

# THE ECONOMIC EFFICIENCY OF FOREST ENERGY WOOD CHIP PRODUCTION IN REGIONAL USE – A CASE STUDY

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**Received: April 8, 2013**

## Abstract

ŠAFAŘÍK DALIBOR, BADAL TOMÁŠ: *The economic efficiency of forest energy wood chip production in regional use – A case study.* Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 2013, LXI, No. 5, pp. 1391–1398

This regional project case study deals with the limiting factors of economic efficiency in the production of forest energy wood chips. The evaluation of production efficiency made use of data obtained from the Lesy města Brna, a.s. (Forest of the City of Brno, Corp.), which were subjected to two static methods of investment evaluation: an analysis of the tipping point and determination of the limit of variable costs and a dynamic modified tipping point analysis using cash flow (i.e. cash break even analysis). The results have confirmed an established hypothesis, namely that the decisive factor in the profitability of the production of forest energy wood chips hinges on the costs incurred in the gathering of raw material and the distribution of the produced chips. The results include a further limiting factor: transportation costs to the final consumption location. The output of the study is a recommendation that the concentration of residual forest materials not exceed a distance of 250 m from the place of production to the point of disintegration and that the transport distance of energy chips not exceed 50 km from the place of disintegration to the final consumption point. These limiting values help quantify the full internal costs per cost unit, full internal cost profitability, total revenue profitability and annual profitability expressed in terms of fixed assets depreciation without factoring in financial aid.

energy wood chips, economic efficiency, profitability, tipping point, variable costs

On 8 November 2012, the Government of the Czech Republic negotiated an update to the State Energy Concept (SEC) and – prior to final approval – requested an assessment of its impact on the environment. Key aspects of SEC include diversification and strategic flexibility. SEC is designed to make use of all available energy sources, while respecting their specific conditions. In the case of renewable energy sources (RES), this refers primarily to their use in a range accessible within the conditions of the Czech Republic, i.e. with respect to the decentralised production of electricity and heat as well as in view of growing regional demand. The strategic document also takes into account the limited financial support available for RES (MIT, 2012).

Forest energy wood chips (FEWC), which constitute the output of the processing of energy

dendromass, may be considered dominant in the RES context. However, its rational use at regional level is prevented by the currently inefficient system of financial aid for the use of energy wood chips for electricity production, which was instrumental in the initial stage of development of the utilization of this type of RES, but which does not respect the principles of economic efficiency of FEWC production, thereby distorting the market environment.

One of the basic indicators in assessing the economic efficiency is economization, i.e. a ratio indicating cost savings on comparable production volumes. The case study presented in this study aims to point out the limiting economic efficiency factors encountered in the production of FEWC in regional conditions as well as focusing on their quantification. The main limiting economic

efficiency factors include the following: the concentrating distance of logging residues (LR) prior to the process of disintegration (chipping) and the transport distance involved in the distribution of produced wood chips to the point of final consumption. For study purposes, a working hypothesis was formulated: *The decisive economic efficiency factor of FEWC production is the cost of gathering the raw material and transporting the manufactured chips.*

The study could have relied on a number of already published results, but findings listed by various authors often differ both in terms of direct production costs and in terms of internal FEWC production costs; e.g. Havlíčková *et al.* (2010) lists the value of direct production costs at 195 CZK.m<sup>-3</sup>, Chytrý (2007) indicates the value of internal production costs (including overhead) at 212 CZK.prm<sup>-1</sup> (138 CZK.m<sup>-3</sup>). The value of internal FEWC production cost has recently also been influenced by the price of the raw material, i.e., LR, which – according to calls for tenders carried out by the Lesy České republiky, s. p. (Forests of the Czech Republic, S. E – LČR) in October 2011 – ranges from 15.68 to 46 CZK.m<sup>-3</sup> of harvested wood substance on stump, i.e. 6.27–18.40 CZK.prm<sup>-1</sup>. The cardinal question, however, is the amount of internal production cost price as limited by the distance between the point of LR concentration, point of LR disintegration and point of final FEWC consumption. In this case, the maximum economically viable distance of 60 km remains an undisputed standard for the transportation of processed FEWC – see e.g. Kára (2006) and Chytrý (2007). The experience acquired by the Österreichische Bundesforste AG (Austrian Federal Forests) regarding the production and sales of forest energy wood chips to the Wien Simmering power station indicates that economically viable road transport must be limited to a maximum distance of 60 km. However, chips are also transported to more distant destinations. In the 60 to 100 km range, large-volume road transport or rail may be used, while the 100–200 km range calls exclusively for river transport Fink (2004).

## MATERIAL AND METHODS

Economic efficiency may be evaluated using a variety of methods which can be divided into two groups: static and dynamic. In order to provide the most meaningful results – production efficiency indicators – and a subsequent summary of the findings obtained, it is essential to always accurately describe and formulate the point of departure. A significant problem encountered by many researchers during the process of the evaluation of the economic efficiency of forest energy wood chip production in the Czech Republic is the lack of publicly available data relevant to production costs and revenue. The evaluation of economic efficiency of FEWC production and the assessment of limiting production factors focused on data covering the period from 2004 to 2008 in the Lesy města Brna,

a. s. (Forests of the City of Brno, Corp., municipal forest enterprise, LMB). This approach was utilized for the following reasons:

- mixed forest stand composition of the LMB is similar to the mixed forests encountered throughout the Czech Republic (see Tab. I),
- FEWC produced from LR by the LMB was supplied as a homogeneous mixture in a ratio of mixed coniferous and deciduous forest material corresponding to LMB forest composition,
- production of forest energy wood chips at the LMB was launched in 2004, i.e. in the year when the Czech Republic was admitted to the European Union as full member and was thus subject to international obligations arising from Directive No. 77/2001/EC,
- data obtained from the LMB for the period from 2004 to 2008 represents a coherent set of economic information regarding the individual stages of LR production in regional conditions, from LR production to concentration, chipping and implementation.

During the selected reference period (2004 to 2008), FEWC have been produced by the LMB by processing LR in the forests of the statutory city of Brno as supplied primarily by TEZA, a. s., a company controlled by the statutory city of Brno (as is the case with LMB). LMB was the sole and exclusive supplier of forest energy wood chips sold to supply heat to the Bystrc I. and II. housing estates in an annual volume of 22,000–25,000 prms (8,800–10,000 m<sup>3</sup>) as required by the current heating season. The technological production process included the following steps:

- preparation of materials,
- concentration, which includes the sub-operations of bundling, moving hauling road – roadside “HR-RS”, moving stump – roadside “S-RS” and trolley carting,
- production by chipping,
- transportation.

The production itself utilized a chipper operated at our expense and consisting of a power source – FENDT VARIO 716 tractor, JENZ HEM 420 Z chipper. The carting was carried out by a KRONOS cart towed by a VALTRA tractor, likewise operated at our expense. The transportation of produced chips to boiler rooms in Brno Bystrc was carried out by a MERCEDES-BENZ ACTROS 2641 lorry, also at our expense. The moving of LR and transport of produced wood chips to potential other customers was both provided in the form of service purchase. The maximum annual production volume was determined with respect to terrain conditions and with regard to the risk of forest soil degradation and the maximum production performance of 40,000 prms (16,000 m<sup>3</sup>) of forest energy wood chips per year, i.e. approximately 35–37% of the annual LMB logging cut. Due to the small storage capacity of the boiler house in Brno – Bystrc, part of the produced chips were stored in a rented roofed storage hall.

## I: LMB and Czech Republic mixed forests

Mix category	Stand groups		
	predominantly coniferous	predominantly deciduous	mixed
Representation	less than 25 % of deciduous trees	less than 25 % of coniferous trees	
% of LMB stand area	61.1	38.9	
% of CR stand area	66.7	15.3	17.0

Source: UHUL, LMB

## II: Breakdown of full forest energy wood chip production costs in dependence on changes in production volume

Cost category	cost type/performance	production volume up 25 thousand prms	production volume 26–40 thousand prms	monetary expenditures
Fixed [CZK]	annual depreciation: VALTRA	52,236	52,236	no
	annual depreciation: KRONOS	108,456	108,456	no
	annual depreciation: FENDT	441,144	441,144	no
	annual depreciation: JENZ	453,576	453,576	no
	annual depreciation: MERCEDES	250,584	250,584	no
	annual rent of warehouse	150,000	150,000	yes
	annual production cost	350,000	350,000	yes
	annual administrative cost	500,000	500,000	yes
	total	2,305,996	2,305,996	
Variable [CZK.prms <sup>-1</sup> ]	personal cost	79	89	yes
	service/concentration	39	61	yes
	material consumption; service/transport	100	117	yes
	total	218	267	
Indirect [CZK]	annual sales cost	100,000	150,000	yes

Source: Internally acquired information from the management accounting databases of Lesy města Brna, a. s., 2004–2008

The need for storage only arose when production topped 10 thousand prms.

For the above reasons, it is possible – though with some reservations – to consider this a representative sample, the evaluation of which may yield conclusions of a more general nature.

The evaluation of the efficiency of the production of wood chips as a material bearing energy value should be primarily associated with the creation and maximizing of profits. As a secondary consideration, a different system of cleaning and residue disposal may present an alternative method of savings. Two evaluation methods were therefore chosen from amongst the range of static methods:

- graphical tipping point analysis,
- variable cost limit establishment.

The dynamic modified tipping point analysis using cash flow (i.e. cash break even analysis) was also implemented.

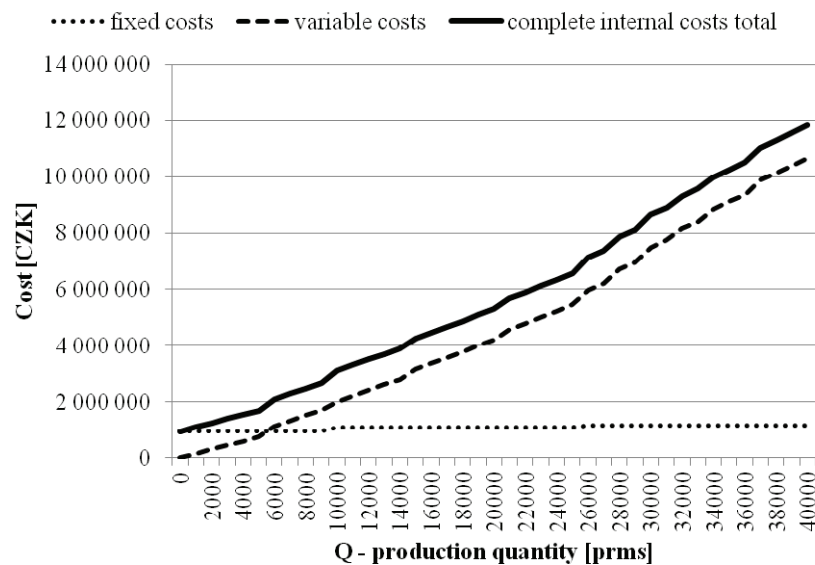
## RESULTS

### Graphical tipping point analysis

In order to carry out a graphical tipping point analysis, it is essential to first carry out cost stratification – see Tab. II.

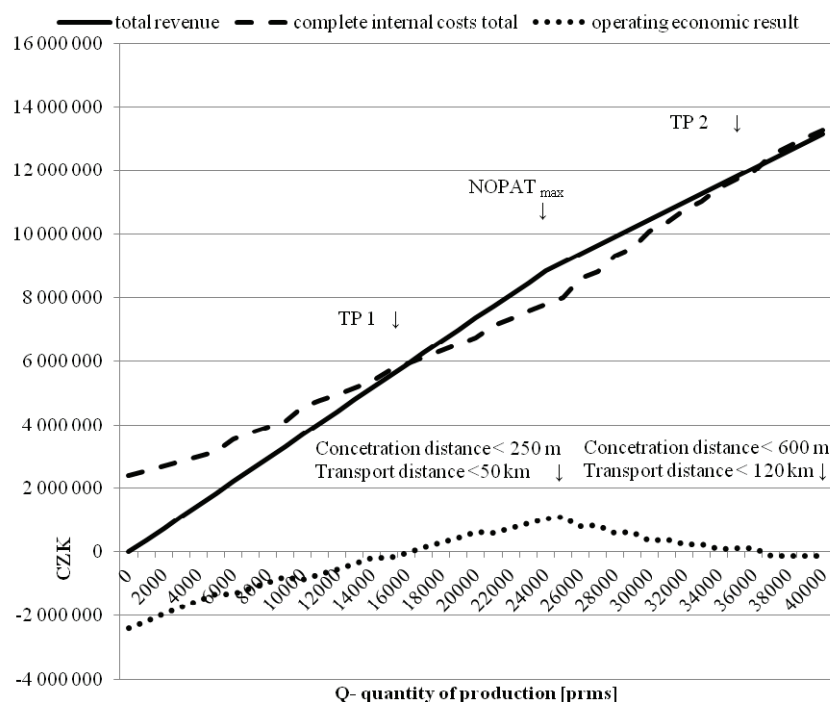
Since, in principle, this is a decision-making economic management process, i.e. a calculation, it is essential to provide an identification and breakdown of the costs with respect to changes in production volume. An annual production volume of 22–25 thousand prms of FEWC was achieved in stands with an average concentration distance of up to 250m from the logging site to the RS point and an average transportation distance of 50km to the point of final consumption. In the event of increased production volume up to a maximum value of 40,000 prms due to increased demand, it was necessary to concentrate LR from a greater distance (up to 600m) and transport the processed wood chips to a distance of up to 120 km.

The data file set referencing the structure and development of the full internal cost of forest energy wood chip production as dependent on changes in production volume according to the investigation carried out during the 2004–2008 reference period is not attached due to size constraints but may be obtained from the authors. Figure 1 illustrates the development of complete, variable and fixed production costs. The development of fixed costs is not entirely linear; a sharp increase is evident following an increase in production volume after reaching 10 thousand prms as a result of the need for wood chip storage in a rented warehouse and



1: Development of complete, variable and fixed forest energy wood chip production costs

Source: Internally acquired information from the management accounting databases of Lesy města Brna, a. s., 2004–2008



2: Graphical tipping point analysis of forest energy wood chip production

Source: Internally acquired information from the management accounting databases of the Lesy města Brna, a. s., 2004–2008

again following production reaching 26 thousand prms, this time as a result of increased sale costs.

Fig. 2, which illustrates the results of the graphical tipping point analysis, indicates that the maximum profit and thus the highest production efficiency of forest energy wood chips under the above described manufacturing conditions at an average market price achieved during the selected reference period is achieved with a production volume of

$q_{opt} = 25,000$  prms ( $10,000 \text{ m}^3$ ), which corresponds to 62.5% of the maximum production capacity and approximately 23% of the volume of the annual LR cut performed by LMB. The maximum profit is thus achieved at an average concentration distance of 250m and an average logging distance of 50km from the place of production to the point of final consumption. The maximum profit with respect to the optimal production sales volume is achieved

when marginal revenue equals marginal cost, which occurs in the range of 24–25 thousand prms per year. Once this volume is exceeded, the addition of variable personal costs amounts to 12.6% of the variable service purchase costs (concentration) 56.4% and variable costs of chip transportation 17.0%.

### Determination of the variable costs limit

The determination of the variable costs limit is carried out in a two-fold manner:

- 1) taking into account full internal costs,
- 2) taking into account only those costs which constitute cash expenses.

The calculation also includes the minimum production price for production volumes of 25 thousand prms and 40 thousand prms while respecting the full internal cost.

Ad 1)  $Q = 25,000$  prms; concentration distance < 250 m, transport distance < 50 km

$$a_{\lim 1} = c - \frac{b}{Q} \quad (1.1)$$

$$= 368 - \frac{(1,305,996 + 150,000 + 850,000 + 100,000)}{25,000}$$

$$a_{\lim 1} = 272 \text{ CZK.prms}^{-1}$$

Ad 1)  $Q = 40,000$  prms; concentration distance < 600 m, transport distance < 120 km

$$a_{\lim 1} = c - \frac{b}{Q} \quad (1.2)$$

$$= 329 - \frac{(1,305,996 + 150,000 + 850,000 + 150,000)}{40,000}$$

$$a_{\lim 1} = 269 \text{ CZK.prms}^{-1}$$

Ad 2)  $Q = 25,000$  prms; concentration distance < 250 m, transport distance < 50 km

$$a_{\lim 2} = c - \frac{b}{Q} \quad (1.3)$$

$$= 368 - \frac{(150,000 + 850,000 + 100,000)}{25,000}$$

$$a_{\lim 2} = 324 \text{ CZK.prms}^{-1}$$

Ad 2)  $Q = 40,000$  prms; concentration distance < 600 m, transport distance < 120 km

$$a_{\lim 2} = c - \frac{b}{Q} \quad (1.4)$$

$$= 329 - \frac{(150,000 + 850,000 + 150,000)}{40,000}$$

$$a_{\lim 2} = 300 \text{ CZK.prms}^{-1},$$

where:

$a_{\lim}$  .... variable cost limit in CZK.prms<sup>-1</sup>

$b$ .....fixed costs in CZK

$c$ .....market price in CZK.prms<sup>-1</sup>

$Q$ .....produced quantity.

The minimum price sum calculated whilst respecting the full internal cost is derived from the following equation:

$$a_{\lim 1} = c - \frac{b}{Q}, \quad (1.5)$$

where:

$a$ .....variable cost in CZK.prms<sup>-1</sup>

$b$ ..... fixed costs in CZK

$c_{\min}$ ..... minimum market price in CZK. prms<sup>-1</sup>

$Q$ .....produced quantity.

$$c_{25000} = \frac{(1,305,996 + 150,000 + 850,000 + 100,000)}{25,000} + 218 \quad (1.6)$$

$$c_{25000} = 314 \text{ CZK.prms}^{-1}$$

$$c_{40000} = \frac{(1,305,996 + 150,000 + 850,000 + 150,000)}{40,000} + 267 \quad (1.7)$$

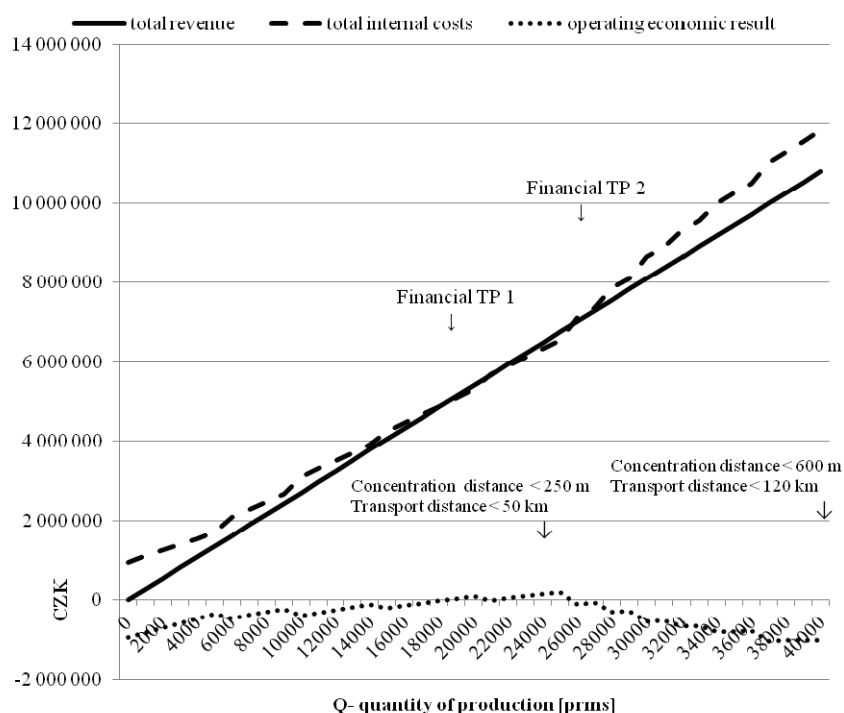
$$c_{40000} = 328 \text{ CZK.prms}^{-1}$$

The final calculations indicate higher economic forest energy wood chip production efficiency in the given production and marketing conditions as long as the concentration distance does not exceed 250 m and the distance to the point of final consumption does not exceed 50 km. While in the case of option No. 1 the variable cost limit of an annual production volume of 25 thousand prms is higher than in the case of annual production volume of 40 thousand prms, a lower minimum market price may be requested. In the case of option No. 2 the variable cost limit is lower in case of annual production volume of up to 25 thousand prms. It should be noted that if the calculated variable cost and market price limit values are reached, no accounting profit will be achieved.

Cash flow tipping point analysis (i.e. cash break even analysis).

A cash break even analysis constitutes an analytical procedure examining the impact situation involving a decline in market prices due to changes in the equilibrium of supply and demand and its influence on the profitability of forest energy wood chip production. The purpose of this analytical procedure is to verify the claim of the hypothesis, i.e. that the cost of raw material concentration and chip distribution is a decisive factor in the profitability of forest energy wood chip production even in the event of a decline in market prices. The construction of curves indicating costs, revenues and operating results assumes that the company will lose the position of exclusive supplier and after a certain period will be forced to sell the manufactured product at lower prices. The supposition therefore stipulates that the calculations do not include the





3: Graphical tipping point analysis of the production of forest energy wood chips using cash flow

depreciation of tangible fixed assets (i.e. production equipment) and only include operating cash-flow over the tipping point without being threatened by insolvency.

Fig. 3 clearly indicates that even with a reduction in market prices to 270 CZK.prms<sup>-1</sup> (675 CZK.m<sup>-3</sup>), which, among other things, corresponds to market prices in 2007/2008, albeit in this case with a sustained DAP parity according to INCOTERMS and a sustained level of variable costs, the production is profitable in case LR concentration does not exceed 250m and transportation distance does not exceed 50km. However, the profit area is narrowed to a production volume of 22 to 25 thousand prms per year.

## DISCUSSION

Calculations and results show that the highest profitability under given production conditions and market options is achieved in case LR concentration does not exceed 250m from the logging site to the processing site and transportation distance does not exceed 50km from the processing site to the final consumption point. With the indicated distances, the production conditions and market options will result in the following:

- full internal costs per cost unit: 314 CZK.prms<sup>-1</sup> (785 CZK.m<sup>-3</sup>) prior to the deduction of the price of the input material (LR),
- full internal cost profitability of 17.19%,
- total return on sales 14.67%,

- annual profitability expressed in terms of fixed asset depreciation (capital assets involved in production) of 103.37%.

With respect to the above results, it is essential to emphasize that the cost of expressing the depreciation of fixed assets (approximately 30% of the full internal cost) was not influenced by any financial support. In the context of information provided in the Material and methodology section, this manner of RES utilization represents an economic niche delimited by the ability to compete with the current conventional technologies of heat production by fulfilling the economic criteria of effective input and production usage.

Furthermore, it may be concluded that the actual potential of obtaining public financial support for the acquisition of technology for FEWC production of up to 50% of the total eligible costs may reduce the value of the full internal FEWC production costs by up to 15%. These economic findings are supported by claims about the ease of FEWC usage in local plants and heating plants.

The results of the evaluation of the economic efficiency of FEWC production, as presented in this case study, provide further discussion material supporting the use of forest dendromass in regional conditions, especially as regards the relations between concentration distance, transport distance, productivity of work, energy balance and carbon balance. The results are all the more valuable because the cost inputs of the study were not influenced by any financial support; therefore they very accurately reflect economic reality.

As for the concentration distance of LR, considering the criteria of economic efficiency, productivity of work and optimum costs, the most appropriate distance is 200–300m; this is also supported by the results obtained by Athanassiadis *et al.* (2002), Klvac *et al.* (2003) and a comprehensive study by the FMI (2010), where the curves of productivity and of Class I forwarder (capacity up to 10 tonnes) and Class II forwarder costs (capacity of 10–12 tonnes; this classification is used in Scandinavia) intersect within the concentration distance range of 200–300m, which roughly corresponds to a productivity of 20–25m<sup>3</sup> per 1 hour of uninterrupted machine work. If the concentration distance exceeds 600m, the productivity of machinery goes down to 12–18m<sup>3</sup> per 1 hour of work.

As for the transport distance, considering the criterion of lowest energy balance, the most appropriate average transport distance is 50 km (Karjalainen & Asikainen, 1996; FMI, 2010) – see Tab. III, which shows how the average transport distance can affect the energy balance. Comparing the results of this case study and of the FMI study for transport distances of 50, 100 and 150 km, we can conclude that a transport distance of 120 km or more is no longer profitable in regional conditions, and that the energy balance for 150 km is more than twice the value for the 50 km distance, which is recommended as the optimal transport distance and, according to the results of the case study, yields the highest economic efficiency.

The decisive factor for the profitability of FEWC transport is a short distance from the processing site

to customers. This currently represents a significant problem because in the Czech Republic, although it is a small country, the network of local incineration plants is too loose to meet this economic and environmental criterion. Even for big customers, such as the Wien Simmering power station (Austria) or Plzeňská teplárenská, the maximum profitable transport distance is 60–80 km; Fink (2004), Chytrý (2007), FMI (2010).

## CONCLUSION

Crucial issues encountered in connection with the solution of economic forest energy wood chip production efficiency issues involved in the manufacturing of electric power and heat include first and foremost production cost price as limited by the distance between the point of logging residue concentration and the point of disintegration and, furthermore, the transport distance to the point of final product (i.e. wood chips) consumption. The results show that the highest profitability under the given production conditions and in the given sales environment is achieved in case logging residue concentration does not exceed 250 m from the logging site to the processing site and transportation distance does not exceed 50 km from the processing site to the final consumption point. The final statement relevant to the hypothesis is as follows:

The decisive factors in the profitability of the production of forest energy wood chips are the costs of concentrating wood substance and manufactured chip distribution – the hypothesis has been confirmed and expanded to include transportation costs to the place of final consumption.

III: Energy balance of FEWC transport for distances of 50, 100 and 150 km

Average transport distance [km]	hauling rig	energy balance [MJ.prms <sup>-1</sup> ] the operational phase
50	small 35 prms	80.9
	large 70 prms	49.2
100	small 35 prms	133.0
	large 70 prms	72.8
150	small 35 prms	185.3
	large 70 prms	98.4

Source: UHUL, 2010

## SUMMARY

The objective of the work presented was to analyze the limiting factors of FEWC production profitability with the help of a case study. In order to evaluate production efficiency, actual FEWC production data output was used, with results generalized and conclusions and practical recommendations made. An initial working hypothesis was formulated: *The decisive economic efficiency factor of FEWC production is the cost of gathering the raw material and transporting the manufactured chips.* Input data was acquired from the accounting records of the Lesy města Brna, a. s. for the period of 2004–2008, which represents a comprehensive set of economic information about all relevant stages of FEWC production. All data was subjected to two static investment evaluation methods – graphic tipping point analysis and variable cost limit determination – and one dynamic method – modified cash flow tipping point analysis (i.e. cash break even analysis). The results have confirmed the established hypothesis, namely that the decisive factor in the profitability of FEWC production is the cost of concentrating the raw material and the subsequent distribution of the processed chips; however, an additional limiting

factor has been added: transportation costs to the point of final consumption. The results indicate that the highest profitability is achieved in case the LR concentration distance does not exceed 250 m from the logging site to the processing site and transportation distance does not exceed 50 km from the processing site to the final consumption point. Given these limiting distances and production and marketing conditions, full internal costs per cost unit stand at 314 CZK.prms<sup>-1</sup> (785 CZK.m<sup>-3</sup>) without any deductions of the input material (LR); full internal cost profitability stands at 17.19% with total revenue profitability at 14.67% and annual profitability in terms of depreciation of fixed assets (capital assets involved in the production) at 103.37%. With respect to the above results, it is essential to emphasize that the cost of expressing the depreciation of fixed assets (approximately 30% of the full internal cost) was not influenced by any financial support. The results of this case study form a contribution to the furthering of our knowledge of the economic efficiency of forest energy wood chip production in the Czech Republic in the 2004–2008 period.

### List of abbreviations

AG	Joint-stock company (Aktiengesellschaft)	MIT	Ministry of Industry and Trade
TP	Tipping point	RS	Production site (roadside)
CR	Czech Republic	RES	Renewable energy sources
DAP	Delivered at Place	S	Production site (stump)
EC	European Community	SEC	State Energy Concept
INCOTERMS	International Commercial Terms	PRM	Stacked cubic metre
FEWC	Forest energy wood chips	PRMS	Cubic metre of wood loose (bulk volume)
HS	Production site (hauling road)	UHUL	Ústav pro hospodářskou úpravu lesů (Forest Management Institute)
LR	Logging residue		

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