Annals of Warsaw University of Life Sciences – SGGW
Agriculture No 68 (Agricultural and Forest Engineering) 2016: 113–121
(Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 68, 2016)

Logistics of delivery of cones of selected species of forest trees. Part 2: Cone transport

MONIKA ANISZEWSKA, ARKADIUSZ GENDEK
Department of Agricultural and Forest Machinery, Warsaw University of Life Sciences – SGGW

Abstract: *Logistics of delivery of cones of selected species of forest trees. Part 2: Cone transport.* The basic problem during cone transport is their bulk density, which influences directly the quantity of energy stored in the volumetric unit of load. The article presents an analysis of profitability of transport of empty cones, which can be used at husking mills or local power plants to generate heat energy through their incineration. Cones of three species were analyzed – common pine, Norway spruce and European larch, and vehicles of varying load capacities and cargo space (from 2.4 to 91 m^3). The load mass was established, as well as its value at a minimum purchase price and the potential quantity and value of energy, which can be produced. It was found that purchase of cones at the price proposed by the forest services and their transport between husking mills was not profitable. On the other hand, it will be possible to use the cones as fuel by husking mills operating within the structures of the State Forests. In order to attain minimum profitability, the value of the cone load must include only the transport costs, and the transport vehicles used should have large stowage volume. On the basis of the theoretical analysis conducted, it can be stated in general that the cones should be used locally, preferably at the husking mill, in which they were processed. Alternative use of cones may include gardening, where cones are used for mulching to protect flower beds against weeds, and for decorative purposes.

Key words: biomass, energy, bulk density, cone transport, calorific value

INTRODUCTION

Transport of biomass in various forms (chips, packages, pellets and briquettes), including biomass of forest origin, is one of the key factors influencing the costs of obtaining heat energy as a result of incineration. Of key importance here is the size, form of the material and its bulk density [Keane et al. 2005, Bergström et al. 2008, Nurek and Roman 2014, Spinelli et al. 2015, Gendek et al. 2016] and calorific value. Referring to bulk density of cones as forest biomass, it is necessary to emphasize also their variety, which has been mentioned in the publications of Barzdajn [1996], Kulej and Skrzyszewska [1996], Buraczyk [2009], as well as Politi et al. [2011]. In the case of forest biomass, the best results are achieved in transport of round timber, and the worst – in transport of loose tree branches.

Authors of many publications mention substantial dispersion of forest biomass [Pieriegud 2015, Gendek and Nurek 2016, Nurek and Gendek 2016], including cones [Peters et al. 2003] and the associated need for appropriate work organization. A significant issue is timeliness of deliveries to power plants, seasonality and the associated necessity to adapt to the changing environmental conditions. Therefore, the suppliers have to display inventiveness [Antonowicz 2015]. Analyzing the form and bulk density of fuel biomass, Lisowski et al. [2015] found that biomass should be transported in compacted form. However, as it has been underlined by Baum et al. [2012], only good organization of the biomass market will allow for full use of the fuel biomass for production of the so-called green energy.

One of the types of forest biomass, which can be used for energy production purposes, are empty cones, remaining at husking mills after seed extraction. Therefore, purchase of these cones and their sale to heat and power plants can be considered. In the husking mills of Poland, husking machines are powered and heated mainly by electricity [Aniszewska 2012, Aniszewska and Kuszpit 2015]. In older type mills, some of the heat energy used in the husking process comes from incineration of empty cones as well. Such cones are characterized by low moisture content – around 8% [Aniszewska 2012, Aniszewska and Bereza 2014], and no additional expenditures are required for their drying, unlike in the case of other types of biomass [Głowacki and Gendek 2012]. However, the quantity of cones available in the season and the quantity of heat energy (18–19 MJ·kg^{-1}), which can be generated by them [Aniszewska and Gendek 2014, Gendek 2015] is not sufficient to cover the demand sufficiently to make the husking mill entirely self-reliant. In such cases, husking mills, which cannot use energy obtained from incineration of empty cones, can either sell or transfer cones to husking mills that are adapted to their use or sell them to local heat producing plants. The main problem associated with transport of empty cones is their low bulk density, at the level of 100–200 kg·m^{-3} [Aniszewska and Gendek 2016], and the substantial distance between husking mills.

The issue of cone transport has not been discussed in research so fat. Therefore, the objective of the analysis is to determine the real volume, mass and profitability of purchase and transport of empty cones between husking mills. Due to the fact that some of the husking mills in the country are powered only with electricity, the analyses conducted for them should be considered as entirely theoretical.

MATERIAL AND METHODS

The detailed methodology and average calorific value of cones of common pine, Norway spruce and European larch after the seed extraction process has been described by Aniszewska and Gendek [2014]. In order to specify the potential quantity of energy contained in the transport load and costs associated with transport of cones, for common pine, the calorific value applied was 18.11 MJ·kg^{-1}, for Norway spruce – 19.25 MJ·kg^{-1} and for European larch – 19.28 MJ·kg^{-1}.

The detailed methodology of determination of bulk density and the replacement coefficient was described in part of the study [Aniszewska and Gendek 2016]. The parameters of the load transported were specified for three transport vehicles.

For cones of the examined species, transport load mass was calculated, as the potential quantity of energy that can be obtained from a given load mass, load value according to the purchase price of cones at the husking mill, as well as the value of energy stored in the load according to contract price offered by the power plant. The following correlations were applied:

$$m_l = v_p \cdot BD_d \quad (1)$$

$$E_l = m_l \cdot Q_w \quad (2)$$

$$W_E = E_l \cdot p_{pc} \cdot 10^{-3} \quad (3)$$

$$W_z = m_l \cdot p_z \quad (4)$$

where:
m_l – load mass [kg];
v_p – cargo space volume [m^3];
BD_d – average bulk density [kg·m^{-3}];
E_l – energy in load transported [MJ];
Q_w – calorific value [MJ·kg^{-1}];
W_E – value of energy in load transported [PLN];
p_{pc} – contract price [PLN·GJ^{-1}];
W_s – load value according to cone purchase price [PLN];
p_z – cone purchase price [PLN·kg^{-1}].

The average bulk density (BD_d) for cones of the examined species was based on calculations provided in the first part of the study [Aniszewska and Gendek 2016].

The calculations were based on contract price (p_{pc}) 21.5 PLN·GJ^{-1} for years 2013–2015, agreed upon between the biomass supplier and an exemplary power plant.

Distances between husking mills (±1 km) have been specified on the basis of the shortest route determined using Google Maps. It was assumed that cones would be used locally, and their transport could take place between the five nearest husking mills using traditional ways of generating heat.

RESULTS AND DISCUSSION

Examining the possibility of transport of cones between husking mills or from a husking mill to a recipient, it is necessary to take into account the type and size of transport vehicle, the potential quantity of energy that can be obtained from a given mass and its value in relation to the cost of purchase of the cones. Detailed data has been presented in Table 1. For a truck tractor (vehicle A) with a semitrailer of capacity of 91 m^3, taking into account bulk density for a given species, a single load transported had the lowest mass for spruce cones (9.72 Mg) and the highest – for larch cones (18.75 Mg). Using the cones gathered and transported, it was possible to generate from 187.12 GJ of energy for Norway spruce to 361.58 GJ for European larch. Comparing the cost of purchase of cones to calorific value of the load transported, it can be concluded that at the price of 1 PLN·kg^{-1} offered according to the husking mill price list, transport turned out to be unprofitable. In the case of spruce cones, purchase of the load required an expenditure of 9,720.62 PLN, while the calorific value of the load, according to the price offered by the heat and power plant, was 4,023.12 PLN. The costs of cones and calorific values would be similar for empty pine cones – 17,910.62 and 6,973.77 PLN, respectively, and for larch cones – 18,754.19 and 7,773.99 PLN, respectively. Thus, in any case, the price of purchase of empty cones at 1 PLN·kg^{-1} was about 2.5 times higher than the value of energy that could be generated. Therefore, purchase of cones at the husking mill for resale to heat and power plants turned out to be unprofitable.

The cost simulation showed that in order for the purchase to be profitable, the price offered by husking mills should be much less than 0.4 PLN·kg^{-1}. This value is similar to that offered in 2012 by the husking mill in Grotniki. It should be

TABLE 1. Characteristics of vehicles and the cone loads transported

Parameter	Unit	Vehicle A	Vehicle B	Vehicle C
		brand/model		
		truck tractor Volvo FH with semitrailer Knapen	Kamaz 551 box-type	delivery truck Lublin 3.5 t
Semitrailer/box dimensions length/ /width/height	m	13.5/2.5/2.7	4.5/2.5/0.8	3.3/1.8/0.4
Capacity of the semitrailer/box	m^3	91.0	9.0	2.4
Transport rate*	$PLN·km^{-1}$	3.80	2.30	2.20
Common pine				
Cone sale price min/max	$PLN·kg^{-1}$	1.00**/2.50		
Load mass	Mg	17.91	1.77	0.47
Quantity of heat energy generated by cone incineration	GJ	324.36	32.08	8.55
Load value according to min price** of cone purchase	PLN	17 919.62	1 771.38	472.37
Value of energy obtained by incineration of cones	PLN	6 973.77	689.71	183.92
Norway spruce				
Cone sale price min/max	$PLN·kg^{-1}$	1.00**/2.50		
Load mass	Mg	9.72	0.96	0.26
Quantity of heat energy generated by cone incineration	GJ	187.12	18.51	4.94
Load value according to min price** of cone purchase	PLN	9 720.62	961.38	256.37
Value of energy obtained by incineration of cones	PLN	4 023.12	397.89	106.10
European larch				
Cone sale price min/max	$PLN·kg^{-1}$	1.00**/2.50		
Load mass	Mg	18.75	1.85	0.49
Quantity of heat energy generated by cone incineration	GJ	361.58	35.76	9.54
Load value according to min price** of cone purchase	PLN	18 754.19	1 854.81	494.62
Value of energy obtained by incineration of cones	PLN	7 773.99	768.86	205.03

*Rates offered by transport company – March 2015.
**Results for minimum cone price offered by husking mill (1 $PLN·kg^{-1}$).

added, however, that this price does not include transport costs.

In the case of the truck (vehicle B) of lesser load capacity (9 m^3), the situation was analogical as in the case of vehicle A. The transported load mass was from 0.96 Mg for spruce cones to 1.85 Mg for lark cones.

The load mass and quantity of energy that can be attained was similar also for the smallest vehicle (C) of load capacity of 2.4 m^3. In the case of this vehicle, the load mass ranged from 0.26 Mg for spruce cones and 0.49 Mg for larch cones. Similarly, the value of purchase of cones at the husking mill was about 2.5 times higher than the attainable quantity of energy. Purchase of cones even at a minimum price and their resale to a plant generating heat energy turned out to be unprofitable for the agent or the end recipient. One of the solutions to improve profitability may be individual negotiation of prices per 1 kg of empty cones between the husking mill and the agent or the end recipient.

On the basis of differences indicated between the cost of purchase and transport and profit, the only solution may turn out to be transfer of cones on the basis of cooperation between husking mills. Husking mills interested in cones would not bear the costs associated with purchase, but only the transport costs.

Transport distances determined according to the shortest route between husking mills have been presented in Table 2. The average transport distance

TABLE 2. Transport distances between husking mills [km]

×	Białogard	Brzesko	Czarna Białostocka	Dębno	Dukla	Grotniki	Jarocin	Jedwabno	Klosonowo	Lasowice Wielkie	Łochów	Miłków LBG	Ruciane–Nida	Siedlisko	Wirty	Zwierzyniec
Białogard	–	752	627	236	874	426	301	388	139	459	499	468	457	336	191	779
Brzesko	752	–	529	630	114	339	411	497	577	255	363	428	505	471	548	221
Czarna Białostocka	627	529	–	710	509	346	372	213	493	504	158	677	173	617	434	375
Dębno	236	630	710	–	746	390	263	485	256	412	567	315	553	182	306	734
Dukla	874	114	509	746	–	461	533	550	668	354	402	550	569	593	640	181
Grotniki	426	339	346	390	461	–	163	256	310	159	203	351	307	316	284	395
Jarocin	301	411	372	263	533	163	–	418	238	159	340	215	436	134	290	532
Jedwabno	388	497	213	485	550	256	418	–	269	396	155	554	68	473	209	418
Klosnowo	139	577	493	256	668	310	238	269	–	375	381	438	338	303	66	602
Lasowice Wielkie	459	255	504	412	354	159	159	396	375	–	361	231	491	235	414	401
Łochów	499	363	158	567	402	203	340	155	381	361	–	533	158	474	362	274
Miłków LBG	468	428	677	315	550	351	215	554	438	231	533	–	663	149	482	639
Ruciane–Nida	457	505	173	553	569	307	436	68	338	491	158	663	–	604	269	436
Siedlisko	336	471	617	182	593	316	134	473	303	235	474	149	604	–	407	686
Wirty	191	548	434	306	640	284	290	209	66	414	362	482	269	407	–	577
Zwierzyniec	779	221	375	734	181	395	532	418	602	401	274	639	436	686	577	–

between all husking mills in the country is 402.73 km (*SD* = 171.67) and it is within the range of 66 to 874 km.

Taking into account the local use of cones as fuel for equipment in the husking mills that incinerate cones, for every husking mill, average distances were determined between the mill and five other plants, which are the closest. As a result, the average transport distance decreased from 403.63 to 225.6 km (*SD* = 83.27) and closed within the range of minimum distance of 66 km to the maximum of 461 km (Table 3).

ficient quantity of heat energy to cover the transport costs between all husking mills in the country. Therefore, it is possible to transport the load even between the farthest husking mills of Dukla and Białogard at the distance of 847 km.

Using a transport truck of capacity of 9 m^3 (vehicle B), it is possible to determine the maximum transport distance, for which the heat energy value from incineration of the load will cover the transport costs. Pine and larch cones can be transported by this vehicle at the maximum distance of 375 and 400 km,

TABLE 3. Average distance between the five closest husking mills [km]

Husking mill	*AVG*	Min	Max	*SD*	*CV*	*SE*
Białogard	240.6	139.0	336.0	79.9	33.22	35.74
Brzesko	258.4	114.0	363.0	99.6	38.55	44.55
Czarna Białostocka	252.4	158.0	372.0	99.8	39.54	44.63
Dębno	248.6	182.0	306.0	45.1	18.16	20.19
Dukla	302.4	114.0	461.0	148.3	49.04	66.32
Grotniki	213.0	159.0	284.0	55.7	26.15	24.91
Jarocin	181.8	134.0	238.0	43.1	23.69	19.26
Jedwabno	180.2	68.0	256.0	72.2	40.09	32.31
Klosonowo	193.6	66.0	269.0	87.8	45.33	39.25
Lasowice Wielkie	207.8	159.0	255.0	45.5	21.88	20.33
Łochów	189.6	155.0	274.0	51.2	27.02	22.91
Miłków LBG	252.2	149.0	351.0	80.9	32.08	36.19
Ruciane-Nida	195.0	68.0	307.0	94.9	48.65	42.43
Siedlisko	200.6	134.0	303.0	69.1	34.46	30.91
Wirty	203.8	66.0	284.0	86.4	42.40	38.64
Zwierzyniec	289.2	181.0	395.0	93.7	32.41	41.92
×	Total					
	225.6	66.0	461.0	83.27	36.92	9.31

For a truck tractor with a semitrailer (vehicle A), it turned out that the transported cone mass, regardless of the tree species, can be used to generate a suf-

respectively. The transport distance for spruce cones is almost two times lower (210 km) – Figure. Using the indicated type of vehicle, it is possible to transport

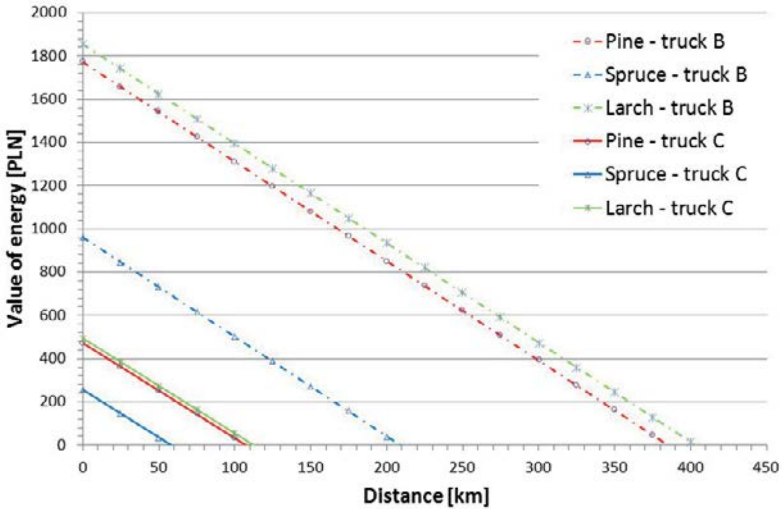

FIGURE. The balance of heat energy obtained from incineration of cones, taking into account the transport costs for a specific distance using vehicles B and C

cones within the local market between the closest husking mills; in the case of spruce cones, this solution is feasible to the boundary of average distance, illustrated by Table 3.

Due to economic reasons, the least advantageous solution is to use small commercial vehicles (vehicle C). The limit of profitability of transport of spruce cones turned out to be less than 60 km, which is lower than the smallest distance between the closest husking mills of Wirty and Klosnowo (66 km). In transport of empty pine and larch cones, the limit of profitability was a distance of 108 to 114 km (Fig.). In this case, transport between husking mills Klosnowo – Wirty (66 km), Jedwabno – Ruciane-Nida (68 km) and Dukla – Brzesko (114 km) would be feasible.

SUMMARY

Use of empty cones for production of heat at the existing husking mills in Poland is not the only solution. The alternatives may include, for instance, gardening, where cones are used for mulching, to ensure protection against weeds, and as decorative elements – they are often dyed in various colors.

On the basis of the theoretical analysis conducted, it can be stated in general that the cones should be used locally, preferably at the husking mill, in which they were processed.

Use as fuel by husking mills can be profitable only if the sole cost is that of transport. In such case, truck tractors with semitrailers of large capacity turned out to be the most useful.

Regardless of the type of vehicle, taking into account the minimum cost of purchase of cones, proposed by the Forestry management, that is, 1 PLN per 1 kg, the value of heat energy generated turned out to be 2.5 times lower. Therefore, purchase of cones via agents and their transport to husking mills, in which they are used as fuels, turned out to be unprofitable.

It is possible to use trucks with smaller stowage space; however, profitability will depend on the transport distance and bulk density of the cones. The least advantageous solution, as it turns out, is use of small commercial vehicles, for which transport of pine and larch cones was limited to the distance of about 110 km. On the other hand, transport of spruce cones turned out to be entirely unprofitable, as the minimum distance between the husking mills is greater than the maximum transport distance.

REFERENCES

ANISZEWSKA M. 2012: Dynamika procesu pozyskania nasion w jedno-i dwuetapowych procesach łuszczenia szyszek sosny zwyczajnej *Pinus sylvestris.* Rozprawy Naukowe i Monografie. Wydawnictwo SGGW, Warszawa.

ANISZEWSKA M., BEREZA B. 2014: Analysis of water absorption process in the cones of common pine (*Pinus sylvestris* L.). Annals of Warsaw University of Life Sciences – SGGW, Agriculture (Agricultural and Forest Engineering) 63: 105–112.

ANISZEWSKA M., GENDEK A. 2014: Comparison of heat of combustion and calorific value of the cones and wood of selected forest tree species. Forest Research Papers 75 (3): 231–236. DOI: 0.2478/frp-2014-0022.

ANISZEWSKA M., GENDEK A. 2016: Logistics of the supplies of selected forest tree species cones. Part 1. Cone density and substitution coefficient. Annals of Warsaw University of Life Sciences – SGGW, Agriculture (Agricultural and Forest Engineering) 67: 121–130.

ANISZEWSKA M., KUSZPIT D. 2015: Analysis of Acquisition and Potential Usage of Conifer Cones from Polish Seed Extraction Houses between 2009–2012. Annals of Warsaw University of Life Sciences – SGGW, Agriculture (Agricultural and Forest Engineering) 65: 93–101.

ANTONOWICZ M. 2015: O innowacjach produktowych i marketingowych w usługach transportowo-logistycznych. Logistyka 2: 1131–1139.

BARZDAJN W. 1996: Ocena wartości diagnostycznej morfologicznych cech szyszek świerka pospolitego [*Picea abies* (L.) Karst.] w celu wyróżnienia jego proweniencji. Sylwan 140 (9): 61–75.

BAUM R., WAJSZCZUK K., WAWRZYNOWICZ J. 2012: Modelowe rozwiązanie logistyczne dla lokalnego rynku biomasy. Logistyka 4: 846–854.

BERGSTRÖM D., ISRAELSSON S., ÖHMAN M., DAHLQVIST S.A., GREF R., BOMAN C., WÄSTERLUND I. 2008: Effects of raw material particle size distribution on the characteristics of Scots pine sawdust fuel pellets. Fuel Processing Technology 89: 1324–1329. doi:10.1016/j.fuproc.2008.06.001.

BURACZYK W. 2009: Morphological changeability of cones of Norway spruce [*Picea abies* (L.) Karst.] in the Białowieża Forest. Folia Forestalia Polonica A, 51 (2): 154–160.

GENDEK A. 2015: Combustion heat and calorific value of the mix of sawdust and cones of common pine (*Pinus sylvestris* L.). Annals of Warsaw University of Life Sciences, Agriculture (Agricultural and Forest Engineering) 66: 137–144.

GENDEK A., ANISZEWSKA M., CHWEDORUK K. 2016: Bulk density of forest energy chips. Annals of Warsaw University of Life Sciences, Agriculture (Agricultural and Forest Engineering) 67: 101–111.

GENDEK A., NUREK T. 2016: Variability of energy woodchips and their economic effects. Folia Forestalia Polonica A, 58 (2): 62–71. DOI:10.1515/ffp-2016-0007.

GŁOWACKI SZ., GENDEK A. 2011: Application of forced drying methods in preparation of forest chips for energy purposes. Annals of Warsaw University of Life Sciences, Agricultute (Agricultural and Forest Engineering) 58: 29–34.

KEANE R.E., REINHARDT E.D., SCOTT J., GRAY K., REARDON J. 2005: Estimating forest canopy bulk density using six indirect methods. Canadian Journal of Forest Research 35 (3): 724–739. DOI: 10.1139/X04-213.

KULEJ M., SKRZYSZEWSKA K. 1996: Wstępna ocena zmienności szyszek świerka istebniańskiego na przykładzie wybranych drzewostanów nasiennych Nadleśnictwa Wisła. Sylwan 140 (5): 105–120.

LISOWSKI A., KOSTRUBIEC M., DĄBROWSKA-SALWIN M., ŚWIĘTOCHOWSKI A. 2015: Cechy peletów z biomasy roślinnej w aspekcie logistyki dostaw. Logistyka 5: 351–356.

NUREK T., GENDEK A. 2016: Wpływ wybranych czynników logistycznych na wydajność i koszty eksploatacji maszyn leśnych. Zeszyty Naukowe SGGW, Ekonomika i Organizacja Logistyki 1 (2): 45–55.

NUREK T., ROMAN K. 2014: Effect of mineral matter content on specific density of forest biomass. Annals of Warsaw University of Life Sciences, Agriculture (Agricultural and Forest Engineering) 64: 109–116.

PETERS S., BOUTIN S., MacDONALD E. 2003: Pre-dispersal seed predation of white spruce cones in logged boreal mixedwood forest. Canadian Journal of Forest Research 33 (1): 33–40.

PIERIEGUD J. 2015: Polski rynek usług transportu samochodowego i kolejowego – bilans dziesięciolecia w Unii Europejskiej. Logistyka 1: 8–12

POLITI P.I., GEORGHIOU K., ARIANOUTSOU M. 2011: Reproductive biology of Abies cephalonica Loudon in Mount Aenos National Park, Cephalonia, Greece. Trees 25: 655–668. DOI:10.1007/s00468-011-0542-1.

SPINELLI R., DE FRANCESCO F., ELIASSON L., JESSUP E., MAGAGNOTTI N. 2015: An agile chipper truck for space-constrained operations. Biomass and Bioenergy 81: 137–143. DOI:10.1016/j.biombioe.2015.06.017.

Streszczenie: *Logistyka dostaw szyszek wybranych gatunków drzew leśnych. Część 2: Transport szyszek.* Podstawowym problemem podczas transportu szyszek jest ich gęstość usypowa, która bezpośrednio wpływa na ilość energii zgromadzonej w jednostce objętościowej ładunku. W artykule przedstawiono analizę opłacalności transportu pustych szyszek, które mogą być wykorzystane w wyłuszczarniach lub lokalnych zakładach energetycznych do wytwarzania energii cieplnej w wyniku ich spalania. Analizie poddano szyszki trzech gatunków – sosny zwyczajnej, świerka pospolitego i modrzewia europejskiego, a do transportu zaproponowane zostały samochody o różnej ładowności i pojemności przestrzeni ładunkowej (od 2,4 do 91 m^3). Wyznaczona została masa ładunku, jego wartość przy minimalnej cenie zakupu oraz potencjalna ilość i wartość energii, którą można z niej wytworzyć. Stwierdzono, że zakup szyszek po cenie proponowanej przez nadleśnictwa i ich transport między wyłuszczarniami nie jest opłacalny. Możliwe będzie natomiast wykorzystywanie szyszek do celów opałowych przez wyłuszczarnie funkcjonujące w PGL Lasach Państwowych. Aby uzyskać minimalną opłacalność, wartość ładunku szyszek musi uwzględniać tylko koszt transportu, a do ich przewiezienia należy używać samochodów o dużej pojemności komory ładunkowej. Na podstawie przeprowadzonych rozważań teoretycznych można ogólnie stwierdzić, że szyszki powinny być wykorzystywane lokalnie, najlepiej bezpośrednio w wyłuszczarni, w której były łuszczone. Alternatywą wykorzystania szyszek może być np. ogrodnictwo, gdzie stosuje się je do ściółkowania rabat jako ochrona przed chwastami oraz jako element ozdobny.

MS received February 2016

Authors' address:
Arkadiusz Gendek, Monika Aniszewska
SGGW
Wydział Inżynierii Produkcji
Katedra Maszyn Rolniczych i Leśnych
02-787 Warszawa, ul. Nowoursynowska 164
e-mail: arkadiusz_gendek@sggw.pl
monika_aniszewska@sggw.pl