Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Biomass and Bioenergy 27 (2004) 671–693
BIOMASS & BIOENERGY
www.elsevier.com/locate/biombioe

Wood pellet production costs under Austrian and in comparison to Swedish framework conditions

Gerold Thek[a,*], Ingwald Obernberger[a,b]

[a]Bios Bioenergiesysteme GmbH, Inffeldgasse 21B, A-8010 Graz, Austria
[b]Graz University of Technology,Institute for Resource Efficient and Sustainable Systems, Inffeldgasse 21B, A-8010 Graz, Austria

Received 4 December 2002; received in revised form 8 July 2003; accepted 28 July 2003

Abstract

Owing to the rapidly increasing importance of pellets as high-quality biomass fuel in Austria and Europe within the last years, many companies, mainly from the wood industry, are thinking of entering this market. The calculation of the production costs before starting a pellet plant is essential for an economic operation. Based on comprehensive investigations within the EU-ALTENER project "An Integrated European Market for Densified Biomass Fuels" calculations of the pellet production costs loco factory for different framework conditions with basic data based on already realised plants as well as a questionnaire survey of pellet producers in Austria, South Tyrol and Sweden have been performed.

The production costs for wood pellets are mainly influenced by the raw material costs and, in the case of using wet raw materials, by the drying costs. Depending on the framework conditions these two parameters can contribute up to one-third of the total pellet production costs. Other important parameters influencing the pellet production costs are the plant utilisation (number of shifts per week) as well as the availability of the plant. For an economic production of wood pellets at least three shifts per day at 5 days per week are necessary. An optimum would be an operation at 7 days per week. A low plant availability also leads to greatly increased pellet production costs. A plant availability of 85–90% should therefore be achieved.

The calculations show that a wood pellet production is possible both in small-scale (production rates of some hundred tonnes per year) as well as in large-scale plants (some ten thousand tonnes per year). However, especially for small-scale units it is very important to take care of the specific framework conditions of the producer, because the risk of a non-economic pellet production is considerably higher than for large-scale systems.

The direct comparison of typical pellet production costs in Austria and Sweden showed the Swedish pellet production costs to be considerably lower due to larger plant capacities, the combination of pellet production and biomass CHP or biomass district heating plants and the implementation of technologies which allow an efficient heat recovery from the

*Corresponding author. Tel.: +43-316-481300-63; fax: +43-316-481300-4.
E-mail address: thek@bios-bioenergy.at (G. Thek).

doi:10.1016/j.biombioe.2003.07.007

dryers. Moreover, another difference between the Austrian and the Swedish framework conditions is the price of electricity, which is much lower in Sweden.

Keywords: Pellets; Pelletisation; Production costs

1. Introduction and objectives

Both the production and the demand for wood pellets in Austria as well as in several other European countries show currently a strong increase. Many companies, mainly from the wood industry, which have appropriate raw materials available for the production of wood pellets are already active in this field or are thinking of entering this market. Moreover, companies, which would have to buy raw materials for the wood pellet production and also companies with drying capacities are interested in the market for wood pellets. To start a pellet production plant it is essential to calculate the pellet production costs in advance in order to consider and investigate specific framework conditions of the producer for an economic operation.

Comprehensive investigations and calculations of the production costs of wood pellets under consideration of all relevant parameters and for different framework conditions have been performed within the EU-ALTENER project "An Integrated European Market for Densified Biomass Fuels (INDEBIF)" [1]. The calculations are based on data from planned and already realised pellet production plants. Furthermore, data obtained from a questionnaire survey of producers of wood pellets in Austria, South Tyrol and Sweden have been considered for the calculation of the production costs. Distribution costs (by an own distribution system from the producer or by retailers) are not considered, following the costs calculated are pellet production costs loco factory.

Further objectives of the work were the performance of sensitivity analyses of important cost factors in the pellet production process as well as a comparison of Austrian and Swedish pellet production costs.

2. Methodology

An economic evaluation of the steps of the manufacturing process was made using the full costing method based on the guideline VDI 2067 [2]. According to this guideline, the different types of costs are divided into four cost groups. These are:

- the costs based on capital (capital and maintenance costs),
- the consumption costs,
- the operating costs
- and other costs.

The costs based on capital consist of the annual capital and maintenance costs. The annuity (annual capital costs) can be calculated by multiplying the capital recovery factor (CRF, see Eq. (1)) with the investment costs. The annual maintenance costs are calculated in per cent of the whole investment costs on the basis of guiding values and are evenly spread over the years of the utilisation period. The capital and maintenance costs are calculated for each unit of the overall pelletisation plant, taking the different wear and utilisation periods into consideration. The total capital and maintenance costs can be calculated by addition of these subtotals:

$$\mathrm{CRF} = \frac{(1+i)^n i}{(1+i)^n - 1} \tag{1}$$

Explanations: CRF = capital recovery factor; i = calculated interest rate in %; n = utilisation period in years

No investment subsidies are considered for the calculation of the pellet production costs. The interest rate considered is generally 7% p.a. (no difference between own and outside capital).

All costs in connection with the manufacturing process, e.g. the costs for raw material, the heat for drying and the electricity demand are included in the group of consumption costs. The operating costs comprise costs originating from the operation of the plant, e.g. personnel costs. The other costs include costs such as insurance rates, overall dues, taxes and administration costs and are calculated as a percentage of the overall investment costs. These costs are calculated according to already gained experiences from pellet production plants in operation (data from engineering companies, a questionnaire survey and discussions with plant operators).

The following parameters must be considered in a detailed calculation of the pellet production costs:

- The investment costs of all units of the pellet production process as well as of construction, offices and data processing, market introduction and planning as well as the utilisation period and maintenance costs of all units and facilities.
- The raw material costs as well as the water content and the bulk density of the raw material used.
- The price for electricity, the electrical power required for all electrical installations and a simultaneity factor, which considers the fact that not all electrical installations operate on full load at the same time.
- The interest rate.
- The equipment availability, which considers both scheduled and unscheduled shutdowns.
- In case a preceding dryer is installed at the start of the process line, the specific heat costs and the heat demand for drying, furthermore the recoverable heat and the profit from heat sales in case that heat recovery takes place.
- The costs and the demand on bio-additives that may be used and the corresponding dosing system.
- If a conditioning unit working with steam is used, the demand and the costs of the steam.
- The storage costs, depending on the storage capacity and the kind of storage system used (storehouse and/or silo storage).
- The kind of shift work operated (plant utilisation).
- The personnel costs both in production, marketing and administration.
- The annual pellet production rate as well as the water content and the bulk density of the pellets produced.
- Other costs.

From these data both the total pellet production costs as well as the costs caused by each unit or cost factor of the pelletisation process can be calculated.

3. Results for Austria

The total pelletisation process has been separated into general investments, drying (if used), grinding, pelletisation, cooling, storage, peripheral equipment, personnel and raw material. A base case scenario has been calculated, which is compared with other Austrian scenarios (see later in this section) as well as with typical Swedish framework conditions (see Section 4). The framework conditions for the calculation of this base case scenario are shown in Table 1, the results are shown in Table 2 and Fig. 1.

As shown in Fig. 1, the specific pellet production costs are dominated by the consumption costs (raw material, heat and electricity costs), followed by the operating costs (personnel costs) and the costs based on capital. The other costs are of minor relevance.

In addition, the pellet production costs of 11 different case studies covering small as well as large-scale applications have been calculated taking Austrian framework conditions into consideration. The main differences in the framework conditions of the scenarios 1–6, which are based on wet raw material and therefore making drying necessary, compared to the base case scenario (see Table 1) are shown in Table 3. All scenarios (except scenario 2) are based on a 7 days per week and three shifts per day operation, which corresponds to about 24,000 t of pellets produced per year. Scenario 5 is an upscale of the base case scenario applying three pellet mills and three tube bundle dryers of the same capacity. Although one dryer with a higher capacity would be more meaningful and cheaper, this case showed the lowest specific pellet production costs of all

Table 1
Framework conditions for the calculation of the pellet production costs for the base case scenario

Parameters	Unit	Value
General conditions		
Price for electricity	€/MWh	50.87
Interest rate	% p.a.	7.00
Other costs	% p.a.	0.50
Equipment availability	%	90.00
Simultaneity factor (electrical installations)	%	85.00
Utilisation period construction	a	50.00
Service and maintenance costs construction	%	1.00
Utilisation period office and data processing	a	5.00
Service and maintenance costs office and data processing	%	1.00
Utilisation period market introduction	a	10.00
Raw material data		
Raw material		Sawdust
Water content	wt% (w.b.)	55.00
Bulk density (d.b.)	kg (d.b.)/m^3	120.00
Raw material price	€/m^3	4.36
Drying data		
Dryer type		Tube bundle dryer
Specific heat costs (steam)	€/MWh	21.80
Required electric power (including feeding)	kW	77.50
Heat demand for drying (per ton vaporised water)	kWh/$t_{\text{evaporated water}}$	1000.00
Utilisation period	a	15.00
Service and maintenance costs	%	2.50
Grinding data		
Grinding unit type		Hammer mill
Required electric power	kW	110.00
Utilisation period	a	10.00
Service and maintenance costs	%	18.00
Pellet mill data		
Pellet mill type		Ring die pellet mill
Required electric power	kW	233.00
Steam consumption for conditioning per ton pellets produced	wt%	4.00
Specific heat costs (steam)	€/t	11.73
Bio-additive demand	%	1.00
Costs for bio-additives	€/t_{pellets}	1.82
Utilisation period	a	10.00
Service and maintenance costs	%	10.00
Cooling data		
Cooler type		Counterflow cooler
Required electric power	kW	12.00
Utilisation period	a	15.00
Service and maintenance costs	%	2.00
Storage data		
Kind of storage		Silo storage
Utilisation period	a	20.00
Service and maintenance costs	%	1.50
Storage capacity (in % of the annual pellet production)	%	7.61
Peripheral equipment data (conveying systems, intermediate storage, steel construction)		
Required electric power	kW	90.00
Utilisation period	a	10.00
Service and maintenance costs	%	2.00

Table 1 (*continued*)

Parameters	Unit	Value
Pellets data		
Pellet production rate	t (w.b.)/h	3.00
Annual pellet production	t (w.b.)/a	23,652.00
Water content pellets	wt% (w.b.)	10.00
Bulk density pellets	kg (w.b.)/m^3	610.00
Diameter pellets	mm	6.00
Retail price for pellets (exclusive of VAT)	€/t (w.b.)	162.72
Kind of shift work		
Shifts per day		3.00
Working days per week		7.00
Annual operating hours	h p.a.	7884.00
Personnel data		
Hourly rate	€/h	21.80
Annual basis for personnel hours	h p.a.	8760.00
Persons per shift		1.00
Persons for substitution per shift		0.25
Personnel for administration and marketing	€/a	66,000.00

Explanations: wt%—weight per cent; w.b.—wet base; d.b.—dry base; the retail price for pellets is an average price for the year 2002 based on information from pellet retailers; data source [1–3,5,9,10].

Table 2
Calculation of the pellet production costs for the base case scenario

	Investment costs €	Capital costs € p.a.	Maintenance costs € p.a.	Consumption costs € p.a.	Operating costs € p.a.	Other costs € p.a.	Total costs € p.a.	Specific costs €/$t_{pellets}$
General investments	580,080	55,050	4,650			2,900	62,601	2.6
Drying	375,000	41,173	9,375	542,033		1,875	594,456	25.1
Grinding	84,000	11,960	15,120	37,499		420	64,999	2.7
Pelletisation	190,000	27,052	19,000	133,574		950	180,576	7.6
Cooling	13,000	1,427	260	4,091		65	5,843	0.2
Storage	291,000	27,468	4,365	10,251		1,455	43,540	1.8
Peripheral equipment	500,000	71,189	10,000	30,681		2,500	114,370	4.8
Personnel					304,710		304,710	12.9
Raw material				773,420			773,420	32.7
Total	2,033,080	235,319	62,770	1,531,550	304,710	10,165	2,144,514	90.7
Specific costs in €/$t_{pellets}$		9.9	2.7	64.8	12.9	0.4		90.7

Explanations: data source [1–3,5,9,10].

scenarios compared. Another important difference is the application of a belt dryer in scenario 3 and of a superheated steam dryer in scenario 4. The different drying technologies are discussed in Section 3.2 in more detail.

In addition, five scenarios, which are based on dry raw material, have been calculated. For these case studies no drying unit is necessary. An overview of the framework conditions for these scenarios compared to the base case scenario (see Table 1) is shown in Table 4. The results indicate that scenarios 10 and 11, which are characterised by comparatively low annual pellet production rates show specific pellet production costs above

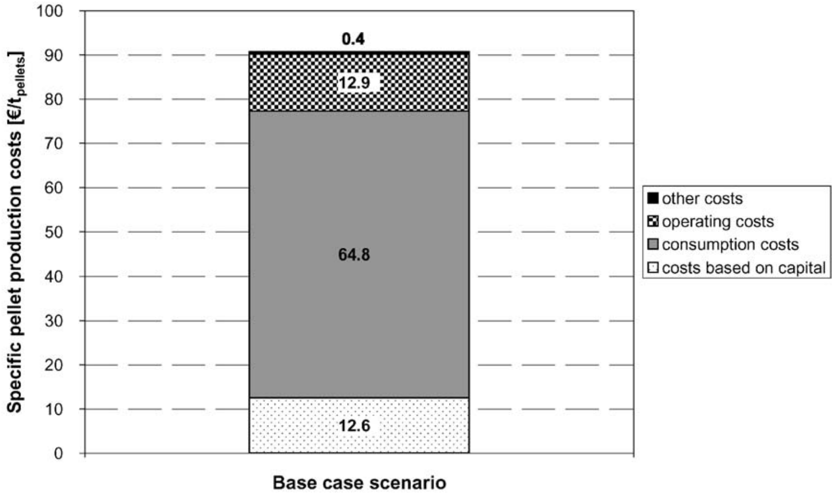

Fig. 1. Pellet production costs and their composition according to the guideline VDI 2067 for the base case scenario.
Explanations: specific pellet production costs loco factory 90.7 €/$t_{pellets}$; the calculation is based on the framework conditions according to Tables 1 and 2 (base case scenario); data source [1,3].

the limit for an economic operation (the upper limit for pellet production costs in order to assure an economically meaningful operation under Austrian framework conditions can be assumed to be about 110 €/$t_{pellets}$ at present (autumn 2002)). These two scenarios point out the high risk of an uneconomic pellet production for small-scale applications. If there are appropriate framework conditions, however, even a small-scale pellet production plant can be economic, which is shown in scenario 7. Owing to the inefficiency of scenarios 10 and 11, they have not been taken into consideration for further comparisons shown in this paper.

The results of all calculations (except scenarios 10 and 11) are summarised in Fig. 2. The different units and cost factors of the pelletisation process are discussed in the following chapters.

3.1. General conditions

The general investments include investments for construction, offices and data processing as well as market introduction and planning. The general investment costs considered in the calculations range from about 3000 € for small-scale applications up to about 1.39 million € for large-scale applications and are mainly caused by construction costs, which represent on average about 75% of the general investment costs.

The utilisation period and the maintenance costs chosen for construction according to the guideline VDI 2067 are 50 years and 1% of the investment costs per year, respectively. Investments in offices and data processing are calculated with a utilisation period of 5 years and maintenance costs of 1% of the investment costs per year. The utilisation period for market introduction has been calculated with 10 years (without maintenance costs).

Low general investment costs can be achieved by using existing infrastructure, whereas the erection of new infrastructure is linked with high general investment costs. The influence of the general investments on the total pellet production costs is comparatively low.

The price for electricity in Austria depends on the annual electricity consumption of a client and amounts to about 95 €/MWh below 1.0 GWh/a, to about 73 €/MWh between 1.0 and 1.5 GWh/a and to about 51 €/MWh above 1.5 GWh/a. Special framework conditions can lead to electricity costs below these prices, e.g. if the operator of the pellet production plant is also owner of a small hydropower power plant. Such a case has been taken into consideration in scenario 7 (see Table 4).

Table 3
Main differences in the framework conditions of scenarios 1–6 compared to the base case scenario

Parameters	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
General conditions							
Total electricity consumption	GWh/a	3.59	2.27	4.05	3.75	9.08	3.63
Specific electricity consumption	$kWh/t_{pellets}$	151.87	134.58	171.42	158.67	128.02	153.57
Total investment costs	€	2,230,452.00	1,810,480.00	2,165,580.00	3,501,180.00	5,019,100.00	2,133,780.00
Drying data							
Dryer type		Tube bundle dryer (A)	Tube bundle dryer (C)	Belt dryer	Superheated steam dryer	3 tube bundle dryers (B)	Tube bundle dryer (B)
Required electric power	kW	94.00	75.00	160.00	115.00	232.50	97.00
Heat demand for drying	$kWh/t_{ev.w.}$	1000.00	1000.00	1100.00	865.00	1000.00	1000.00
Pellet mill data							
Pellet mill type		Flat die	Ring die	Ring die	Ring die	3 ring dies	Ring die
Required electric power	kW	250.00	233.00	233.00	233.00	699.00	233.00
Pellets data							
Annual pellet production	t (w.b.)/a	23,652.00	16,894.29	23,652.00	23,652.00	70,956.00	23,652.00
Specific pellet production costs	$€/t_{pellets}$	94.60	92.00	90.20	84.00	79.60	91.50

Explanations: w.b.—wet base; A, B, C—different dryer manufacturers; data source [1,5–9].

Table 4
Main differences in the framework conditions of scenarios 7–11 compared to the base case scenario

Parameters	Unit	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11
General conditions						
Price for electricity	€/MWh	36.34	72.70	50.87	94.50	94.50
Total electricity consumption	GWh/a	0.03	1.42	2.98	0.08	0.29
Specific electricity consumption	$kWh/t_{pellets}$	75.29	84.29	126.08	88.40	128.56
Total investment costs	€	41,000.00	1,167,060.00	1,635,580.00	138,860.00	633,880.00
Raw material data						
Raw material price	€/m^3	1.09	4.00	4.00	4.00	4.00
Grinding/sieving data						
Grinding unit type		No grinding unit	Sieve	Hammer mill	No grinding unit	Sieve
Required electric power	kW		2.50	110.00		2.50
Utilisation period	Years		15.00	10.00		15.00
Service and maintenance costs	%		10.00	18.00		10.00
Investment costs	€		18,000.00	84,000.00		18,000.00
Pellet mill data						
Pellet mill type		Flat die	Ring die	Ring die	Ring die	Ring die
Required electric power	kW	50.00	233.00	233.00	40.00	154.00
Cooling data						
Cooler type		No cooler	Counterflow cooler	Counterflow cooler	No cooler	No cooler
Storage data						
Kind of storage		Warehouse	Silo/warehouse	Silo	Silo	Silo/warehouse
Pellets data						
Pellet production rate	t (w.b.)/h	0.70	3.00	3.00	0.50	1.20
Annual pellet production	t (w.b.)/a	430.70	16,894.29	23,652.00	938.57	2252.57
Kind of shift work						
Shifts per day		1.00	3.00	3.00	1.00	1.00
Working days per week		1.48	5.00	7.00	5.00	5.00
Annual operating hours	h p.a.	615.29	5631.43	7884.00	1877.14	1877.14
Personnel data						
Hourly rate	€/h	7.27	21.80	21.80	21.80	21.80
Persons per shift		1.00	1.00	1.00	1.00	1.00
Persons for substitution per shift			0.25	0.25	0.25	0.25
Personnel for administration and marketing	€/a	3000.00	66,000.00	66,000.00	2600.00	7700.00
Specific pellet production costs	€/$t_{pellets}$	51.80	83.10	83.70	149.50	138.30

Explanations: w.b.—wet base; data source [1,3,9].

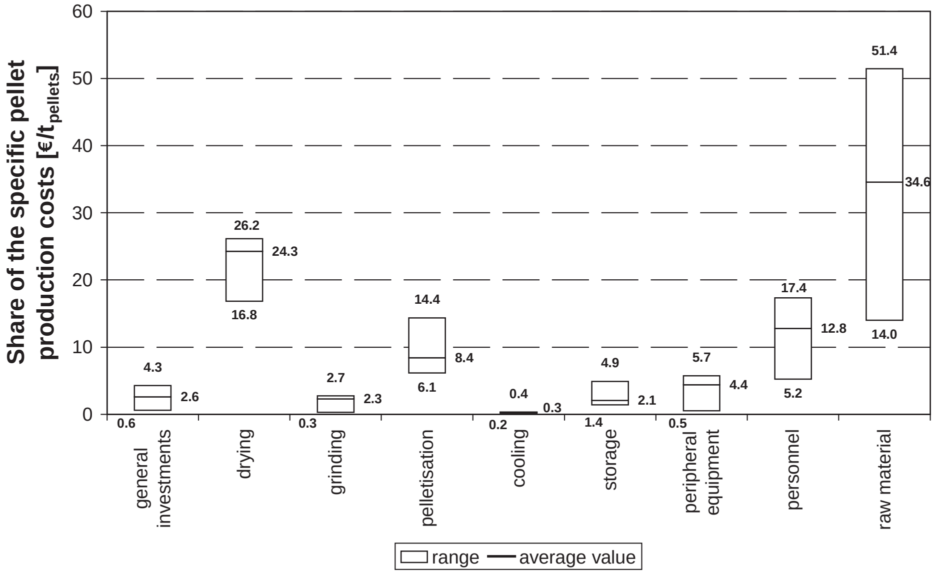

Fig. 2. Production costs caused by each step or cost factor of the pelletisation process.
Explanations: specific pellet production costs loco factory; the calculation is based on a total number of 10 pellet plants investigated; variation of the production capacity between 430 and 79,000 t/a; variation of the annual full load operating hours between 615 and 8,000 h p.a.; data source [1,3].

Insurance rates, overall dues, taxes and administration costs are summarised under other costs. These costs are taken into consideration with an amount of 0.5% of the overall investment costs per year, which is a guiding value according to VDI 2067 [2].

The equipment availability has been assumed to be 90% and the simultaneity factor for electricity demand (= electric power needed on average/ nominal electric power of all units × 100) to be 85%. Both figures remained unchanged for all scenarios calculated and are based on experiences of plant operators [1,9].

3.2. Drying

For the calculation of the drying costs the most common technologies in Austria, tube bundle dryer and belt dryer, have been considered. Furthermore, the possibility of the use of a fluidised bed dryer operated with superheated steam (superheated steam dryer) has been investigated. A comparison of different types of tube bundle dryers as well as a belt and a superheated steam dryer is shown in Table 5 and Fig. 3. The results show that the specific drying costs can vary between 16.85 and 26.16 €/$t_{pellets}$. The specific drying costs of tube bundle dryers and belt dryers are dominated by the consumption costs, because of the high heat demand for drying the raw material. The consumption costs can be reduced significantly if a superheated steam dryer is applied (due to its heat recovering potential, see later in this section). Due to the high investment costs for such dryers, the costs based on capital are higher than the consumption costs.

The possibility of using hot water instead of steam as heating medium in belt dryers leads to slightly lower drying costs compared to tube bundle dryers in spite of higher investment costs due to the cheaper heat price. Depending on the heating medium used, the specific heat costs considered vary between 18.0 (hot water, 90 °C) and 21.8 €/MWh (saturated steam, 16 bar, 201 °C; superheated steam, 0.5–2 bar, 170–200 °C).

Depending on the drying system used and the size of the plant, the investment costs considered for the dryers vary between 360,000 (tube bundle dryer) and almost 1.5 million € (superheated steam dryer). The utilisation period for all drying systems

Table 5
Calculation of the drying costs for different drying systems

Related scenario in Table 3		1	2	Base case scenario	6	5	3	4
Dryer type		Tube bundle dryer (A)	Tube bundle dryer (C)	Tube bundle dryer (B)	Tube bundle dryer (B)	3 tube bundle dryers (B)	Belt dryer	Superheated steam dryer
Heating medium		Saturated steam, app. 15 bar	Saturated steam, app. 15 bar	Saturated steam, app. 15 bar	High temperature water, 185°C	Saturated steam, app. 15 bar	Hot water, 90°C	Superheated steam, 0.5–2 bar
Water evaporation rate	t/h	3.00	3.00	3.00	3.00	9.00	3.00	3.00
Specific heat costs	€/MWh	21.80	21.80	21.80	21.80	21.80	21.80	21.80
Profit heat-selling	€/MWh							20.00
Required electric power (including feeding)	kW	94.00	75.00	77.50	97.00	232.50	160.00	115.00
Heat demand for drying	kWh/$t_{ev.w}$	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Recoverable heat	%							80.00
Utilisation period	years	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Service and maintenance costs	%	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Investment costs	€	509,000.00	360,000.00	375,000.00	470,000.00	1,125,000.00	500,000.00	1,460,000.00
Capital costs	€ p.a.	55,885.46	39,526.06	41,172.98	51,603.47	123,518.95	54,897.31	160,300.15
Maintenance costs	€ p.a.	12,725.00	9000.00	9375.00	11,750.00	28,125.00	12,500.00	73,000.00
Costs based on capital	€ p.a.	68,610.46	48,526.06	50,547.98	63,353.47	151,643.95	67,397.31	233,300.15
Specific costs based on capital	€/$t_{pellets}$	2.90	2.87	2.14	2.68	2.14	2.85	9.86
Electricity costs	€ p.a.	32,044.62	18,262.51	26,419.77	33,067.32	79,259.30	54,544.03	39,203.53
Heat costs	€ p.a.	515,613.60	368,295.43	515,613.60	515,613.60	1,546,840.80	468,309.60	118,662.08
Consumption costs	€ p.a.	547,658.22	386,557.94	542.033.37	548,680.92	1,626,100.10	522,853.63	157,865.61
Specific consumption costs	€/$t_{pellets}$	23.15	22.88	22.92	23.20	22.92	22.11	6.67
Other costs	€ p.a.	2545.00	1800.00	1875.00	2350.00	5625.00	2500.00	7300.00
Specific other costs	€/$t_{pellets}$	0.11	0.11	0.08	0.10	0.08	0.11	0.31
Total drying costs	€ p.a.	618,813.68	436,884.01	594,456.35	614,384.39	1,783,369.05	592,750.95	398,465.76
Total specific drying costs	€/$t_{pellets}$	26.16	25.86	25.13	25.98	25.13	25.06	16.85

Explanations: ev.w.…evaporated water; A, B, C…different dryer manufacturers; data source [1,5–9].

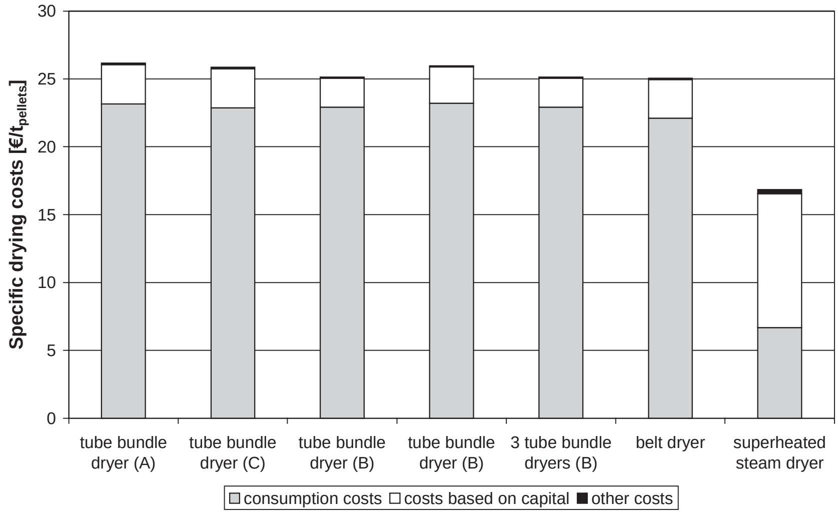

Fig. 3. Drying costs of different drying systems and their composition according to the guideline VDI 2067. Explanations: calculation of the specific drying costs according to Table 5; data source [1,5–9].

has been chosen with 15 years. The maintenance costs considered are between 2.5 (tube bundle dryer and belt dryer) and 5.0% (superheated steam dryer) of the investment costs per year (both figures based on experiences of pellet production plant operators [1,12,9]). The heat demand for drying varies between 865 (superheated steam dryer) and 1100 kWh (belt dryer) per tonne evaporated water, depending on the system used and based on information from several dryer manufacturers [5–8].

The investment costs for a superheated steam dryer are significantly higher compared than those for tube bundle or belt dryers (based on a similar capacity). The main advantage of such a dryer is the high potential of heat recovery given. Surplus steam from the evaporation of water is extracted from the system and can be used for another process as a heating source (e.g. for hot water production in district or process heating networks). By this means energy recovery in the order of 80–90% of the heat input into the dryer is possible [6]. In spite of the significantly higher investment costs of a superheated steam dryer, this results in specific drying costs below the ones of tube bundle dryers and belt dryers of the same capacity (annual pellet production of about 24,000 t), provided that the recovered heat can be utilised. The advantage of superheated steam dryers is even more significant for large-scale applications with annual pellet production rates of about 70,000 t/a and more, which are common in Sweden.

The share of the drying costs on the total pellet production costs is substantial. The lowest drying costs can be achieved if the heat needed for drying is produced internally by using residues available in the company (e.g. by bark combustion in a biomass heating plant or a biomass CHP plant).

3.3. Grinding

The grinding units used are usually hammer mills. If a very homogeneous raw material is available, a sieving machine could be used instead of a grinding unit. The fine fraction could directly be used in the pellet mill. The coarse fraction could be fed into a smaller dimensioned grinding unit or used as fuel, if a biomass combustion plant is available. Many pellet producers, however, have a hammer mill in operation for homogenisation purposes, even if they use only sawdust as raw material.

The investment costs considered for grinding units range between 62,000 € (hammer mill with a capacity of about 2.5–3 t (d.b.)/h) and 168,000 €

(2 larger hammer mills with a total capacity of about 9 t (d.b.)/h), depending on the plant size and the equipment used. The maintenance costs of hammer mills are relatively high with 18% of the investment costs per year. The utilisation period chosen for all scenarios shown in the Tables 1, 3 and 4 for hammer mills according to information from manufacturers is 10 years. Two cases have been calculated with a sieving machine with investment costs of 18,000 €, an utilisation period of 15 years and maintenance costs of 10% of the investment costs per year (see Table 4).

The grinding unit is the second largest electricity consumer in the pelletisation process (behind the pellet mill). However, the influence of the grinding costs on the total pellet production costs is comparatively low.

3.4. Pelletisation

The costs for pelletisation itself also include costs for steam conditioning and biological additives, if such media are used. Two main technologies are available for pelletisation, i.e. ring die and flat die pellet mills. Most of the pellets produced in Austria are produced with ring die pellet mills. These pellet mills usually show slightly lower investment costs. Furthermore, based on experiences of several Austrian pellet producers, ring die pellet mills show a higher equipment availability. Comparatively high pellet production costs result from pellet mills with low throughputs.

The investment costs taken into consideration for pellet mills range from about 18,000 € for a micro-scale application (special framework conditions of the producer; production capacity 700 kg (w.b.)/h) to about 570,000 € for a large-scale application using 3 pellet mills (total production capacity 9 t (w.b.)/h). Taking these pellet production capacities and the different annual operating hours into consideration, annual pellet production rates between 430 and 71,000 t/a result, which are considered in the economic calculations.

Owing to the wear of rollers and dies, the maintenance costs are relatively high and amount to about 10–16% of the investment costs per year. The utilisation period of pellet mills is usually assumed to be between 10 and 15 years. The base case scenario (see Tables 1 and 2) has been calculated with maintenance costs of 10% of the investment costs per year and a utilisation period of 10 years. Biological additives are, if any, usually added in an amount of about 1 wt% of the pellet mass and are therefore of minor importance for the total pellet production costs. Moreover, the costs for steam conditioning (if applied) are of minor relevance concerning the total pellet production costs.

The pelletisation itself is one of the main cost factors of the overall pelletisation process (besides drying, personnel and raw material). The main cost factor of the pelletisation step itself is the electricity consumption, followed by the investment costs.

3.5. Cooling

The coolers commonly used are counterflow coolers. For very small pellet mills with low throughputs a subsequent cooler is optional. The investment costs considered in the different cases shown in the Tables 1–4 vary between zero (no cooler) and 26,000 €, depending on the plant size and the equipment used (13,000 € for a counterflow cooler with a capacity of about 5 t (w.b.)/h; twice as much for a capacity of about 10 t (w.b.)/h). The chosen utilisation period of 15 years and maintenance costs of about 2.0% of the investment costs per year are based on information from operators of pellet production plants.

The costs for cooling are small and not relevant for the total pellet production costs.

3.6. Storage

Storage costs are greatly influenced by the storage capacity and the kind of storage chosen. The storage capacity of most Austrian pellet producers is less than 10% of the annual pellet production capacity [1], the most widely used storage systems are silos. Warehouses are used only by a few smaller pellet producers.

The variation of investment costs for storage systems is between 20,000 € (warehouse for a small-scale producer with a storage capacity of about 120 t) and 742,000 € (silo storage for a large-scale producer with a storage capacity of about 5400 t), depending on the plant size, the storage capacity and the storage system used. The utilisation period has been chosen with 20 years for silo storage systems and with 50 years for warehouses with maintenance costs of 1.0% for warehouses and 1.5% of the investment costs for silos. Owing to the fact that the most common pellet storage system applied in Austria is silo storage, it has been considered for almost all scenarios calculated. For specific cases, usually small-scale pellet production units, warehouses have been taken into consideration instead of silo storage.

In spite of quite high investment costs for the storage system in several cases, the influence of the storage costs on the total pellet production costs is relatively low.

3.7. Peripheral equipment

Peripheral equipment includes the costs of investments and electrical power required for motors of feeding screws, the sieving machine, fans, cell air locks, etc. The utilisation period of these systems has been chosen with 10 years, the maintenance costs with 2.0% of the investment costs per year. The investment costs of peripheral equipment can be about 15,000 € for small-scale applications (and even lower in specific cases) and can reach 1.0 million € for large-scale applications.

The influence of the costs caused by peripheral equipment on the total pellet production costs is low.

3.8. Personnel

Personnel costs include both costs for personnel in the production as well as in marketing and administration. In the production usually one person is needed for the whole pelletisation plant per shift (both for small-scale and large-scale applications). Small-scale applications usually are not equipped with process control technologies, which make a fully automatic operation possible. Large-scale applications need one person to control the process, even if there is an appropriate control technology for a fully automatic operation installed. In addition to the personnel needed per shift, a quarter person has been calculated for substitution. Additional personnel would be needed, if a manually operated packing unit were used. However, packed pellets are not very common in Austria and are either packed with fully automatic packing units or cover only a small part of the overall pellet production and are therefore manually packed. Packing can be controlled by the person also responsible for the pelletisation process. Due to the minor relevance of packed pellets in Austria, packing has not been taken into consideration as an extra cost factor.

The kind of shift work chosen for the base case scenario (see Table 1) and for several other scenarios (see Tables 3 and 4) is 7 working days per week with 3 shifts per day. Taking the equipment availability of 90% into consideration, this results in almost 7900 operating hours per year. Some Austrian pellet producers already apply this operation mode; some intend to introduce this operation mode in the near future. Another operation mode applied by Austrian pellet producers is to work at 5 days per week with 3 shifts per day (about 5600 annual operating hours), which has been considered in scenarios 2 and 8 (see Tables 3 and 4). The small-scale application calculated in scenario 7 (see Table 4) is in operation for about 615 h per year (operation according to the availability of the raw material from the own wood working industry).

The requirement for personnel in marketing and administration depends on the sales strategy of the producer and can range from a person covering this job part time (which is possible if the pellets from small-scale producers are sold to wholesalers, especially if long-term contracts for delivery exist) up to 4 persons active in marketing and administration in case of large-scale producers with an own marketing and distribution system. All scenarios calculated are based on 2 persons active in this field (except scenario 7 where a part time job has been considered).

The costs for personnel in the production process have been calculated on the basis of a hourly rate of 21.8 € (including all costs like salary, taxes, etc.). For the base case scenario 10,950 annual working hours are needed (1 person per shift, a quarter person for substitution per shift, 3 shifts per day, 7 working days per week). This demand can be covered by 6.25 persons (1752 h per year) and leads to annual personnel costs of 238.710 € in the production. Special framework conditions can lead to personnel costs clearly below this rate. One case (scenario 7) has been investigated, where personnel are available for an hourly rate of about 7.3 €. However, this specific producer is a micro-scale pellet producer and therefore such a low hourly rate cannot be generalised. The costs for personnel in marketing and administration is based on annual costs per employee of 33,000 € (including all costs like salary, taxes, etc.). Taking Austrian framework conditions into consideration, pellets are usually a by-product (from sawmills, wood processing industry, etc.). Management costs have therefore not been taken into consideration.

Personnel costs are a cost factor of medium importance in pellet production.

3.9. Raw material

Finally, the raw material costs represent a substantial cost factor in the calculation of the total pellet production costs. The most important influencing variable in this context is, whether the raw material used is dry or wet. Dry raw materials are usually more expensive than wet raw materials. However, due to the fact that the pelletisation of dry raw materials does not require drying equipment, the total pellet production costs can be reduced significantly by using dry raw materials.

Wet sawdust with a water content of 55.0 wt% (w.b.) and a bulk density of 267 kg (w.b.)/m^3 formed the basis for the calculations of the base case scenario and of the scenarios shown in Table 3. Scenarios 7–11, which are shown in Table 4, are based on dry wood shavings as raw material with a water content of 10 wt% (w.b.) and a bulk density of 78 kg (w.b.)/m^3.

The raw material prices loco pellet producer taken into consideration are 4.36 €/m^3 (or 36 €/t (d.b.)) for wet sawdust and 4.0 €/m^3 (or 57 €/t (d.b.)) for dry wood shavings. The prices indicate representative average prices for the year 2001 under Austrian side constraints (softwood, prices loco pellet producer including transportation costs). However, the raw material prices can vary in a broad range according to local and national side constraints and therefore the specific framework conditions must be taken into consideration carefully on a case-by-case basis. The price for wet sawdust loco pellet producer can vary between 4.30 and 8.10 €/m^3 and for dry wood shavings between 2.84 and 4.65 €/m^3 [3,9]. Special framework conditions can lead to prices even below these prices. Such a case has been taken into consideration in scenario 7, which is shown in Table 4. In this case, a small wood working industry has no possibility to use their own residues (wood shavings). Due to the small amount of wood shavings available it is difficult to sell them and therefore the price that can be achieved amounts to only about 1.09 €/m^3. Due to the high quality of pellets and an already established market for pellets, the upgrade of the wood shavings to wood pellets leads to a considerable added value.

Transport costs are included in the prices stated above and amount to about 1.49 €/km (based on an ordinary truck with a transport capacity of 95 m^3) [10]. Taking an average transport distance of about 50 km into consideration, the transport costs amount to about 0.80 €/m^3, both for wet sawdust and for dry wood shavings. In general, the raw material prices show an increasing trend due to the general increase of thermal biomass utilisation in Austria.

3.10. Evaluation and sensitivity analyses

An overview of the average composition of the total pellet production costs both for dry and wet raw material is shown in Fig. 4. The main shares of the pellet production costs are the costs for raw material and for drying, if wet raw material is used. These costs can cover up to two thirds of the total pellet production costs. The pellet production costs from dry raw material are dominated by the costs for the raw material.

Fig. 5 gives an overview of the influence of different parameters on the total pellet production costs. The specific pellet production costs are mainly influenced by the pellet throughput, the

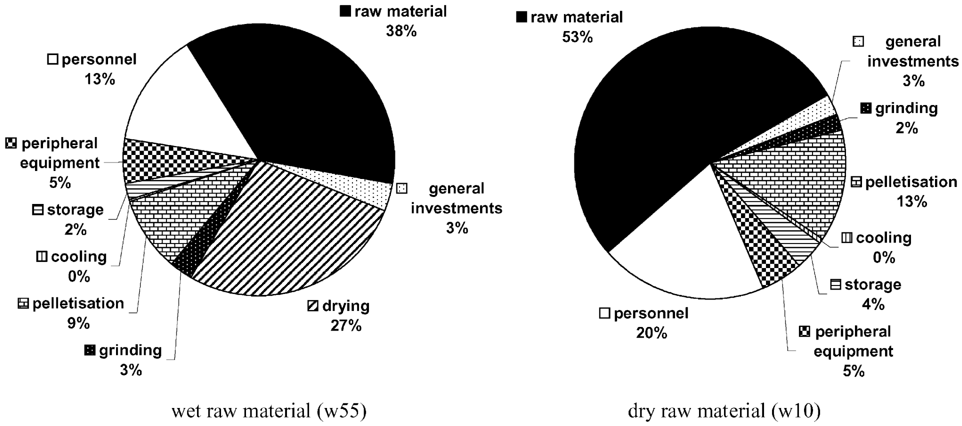

Fig. 4. Share of the different cost factors of a pellet plant among the total production costs considering wet and dry raw material. Explanations: the calculation is based on a total number of 10 pellet plants investigated (seven plants using wet raw material, three plants using dry raw material); variation of the production capacity between 430 and 79,000 t/a; variation of the annual full load operating hours between 615 and 8,000 h p.a.; plant availability 90%; production costs loco factory vary between 79.6 and 94.6 €/$t_{pellets}$ on average for wet raw material and between 51.8 and 83.7 €/$t_{pellets}$ for dry raw material; data source [1,3].

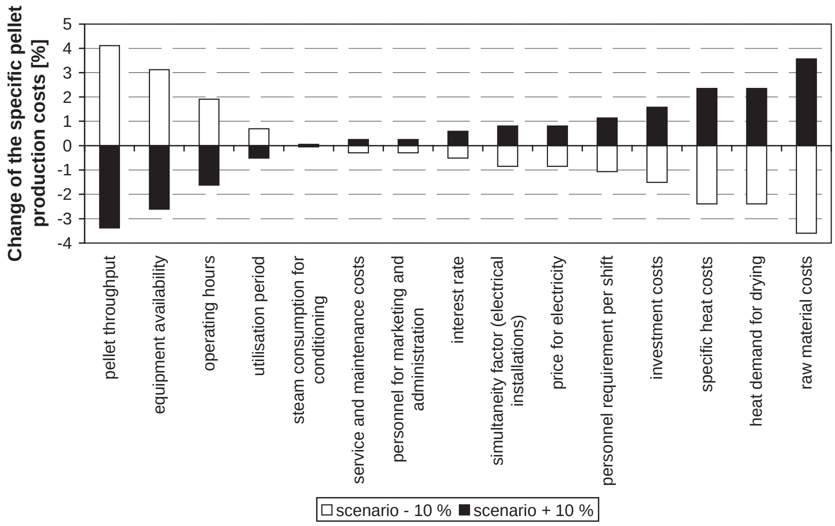

Fig. 5. Influence of different parameters on the total pellet production costs.
Explanations: the calculation is based on the framework conditions according to Tables 1 and 2 (base case scenario); sensitivity analysis performed by varying each parameter one by one by plus or minus 10%; data source [1,3].

equipment availability, the annual operating hours, the specific heat costs, the heat demand for drying and the raw material costs.

The pellet throughput can e.g. be increased by using appropriate bio-additives (e.g. maize or rye flour), which act as a lubricant in the pellet mill. As it is shown in Fig. 6 this is a good possibility to decrease the total pellet production costs. On the other hand, a low throughput (e.g. caused by a raw material which is too dry) leads to increased pellet production costs.

Plant availability (as a percentage of the theoretically possible annual full load operating hours) and plant utilisation (number of shifts per week, see Fig. 7) are further important influencing factors on the total pellet production costs. Based

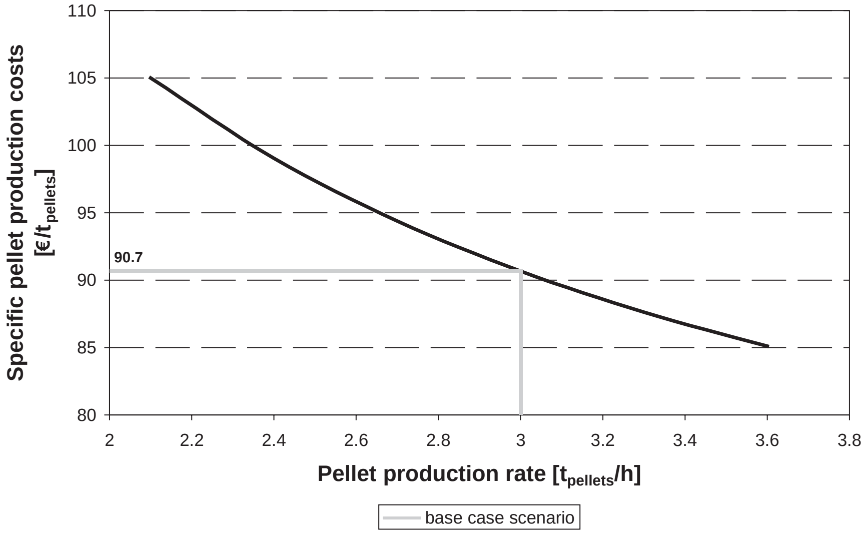

Fig. 6. Dependency of the total pellet production costs on the production rate.
Explanations: the calculation is based on the framework conditions according to Tables 1 and 2 (base case scenario); variation of the pellet production rate starting from 2.1 to 3.6 $t/_{pellets}/h$; specific pellet production costs loco factory; data source [1,3].

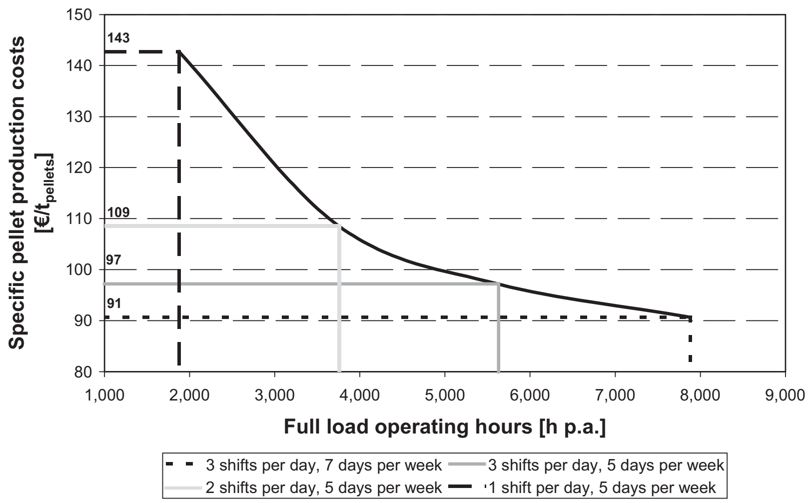

Fig. 7. Dependency of the total pellet production costs on the annual full load operating hours.
Explanations: the calculation is based on the framework conditions according to Tables 1 and 2 (base case scenario); variation of the annual full load operation hours between 7,884 and 1,877 h p.a.; specific pellet production costs loco factory; data source [1,3].

on the results shown in Fig. 7, the pellet production will become uneconomic (total pellet production costs of more than 110 €/$t_{pellets}$) below about 3500 annual full load operating hours, depending on the specific framework conditions of the producer, however. Due to the fact that the scenario shown in Fig. 7 is based on wet raw material, it is not meaningful to operate the plant only one or two shifts per day, because a daily start-up and shut-down of the dryer cannot be recommended. Therefore, at least three shifts per day at 5 days per week are recommended for an economic production of wood pellets. The optimum would be a 7-day per week operation.

A low plant availability leads to a similar effect. Based on the base case scenario a plant availability of at least 52% should be achieved for an economic operation of the plant. However, a plant availability of 85–90% can usually be achieved by pellet producers and should therefore be the aim for an economic pellet production.

An important question in this context is the needed production rate for an economic use of dryers in a pellet production process. The specific investment costs for dryers and therefore the total pellet production costs show a strong increase with decreasing water evaporation capacity (see Fig. 8). Based on several calculations made for different drying technologies and plant capacities, the lower limit for an economic use of a dryer in a pellet production process (total pellet production costs of 110 €/$t_{pellets}$ or more) lies between 12,000 and 15,000 t of pellet production per year (depending on the technology used and the kind of shift work). The use of dryers in small-scale pellet production plants can therefore not be recommended.

The influence of the specific heat costs on the total pellet production costs is shown in Fig. 9. They have been assumed to be 21.80 €/MWh for the base case scenario (related to the energy content of the steam). This price can be achieved under Austrian framework conditions but it may vary in a broad range, depending on the specific framework conditions given at a site.

A strong influence on the total pellet production costs is also given by the heat demand for drying. However, the possibilities to influence the heat demand for drying are confined to the choice of the drying technology, because if once a dryer has been chosen there is no more possibility to influence the heat demand.

The dependency of the total pellet production costs on the raw material price (wet sawdust) is shown in Fig. 10. Considering the possible variation of the raw material price from 4.30–8.10 €/m^3, the resulting pellet production costs vary between 90.2 and 118.7 €/$t_{pellets}$. Thus, it becomes obvious that the economy of a pellet production plant is strongly dependent on the raw material price. In the scenario shown in Fig. 10, the upper limit for an economic pellet production will be exceeded if the raw material price is 6.94 €/m^3 or more.

4. Comparison of the pellet production costs under typical Austrian and Swedish framework conditions

A comparison of the pellet production costs in Austria and Sweden has also been carried out within this project. The method used for the

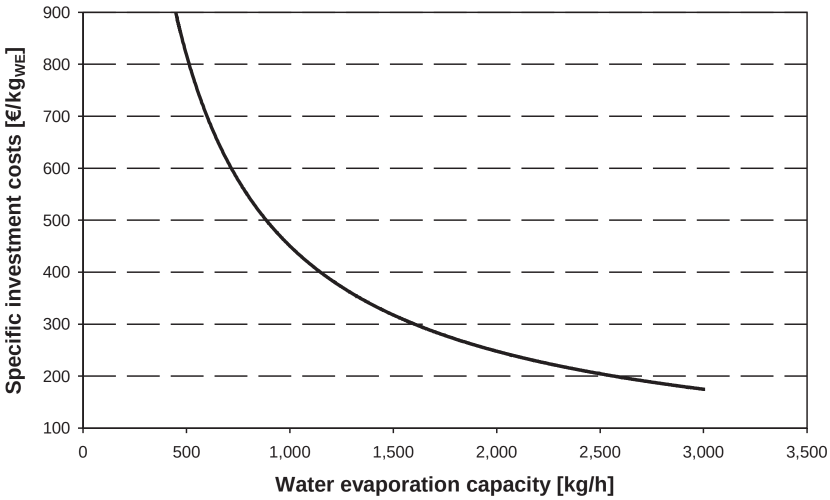

Fig. 8. Dependency of the specific investment costs of belt dryers on the water evaporation capacity. Explanations: WE…water evaporated; data source [7].

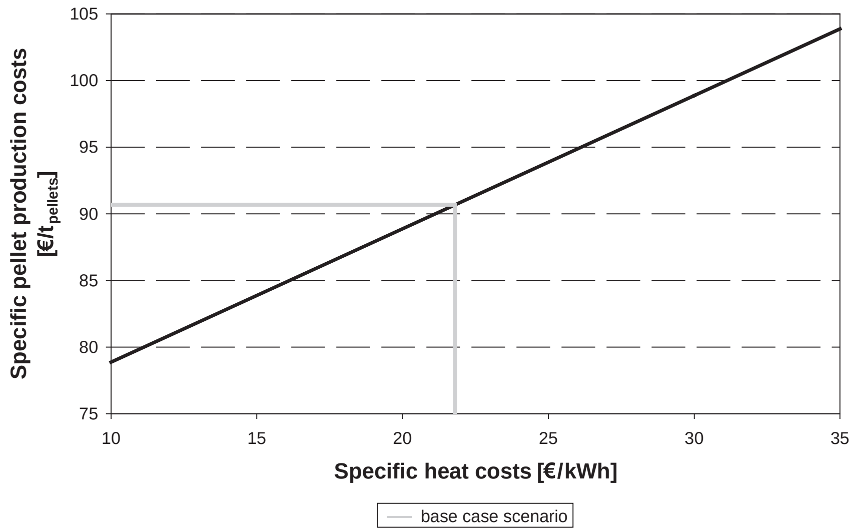

Fig. 9. Dependency of the total pellet production costs on the specific heat costs.
Explanations: the calculation is based on the framework conditions according to Tables 1 and 2 (base case scenario); variation of the specific heat costs between 10 and 35 €/kWh; specific pellet production costs loco factory; data source [1,3].

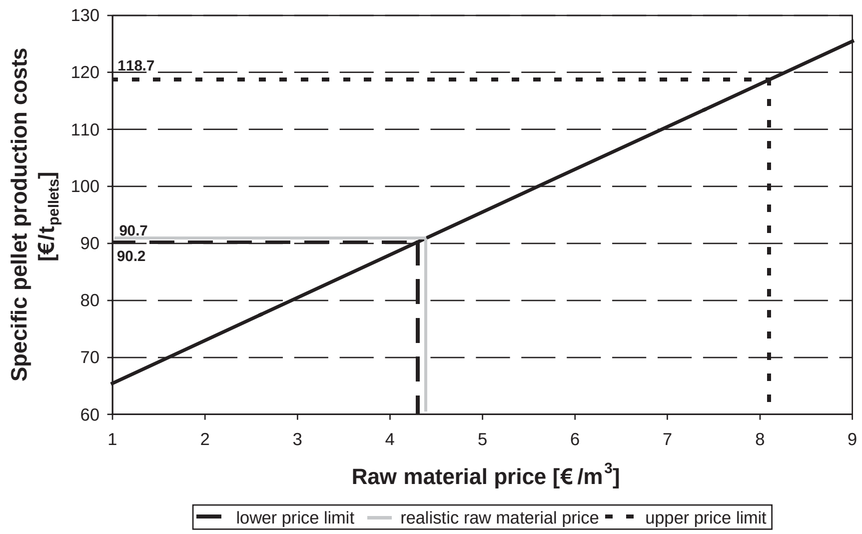

Fig. 10. Dependency of the total pellet production costs on the raw material price.
Explanations: the calculation is based on the framework conditions according to Tables 1 and 2 (base case scenario); variation of the raw material price between 1.0 and 9.0 €/m^3; sawdust; water content 55 wt% (w.b.); bulk density 267 kg (w.b.)/m^3; specific pellet production costs loco factory; data source [1,3].

calculation of the pellet production costs in Sweden was the same as that used for Austria. The differences regarding general framework conditions between the Austrian and Swedish calculations are shown in Table 6, all other parameters are similar (see Table 1). The calculation of the specific pellet production costs under Swedish framework conditions is shown in

Table 6
Main differences of the general framework conditions between Austria and Sweden for the calculation of pellet production costs

Parameters	Unit	Austria	Sweden
General conditions			
Price for electricity	€/MWh	50.87	27.10
Total electricity Consumption	GWh/a	3.50	10.98
Specific electricity consumption	$kWh/t_{pellets}$	148.04	137.70
Equipment availability	%	90.00	91.00
Investment costs construction	€	436,000.00	870,000.00
Investment costs data processing	€	29,000.00	100,000.00
Service and maintenance costs market introduction	%		3.00
Total investment costs	€	2,033,080.00	5,933,750.00
Raw material data			
Raw material		Sawdust	Sawdust
Water content	wt% (w.b.)	55.00	57.00
Bulk density (d.b.)	kg (d.b.)/m^3	120.00	150.00
Raw material price	€/m^3	4.36	5.10
Drying data			
Dryer type		Tube bundle dryer	Drum dryer
Specific heat costs	€/MWh	21.80	17.95
Profit from heat sale	€/MWh		21.70
Required electric Power (including feeding)	KW	77.50	350.00
Heat demand for drying	$kWh/t_{ev.w.}$	1000.00	861.00
Recoverable heat	%		50.00
Specific heat consumption	$kWh/t_{pellets}$	1021.52	504.02
Utilisation period	A	15.00	10.00
Investment costs	€	375,000.00	2,400,000.00
Grinding/sieving data			
Grinding unit type		Hammer mill	Hammer mill
Required electric power	kW	110.00	350.00
Investment costs	€	84,000.00	360,000.00
Pellet mill data			
Pellet mill type		Ring die	Ring die
Required electric power	kW	233.00	750.00
Steam consumption for conditioning per ton pellets produced	wt%	4.00	2.50
Specific heat costs (steam)	€/t	11.73	9.66
Bio-additive demand	%	1.00	
Costs for bio-additives	€/$t_{pellets}$	1.82	
Service and Maintenance costs	%	10.00	13.00
Investment costs	€	190,000.00	600,000.00
Cooling data			
Cooler type		Counterflow cooler	Counterflow cooler
Required electric power	kW	12.00	50.00
Investment costs	€	13,000.00	240,000.00
Storage data			
Kind of storage		Silo	Warehouse
Utilisation period	a	20.00	50.00
Service and maintenance costs	%	1.50	2.50
Investment costs	€	291,000.00	870,000.00
Storage capacity (in % of the annual pellet production)	%	7.61	36.00
Retail price for pellets (exclusive of VAT)	€/t (w.b.)	162.72	143.50
Peripheral equipment data (conveying systems, intermediate storage, steel construction)			
Required electric power	kW	90.00	120.00
Investment costs	€	500,000.00	435,000.00

Table 6 (*continued*)

Parameters	Unit	Austria	Sweden
Pellets data			
Pellet production rate	t (w.b.)/h	3.00	10.00
Annual pellet production	t (w.b.)/a	23,652.00	79,716.00
Water content pellets	wt% (w.b.)	10.00	8.00
Bulk density pellets	kg (w.b.)/m^3	610.00	585.00
Diameter pellets	mm	6.00	8.00
King of shift work			
Annual operating hours	h p.a.	7884.00	7971.60
Personnel data			
Hourly rate	€/h	21.80	15.70
Persons per shift		1.00	2.30
Persons for substitution per shift		0.25	0.10
Personnel for administration and marketing	€/a	66,000.00	110,000.00

Explanations: wt%—weight per cent; w.b.—wet base; d.b.—dry base; ev.w.—evaporated water; data source [1,3–5,9].

Table 7
Calculation of the pellet production costs under Swedish framework conditions

	Costs based on capital € p.a.	Consumption costs € p.a.	Operating costs € p.a.	Other costs € p.a.	Total costs € p.a.	Specific costs €/$t_{pellets}$
General investments	107,256			5,144	112,400	1.4
Drying	401,706	619,578		12,000	1,033,284	13.0
Grinding	116,056	64,269		1,800	182,125	2.3
Pelletisation	163,427	156,971		3,000	323,397	4.1
Cooling	31,151	9,181		1,200	41,532	0.5
Storage	84,790	144,134		4,350	233,275	2.9
Peripheral equipment	70,634	22,035		2,175	94,844	1.2
Personnel			457,956		457,956	5.7
Raw material		2,493,516			2,493,516	31.3
Total	975,020	3,509,685	457,956	29,669	4,972,330	62.4
Specific costs in €/$t_{pellets}$	12.2	44.0	5.7	0.4		62.4

Table 7. The most important differences in the framework conditions are discussed below.

The production rates for Austria and Sweden have been chosen on the basis of the typical and most important situations pertaining to pellet production in these countries. These production rates result in an annual pellet production of about 24,000 t of pellets in Austria and about 80,000 t of pellets in Sweden.

The price of electricity in Sweden amounts to only about 50% of the Austrian price. This big difference results on the one hand from the generally low level of electricity prices in Sweden and on the other hand from the considerably larger total electricity consumption of about 11.0 GWh/a due to the higher plant capacity.

The investment costs for the drying systems are totally different for the Austrian and the Swedish case. In the calculation of pellet production costs in Austria a dryer (in this specific case a tube bundle dryer) has been considered. In Sweden, the erection of a new pellet production plant is usually combined with the erection of a new biomass CHP plant or a biomass district heating plant. The heat produced from the plant is used for the dryer, usually a directly heated drum dryer (direct utilisation of the hot flue gas from the combustion chamber in the dryer). The wet and cooled flue gas leaving the drum dryer passes through a gas cleaning and heat recovering system (e.g. cyclones, flue gas condensation units). By this means about 50% of the heat needed for drying the raw material can be recovered and utilised as district heat. An example for such a drying system is described by Mared [11].

Owing to this combination of a pellet production plant with a biomass CHP plant or a biomass district heating plant, the investment costs for the drying system in the Swedish case cover both the investment of the dryer as well as the proportionate investment of the biomass CHP plant or the biomass district heating plant (the part of the biomass CHP plant or biomass district heating plant utilised for the drying process). This means, that the capital costs and the other costs related to the heat production are directly considered (in the total capital costs of the pellet production plant). Therefore, the specific heat costs are lower, because only the operating and consumption costs of the CHP or the biomass district heating plant are included in the heat price.

The total investment costs are higher in the Swedish case, resulting not only from the drying system but also from the larger equipment needed due to the higher capacity of the plant.

The specific electricity consumption in the Swedish case is considered to be about 7% lower due to the higher plant capacity. Furthermore, the specific heat demand for drying is about half of that required in Austria due to the fact that about 50% of the heat needed for drying can be recovered (as described above).

The direct comparison of typical pellet production costs in Austria and Sweden (see Figs. 11 and 12) shows the Swedish pellet production costs to be considerably lower. As shown in Fig. 11, this is mainly due to the fact that heat from the dryer can be recovered and used in a district heating network. Therefore, the Swedish drying costs amount to only about half the Austrian drying costs. Furthermore, the larger plant capacity influences all cost factors shown in Fig. 11 (except the specific raw material costs) and therefore contributes substantially to the decreased pellet production costs. Moreover, a difference

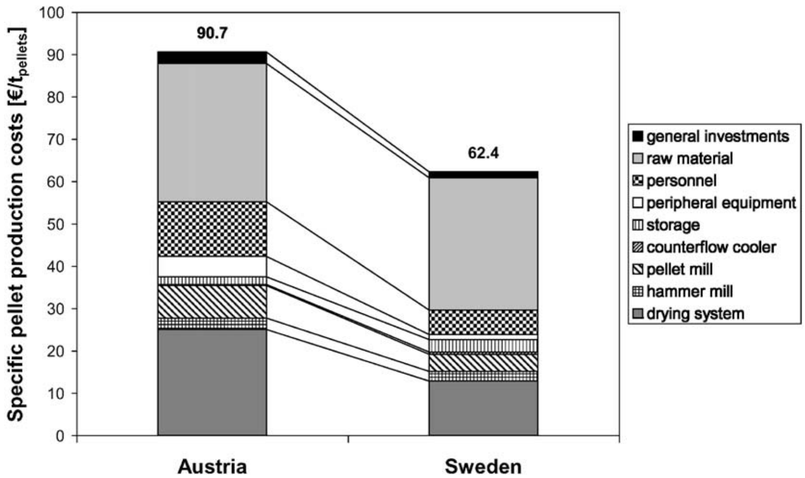

Fig. 11. Comparison of average pellet production costs in Austria and Sweden as well as their composition according to the steps and cost factors of the pellet production process.

Explanations: the Austrian calculation is based on the framework conditions according to Tables 1 and 2 (base case scenario); differences of the general framework conditions between Austria and Sweden for the calculation of pellet production costs are shown in Table 6; calculation of the pellet production costs under Swedish framework conditions according to Table 7; data source [1,3,4].

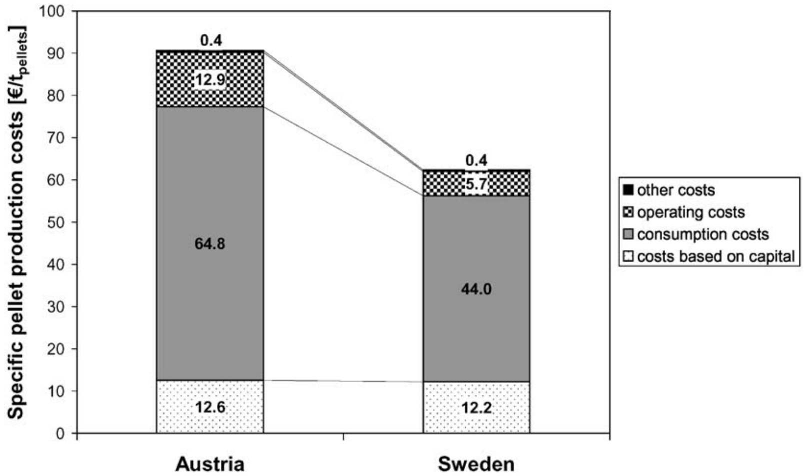

Fig. 12. Comparison of average pellet production costs in Austria and Sweden as well as their composition according to the guideline VDI 2067.
Explanations: the Austrian calculation is based on the framework conditions according to Tables 1 and 2 (base case scenario); differences of the general framework conditions between Austria and Sweden for the calculation of pellet production costs are shown in Table 6; calculation of the pellet production costs under Swedish framework conditions according to Table 7; data source [1,3,4].

between Austria and Sweden is the price of electricity, which is much lower in Sweden. The specific electricity costs in Sweden amount to only about 3.7 €/$t_{pellets}$ compared to 7.5 €/$t_{pellets}$ in Austria.

Fig. 12 shows the composition of the specific pellet production costs for Austrian and Swedish framework conditions calculated according to the guideline VDI 2067. It can be seen that the costs based on capital and the other costs are about the same in both cases. The consumption costs and the operating costs are significantly lower in the Swedish case (the consumption costs mainly due to the reduced heat demand for drying and the operating costs due to the lower specific requirement for personnel).

The Swedish pellet production costs are about one third lower than the Austrian ones. Without taking the cost difference caused by different drying systems into consideration, the Swedish pellet production costs would increase to 73.6 €/$t_{pellets}$ and the difference between the Austrian and Swedish pellet production costs would therefore be reduced to about 19%. This difference is, as already explained, mainly caused by the larger plant capacity (economy-of-scale effect; synergy effects regarding personnel in larger plants) and the lower price for electricity in the Swedish case.

Thus, pellet production costs in Austria could be optimised by increasing the plant capacities. Moreover, a sensible way to reduce the pellet production costs would be the combination of pellet production plants with decentralised biomass CHP plants.

5. Conclusions

The calculations for Austrian framework conditions show that economic wood pellet production is possible both in small-scale (production rates of some hundred tonnes per year) as well as in large-scale plants (production rates of some 10,000 t per year). However, for small-scale units in particular it is very important to take care of the specific framework conditions of the producer, because the risk of a non-economic pellet production is substantially higher than for large-scale systems. For economic reasons, the use of dryers in small-scale pellet production plants cannot be recommended.

The main cost factors are the drying costs (if wet raw material is used), followed by the raw material costs. The pelletisation itself and personnel costs are also of great relevance. Moreover, the pellet production costs are strongly influenced by the plant utilisation.

The direct comparison of typical pellet production costs in Austria and Sweden shows the Swedish pellet production costs to be considerably lower. The main reasons for this result are the larger plant capacity (economy-of-scale effect) and an efficient heat recovering system from the dryers usually applied in Sweden. Another difference is the price of electricity, which is in general much lower in Sweden. If the drying costs were assumed to be the same, the difference between the total pellet production costs would be reduced from about one third to about 19%.

Possibilities to reduce the pellet production costs in Austria could therefore be increased plant capacities and the combination of decentralised biomass CHP plants or biomass district heating plants with pellet production plants in order to reduce the drying costs. A substantial reduction of the electricity price in Austria is not realistic. The combination of decentralised biomass CHP plants with pellet production plants in Austria is an economically and ecologically very interesting solution for future applications (provided that the pellet production plant uses wet raw material with drying demand), due to the facts that heat production and heat consumption can be optimally adjusted, that the heat for drying is also produced from biomass and that high feed-in tariffs for green electricity are valid in Austria.

References

[1] Thek G, Obernberger I. An integrated European market for densified biomass fuels (INDEBIF). Austrian Country Report (final Report), EU-ALTENER-Project AL/98/520. Graz, Austria: BIOS BIOENERGIESYSTEME GmbH; 2002.

[2] Richtlinie VDI, 2067. Betriebstechnische und wirtschaftliche Grundlagen—Berechnung der Kosten von Wärmeversorgungsanlagen. Düsseldorf, Germany: VDI-Verlag GmbH; 1983.

[3] MUT. Holzpreise in der Steiermark im Februar 2001, MUT—Märkte/Unternehmen/Trends. Folge 11, Zeitschrift der Wirtschaftskammer Steiermark: Graz, Austria; March 2001.

[4] Zakrisson M. Comparison of international pellet production costs, Examensarbeten Nr 39. SLU, Uppsala, Sweden: Department of Forest Management and Products, 2002 [in Swedish].

[5] Ponndorf. Company brochure, written and verbal information. Kassel, Germany: Ponndorf Maschinenfabrik GmbH, 2001.

[6] Stork. Company brochure and written information. Stork Engineering, Göteborg, Sweden, 2001.

[7] Swiss Combi. Homepage, http://www.swisscombi.ch, written and verbal information, SWISS COMBI W. Kunz dryTec AG, Dintikon, Switzerland, 2002.

[8] Büttner. Company brochure, written and verbal information, Büttner Gesellschaft für Trocknungs- und Umwelttechnik mbH, Krefeld, Germany, 2001.

[9] Repke V. Verbal and written information, Dipl.-Ing. (FH) V. Repke Holzindustrieberatung, Olang/BZ, Italy, 2000.

[10] Stockinger H, Obernberger I. Systemanalyse der Nahwärmeversorgung mit Biomasse, Schriftenreihe "Thermische Biomassenutzung", Band 2, ISBN 3-7041-0253-9, dbv-Verlag of University of Technology Graz, Graz, Austria, 1998.

[11] Mared J. Pellets production connected to district heating. In: Proceedings of the 1st World Conference on Pellets. Stockholm, Sweden: Swedish Bioenergy Association, September 2002. p. 69–70. ISBN 91-631-2833-0.

[12] Petersson A. Pellets production in an energy combine. In: Proceedings of the 1st World Conference on Pellets, Stockholm, Sweden: Swedish Bioenergy Association, 2002. p. 65. September 2002, ISBN 91-631-2833-0.