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# THE PROFITABILITY OF CONVERTING SAWMILL BY-PRODUCTS INTO ENERGY

*An analysis of the profitability of generating energy from sawmill by-products was carried out by applying a method embracing a number of indicators to facilitate the evaluation.. The research accounted for both those sawmills generating energy for their own internal usage, setting the profitability threshold of substituting a given source of energy for post-production wood, as well as those generating energy from biomass with the intention of further sales. It has been proven that wood waste is the ideal type of sawmill by-product in relation to all kinds of fuels being replaced, while energy production from pulp chips with 25% moisture content is the least profitable, hence they should be sold unprocessed. An entrepreneur generating energy from biomass purchased outside his plant reaches the highest margin level of 15% when burning wet defibered chips with 50% moisture content and wood waste.*

**Keywords:** wood by-products, generating energy from wood biomass, profitability of processing.

## Introduction

In order to fulfill EU obligations concerning the share of renewable energy in the overall national energy balance, there has been a rapid growth in the utilization of biomass, the most easily accessible source of renewable energy in Poland. According to expert estimations [Polityka ekologiczna 2010] if this trend continues, this will lead by 2020 to a five-fold (20 mln tonnes) increase in energy plant demand for biomass.

The most easily accessible type of biomass is wood biomass. As an energy-generating fuel it can be obtained from eucalyptus, willow, poplar or Pennsylvania mallow plants, forest waste not used by the paper or board industry, post-production waste from sawmills and carpentry houses, as well as waste from other industry sectors, such as from mines, the building sector or railways.

Currently the most frequently used types of biomass embrace: forest biomass namely fuel wood and wood of irregular shape - wigs, trimmings, brushwood, and

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post-production waste from the wood sector in the form of bark, wood particles, sawdust, wood chips and other wood waste.

According to estimates from the State Forests General Board of Directors, the technical potential of forestry wood which can be used for energy amounts to approximately 41.6 PJ (6.1 mln $m^3$). While the technical potential of wood waste from the wood sector and other sources has been estimated by the Institute of Wood Technology to have reached 58.1 PJ (8.3 mln $m^3$), the total share of this type of biomass in the overall technical potential of biomass in Poland (755 PJ) accounts for 13.2% [Krajowy Plan Działania... 2010].

The basic volume of wood biomass is generated by the wood industry in numerous forms of post-production residues (wood waste). It is estimated that from 100 $m^3$ of forest wood, waste accounts for 64%, including 10 $m^3$ of bark, 15 $m^3$ of wigs, 20 $m^3$ fuel bole (wigs and stumps), and 19 $m^3$ of sawdust and chips. The main product,lumber, constitutes 36 $m^3$, out of which only 20-25 $m^3$ will, following the conversion process, become part of finished products [Janowicz 2006]. Basic groups of wood by-products, their brief characteristics and areas of usage are shown in table 1.

**Table 1. Characteristics of various groups of wood by-products**
***Tabela 1. Charakterystyka różnych grup pozostałości drzewnych z przerobu litego drewna***

| Group<br>*Grupa* | Origin/characteristics<br>*Źródło pochodzenia/charakterystyka* | Usage<br>*Zastosowanie* |
|---|---|---|
| 1 | 2 | 3 |
| Waste-wood<br>*Odpady kawałkowe* | – pieces of trunks, wigs and roots between 15 and 30 cm long<br>*kawałki pni, gałęzi i korzeni o długości 15-30 cm*<br>– the leftovers following conversion of logs in a sawmill: wings and edgings<br>*pozostałości po przecieraniu kłód w tartaku: opoły, zrzyny*<br>– the remains of construction lumber cut to pre-ordered size<br>*resztki drewna konstrukcyjnego, przycinanego na wymiar*<br>– remains from the production of half-finished products (for example strips) cut to particular size<br>*odpad z produkcji półproduktów (np. fryzów) przycinanych na wymiar* | – direct burning<br>*bezpośrednie spalanie*<br>– converting into chips for cellulose and chipboard industry and energy sector<br>*przerób na zrębki dla przemysłu celulozowego i płytowego oraz energetyki* |
| Sawdust<br>*Trociny* | – by-products of converting wood in sawmills and carpenter's workshops<br>*produkt uboczny z przecierania drewna w tartakach i stolarniach*<br>– difficult for storing<br>*trudne w magazynowaniu*<br>– prone to scalding ( beech sawdust)<br>*skłonne do zaparzania (trociny bukowe)*<br>– prone to damp<br>*podatne na zawilgocenia* | – direct burning (mainly wet)<br>*bezpośrednie spalanie (głównie mokre)*<br>– conversion into pellets and wood briquettes<br>*przerób na granulat drzewny i brykiety* |

Table 1. Continued
*Tabela 1. Ciąg dalszy*

| | | |
|---|---|---|
| Wood particles *Wióry* | – by-product of converting dry wood in furniture factories and carpenter's workshops *produkt uboczny obróbki suchego drewna (skrawanie, frezowanie) w fabrykach mebli i stolarniach*<br>– small amount of mineral pollutants *niewielka ilość zanieczyszczeń mineralnych* | – direct burning *bezpośrednie spalanie*<br>– conversion into pellets and briquettes *przerób na granulat drzewny i brykiety* |
| Wood chips *Zrębki drzewne* | – wooden pieces irregular in shape between 5 and 50mm long *ścinki drzewne o nieregularnych kształtach, długości 5-50 mm.*<br>– product of grinding sawmill residue and secondary conversion as well as that from the first clearing and other post-cutting residue *produkt rozdrobnienia odpadów z przemysłu tartacznego i przerobu pogłębionego oraz z pierwszego trzebienia drzewostanów, wierzchołków i innych pozostałości po wyrębach*<br>– sensitive to changes in humidity *wrażliwe na zmiany wilgotności powietrza*<br>– prone to fungus-related illnesses *podatne na choroby grzybowe* | – direct burning in boilers *bezpośrednie spalanie w kotłach*<br>– production of chipboard (defibered chips- with bark) and paper (pulp chips- debarked) *produkcja płyt wiórowych (zrębki defibracyjne- z korą) i papieru (zrębki papiernicze--pozbawione kory)*<br>– used in metallurgy *topnik w hutnictwie*<br>– converted into pellets and briquettes following previous grinding (less often) *przerób na granulat drzewny i brykiety po uprzednim rozdrobnieniu (rzadziej)* |
| Wood dust *Pył drzewny* | – by-product of converting dry wood in furniture factories and carpenter's workshops *odpad z obróbki suchego drewna w fabrykach mebli i stolarniach* | – accessory in the production of briquettes *dodatek do produkcji brykietów* |
| Bark *Kora* | – by-product from converting logs in sawmills and pulp mills *odpad z korowania kłód w tartakach i celulozowniach*<br>– high content of mineral pollutants *duża zawartość zanieczyszczeń mineralnych* | – direct burning *bezpośrednie spalanie*<br>– raw material for briquettes production (mixed with other types of wood residue) *surowiec do produkcji brykietów drzewnych zmieszany z innymi rodzajami odpadów drzewnych* |

Source: own elaboration
*Źródło: opracowanie własne*

Research carried out by the Institute of Wood Technology [Szostak, Ratajczak, Bidzińska, Gałecka 2004] into the Polish industrial wood waste market showed that the majority of post-production waste is generated by the sawmill sector together with the laminated board sector –approximately 60%. The source of 14% of this is the furniture sector and 10.4% is generated by the wood panel sector. In the structure of wood waste the domineering part is taken by solid waste, namely 46.4%. Most of it is generated by the sawmill industry (70.1%), which, due to its character, is also the leader in the production of sawdust and chips (74.4%).

One of the options concerning the use of sawmill post-production wood waste is its direct conversion into energy. Such a decision concerning the processing of this type of by-product requires a profitability analysis, which would also take into account other options as regards its usage. Such an evaluation is made possible by the formula described by Mikołajczak [2008], that is, the formula of pricing post--production wood waste into energy:

$$W_{ei} = c_{je} g \frac{19{,}5 - 2{,}5 w_o}{1 + w_o} \left( 1 - \frac{m_j}{1 - p} \right) - k_{pi} - k_{ti} \qquad [\mathrm{PLN/m^3}] \qquad (1)$$

where: $W_{ei}$ – value of a certain type of wood waste of "i" number when processed into energy [PLN/m$^3$],

$i$ – number of type of wood waste product being processed, i ∊ <1, n>,

$c_{je}$ – unit sales price of energy obtained from burning by-products [PLN/GJ],

$g$ – bulk density of the type of by-product being burnt [t/m$^3$],

$w_o$ – absolute moisture of the type of by-product being burnt.

$m_j$ – assumed net profit margin level, satisfactory for the producer, $m_j$: {0,01; 0,05; ... 0,15},

$p$ – income tax (CIT), for 2011 = 0,19,

$k_{pi}$ – unit cost of processing into energy a given type of by-product of "i" number along with the remaining unit operating costs [PLN/m$^3$],

$k_{ti}$ – unit cost of transporting a given type of by-product of "i" number to the place of its processing into energy [PLN/m$^3$].

## Methodology

### The use of sawmill by-products in the direct generation of energy for own purposes

In the case of a sawmill determining the value of wood by-products converted into energy in accordance with the formula (1), this most frequently means determining the profitability of substituting a given type of energy source with post-production wood. Energy obtained from wood waste burning is then used for own use, most often lumber drying and social needs. It is not aimed at further sales, thus the calculations account for a zero margin level ($m_j$). Then the value of by-products burnt at the place where they have been generated can be shown as follows:

$$w_{ei} = c_{je} g \frac{19{,}5 - 2{,}5 w_o}{1 + w_o} - k_{pi} - k_{ti} \qquad [\mathrm{PLN/m^3}] \qquad (2)$$

Because sawmill by-products may substitute any fuel used for energy purposes, their value when processed into energy was determined individually for each of 7 groups (sawdust: $w_o$ = 10% and 50%, defibered chips and pulp chips: $w_o$ = 25% and 50%, wood waste $w_o$ = 25%) subsequently replacing them for various other forms of energy sources. For example, in order to determine in this type of processing the value of sawdust, which substitutes natural gas, the assumption was made that $c_{je}$ is a unit price of energy generated from natural gas, which should be interpreted as sales of energy from wood biomass at the price level of natural gas.

**The use of sawmill by-products in the direct processing into energy with the intention of selling.**

In the case of an entrepreneur generating energy from wood biomass with the intention of further sales, determining the value of the individual types being processed and comparing this with the price of purchased material being burnt enables an estimation of the possibility of obtaining an expected net profit margin level. A producer of wood and wood feedstock selling to the network only the excess amount of energy not used by himself, should consider the alternative of selling by-products being assigned for energy usage when evaluating the profitability .

In the calculations here both types of producers have been accounted for, that is, the producer who uses the energy surplus generated by the by-products for his own purposes, and sells to the network (excluding costs of transport), as well as the producer of energy generated from biomass, buying the raw material on the market (including costs of transport). In both cases, three levels of expected margin have been assumed ($m_j$ = 5%, 10%, 15%). The price of the energy unit ($c_{je}$), was assumed as the price of electric energy generated from renewable energy sources. Its level is determined on the basis of the provisions of the Act on Energy Law [Ustawa 1997] published annually by 31st March in the bulletin of the President of the Energy Regulatory Office, and equals the average sales price of electric energy on a competitive market in the previous calendar year. In 2010, this price binding transactions between distributors purchasing energy from renewable resources from its producers amounted to 197.21 PLN/kWh (for 2011 – 195.34 PLN/kWh),

**The profitability of processing sawmill by-products into energy generated as a by-product (excluding cost of transport) and basic (including cost of transport)**

A profitability analysis of converting sawmill by-products was carried out based on the ratios defined by Mikołajczak (2011):

– maximum margin:

$$m_{egr} = \frac{1}{c_{je}}(1-p)\left[c_{je} - \frac{(k_{pi}+k_{ti}+c_{pub})(1+w_0)}{g(19{,}5-0{,}25w_0)}\right] \quad (3)$$

where: $m_{egr}$ – maximum margin – the highest margin level to be obtained conditioned by the remaining variables,
$c_{pub}$ – unit sales/purchase price of a given type of by-product [PLN/m³],

– maximum costs of conversion:

$$k_{p\max} + k_{t\max} = c_{je}g\frac{19{,}5-2{,}5w_0}{1+w_0} - c_{pub} \quad [\text{PLN/m}^3] \quad (4)$$

– maximum unit cost of transport:

$$k_{t\max} = c_{je}g\frac{19{,}5-2{,}5w_0}{1+w_0} - c_{pub} - k_{jp} \quad [\text{PLN/m}^3] \quad (5)$$

– maximum distance for obtaining raw material:

$$l_e = \frac{k_{t\max}v}{2s_{km}} \quad [\text{km}] \quad (6)$$

where: $v$ – capacity of by-products being transported by cartage over the distance $l$ [m³],
$s_{km}$ – unit cost of transport services of by-products to the place of conversion [PLN/km],

– maximum purchase price of raw material to be processed:

$$c_{pub\max} = c_{je}g\frac{19{,}5-2{,}5w_0}{1+w_0} - k_{pi} - k_{ti} \quad [\text{PLN/m}^3] \quad (7)$$

– the lowest sales price of generated energy, deemed satisfactory by the producer:

$$c_{e\min} = \frac{(c_{pub}+k_{pi}+k_{ti})(1+w_0)}{g(19{,}5-2{,}5w_0)} \quad [\text{PLN/GJ}] \quad (7)$$

where: $c_{emin}$ – minimum sales price of energy.

## Results and analysis

### The use of sawmill post-production by-products in direct conversion into energy for own use.

The results of the calculations carried out are shown in table 2. Their analysis allows us to make the following statements:

1. Burning sawdust with a moisture content of 10% may be an economical alternative for all but firewood and coal energy sources. At the same time the increase in the cost of generating heat units due to the cost of cartage makes the energy generated from dry sawdust financially unattractive even in comparison with pellets.
2. Using sawdust of 50% moisture content for heat production, due to its lower price, is more profitable than using each of the fuels under analysis.
3. Heating using wet defibered chips is competitive compared with all the fuels under analysis even if the chips have to be transported.
4. Using defibered chips of 25% of moisture instead of coal is unprofitable in the case of their usage in the same place as they have been generated. Transported chips are also uncompetitive in comparison with eco-coal and fireplace wood.
5. The least profitable fuel among the wood by-products are pulp chips of 25% moisture content. Those burnt where they have been generated are less profitable than both types of coal and firewood. The need to transport them also lowers their economic attractiveness in relation to pellets and wooden briquettes.
6. Matchless in comparison with all substituted kinds of fuels is solid wood waste, regardless of the place of further processing.

**Table 2. Profitability of generating energy from 10% moisture sawdust (bulk density 0.150 t/m$^3$) and 50% moisture (bulk density 0.250 t/m$^3$), defibered chips of 25% moisture (bulk density 0.200 t/m$^3$) and 50% moisture (bulk density 0.300 t/m$^3$), pulp chips of 25% moisture (bulk density 0.200 t/m$^3$) and 50% moisture (bulk density 0.300 t/m$^3$), waste wood of 25% moisture (bulk density 0.200 t/m$^3$), substituted by various energy carriers**
***Tabela 2. Opłacalność przerobu na energię trocin o wilgotności 10% (gęstość usypowa 0,150 t/m$^3$) i 50% (gęstość usypowa 0,250 t/m$^3$), zrębków defibracyjnych o wilgotności 25% (gęstość usypowa 0,200 t/m$^3$) i 50% (gęstość usypowa 0,300 t/m$^3$), zrębków papierniczych o wilgotności 25% (gęstość usypowa 0,200 t/m$^3$) i 50% (gęstość usypowa 0,300 t/m$^3$), odpadów kawałkowych o wilgotności 25% (gęstość usypowa 0,200 t/m$^3$), zastępowanych różnymi nośnikami***

| Burnt material *Spalany materiał* | Price of burnt material *Cena spalanego materiału* [PLN/m3] | Type of substituted energy carrier *Rodzaj zastępowanego nośnika energii* | Unit price of substituted energy carrier *Cena jednostki energii zastępowanego nośnika* [PLN/GJ] | Value converted into energy excluding cost of transport *Wartość w przerobie na energię bez kosztów transportu* [PLN/m3] | Value converted into energy including cost of transport *Wartość w przerobie na energię z kosztami transportu* [PLN/m3] |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |

Table 2. Continued
*Tabela 2. Ciąg dalszy*

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| sawdust, MSTR = 10%<br>*trociny, $w_o$ = 10%* | 120.00 | firewood<br>*drewno kominkowe* | 45.29 | 109.32 | 97.72 |
| | 120.00 | briquettes<br>*brykiety drzewne* | 54.17 | 132.63 | 121.03 |
| | 120.00 | pellets<br>*granulat drzewny* | 53.62 | 131.19 | 119.59 |
| | 120.00 | coal bricks<br>*węgiel kostka* | 42.86 | 102.94 | 91.34 |
| | 120.00 | węgiel ekogroszek<br>*coal* | 45.71 | 110.44 | 98.84 |
| | 120.00 | natural gas<br>*gaz ziemny* | 66.84 | 165.91 | 154.31 |
| | 120.00 | fuel oil<br>*olej opałowy* | 96.90 | 244.80 | 233.20 |
| | 120.00 | liquified petroleum gas<br>*gaz płynny LPG* | 108.90 | 276.31 | 264.71 |
| | 120.00 | electric energy G12<br>*energia elektryczna G12* | 119.44 | 303.98 | 292.38 |
| | 120.00 | electric energy G11<br>*energia elektryczna G11* | 138.89 | 355.02 | 343.42 |
| sawdust, MSTR = 50%<br>*trociny, $w_o$ = 50%* | 103.00 | firewood<br>*drewno kominkowe* | 45.29 | 126.71 | 116.71 |
| | 103.00 | briquettes<br>*brykiety drzewne* | 54.17 | 153.73 | 143.73 |
| | 103.00 | pellets<br>*granulat drzewny* | 53.62 | 152.06 | 142.06 |
| | 103.00 | coal bricks<br>*węgiel kostka* | 42.86 | 119.32 | 109.32 |
| | 103.00 | coal<br>*węgiel ekogroszek* | 45.71 | 128.02 | 118.02 |
| | 103.00 | natural gas<br>*gaz ziemny* | 66.84 | 192.31 | 182.31 |
| | 103.00 | fuel oil<br>*olej opałowy* | 96.90 | 283.75 | 273.75 |
| | 103.00 | liquified petroleum gas<br>*gaz płynny LPG* | 108.90 | 320.26 | 310.26 |
| | 103.00 | electric energy G12<br>*energia elektryczna G12* | 119.44 | 352.34 | 342.34 |
| | 103.00 | electric energy G11<br>*energia elektryczna G11* | 138.89 | 411.50 | 401.50 |

Table 2. Continued
*Tabela 2. Ciąg dalszy*

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| defibered chips, MSTR = 25%<br>*zrębki defibracyjne, $w_o$ = 25%* | 120.00 | firewood<br>*drewno kominkowe* | 45.29 | 125.77 | 117.87 |
| | 120.00 | briquettes<br>*brykiety drzewne* | 54.17 | 152.59 | 144.69 |
| | 120.00 | pellets<br>*granulat drzewny* | 53.62 | 150.94 | 143.04 |
| | 120.00 | coal bricks<br>*węgiel kostka* | 42.86 | 118.44 | 110.54 |
| | 120.00 | coal<br>*węgiel ekogroszek* | 45.71 | 127.07 | 119.17 |
| | 120.00 | natural gas<br>*gaz ziemny* | 66.84 | 190.88 | 182.98 |
| | 120.00 | fuel oil<br>*olej opałowy* | 96.90 | 281.65 | 273.75 |
| | 120.00 | liquified petroleum gas<br>*gaz płynny LPG* | 108.90 | 317.89 | 309.99 |
| | 120.00 | electric energy G12<br>*energia elektryczna G12* | 119.44 | 349.73 | 341.83 |
| | 120.00 | electric energy G11<br>*energia elektryczna G11* | 138.89 | 408.45 | 400.55 |
| defibered chips, MSTR = 50%<br>*zrębki defibracyjne, $w_o$ = 50%* | 120.00 | firewood<br>*drewno kominkowe* | 45.29 | 152.05 | 145.45 |
| | 120.00 | briquettes<br>*brykiety drzewne* | 54.17 | 184.47 | 177.87 |
| | 120.00 | pellets<br>*granulat drzewny* | 53.62 | 182.47 | 175.87 |
| | 120.00 | coal bricks<br>*węgiel kostka* | 42.86 | 143.18 | 136.58 |
| | 120.00 | coal<br>*węgiel ekogroszek* | 45.71 | 153.61 | 147.01 |
| | 120.00 | natural gas<br>*gaz ziemny* | 66.84 | 230.76 | 224.16 |
| | 120.00 | fuel oil<br>*olej opałowy* | 96.90 | 340.49 | 333.89 |
| | 120.00 | liquified petroleum gas<br>*gaz płynny LPG* | 108.90 | 384.31 | 377.71 |
| | 120.00 | electric energy G12<br>*energia elektryczna G12* | 119.44 | 422.80 | 416.20 |
| | 120.00 | electric energy G11<br>*energia elektryczna G11* | 138.89 | 493.79 | 487.19 |

Table 2. Continued
*Tabela 2. Ciąg dalszy*

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| pulp chips, MSTR = 25% *zrębki papiernicze, $w_o$ = 25%* | 151.00 | firewood drewno *kominkowe* | 45.29 | 125.77 | 117.87 |
| | 151.00 | briquettes *brykiety drzewne* | 54.17 | 152.59 | 144.69 |
| | 151.00 | pellest *granulat drzewny* | 53.62 | 150.94 | 143.04 |
| | 151.00 | coal bricks *węgiel kostka* | 42.86 | 118.44 | 110.54 |
| | 151.00 | coal *węgiel ekogroszek* | 45.71 | 127.07 | 119.17 |
| | 151.00 | natural gas *gaz ziemny* | 66.84 | 190.88 | 182.98 |
| | 151.00 | fuel oil *olej opałowy* | 96.90 | 281.65 | 273.75 |
| | 151.00 | liquified petroleum gas *gaz płynny LPG* | 108.90 | 317.89 | 309.99 |
| | 151.00 | electric energy G12 *energia elektryczna G12* | 119.44 | 349.73 | 341.83 |
| | 151.00 | electric energy G11 *energia elektryczna G11* | 138.89 | 408.45 | 400.55 |
| pulp chips, MSTR = 50% *zrębki papiernicze, $w_o$ = 50%* | 151.00 | firewood *drewno kominkowe* | 45.29 | 152.05 | 145.45 |
| | 151.00 | briquettes *brykiety drzewne* | 54.17 | 184.47 | 177.87 |
| | 151.00 | pellets *granulat drzewny* | 53.62 | 182.47 | 175.87 |
| | 151.00 | coal bricks *węgiel kostka* | 42.86 | 143.18 | 136.58 |
| | 151.00 | coal *węgiel ekogroszek* | 45.71 | 153.61 | 147.01 |
| | 151.00 | natural gas *gaz ziemny* | 66.84 | 230.76 | 224.16 |
| | 151.00 | fuel oil *olej opałowy* | 96.90 | 340.49 | 333.89 |
| | 151.00 | liquified petroleum gas *gaz płynny LPG* | 108.90 | 384.31 | 377.71 |
| | 151.00 | electric energy G12 *energia elektryczna G12* | 119.44 | 422.80 | 416.20 |
| | 151.00 | electric energy G11 *energia elektryczna G11* | 138.89 | 493.79 | 487.19 |

Table 2. Continued
*Tabela 2. Ciąg dalszy*

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| waste wood, MSTR = 25% *odpady kawałkowe, $w_o$ = 25%* | 105.00 | firewood *drewno kominkowe* | 45.29 | 125.77 | 117.87 |
| | 105.00 | briquettes *brykiety drzewne* | 54.17 | 152.59 | 144.69 |
| | 105.00 | pellets *granulat drzewny* | 53.62 | 150.94 | 143.04 |
| | 105.00 | coal bricks *węgiel kostka* | 42.86 | 118.44 | 110.54 |
| | 105.00 | coal *węgiel ekogroszek* | 45.71 | 127.07 | 119.17 |
| | 105.00 | natural gas *gaz ziemny* | 66.84 | 190.88 | 182.98 |
| | 105.00 | fuel oil *olej opałowy* | 96.90 | 281.65 | 273.75 |
| | 105.00 | liquified petroleum gas *gaz płynny LPG* | 108.90 | 317.89 | 309.99 |
| | 105.00 | electric energy G12 *energia elektryczna G12* | 119.44 | 349.73 | 341.83 |
| | 105.00 | electric energy G11 *energia elektryczna G11* | 138.89 | 408.45 | 400.55 |

Calculations on the basis of data provided by an entrepreneur utilizing wood by-products for energy purposes with the following assumptions:
- depreciation in accordance with annual depreciation rate – 7% position 3 symbol KŚT:"Boilers and energy machines" and rate 2.5%, position 01, symbol KST 10: "Non-residential housing" [Ustawa 1992],
- investment value including the boiler house – 2 000 000 PLN (boiler 2 326 kW). 1 744 500 PLN,
- remaining operating costs 28 466 PLN per year,
- annual conversion – 2000m$^3$ of by-products,

$c_{je}$ = 54.52 PLN/GJ – average sales price for energy at which distributors are obliged to buy electric energy from producers generating it from RES, (article. 23 part 2 point 18 letter b) [Ustawa 1997]; average for two years has been accepted: 2010 (197.21 PLN/kWh) and 2011 (195.32 PLN/MWh) calculated in GJ.

*Obliczenia na podstawie danych udostępnionych przez przedsiębiorcę wykorzystującego drzewne produkty uboczne na cele energetyczne, przy następujących założeniach:*
- *amortyzacja - zgodnie z wykazem rocznych stawek amortyzacyjnych – stawka 7%, pozycja 03, symbol KŚT 3: „Kotły i maszyny energetyczne" oraz stawka 2,5%, pozycja 01, symbol KŚT 10: „Budynki niemieszkalne" [Ustawa 1992],*
- *wartość inwestycji łącznie z budynkiem kotłowni – 2 000 000 PLN (kocioł 2 326 kW). 1 744 500 PLN,*
- *pozostałe koszty operacyjne 28 466 PLN/rok,*
- *przerób roczny – 2 000 m$^3$ produktów ubocznych,*

*$c_{je}$ = 54,52 PLN/GJ – średnia cena sprzedaży energii elektrycznej na rynku konkurencyjnym, po której spółki dystrybucyjne mają obowiązek kupować energię elektryczną od wytwórców z OZE, (art. 23 ust. 2 pkt 18 lit.*

*b) [Ustawa 1997]; przyjęto średnią z dwóch lat: 2010 (197,21 PLN/kWh) i 2011 (195,32 PLN/MWh) w przeliczeniu na GJ.*
Source: own elaboration
*Źródło: opracowanie własne*

**The use of sawmill post-production by-products in direct energy generation with the intention of further sales**

The results of calculations presented in table 3 show that for the owner of sawmill by-products it is more profitable to sell:
– pulp chips of moisture content of 25% - for all assumed margin levels,
– dry sawdust, when the producer estimates reaching a 10% and 15% margin level,
– pulp chips of 50% moisture content – for 15% margin level
– than to generate energy from them.

An entrepreneur generating energy based on purchased wood biomass wanting to obtain a 5% or 10% margin should not burn pulp chips of 25% moisture content and dry sawdust. Reaching a 15% margin will only be possible when using defibered chips with a moisture content of 50% and wood waste.

**Table 3. Value of sawmill by-products converted into energy including and excluding cost of transport**
***Tabela 3. Wartość tartacznych produktów ubocznych w przerobie na energię z kosztami i bez kosztów transportu***

| Type of by-product *Rodzaj produktów ubocznych* | | By-product price *Cena produktu ubocznego* [PLN/m³] | Value of by-products in conversion divided into energy *Wartość odpadów w przerobie na energię* | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | with margin *z marżą* | | | with margin *z marżą* | | |
| | | | 5% | 10% | 15% | 5% | 10% | 15% |
| | | | without transport cost *bez kosztów transportu* [PLN/m³] | | | including transport cost *z kosztami transportu* [PLN/m³] | | |
| Sawdust *Trociny* | $w_0$ = 10% | 120.00 | 124.72 | 115.89 | 107.05 | 113.12 | 104.29 | 95.45 |
| | $w_0$ = 50% | 103.00 | 144.57 | 134.33 | 124.09 | 134.57 | 124.33 | 114.09 |
| Defibered chips *Zrębki defibracyjne* | $w_0$ = 25% | 120.00 | 143.50 | 133.33 | 123.17 | 135.60 | 125.43 | 115.27 |
| | $w_0$ = 50% | 120.00 | 173.48 | 161.19 | 148.90 | 166.98 | 154.69 | 142.40 |
| Pulp chips *Zrębki papiernicze* | $w_0$ = 25% | 151.00 | 143.50 | 133.33 | 123.17 | 135.60 | 125.43 | 115.27 |
| | $w_0$ = 50% | 151.00 | 173.48 | 161.19 | 148.90 | 166.98 | 154.69 | 142.40 |
| Waste wood $w_0$ = 25% *Odpady kawałkowe* | | 105.00 | 143.50 | 133.33 | 123.17 | 135.60 | 125.43 | 115.27 |

Source: own elaboration
*Źródło: opracowanie własne*

**The profitability of processing sawmill by-products into energy generated as a by-product (excluding costs of transport) and basic (including cost of transport)**

Defibered chips of 50% moisture content ($m_{gr}$ = 26,8%) as well as sawdust of the same moisture content ($m_{gr}$ = 25,3%) produce the highest profitability when processed into energy (table 4) if burnt in the place where they were produced. When an energy producer purchases the raw material, the border margin decreases by 4.9% and 2.7% respectively. The owner of pulp chips of 25% moisture content ($m_{gr}$ = 1,3%) will operate on the limits of profitability. Adding the cost of transport will make the conversion of that material into energy unprofitable ($m_{gr}$ = –2,6%).

Subsequent ratios confirm regularities proven earlier in the analysis of border margin, that is the highest profitability is characteristic of converting defibered chips of 50% moisture content into energy and the lowest of pulp chips of 25% moisture content. Hence:

1. The maximum cost of processing including the cost of transport ranges from 13.65 PLN/$m^3$ (pulp chips of 25% moisture content) up to 79.05 PLN/$m^3$ (defibered chips of 50% moisture content).
2. The maximum distance from which the raw material is obtained, resulting directly from determining the maximum cost of transport ranges from 7 km (in the case of pulp chips of 25% moisture content) up to 181 km (in the case of defibered chips of 50% moisture content).
3. The maximum price of purchasing raw material for further processing should not exceed: in the case of dry sawdust: 121.96 PLN/$m^3$, wet sawdust: 144.81 PLN/$m^3$, defibered chips of 50% moisture content: 179.26 PLN/$m^3$, pulp chips of 25% moisture content: 145.79 PLN/$m^3$ at current (December 2011) prices of unprocessed by-products, respectively: 120 PLN/$m^3$, 103 PLN/$m^3$, 120 PLN/$m^3$, 151 PLN/$m^3$.
4. The lowest sales price of energy generated from pulp chips of 25% moisture content to be accepted by the producer, is higher (56.25 PLN/GJ) than the price at which the distributors are obliged to purchase electric energy from the producers of energy generated from renewable energy sources (54.52 PLN/GJ).
5. The maximum prices of purchasing wood by-products indicate some possibilities of accepting change in this area. The break-even point is the decrease in prices of pulp chips of 25% moisture content – of 3.5%,an increase in the price of defibered chips of 50% moisture content – of 49% as well as a price increase on average of 24% for the remaining by-products, keeping the rest of the parameters stable.

**Table 4. Profitability of processing wood by-products into pellets, briquettes and energy generated as by-product (excluding cost of transport) and basic (including cost of transport)**
***Tabela 4. Opłacalność przerobu drzewnych produktów ubocznych na energię, wytwarzaną jako produkt uboczny (bez kosztów transportu) oraz podstawowy (z kosztami transportu)***

| Type of by-products *Rodzaj produktów ubocznych* | | By-product price *Cena produktu ubocznego* $c_{pub}$ [PLN / m³] | Break-even margin *Marża graniczna* $m_{gr}$ [%] | | Maximum unit costs of conversion including transport *Maksymalne jednostkowe koszty przerobu łącznie z kosztami transportu* $k_p + k_t$ [PLN/m³] | Maximum cost of transport per unit *Maksymalne jednostkowe koszty transportu* $k_t$ [ [PLN/m³] | Maximum distance from which raw materials can be transported* *Maksymalna odległość pozyskiwania surowca** l [km] | Maximum purchase price of raw materials for conversion *Maksymalna cena zakupu surowca do przerobu* $c_{odp}$ [PLN/m³] | Minimum selling price of energy *Minimalna cena zbytu energii* $c_{min}$ [PLN/GJ] |
|---|---|---|---|---|---|---|---|---|---|
| | | | by-production *produkcja uboczna* | basic production *produkcja podstawowa* | | | | | |
| Sawdust *Trociny* | $w_0$ =10% | 120.00 | 7.67 | 1.11 | 23.12 | 13.56 | 37.32 | 121.96 | 53.78 |
| | $w_0$ =50% | 103.00 | 25.30 | 20.41 | 62.88 | 51.81 | 142.64 | 144.81 | 40.78 |
| Defibered chips *Zrębki defibracyjne* | $w_0$ =25% | 120.00 | 16.56 | 12.67 | 44.65 | 33.66 | 92.68 | 145.76 | 45.99 |
| | $w_0$ =50% | 120.00 | 26.76 | 24.12 | 79.05 | 65.76 | 181.07 | 179.26 | 38.29 |
| Pulp chips *Zrębki papiernicze* | $w_0$ =25% | 151.00 | 1.31 | -2.58 | 13.65 | 2.66 | 7.33 | 145.76 | 56.25 |
| | $w_0$ =50% | 151.00 | 14.15 | 11.50 | 48.05 | 34.76 | 95.71 | 179.26 | 46.78 |
| Waste wood *Odpady kawałkowe* | $w_0$ = 25% | 105.00 | 23.94 | 20.05 | 59.65 | 48.66 | 133.98 | 145.76 | 41.02 |

* transport 25 m³, rate 4.54 PLN/km,
share of various types of packaging in production and sales of pellets and briquettes: big bag1/3, small bag – 1/3, in bulk – 1/3.
** transport 25 m3, stawka 4,54 PLN/km*
*udział różnego typu opakowań w produkcji i sprzedaży granulatu drzewnego oraz brykietów drzewnych: big bag – 1/3, small bag – 1/3, luz – 1/3.*
Source: own elaboration
*Źródło: opracowanie własne*

## Summary

The described method of pricing sawmill by-products when processed into energy allows for a multilateral analysis of the profitability of this form of their usage. It is a useful tool for an entrepreneur enabling an economically- sound decision to be reached concerning how post-production waste from mechanical wood conversion is used. The formula enables a comparison of the profitability of using generated energy for one's own purposes with the profitability of selling it to other buyers and accounting for different margin levels.

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## OPŁACALNOŚĆ PRZEROBU TARTACZNYCH PRODUKTÓW UBOCZNYCH NA ENERGIĘ

### Streszczenie

Wykorzystaniu drzewnych produktów ubocznych do produkcji energii sprzyja nie tylko konieczność spełnienia unijnych zobowiązań w zakresie udziału energii odnawialnej w bilansie energetycznym kraju, ale również zmieniające się relacje cen na rynku nośników energii. Zakłady mechanicznego przerobu drewna, dysponując określonym zasobem odpadów, dążą do jak najbardziej efektywnego ich zagospodarowania. Jedną z możliwości jest produkcja energii: na cele własne i z zamiarem sprzedaży. W pracy przeprowadzono analizę opłacalności takiego przedsięwzięcia. Zastosowano przy tym metodę wyceny tartacznych produktów ubocznych w przerobie na energię, która obejmuje szereg wskaźników umożliwiających przeprowadzenie oceny. Należą do nich: marża graniczna, maksymalne koszty przerobu, maksymalna cena zakupu produktów ubocznych, przeznaczonych do przerobu, maksymalna odległość pozyskiwania surowca oraz minimalna, możliwa do zaakceptowania przez wytwórcę, cena zbytu wytworzonego produktu. W badaniach uwzględniono zarówno przedsiębiorstwa tartaczne, wytwarzające energię na własne cele, oceniając opłacalność zastąpienia określonego rodzaju nośnika energii drewnem poprodukcyjnym, jak i zakłady wytwarzającego energię z biomasy drzewnej z zamiarem sprzedaży. W drugim przypadku, wyznaczoną wartość poszczególnych sortymentów w przerobie na energię, porównano z ceną zakupu spalanego materiału, ustalając możliwość zrealizowania oczekiwanej marży zysku netto. W przeprowadzonych obliczeniach rozpatrzono przypadek przedsiębiorcy, który do sieci sprzedaje jedynie nadmiar energii, wytworzonej z produktów ubocznych na własne cele (bez kosztów transportu), jak i producenta energii wytwarzanej z zakupionego surowca (z kosztami transportu).

**Słowa kluczowe:** drzewne produkty uboczne, wytwarzanie energii z biomasy drzewnej, opłacalność przerobu.