

THE ASSESSMENT OF THE SUITABILITY AND EFFECTIVENESS OF THE TECHNOLOGIES FOR VINEYARD WOOD WASTE UTILIZATION FOR ENERGETIC PURPOSES

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Abstract

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This paper is focused on procedure proposal for implementation of technologies for utilization of waste vine cane from vineyards for the energy purposes, including an assessment of their effectiveness. Evaluated were three variants of technological. Evaluated were 3 variants of technological procedures with using the shredder with discharge spout, shredder with container and the vine cane baler. For the individual variants were modeled operating costs, depending on the extent of the annual use that reflects the size of the vineyard. The operating costs were also confronted with the price of wood chips. The results show a clear recommendations of these technologies for vinicultural businesses with area of vineyards with more than 30–40 ha.

viticulture, wood waste, wood chips

The importance of renewable energy is growing. Czech Republic until recently used in all primary energy sources of approximately 4% from renewable sources of energy. In year 2010 the share of renewable energy sources in the Czech Republic increased to 8%. Across the EU is to achieved 12% share of the energy from renewable sources.

The main share of renewable resources is necessary to ensure by the biomass, because compared to other sources such as hydro, wind and solar energy has many advantages. It is a resource of energy that can be preserved indefinitely and use it according to the specific conditions in various combinations (PETŘÍKOVÁ, SLADKÝ, 2006).

The most important source of energy biomass comes from agriculture. Used are primarily by products, which is especially straw and waste wood after the pruning of vineyards, orchards and ornamental crops (MAGA *et al.*, 2008). In countries with a developed viticulture is a technology for the use of wood waste given a great attention, which is reflected in the development of modern mechanical

systems and consequently also suitable combustion systems (WALG, 2007).

The area of production vineyards in the Czech Republic is 18 000 ha. The waste wood from the vineyard after winter pruning in a wine-growing regions is an important source of raw materials suitable for energetic purposes. The yield of the waste vine cane is significantly influenced by spacing (quantity of the plants per 1 ha), variety, training system etc. and ranges from 1.8–2.5 t.ha⁻¹ (HERZÁN, 1993; ŽUFÁNEK, 1998). Character of the vine cane wood allows its relatively easily to shredding or pressing (ZEMÁNEK, BURG, 2010).

The use of this potential energy source depends mainly on the availability and effectiveness of the used technologies. Previous attempts of the energy use of these materials pointed out a high labor intensity during handling and storage. However, in the last few years the development of modern technology, especially shredders with container and the vine cane balers, induces greater interest in the implementation of these technologies in

the Moravian wine-growing regions (ZEMÁNEK, 2011).

The aim of this paper is the procedure proposal for implementation of technologies for utilization of waste vine cane from vineyards for the energy purposes assessment of their effectiveness for the viticultural businesses.

MATERIAL AND METHODS

The procedure of proposal for implementation of technologies for utilization of waste vine cane from vineyards for the energy purposes assessment of their effectiveness consists of the following steps:

Determination of the production of wood waste vine cane

For determining of the production of wood waste is necessarily based on the number of plants growing on the area and on the average amount of wood obtained from plant.

Production of wood waste is then given by formula:

$$G = \sum_{i=1}^n S_i Q_i, \text{ (t)}$$

where:

S_i ... area of the vineyard (ha)

Q_i ... wood waste yield (t.ha⁻¹)

n ... number vineyards parcels (-).

Indicative values are given in Tab. I.

Determination of potential energy production from the wood waste, and the boiler performance

Of the total production of wood waste can be determined, based on the calorific value, the potential energy (E_p).

$$E_p = G \times H, \text{ (GJ)}$$

where:

G ... production of the wood waste (t)

H ... calorific value (GJ.t⁻¹).

Calorific value of wood waste is determined for raw material with moisture of 10–15%. The values for the selected products shows Table II.

Assuming that the whole amount of wood waste for heating of the building will be used, is possible also to determine the maximum output of the boiler for this amount according to the relationship:

$$P = \frac{E_p \times 10^6}{d \times h \times 3600}, \text{ (kW)}$$

where:

E_p ... potential energy obtained from waste wood (GJ)

d ... number of days of the heating season, usually 200–230, for all year round heating 365

h ... number of hours of full operation of the boiler during the day, usually 10–12 hours.

From the above formula can be also specified minimum cultivation area for the desired output of the boiler:

$$S = \frac{d \times h \times 3600 \times 6}{Q \times H \times 10^6}, \text{ (ha)}$$

where:

d ... number of days of the heating season

h ... number of hours of full operation of the boiler during the day, usually 10–12 hours

Q ... wood waste yield (t.ha⁻¹)

H ... calorific value (GJ.t⁻¹).

The proposal of the technical equipment for the technology

Currently are predominantly used the following technological processes:

The technological process of vine cane shredding to the beside moving transporting machine, when is the vine cane shredded by

I: Number of plants and approximate production vine cane after the pruning, depending on the spacing

Spacing (m)	Number of plants (bushes.ha ⁻¹)	Vine cane production (t.ha ⁻¹)
2.00 × 1.00	5 000	2.20–2.50
2.20 × 1.00	4 500	2.00–2.25
2.50 × 1.00	4 000	1.80–2.00
2.70 × 1.00	3 700	1.70–1.90
3.00 × 1.00	3 300	1.60–1.80

II: Calorific value, Bulk density and demands for storage space for wood chips and packages of the vine cane

Fuel	Calorific value (MJ.kg ⁻¹)	Bulk density (kg.m ⁻³)	The energy content (GJ.m ⁻³)	The energy content (MWh.m ⁻³)	The storage space (m ³ .GJ ⁻¹)	The storage space (m ³ .MWh ⁻¹)
Wood chips	10	180–410	2.95	0.82	0.34	1.22
Vine cane – packages	14	350–400	4.90	1.36	0.20	0.73
Vine cane – chips	14	400–450	5.80	1.63	0.17	0.61
Wood – briquettes, pellets	21	600–1 100	17.85	4.96	0.06	0.20

a tractor trailed shredder with the discharge spout and wood chips is channeled into the cargo space of the transport vehicle moving in the next inter row. The disadvantage of this option is especially need another tractor. Although offering solutions the connection of cargo device behind the crusher, but with regard to the movement of such sets in the inter row, sufficient space for turning, moving out of the inter row, etc. is in practice this solution difficult to implement.

The technological process of vine cane shredding to the reservoir, for which are used carried shredders with a reservoir of volume 1.0–2.5 m³, to which is vine cane chips stored. Emptying into the transport device, mostly tractor trailer, or cage trailer is done at the edge of the vineyard. After the filling, the chips transported away. The volume of containers determines the total weight of shredder after its fulfillment, that puts demands on hydraulic hitch of the tractor. But carried construction of these machines makes much easier the movement in the inter row and turning. For selecting transporting machine is necessary taken into account clearance height of the reservoir.

The technological process of vine cane pressing into the packages uses roller balers for collecting and rolling vine cane into cylindrical packages with a diameter of 0.40 m, length 0.60 m and weight up to 30 kg. Those are subsequently transported away by a tractor and trailer or with trailer cage. The advantage is a lower energy intensity operation, because it is not necessary to crush the material and getting breathable package means its easy to dry. Disadvantages are still primarily perceived greater difficulty in handling and dosing packages into boilers.

The selection of the technology and used machines are based on the general principles for the creation of machine lines, where the most important part of the lines, the shredder or baler. Their aggregation with the tractor depends mainly on the energy requirements, which are for shredder much greater than for the baler. For the shredders with container is also important to consider its weight, which puts greater demands on the tractor hydraulic system. With regard to the movement in the inter

row, it should also take into account the inter row width and required turning radius. The proposal includes also a solution for transportation of the obtained product. For packages of pressed vine cane must also solved loading, for shredders with the reservoir, the choice of transporting vehicle.

Evaluation of the effectiveness of the proposed technologies

Economic evaluation of the proposed technologies is mainly focused on the determination of operating costs of used machinery. In the calculations is included the cost of machinery (depreciation), staff salaries, fuel consumption and other parameters observed during the use of these machines in terms of viticultural companies in 2010 and 2011. For 3 rated technologies were modeled operating costs, depending on the extent of the annual use, which expresses the size of vineyards. The course of operating costs is also confronted with the price of wood chips, which in the current market conditions ranges from 900 to 1500 CZK.t⁻¹. The results allow to assess the effectiveness of various technologies in various operating conditions expressed different performance.

RESULTS AND DISCUSSION

Technical and economic data for the monitored machine is shown in Tabs. III–V.

During calculating of costs for individual machines, the different growing conditions expressed varying performance.

Machines for vine cane shredding or pressing achieve, like other machines in viticulture, different performance in accordance to the length rows, space for the turning and the slope of the terrain.

Short rows and worse terrain reduce performance up to 20 to 30% (ZEMÁNEK, BURG, MICHÁLEK, 2010).

From Graph 1 it can be seen that crusher with discharge spout will, in optimal conditions, achieve performance 1.2 ha.h⁻¹ and is effective from 23 hours per year, about 28 ha per year. But on a vineyards with difficult conditions mean to achieve performance only 0.8 hectares per hour.

III: The technological process of vine cane shredding to the beside moving transporting machine

Work operations	Used machinery	Performance (W ₀₄)	Fuel consumption (l.h ⁻¹)	Cost of machinery (CZK without VAT)
Shredding of the vine cane to a beside moving vehicle (ρ = 440 kg.m ⁻³ , average production of the vine cane 2.5 t.ha ⁻¹)	NEW HOLLAND TN 75V + shredder with discharge spout COBRA PIANURA 1400	0.8–1.2 ha.h ⁻¹	9.0–10.5	990 000 400 000
Transport of wood chips (distance 5 km, v _p = 25 km.h ⁻¹)	NEW HOLLAND TN55V + tractor trailer 5–10 t	2.0 t.h ⁻¹ (0.8 ha.h ⁻¹)	5.3	873 000 212 000

Note: Performance of the transporting machinery is determined from the performance of the shredder. Regards to the significantly longer period of performance compared with the transport will be advantageous to use only one machine for transportation even with the cost of idle time the shredder. That will be in the end reflected in the decrease of shredder performance by 20–25%.

IV: The technological process of vine cane shredding to the reservoir and transport

Work operations	Used machinery	Performance (W_{04})	Fuel consumption ($l.h^{-1}$)	Cost of machinery (CZK without VAT)
Shredding of the vine cane to the reservoir ($\rho = 440 \text{ kg.m}^{-3}$, average production of the vine cane 2.5 t.ha^{-1})	NEW HOLLAND TN 75V + shredder with basket BERTI PICKER C-100	$0.6\text{--}1.0 \text{ ha.h}^{-1}$	$9.5\text{--}10$	990 000 500 000
Transport of wood chips (distance 5 km, $v_p = 25 \text{ km.h}^{-1}$)	NEW HOLLAND TN55V + tractor trailer 5–10t	5.0 t.h^{-1} (2.0 ha.h^{-1})	5.3	873 000 212 000

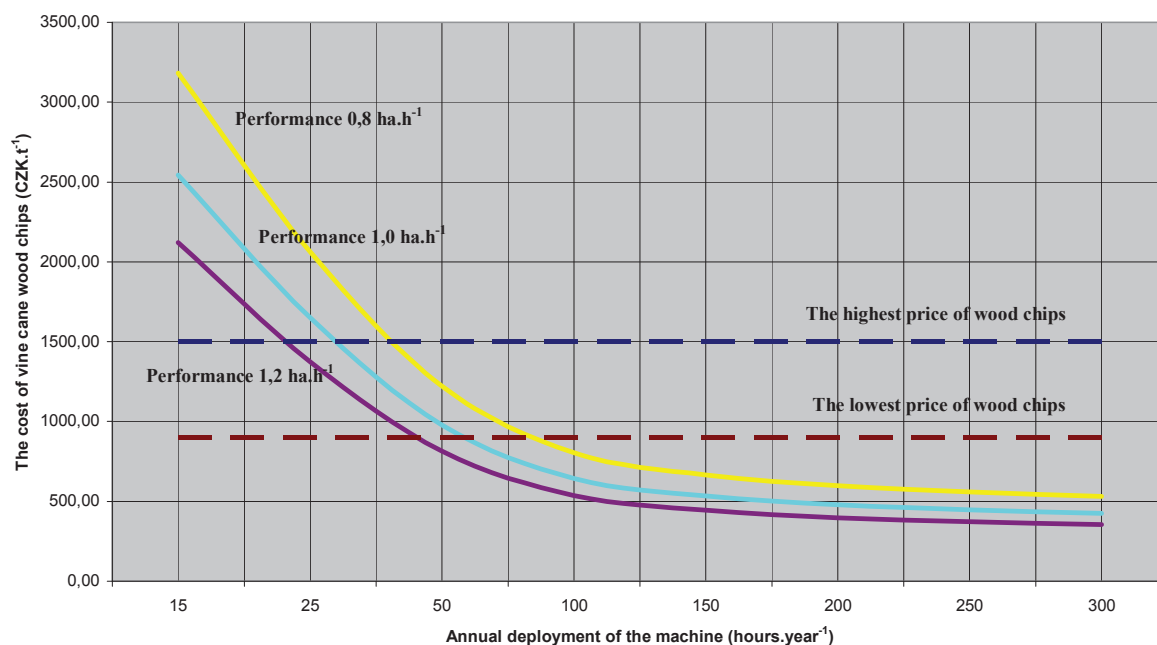
Note: Performance of transportation is determined from the time of two cycles: An empty trailer on one way and ride back with full trailer. There is no included filling time trailer (tractor can be used elsewhere). The filling time is determined by the performance of the shredder.

V: The technological process of vine cane pressing into the packages

operations	Used machinery	Performance (W_{04})	Fuel consumption ($l.h^{-1}$)	Cost of machinery (CZK without VAT)
Pressing of the vine cane ($\rho = 400 \text{ kg.m}^{-3}$, average production of the vine cane 2.5 t.ha^{-1})	NEW HOLLAND TN 55V QUICKPOWER 930	$0.5\text{--}0.7 \text{ ha.h}^{-1}$	$7.0\text{--}8.5$	873 000 450 000
Transport of wood chips (distance 5 km, $v_p = 25 \text{ km.h}^{-1}$) ($\rho = 400 \text{ kg.m}^{-3}$)	NEW HOLLAND TN55V + tractor trailer 5–10t	3.3 t.h^{-1} (1.3 ha.h^{-1})	5.0	873 000 212 000

Note: The performance of transporting machines is determined from the vine cane yield from 1 ha, for 2.5 t.ha^{-1} and the weight of the packages 30 kg it is about 80 pieces.ha⁻¹, trailer with capacity of 5 t holds about 160 pieces packages.

Tractor NH TN75V + shredder with discharge spout



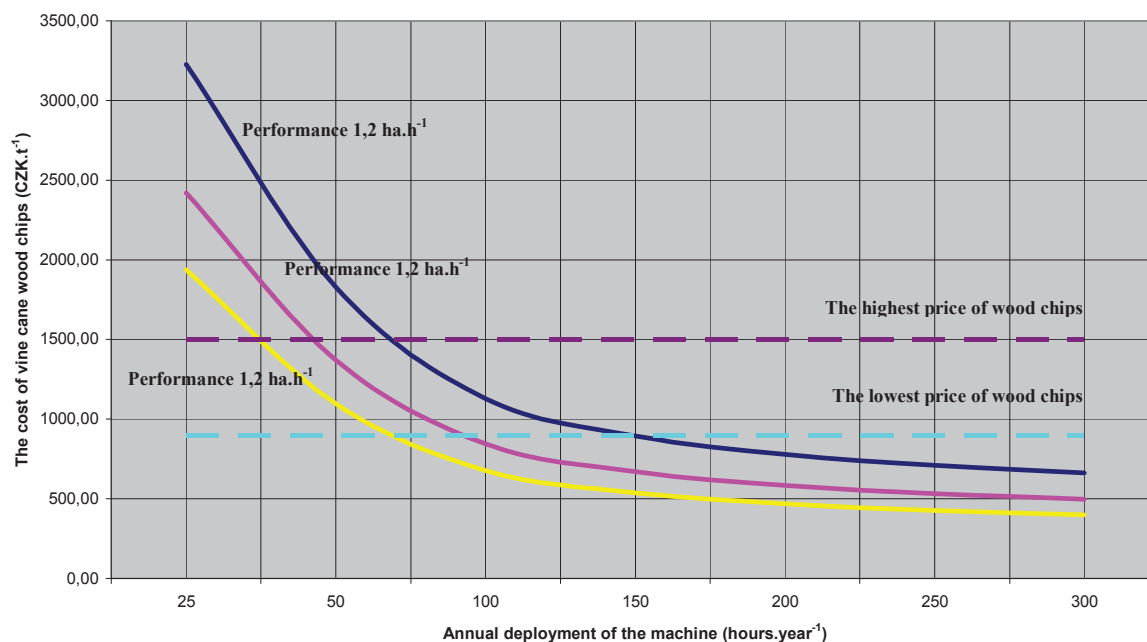
1: The curve of cost for acquiring chips of vine cane (shredder with discharge spout)

This corresponds to the effective deployment of 40 hours per year, which is about 32 ha per year.

Similarly, the combination crusher with reservoir (Graph 2) the effective deployment in optimal conditions is from 37 ha per year, in difficult

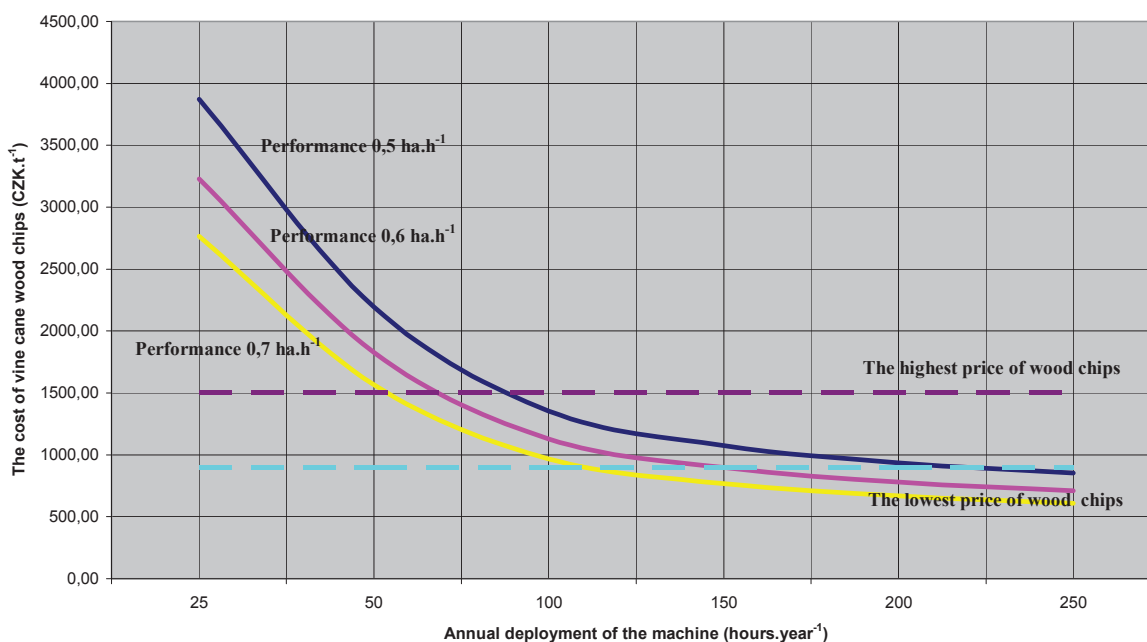
conditions from 42 ha per year. Combination of tractor and baler for pressing (Graph 3) will be effective in favorable conditions from 34 ha per year, in more difficult conditions from 42 ha per year.

Tractor NH TN75V + shredder with reservoir



2: The curve of cost for acquiring chips of vine cane (shredder wit reservoir)

Tractor NH TN75V + vine cane baler



3: The curve of cost for acquiring packages of vine cane (baler)

The effectiveness will be affected by cost of transport, which will be given by used machinery for transport and transport distances (SOUČEK, 2007). For monitored technology were costs of transportation on a level about 650–850 CZK.t⁻¹ for transporting distances from 5 to 8 km.

The results show a clear recommendations of these technologies for vineyard cultivation area

businesses with more than 30–40 ha. Energy potential that can be used for these areas, in accordance with the relations stated in the methodology, achieves 900–1200 GJ per year and this corresponds to coverage of fuel for year-round operation of boilers with performance 60–80 kW.

The price of wood chips in CZK.t⁻¹, to which the effectiveness of technology was applied (900–1500

CZK.t⁻¹), is based on currently reported prices. Current price of wood chips ranges in values from 980 to 1900 CZK.t⁻¹ (SOUČEK, 2010). MAGA (2007) specified the price of wood chips from 1150 to 1500 CZK.t⁻¹. Price of packages for energy crops states GONDA (2010) in a range from 1559 to 2205 CZK.t⁻¹.

With regard to the increasing demand for wood chips for heating (SINGER, 2010) these prices may be regarded as realistic. The results show that even for the existing medium and large wine-growing businesses in the Czech Republic are described technologies available and can be operated efficiently.

CONCLUSION

The use of waste wood from orchards and vineyards for energetic purposes, in the European countries with a developed viniculture and fruit growing, received considerable attention. Working operations provided by modern equipment allow to obtain wood chips or packages of the vine cane for energetic purposes. Analysis of the effectiveness of the three monitored technologies shows, that these technologies can be effectively applied for a producer with vineyard areas from 30–40 ha. Results of this paper allow to evaluate alternative technical proposals of these technologies and are the basis for further economic analysis.

SUMMARY

This paper dealt with the procedure proposal for implementation of technologies for utilization of waste vine cane from vineyards for the energy purposes, including an assessment of their effectiveness. Evaluated were three variants using technological procedures: shredder with discharge spout, crusher with reservoir and baler. For individual variants were modeled operating costs, depending on the extent of the annual deployment that reflects the area of vineyards. The curves of operating costs in the graph were also confronted with the price of wood chips. The results show a recommendation of these technologies for viticultural businesses with area of vineyards from 30–40 ha.

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