take the bulk weight and the moisture content into account.

4.4.6   Detailed information regarding ash

Move the cursor over the red triangle in the respective cell to show the hidden comments in the spreadsheet.

- Ash content (estimate) [%]

The ash content of wood fuel assortments mainly depends on the proportion of bark and the level of impurities (mineral contamination through storage and manipulation) in the fuel.

Due to varying levels of impurities in wood fuel, only rough estimates of ash content are made in the referenced studies (see Obernberger 1997, "Nutzung fester Biomasse in Verbrennungsanlagen").

For the estimation of the amount of ash, the following ash content values in percent by weight of dry matter (DM) were used:

- firewood:	1.0 %
- wood chips G30 and G50:	1.5 %
- sawdust and wood shavings:	1.0 %
- bark:	6.0 %
- compressed wood:	0.3 – 0.5 %
- compressed bark:	6.0 %

Source: Empirical values, Obernberger 1997, ÖNORM M 7135.

- Ash density (estimate) [kg/m³]

Depending on combustion efficiency and ash type (fly ash or bottom ash), the ash weight is between 300 and 1,000 kg/m³. For calculation purposes, a mean ash weight of 700 kg/m³ was assumed.

Source: Empirical values; Ruckenbauer, Obernberger, Holzner; 1996.

4.4.7 Detailed information regarding price

Move the cursor over the red triangle in the respective cell to show the hidden comments in the spreadsheet.

Activate macros! Enter the fuel price in one of the input fields, and the price will immediately be converted into the other price units.

- **Price per unit in [Euro/t DM]**

Enter the fuel price in Euro per tonne dry matter (DM). The entered value will immediately be converted into the other price units in the fields below, thus allowing immediate comparison of fuel prices in the different price units.

Example: Larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with an energy content of roughly 970 kWh/m³(loose) => enter price in Euro/t DM as "80.00" => immediate conversion into 56.00 Euro/t FS, 15.59 Euro/m³ (Euro/m³(loose)), 16.04 Euro/MWh and 4.46 Euro/GJ.

For price comparisons, it is essential to consider the point of sale and the fuel quality of the wood fuel assortment since transportation and chopping costs can account for a significant part of the overall costs (e.g. point of sale at forest roadside in the form of roundwood or at heating plant or CHP plant in the form of ready-to-use wood chips).

Important note: For the calculations to work as intended, macros have to be activated in the Excel settings. Should the other price unit cells not be updated with the respective converted values after one value has been entered, the macros have not been activated. Please check your Excel settings under Tools => Macro | Security | Security level | Medium.

- **Price per unit in [Euro/t FS]**

Enter the fuel price in Euro per tonne fresh substance (FS). The entered value will immediately be converted into the other price units in the fields below and above, thus allowing immediate comparison of fuel prices in the different price units.

Example: Larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with an energy content of roughly 970 kWh/m³(loose) => enter price in Euro/t FS (equals Euro/m³ as "60.00" => immediate conversion into 85.71 Euro/t DM, 16.71 Euro/m³ (Euro/m³(loose)), 17.19 Euro/MWh and 4.77 Euro/GJ.

For price comparisons, it is essential to consider the point of sale and the fuel quality of the wood fuel assortment since transportation and chopping costs can account for a significant part of the overall costs (e.g. point of sale at forest roadside in the form of roundwood or at heating plant or CHP plant in the form of ready-to-use wood chips).

Important note: For the calculations to work as intended, macros have to be activated in the Excel settings. Should the other price unit cells not be updated with the respective converted values after one value has been entered, the macros have not been activated. Please check your Excel settings under Tools => Macro | Security | Security level | Medium.

- **Price per unit in [Euro/m³ FS]**

Enter the fuel price in Euro per m³ fresh substance (FS). The m³ unit refers to the unit used in wood fuel trade for the selected assortment. The entered value will immediately be converted into the other price units in the fields below and above, thus allowing immediate comparison of fuel prices in the different price units.

Example: Larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with an energy content of roughly 970 kWh/m³(loose) => enter price in Euro/m³ (equals Euro/m³(loose)) as "17.50" => immediate conversion into 89.78 Euro/t DM, 62.85 Euro/t FS, 18.00 Euro/MWh and 5.00 Euro/GJ.

For price comparisons, it is essential to consider the point of sale and the fuel quality of the wood fuel assortment since transportation and chopping costs can account for a significant part of the overall costs (e.g. point of sale at forest roadside in the form of roundwood or at heating plant or CHP plant in the form of ready-to-use wood chips).

Important note: For the calculations to work as intended, macros have to be activated in the Excel settings. Should the other price unit cells not be updated with the respective converted values after one value has been entered, the macros have not been activated. Please check your Excel settings under Tools => Macro | Security | Security level | Medium.

- **Price per unit in [Euro/MWh]**

Enter the fuel price in Euro per MWh. The entered value will immediately be converted into the other price units in the fields below and above, thus allowing immediate comparison of fuel prices in the different price units.

Example: Larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with an energy content of roughly 970 kWh/m³(loose) => enter price in Euro/MWh as "17.00" => immediate conversion into 84.77 Euro/t DM, 59.34 Euro/t FS, 16.52 Euro/m³ (Euro/m³(loose)) and 4.72 Euro/GJ.

For price comparisons, it is essential to consider the point of sale and the fuel quality of the wood fuel assortment since transportation and chopping costs can account for a significant part of the overall costs (e.g. point of sale at forest roadside in the form of roundwood or at heating plant or CHP plant in the form of ready-to-use wood chips).

Important note: For the calculations to work as intended, macros have to be activated in the Excel settings. Should the other price unit cells not be updated with the respective converted values after one value has been entered, the macros have not been activated. Please check your Excel settings under Tools => Macro | Security | Security level | Medium.

- Price per unit in [Euro/GJ]

In addition to the already mentioned units, fuel prices are also shown in Euro/GJ, facilitating conversion between Euro per MWh and Euro per GJ (conversion factor 3.6; i.e. 1 MWh = 3.6 GJ).

Example: Larch, wood chips G30, moisture content 30 % => 1 m³ equals 1*1*1 m or 1 loose m³ of poured wood chips with an energy content of roughly 970 kWh/m³(loose) => enter price in Euro/MWh as "17.00" => immediate conversion into 84.77 Euro/t DM, 59.34 Euro/t FS, 16.52 Euro/m³ (Euro/m³(loose)) and 4.72 Euro/GJ.

For price comparisons, it is essential to consider the point of sale and the fuel quality of the wood fuel assortment since transportation and chopping costs can account for a significant part of the overall costs (e.g. point of sale at forest roadside in the form of roundwood or at heating plant or CHP plant in the form of ready-to-use wood chips).

Important note: For the calculations to work as intended, macros have to be activated in the Excel settings. Should the other price unit cells not be updated with the respective converted values after one value has been entered, the macros have not been activated. Please check your Excel settings under Tools => Macro | Security | Security level | Medium.

4.4.8 Detailed information regarding installation parameters

Move the cursor over the red triangle in the respective cell to show the hidden comments in the spreadsheet.

- **Fuel demand per year [MWh/a]**

The annual fuel demand of an installation can be estimated with the given fuel heat input capacity (MW) and the expected full load hours per year (h) (MW*h = MWh).

The annual full load hours can range from around 1,500 h for small-scale installations for space heat generation to up to 8,000 h for process heat generating facilities for industrial purposes.

For example, the estimated annual fuel demand of a biomass heating plant with a fuel heat input capacity of 1 MW and 1,500 full load hours is 1,500 MWh (corresponding to roughly 2,300 m³(loose) of wood chips), while a biomass CHP plant in the sawmill industry with a fuel heat input capacity of 24 MW and 7,500 full load hours would need 120 times as much fuel, i.e. 180,000 MWh (corresponding to roughly 270,000 m³(loose) of wood chips).

- **Fuel ratio [%]**

Enter the fuel ratio in % for each of your chosen fuel types in the light red cells of this row.

The individual values must always add up to 100 %, otherwise the number in the cell showing the sum will be clearly marked by a dark red background.

- **Fuel volume [m³ FS/a]**

Based on the entered fuel demand in MWh/a and considering the entered percentages for the selected fuel types, the spreadsheet calculates the estimated fuel volume for each assortment and the total fuel volume of the installation in m³ fresh substance (FS) per year.

The m³ unit refers to the respective assortment selected above; in order to avoid a miscalculation of the total fuel volume needed, it is therefore necessary to ensure that the volume unit (m³(solid), m³(stacked), m³(loose)) is the same for each assortment.

Example: The estimated annual fuel demand of a biomass heating plant with a fuel heat input capacity of 1 MW and 1,500 full load hours is 1,500 MWh. 70 % of the used fuel are coniferous wood and non-coniferous wood chips G50 (average moisture content 35 %), 30 % are coniferous wood bark chippings (loose) (average moisture content 50 %). The estimated annual fuel volume is around 2,350 m³(loose). A truck-trailer designed for the transportation of wood chips has a load capacity of roughly 80 m³(loose). Thus, about 30 truck loads of wood chips and bark would be needed to meet the fuel demand of this heating plant.

- **Fuel weight in terms of dry matter [t DM/a]**

Based on the entered fuel demand in MWh/a and considering the entered percentages for the selected fuel types, the spreadsheet calculates the estimated fuel weight for each assortment and the total fuel weight of the installation in tonnes dry matter (DM) per year [t DM/a].

Trading wood in tonnes dry matter (DM) is common practice when dealing with industrial roundwood assortments of inferior quality.

Example: The estimated annual fuel demand of a biomass heating plant with a fuel heat input capacity of 1 MW and 1,500 full load hours is 1,500 MWh. 70 % of the used fuel are coniferous wood and non-coniferous wood chips G50 (average moisture content 35 %), 30 % are coniferous wood bark chippings (loose) (average moisture content 50 %). The estimated annual fuel weight is around 314 tonnes dry matter (DM).

- **Fuel weight in terms of fresh substance [t FS/a]**

Based on the entered fuel demand in MWh/a and considering the entered percentages for the selected fuel types, the spreadsheet calculates the estimated fuel weight for each assortment and the total fuel weight of the installation in tonnes fresh substance (FS) per year [t FS/a].

Example: The estimated annual fuel demand of a biomass heating plant with a fuel heat input capacity of 1 MW and 1,500 full load hours is 1,500 MWh. 70 % of the used fuel are coniferous wood and non-coniferous wood chips G50 (average moisture content 35 %), 30 % are coniferous wood bark chippings (loose) (average moisture content 50 %). The estimated annual fuel weight is around 528 tonnes fresh substance (FS).

- **Ash weight (estimate) [t/a]**

Based on the entered fuel demand in MWh/a and considering the entered percentages for the selected fuel types, the spreadsheet calculates the estimated ash weight for each assortment and the total ash weight of the installation in tonnes per year [t/a].

Example: The estimated annual fuel demand of a biomass heating plant with a fuel heat input capacity of 1 MW and 1,500 full load hours is 1,500 MWh. 70 % of the used fuel are coniferous wood and non-coniferous wood chips G50 (average moisture content 35 %, ash content 1.5 %), 30 % are coniferous wood bark chippings (loose) (average moisture content 50 %, ash content 6 %). The estimated amount of ash produced in the combustion process is around 12 tonnes per year.

- **Ash volume (estimate) [m³/a]**

Based on the entered fuel demand in MWh/a and considering the entered percentages for the selected fuel types, the spreadsheet calculates the estimated ash volume for each assortment and the total ash volume of the installation in m³ per year [m³/a].

Example: The estimated annual fuel demand of a biomass heating plant with a fuel heat input capacity of 1 MW and 1,500 full load hours is 1,500 MWh. 70 % of the used fuel are coniferous wood and non-coniferous wood chips G50 (average moisture content 35 %, 1.5 % ash content with an ash density of around 700 kg/m³), 30 % are coniferous wood bark

chippings (loose) (average moisture content 50 %, 6 % ash content with an ash density of around 700 kg/m³). The estimated amount of ash produced in the combustion process is around 16 m³ per year.

- Fuel costs per year [Euro/a]

Based on the entered fuel demand in MWh/a and considering the entered percentages for the selected fuel types, the spreadsheet calculates the fuel costs for each assortment and the total fuel costs of the installation in Euro per year [Euro/a].

Example: The estimated annual fuel demand of a biomass heating plant with a fuel heat input capacity of 1 MW and 1,500 full load hours is 1,500 MWh. 70 % of the used fuel are coniferous wood and non-coniferous wood chips G50 (average moisture content 35 %, 80 Euro/t DM), 30 % are coniferous wood bark chippings (loose) (average moisture content 50 %, 7 Euro/m³(loose)). The total fuel cost is around 23,000 Euro per year.

- Composite fuel price [Euro/MWh]

Based on the entered fuel demand in MWh/a and considering the entered percentages for the selected fuel types, the spreadsheet calculates the fuel costs for each assortment and the composite fuel price in Euro per MWh [Euro/MWh].

Example: The estimated annual fuel demand of a biomass heating plant with a fuel heat input capacity of 1 MW and 1,500 full load hours is 1,500 MWh. 70 % of the used fuel are coniferous wood and non-coniferous wood chips G50 (average moisture content 35 %, 80 Euro/t DM), 30 % are coniferous wood bark chippings (loose) (average moisture content 50 %, 7 Euro/m³(loose)). The total fuel cost is around 23,000 Euro per year. This corresponds to a composite fuel price of around 15 Euro per MWh.

4.5 Description of the worksheet „Data sheet"

The worksheet "Data sheet" lists all the wood species and fuel types that can be selected in the spreadsheet and contains all data needed for the calculation. (For the calculation of the parameters of other fuels, you must enter your own data in the cells of the spreadsheet's "Other" column; see chapter 4.1.2 "Description of the individual sections ".)

Figure 14: Detail of the worksheet "Data sheet" shows part of the data sheet (because of the worksheet's size, only a detail can be shown here).

Figure 14: Detail of the worksheet "Data sheet"

The first column "Wood species/fuel type" lists the wood species native to Central Europe as well as the wood fuel assortments "bark", "briquettes" and "pellets". Furthermore, the mixed assortments "non-coniferous wood" (subdivided into "non-coniferous softwood" and "non-coniferous hardwood"), "coniferous wood" and "CW & NCW" for a representative mix of coniferous wood and/or non-coniferous wood are listed. The proportion of the respective wood species in the mixed assortments (CW & NCW, coniferous wood, non-coniferous wood, non-coniferous softwood, non-coniferous hardwood) has been taken from the total wood use statistics provided by the Austrian Forest Inventory 2000 - 2002. The calculation values (higher heating value, oven-dry density etc.) for the mixed assortments are weighted according to these proportions.

As an additional service, the columns 2 - 4 contain useful information on the respective wood species, such as abbreviations, botanical names and alternative names.

Column 5 shows the fuel groups the wood species/fuel types belong to. The fuel group is automatically shown in the "Calculation" worksheet when a wood species/fuel type has been selected.

Column 6 shows the hydrogen content, which is 6.0 % for all non-coniferous woods and 6.2 % for all coniferous woods, compressed wood products and non-coniferous wood and coniferous wood (mixed). The hydrogen content is automatically shown in the "Calculation" worksheet when a wood species/fuel type has been selected.

Column 7 shows the higher heating value (HHV) which is around 20.4 MJ/kg DM[6] for all coniferous woods and compressed wood products, and 19.3 MJ/kg DM[7] for all non-coniferous woods. The value for coniferous wood and non-coniferous wood (mixed) - 20.2 MJ/kg DM – is weighted based on the wood species distribution[8].

The columns 8 - 14 contain density values. The columns 8 - 9 show (mean) oven-dry density values and the respective sources, while the columns 10 - 14 list the minimum, mean and maximum bulk density at a moisture content on a dry weight basis of 12 - 15 %[9]. The mean oven-dry density values are used for the calculation and are transferred to the "Calculation" worksheet when a wood species/fuel type has been selected. The bulk density values specified in the "Calculation" worksheet are an approximation based on the mean oven-dry density and the specified moisture content (see 4.4.5 Detailed information regarding density parameters).

The columns 15 - 16 contain the mean total (volumetric) shrinkage. The total shrinkage rate is the sum of longitudinal, radial and tangential shrinkage. The mean total shrinkage rate is used for the calculation and is transferred to the "Calculation" worksheet when a wood species/fuel type has been selected.

The data source for the oven-dry density, the bulk density (moisture content (dry basis) 12 - 15) and the shrinkage values is also given in the data sheet. The Austrian Energy Agency consulted the following sources for the compilation of the spreadsheet:

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[6] According to the standard lower heating value (LHV) of coniferous wood (19.0 MJ/kg DM) and the conversion formula, the higher heating value (HHV) is roughly 20.4 MJ/kg DM (rounded). For the calculation, the spreadsheet uses a value of 20.366931 MJ/kg DM.

[7] According to the standard lower heating value (LHV) of non-coniferous wood (18.0 MJ/kg DM) and the conversion formula, the higher heating value (HHV) is roughly 19.3 MJ/kg DM (rounded). For the calculation, the spreadsheet uses a value of 19.3228482 MJ/kg DM.

[8] Weighted based on the wood species distribution of wood use in Austria (evaluation of the Austrian Forest Inventory 2000/02, BFW), the mixed assortment of coniferous wood and non-coniferous wood has a higher heating value of roughly 20.2 MJ/kg DM (rounded). For the calculation, the spreadsheet uses a value of 20.2060354 MJ/kg DM.

[9] The bulk density values at a moisture content (dry basis) of 12 - 15 % - a value which is relevant for interior work - are listed in the data sheet only for information purposes and are not used for the calculation of parameters. It is important not to confuse the moisture content on a dry weight basis with the moisture content on a wet weight basis.

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1) ÖNORM B 3012 Holzarten – Kennwerte zu den Benennungen und Kurzzeichen der ÖNORM EN 13556

2) Kollmann, F. (1951): Technologie des Holzes und der Holzwerkstoffe, Springer Verlag

3) Wagenführ, R. und Scheiber, C. (1985): Holzatlas, 2. Auflage. VEB Fachbuchverlag Leipzig. || Wagenführ, R. (2004): Bildlexikon Holz, 2. verb. U. erw. Auflage, Fachbuchverlag Leipzig

4) Jonas, A. et al (2005): Energie aus Holz, Informationsbroschüre der Landwirtschaftskammer, 9. überarbeitete Auflage, Landeslandwirtschaftskammer NÖ

5) Eigene Abschätzungen der Österreichischen Energieagentur

Column 17 – "Comments" - contains explanatory notes on some of the wood species/fuel types.

Another table in the data sheet contains the assortments, the respective factors for the conversion from m³(solid) to the commonly used unit for the assortment (m³(solid), m³(stacked) or m³(loose)) and the estimated ash content. These data are also transferred to the "Calculation" worksheet when the assortment has been selected.

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5 Usage examples

The spreadsheet „Calculation of Wood Fuel Parameters" enables you to conveniently and quickly

- compare the parameters of various wood species, bark, compressed wood and other fuels, e.g. lower heating value in kWh/m³ fresh substance (FS), bulk density in kg/m³ fresh substance (FS), etc.

- convert the prices of wood fuel assortment from units used in wood fuel trade to various other units (e.g. conversion from Euro/m³ fresh substance (FS) to Euro/MWh) and compare them

- Calculate data regarding the installation, such as fuel costs and fuel demand per year, amount of ash per year, etc.

5.1 Sale of spruce roundwood in Euro per tonne dry matter (DM)

Stipulated price in Euro/t dry matter (DM): 90.0

Measured moisture content: 30 %

Question 1: What are the specific costs in Euro/MWh?

Question 2: What is the price in Euro/t fresh substance (FS)?

Question 3: What is the price in Euro/m³(solid)?

Figure 15: Calculation example 1

After you have entered the values (see Figure 15: Calculation example 1 steps 1-4), the results are shown in the spreadsheet (see step 5).

Answer 1: What are the specific costs in Euro/MWh? → **18.05**

Answer 2: What is the price in Euro/t fresh substance (FS)? → **63.00**

Answer 3: What is the price in Euro/m³(solid)? → **34.17**

5.2 Purchase of non-coniferous wood chips G30 in Euro per MWh:

Stipulated price in Euro/MWh: 19.00

Measured moisture content: 35 %

Question 1: What is the price in Euro/t dry matter (DM)?

Question 2: What is the price in Euro/t fresh substance (FS)?

Question 3: What is the price in Euro/m³(loose)?

Figure 16: Calculation example 2

After you have entered the values (see Figure 16: Calculation example 2 steps 1-4), the results are shown in the spreadsheet (see step 5).

Answer 1: What is the price in Euro/t dry matter (DM)? → **88.05**

Answer 2: What is the price in Euro/t fresh substance (FS)? → **57.23**

Answer 3: What is the price in Euro/m³(loose)? → **19.07**

6 Bibliography

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