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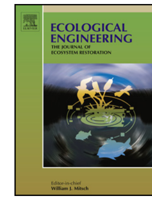

Uses of weeds as an economical alternative to processed wood biomass and fossil fuels

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ABSTRACT

The use of fossil fuels as a main source of energy is directly linked to global climate change (due to CO_2 emission), so there is a necessity to find new, cheap and easily available energy sources for the earth's inhabitants. Nowadays renewable energy sources are forced also for the mitigation of the effects of climate change as a result of greenhouse gases emission control. Decentralized sources of low-cost renewable fuels that may be used, in particular, in those households where there is no possibility of using gas or heat delivered from other sources should be of special interest. This paper describes the possibility of using untreated plants such as Canadian goldenrod (*Solidago canadensis* L.), mugwort wormwood (*Artemisia absinthium* L.) and common tansy (*Tanacetum vulgare* L.) as a source of biofuels. These plants are considered weeds and have many advantages, enabling a wider use for energy purposes, especially in cases where there is a large acreage of land set aside. Clean, full-biogenic, renewable fuel without transportation energy demand and taxes is an interesting economical alternative to usually expensive processed wood biomass, such as pellets or briquettes. The following parameters of the studied fuels were investigated: the yield per hectare, density of growth, dry matter content during the harvest, bulk density, ash content and calorific value. Results revealed that the investigated species could be considered as great primary energy sources due high calorific value (over 16 MJ kg^{-1}), low moisture, low costs and availability. Canadian Goldenrod was found to be especially promising since it covers most of uncultivated land and could be burned in large number of rural households without boiler and heating system change.

1. Introduction

Due to insufficient sources of fossil fuels and substantial carbon dioxide (CO_2) emission, it is necessary to find an alternative energy source for the mitigation of the effects of climate change and environment protection. One of the most popular alternatives is biomass use. Biomass is a source of renewable energy, and its use is still growing (Cucek et al., 2012).

About 2.8 billion people all around the world burns solid fuels to prepare food (WHO Report, 2015) every day. Therefore the household sector is one of the largest emitters of greenhouse gases (GHG), so any efforts to cost-free limitation of this phenomenon are highly desirable (Lin, 2013). First global programme for GHG limitation was Framework Convention on Climate Change (UNFCCC) from 1992 and its extension – Kyoto Protocol (1997) with emission targets. Second big step to GHG emission mitigation set by UNFCCC were Cancun Agreements (November 2010), which cover multi-level actions in GHG topic – also development of clean technologies (Hourcade et al., 2015). As the result of realization pan-European programs or Kyoto Protocol, we can find small decrease of carbon dioxide emission from year to year. European CO_2 emissions equals about 11% of global emissions value, and 2013 was lower by 1.4% compared to 2012 (Olivier et al., 2014). Additionally all scenarios of forecast for CO_2 prices shows growing trend up to 120 US dollars per short tonne (907 kg) in 2050 (Luckow et al., 2015).

In Central Europe, heating systems consume a large amount of energy each year. About 75% of total energy used in typical households in Poland is for heating purposes. Emissions of carbon dioxide

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(CO_2), dust, sulphur and nitrogen oxides are high, especially during winter. Various initiatives around the world are being developed in order to counter observed climate change. One is the promotion of renewable energy sources introduced by the United Nations Environmental Programme (UNEP), European Environment Agency (EEA) and United States Environmental Protection Agency (EPA) (Beringer et al., 2011; Mendu et al., 2012).

Guidelines of Japan-British project "Low Carbon Society" (LCS) aims for minimization of CO_2 emission as one of the main greenhouse gas. Realization of this goal involves transforming our energy systems to create a more secure and sustainable future with the use of the best practices and between the cooperating governments or social groups. Ultimately, the model created by the LCS assumed a 50% reduction of CO_2 emissions by 2050 and the price per emitted tonne of CO_2 at 100–330USD (Skea and Nishioka, 2008). In fact of occurred problems of "carbon capture and storage" (CCS) technology, we should seek other solutions to reduce CO_2 emission.

Energy development strategy, adopted in 2000 by the Council of Ministers, assumes that the share of renewable energy sources in Poland by 2020 in the primary energy balance should be 15%. Wide use of renewable energy sources are considered a method to reduce CO_2 emission and, consequently, decrease human impact on the global warming process.

Diffuse renewable energy sources that can be used to generate heat energy constitute mainly solar and biomass wood. Solar energy is free, but the technology involved in it is still to expensive. This is one of the main barriers for the more common use of new technologies, such as photovoltaic (PV) cells or sun collectors in Poland. In addition, the total number of sunny days is relatively low, even during summer. In the warmest regions (such as southwest Poland), it is possible to detect about 1050 kWh m^{-2} per annum of sun energy. A second possible source of energy is biomass. Its annual resources worldwide are estimated to be at about 420 billion Mg, providing around 6500 EJ of energy, with a potential for 100 EJ per annum (Parikka, 2003). This type of fuel is common in household use all over the world and different technologies exist to produce electricity and heat from biomass, including co-combustion of coal and biomass in power plants (Ciesielczuk et al., 2015). Many plants have high energy value, and they are not used for food production, so they can be successfully used as "second-generation solid biofuels". However, the balance of expenditure on the acquisition and processing of thermal energy is often unfavourable. In addition to the aforementioned negative factors, we should also consider transport from the place of manufacture to the point of use (Zheliezna and Drozdova, 2014). Additionally, production of liquid second-generation biofuels from biomass is often too expensive, so it is possible to use solid raw biomass from your backyard (Kuchler, 2014). In the high-energy industry, exposed to high CO_2 emissions resulting from the combustion of fossil fuels, it is necessary to replace conventional fuels, mostly coal, by alternative fuels, such as biomass. Each household should have an impact on reducing CO_2 emissions into the atmosphere from the burning of fossil fuels. This is possible using second-generation biomass fuels in households (Ferrante and Cascella, 2011). An additional advantage of the combustion of biomass (biofuel) is a zero balance of CO_2 emissions, which primary originates from human activities. Carbon dioxide is naturally present in the atmosphere, from where it is absorbed by plants to form organic compounds during photosynthesis (McKendry, 2002). One of the disadvantages of biomass use is the deforestation phenomenon,which appeared in the first period of co-combustion biomass with carbon in power plants, when huge amount of first-quality wood was cut off and used as biomass. This led to a reduction of green areas that can absorb carbon dioxide. After that, a different biomass sources of agricultural origin was also used for the energy purposes. Nowadays biomass wood mostly comes from special "energetic wood" plantations (willow, aspen, grey alder) and forests, where it is obtained during the process of pruning and cutting, and finally, from wood-processing sources, such as sawmills and carpenters. Agriculture provides mainly straw, a waste by product of agricultural production (Monforti et al., 2013) throughout the country, moreover saving additional costs of transport of the material. Nevertheless, it requires significant storage facilities for large volumes and a special boiler adapted to the combustion of straw. In addition, burned straw do not follow normative regulations (Keppel et al., 2013). However, using straw is troublesome due to the uncertainty of fuel supply and ethical issues regarding the burning of food or feed. Moreover large-scale introduction of bioenergy would raise food prices in all cases/scenarios and is a source of high load of nutrients and pesticides to the environment (Bryngelsson and Lindgren, 2013; Love et al., 2011).

The aim of this work was to find a wider use of plants, that do not compete with crops intended for human consumption or animal feed, as a biomass source of energy. These are characterised by high efficiency, collecting the right amount of lignocelluloses, having little habitat requirements and requiring no tillage. Such plants include mugwort (*Artemisia* sp.) and tansy (*Tanacetum vulgare* L.), which have not been reported in the literature as energetic plants. This new strategy of weed biomass use leads to a reduction of emission due to agrotechnics minimisation and lack of long-distance transportation.

2. Material and methods

2.1. Botanical characteristics

Goldenrod (*Solidago* sp.) is a plant commonly found in Poland. Both the Canadian goldenrod (*S. canadensis* L.) and late goldenrod (*S. gigantea Aiton*) are classified as invasive species (Bohren, 2011; del Fabbro et al., 2014). In inhabited ecosystems, they displace native flora species and become dominant because, as with other invasive species, they can occur in a wide range of soil conditions. Goldenrod owes its success in mastering new areas to a great tolerance to habitat conditions, strong growth, the production of large quantities of seeds, ease of vegetative propagation and the mechanism of allelopathy. Covering large areas with high-density shoots, it contributes to the homogeneity of the landscape and the loss of biodiversity (Bohren, 2011; Vanderhoeven et al., 2005). However, it is a popular honey plant for bees, which is advantageous when compared to the adverse effects caused by pesticides applied on areas containing crop plants (e.g., rape). This plant is marked as S.

Among the species representing the type of mugwort (*Artemisia* sp.) quite commonly found is mugwort wormwood (*A. absinthium* L.). As a folk tradition, it is often used for various treatments, including for gastrointestinal diseases, and as an alcoholic extract for narcotic purposes (Gambelunghe and Melai, 2002). There is also data that suggests that it possibly supports the treatment of breast cancer in humans (Shafi et al., 2012) and there is also the possibility of the control of parasites in farm animals (Gonzalez-Coloma et al., 2015; Tariq et al., 2009). The plant grows well after cutting and flourishes abundantly in sunny environments. It is undemanding in relation to soil conditions and is fully frost-resistant. This plant is marked as A.

Tansy (*Tanacetum vulgare* L.) occurs throughout the country and is a plant with a characteristically unpleasant odour. Its flowers contain essential oils, including thujone, which due to its properties has been used for the treatment of parasitic diseases. These properties mean that it has also been used in folk medicine. The plant spreads rapidly by rhizomes and seeds. In autumn and winter, it is a source of food for wintering bird life in Poland. This plant is marked as T.

Table 1
Main characteristic of moisture content and yield of analysed plants (n = 3).

Plant	Density	Yield	Moisture of harvested plants [%]					
	[plants m^{-2}]	[Mg dm ha^{-1}]	15 Sep	29 Sep	16 Nov	2 Dec	14 Feb	13 Mar
S	121.7(29.0)	15.9(3.8)	58.5(0.3)	54.0(1.3)	57.9(1.3)	32.8(2.4)	12.0(0.3)	10.2(0.4)
A	13.2(4.7)	6.0(2.1)	58.7(0.8)	47.6(6.1)	39.3(3.9)	33.5(4.4)	13.2(0.7)	10.8(0.9)
T	37.3(11.1)	9.2(2.7)	50.2(2.2)	37.9(4.0)	28.4(8.2)	24.2(1.8)	12.7(0.6)	10.6(0.8)

Standard deviation value in brackets.

All these plants are common ruderal species and classified as a nuisance weeds. Its widespread occurrence leads to unilateral changes in the soil (Vanderhoeven et al., 2005).

2.2. Methods

In order to estimate the possibility of using these types of plants for energy purposes, numerous calculations have been performed including: the yield per hectare, density of growth, dry matter content during the harvest, bulk density, ash content and calorific value. The yield of the analysed species was calculated in one year on the basis of sampling on three uncultivated 10 m^2 areas. The dry matter content was determined by weighing after drying at 105 °C until a constant weight was achieved. The ash content was determined after dry mineralisation at 550 °C for 5 h (Hua et al., 2007). The calorific value was determined using a calorimeter machine KL-10 by PN-81/G-04513. Elemental analysis of the biomass was determined using a CHNS analyser vario MACRO cube made by the Elementar Company. The speed of burning was measured in an open fireplace and conducted for vertically orientated 15 cm stem parts of the analysed plants for a dry state and for "natural moisture content" estimated at 17%. This moisture was reached by storing prepared 15 cm dry stem bars for 20 days in 100% relative humidity. The demand for the fuel needed was also determined during the heating season based on sample farms using a biomass stove. In addition, economic analysis was also performed based on the energy of 1 MJ compared to other commonly used fuels.

In addition, the biomass content was determined based on the ^{14}C method, according to the European standard PN-EN 15440:2011. The ^{14}C method is a very reliable and sensitive method for determining biomass fraction (Palstra and Meijer, 2010). This method is recognised around the world for its sensitivity and precision. The radioactive isotope ^{14}C is present in the air due to the effect of cosmic radiation on the nitrogen atoms present in the atmosphere. Fossil fuels, such as coal, do not contain the isotope ^{14}C, but a trace quantity is found in living matter. The half-life for the radioactive decay of ^{14}C is 5730 years. Radiocarbon dating cannot be used for samples older than around 60,000 years, or ten half-lives, where the conditions that would eventually create coal began to develop about 300 million years ago, during the Carboniferous period (Libby 1946). Isotope ^{14}C present in the atmosphere is converted into CO_2, and after this process, CO_2 is converted into organic compounds (e.g., cellulose). The ^{14}C concentration in living matter is stable and in equilibrium with its concentration in the air. The concentration of ^{14}C is gradually reduced to zero along with the disappearance of the radioactive isotope in dead matter.

The sample preparation for liquid scintillation counting was done using the Sample Oxidizer by PerkinElmer. Dried environmental samples were combusted completely in the oxygen atmosphere to CO_2 and water. During this process, total CO_2 was absorbed by special reagent CarboSorb E (3-methoxypropylamine) and mixed with the liquid scintillation cocktail Permafluor E+. The samples were counted using the low-level liquid scintillation counter 1220 Quantulus.

3. Results and discussion

3.1. Characteristics of the obtained biomass

The results indicate a relatively high yield for the studied plants (Table 1) when compared with typical "energetic plant" crops, in spite of the lack of agrotechnology, including no fertilisation, weed control or irrigation.

Table 1 In traditional energy plant farming, in order to improve yields, some typical agricultural practices are used, such as weeding, which is especially important during the first period after crop planting, irrigation and fertilisation. One of the most important advantages of the analysed plants over other well described energy plants (e.g. willow) is its potential for growth and possibility of harvesting each year without additional need for fertilisation. Calculated dry matter (dm) yield of tansy, especially goldenrod (Table 1) in its wild state, is comparable with yields derived from willow crops, which are 7.2–12.7 Mg dm ha^{-1} (Finnan et al., 2014; Ray et al., 2012). Only a few authors (Biskupski et al., 2012; Hua et al., 2007) studying the use of goldenrod for energy purposes highly appreciate both its yield per hectare and its potential energy. The monoculture that we are dealing with, particularly in the case of goldenrod, mugwort or tansy, allows us, after a few seasons, to determine the optimum harvest date depending on the course of the weather in the growing season. A tractor and rotary mower or McCormick-Deering binder is sufficient for harvesting, a trimmer in small or hard-to-reach areas, or in special cases, even a scythe. Mowed plants can be moved manually, or a loader wagon with a hay rake can be used. The work should be done in December or later, when the plants are already dry (later in decreased humidity, and in particular, the spring harvest), and the seeds sprinkled (Table 1), as confirmed by other authors (Brand et al., 2011). The best moment for this work appears in March due to the lowest humidity of weed yield during this time. Also, dry early spring and end of February could be recommended for harvesting. Mowed biomass should be transported under a canopy in the form of loose sheaves or heaps and dried for a period of 7–10 days, depending on the weather. The exception is in winter or during the spring harvest, for which additional drying is not necessary if the process was performed during good, dry weather. Subsequently, air-dried biomass should be pre shredded into pieces at a length of 15–20 cm. This can be done manually or using simple machines previously used to prepare the chaff. In addition, grinding can be done at the time of the harvest using a harvest machine called "Orcane", but in this case, another drying method for fragmented biomass should be considered. The best option in this case would be a dry, ventilated place. In the case of the proposed weed "crops", one of the most positive effects is lack of biogens and pesticides migration from soil to groundwater, which is a characteristic of willow (*Salix viminalis* L.) and other species of energetic plants (Love et al., 2011).

3.2. Energetic parameters

The calorific value of the uncondensed biomass for the analysed plants was similar to the values of 16.24–16.49 MJ kg^{-1} confirmed by other authors (Table 2). This figure is about 1 MJ kg^{-1} higher

Table 2
Characteristics of the analysed biomass and coal as a solid fuel source (n = 3).

	Carbon (TC) [%]	Hydrogen (TH) [%]	Nitrogen (TN) [%]	Sulphur (TS) [%]	Burning heat [MJ kg^{-1} dm]	Calorific value [MJ kg^{-1} dm]	Organic substances [% dm]	Bulk density [kg m^{-3}]
S	44.8 (0.17)	6.46 (0.01)	0.37 (0.05)	0.198 (0.056)	18.12 (0.50)	16.49[a]	97.9(0.2)	136.4(9.5)
A	44.6 (0.21)	6.30 (0.03)	1.54 (0.61)	0.252 (0.025)	17.87 (0.02)	16.24[a]	97.9(0.6)	122.7(11.7)
T	44.5 (0.35)	6.20 (0.14)	3.06 (1.58)	0.080 (0.024)	18.08 (0.06)	16.47[a]	97.3(0.2)	115.1(6.8)
Brown coal (Bełchatów)	52.6 (0.04)	5.08 (0.05)	0.60 (0.01)	0.712 (0.077)	22.26 (0.10)	20.90	–	722.6(20.4)
Sunflower husk pellets (Juszczak, 2012)	49.5(0.04)	5.98(0.04)	0.86(0.01)	0.04(0.06)	22.97	22.47	98.1	–
Solidago(Hua et al., 2007)	–	–	–	–	16.7–19.2	–	–	–
Oat straw (Poskrobko and Król, 2012)	46.2	6.4	1.35	0.94	15.74	–	94.7	–
Salix viminalis (Fijałkowska and Styszko, 2011)	–	–	–	–	18.55	–	–	–
Pinus sylwestris L. (Sporek, 2013)	–	–	–	–	14.6–14.7	–	–	–
RDF (Swithenbank et al., 2011)	61.2	8.2	1.3	0.2	22.3	–	81.1	–

[a] After correction for 10% moisture and hydrogen content.

Table 3
Burning speed, calorific value of plant biomass and energetically comparable amount of hard coal with mean energy 26 MJ/kg.

	Burning speed [s 1 cm^{-1}] 0% H_2O	17% H_2O	Calorific value [GJ ha^{-1}]	Energy P[a] [PJ]	Hard coal [thow. Mg]	Ecological effect[Mg CO_2]
S	2.40	3.45	288.4	118.13	4,543.4	7,752,192
A	3.40	6.19	107.2	43.91	1,688.8	2,881,536
T	3.05	6.03	166.7	68.28	2,626.2	4,480,869

[a] The potential amount of energy obtained from burning the plant monoculture of private fallow lands.

than the calorific value of soda weed (*Salsola tragus* L.), oat or triticale straw (Yumak et al., 2010; Poskrobko and Król, 2011). A lower calorific value in comparison with the test plants was also recorded for different varieties of biomass for Scots pine (*Pinus sylwestris* L.): for the needles it was 14.9 MJ kg^{-1}, for the trunks 14.7 MJ kg^{-1}, for the branches 14.6 MJ kg $^{-1}$ and for granulated sewage sludge 11–13 MJ kg^{-1} (Sporek 2013; Werle, 2013). Willow (*Salix viminalis* L.) originating from biomass crops achieved a slightly higher (0.3–0.5 MJ kg^{-1}) burning heat than the analysed weed species, but in general, it strongly depends on fertilisation, harvest year and willow clone (Fijałkowska and Styszko, 2011). Particularly important is the low level of humidity for the prepared biomass, which prevents self-heating of a pile and increases calorific value. The content of organic substances for the test was high (Table 2), and thus there was a small amount of ash formed, making the plants perfect for thermal recycling. The disadvantage of this fuel is the low bulk density, which is an important factor resulting in a need to collect it in a relatively large room, ensuring the free flow of air through the plant prism. A decline in the efficiency of the boiler, usually adapted to coal, must also be assumed. High total carbon content (TC) of 44.5%–44.8% is lower than the value

Table 2 of the TC parameter for brown coal (Table 2), but for the biomass, the proportion of organic carbon (TOC) is higher, constituting 94.4%–96.0% and 91.4% for biomass and coal, respectively. Particularly important is the low sulphur content and relatively high hydrogen content. Burning the analysed biomass can therefore produce 1.6–5.04 kg SO_2 Mg^{-1} dm, which is less than the combustion of brown coal (14.24 kg SO_2 Mg^{-1} dm) or hard coal, even after taking into account the lower calorific value.

The results obtained for "natural moisture" depend on the plant species (Table 3). The lowest moisture, 16.6%, was noted for *Tanacetum* and the highest, 18.2%, for *Artemisia*. Burning speed is highly correlated with fuel mass, with a correlation coefficient of 0.90–0.99, and it was different for both the analysed plants and the moisture content. *Solidago* burns very fast in a dry state and 43% longer with water content. *Artemisia* and *Tanacetum* burn slower as dry samples, but moisture content leads to almost double the burning time—82% and 98% longer, respectively. This recommends *Artemisia* and *Tanacetum* for fuel applications, but *Solidago* is more popular and has a higher yield. For more exact fuel consumption forecasts, an additional test should be performed on the analysed plants in the form of chips used in a retort stove.

Taking into account the calorific value of the plants (Table 3), the amount of energy that can be obtained from a 1 ha canopy monoculture was calculated, as well as the potential amount of energy that can be obtained from the biomass of the test plants, which

Table 3 comes from fallow land in the territories of individual farms (409,600 ha), which could be used as fields of energetic plants after weeds sieving. This fallow area is continuously available and could be covered with any of the analysed species. For ecological reasons, the preferred species is tansy (however, the highest energetic effect was reached for *Solidago*), which is a native species considered a monoculture or can be mixed with mugwort. Seeds of tansy constitute a valuable supplement for a winter feeding base diet for national avifauna. Self-sown seed is also a complement to vegetative propagation, which occurs through the growth of rhizomes. For comparison from a 1 ha canopy of Virginia fanpetals, it is possible to obtain 170–205 GJ of energy. This value is still lower than that for a 1 ha field of *Solidago* (Szempliński et al., 2014). If CO_2 emissions from burned biomass are calculated as "zero" due to the balance of CO_2 adsorbed during the assimilation process, it is possible to determine the amount of saved hard coal. In the case of the analysed species, it varies from 2.9 to 7.7 mln Mg CO_2 per annum.

The main point of discussion is the use of the analysed weed species in households' furnaces, mainly in rural areas. Emission indicators included in Table 4 should be therefore considered as the most important factors when comparing burning biomass and traditional solid fuel. The main problem appears to be dust emissions. Dust can be partly removed through fine particulate filters, but in household furnace, it is complicated to use them. In small furnaces with gases of high temperatures, it is only possible to use passive bag filters, but in the case of speed and filtrating resistance of low-exhaust gases, it is necessary to use an air vent first. In addition, it is necessary to use conventional energy for the first air vent operation. It is also possible to use low-cost passive dry cyclones, but their efficiency for fine-particulate (PM 2.5) dust is low. Emissions from individual furnaces, called "low emission", could be a source of diseases and, in effect, a social and economic problem to

Table 4
Emission factors from biomass and hard coal burning need to produce 1 GJ of energy in household stoves.

	CO[kg]	CO_2[a][kg]	NO_2[kg]	SO_2[kg]	Total dust[kg]
S (grate stove)	2.73	0.0[c]	0.224[b]	0.240	0.254
A (grate stove)	2.77	0.0[c]	0.945[b]	0.310	0.259
T (grate stove)	2.73	0.0[c]	1.86[b]	0.097	0.328
Wood (grate stove)	5.30	0.0[c]	0.074	0.020	0.695
Sunflower Husk pellets (retort stove) (Juszczak, 2012)	5.32	nd	0.469	nd	0.030
Hard coal (grate stove)	4.60	87.50	0.110	0.600	0.404
Hard coal (retort stove)	0.138	65.62	0.086	0.390	0.032

nd – No data available.
[a]CO2 emission factors according to the document, Guidelines of the Ministry of Environment, Natural Resources and Forestry. The information and instructional materials are entitled: "The emission of pollutants into the air from fuel combustion processes", 1996).
[b]Oxides of nitrogen in relation to NO_2 corrected for the content of TN.
[c]It is assumed that the combustion of biomass carbon emissions does not exceed the level of CO_2 collected during the process of assimilation, therefore, the balance of CO_2 is zero.

Table 5
The fraction of the biomass and CO_2 emissions factors based on an analysis using ^{14}C carbon.

Name of sample	The fraction of biomass	Uncertaintyk = 2, α = 95%	Emission indicator[a]
S	101.6%	21.8%	99.54 kg CO_2 GJ^{-1}
A	99.0%	21.2%	99.66 kg CO_2 GJ^{-1}
T	98.0%	21.4%	97.03 kg CO_2 GJ^{-1}

[a] CO_2 emission factor calculated on the basis of the guidelines of the Commission Regulation (EU) No.601/2012 of 21 June 2012.

Table 6
Calculation of CO_2 emissions during harvesting, transport and burning for an average yield of the analysed biomass plants from 409,600 ha.

	Details	Thousand Mg CO_2	GRAND TOTAL (including grinding and burn process)
Grinding	Fuel combustion 20 dm^3 diesel ha^{-1}	42.9	–
Transport (5 km)	Fuel combustion 15 dm^3 diesel per 100 km	6.42	95.94
Transport (10 km)	Trailer 20 m^3	12.8	102.4
Transport (15 km)		19.3	108.8
Burn process	Power consumption 42 W Burn speed 4.5 kg/h Emission: 1.225 kg CO_2 kWh^{-1}[a]	46.6	–

[a] According to Zheliezna and Drozdova (2014).

a great number of people. Especially important is PM1 dust content in exhaust streams due to high concentrations of POP (e.g., benzo(a)pyrene) and heavy metals (Rogula-Kozłowska et al., 2013). A second problem, especially with regards to biomass-fired instalation is nitrogen oxide (NO_x) emissions. As reported by other authors (Sztyma-Horwat and Styszko, 2011) NO_x concentration in exhaust gases is correlated with the burning temperature, so low biomass burning temperature results in low NO_x emission.

Table 4 CO_2 emissions from burned biomass is in fact of biogenic origin, which could be confirmed by carbon isotope ^{14}C method (Table 5).

Table 5 Measuring the carbon isotope content of ^{14}C is the base method for the determination of biomass in alternative fuel. Fundamentally, a fuel produced entirely of biomass should contain 100% biogenic carbon. The obtained results, therefore, confirm theoretical assumptions. The biomass fraction content ranged from 98.0% to 101.6% (Table 5). The differences between the theoretical content and the research results are caused by uncertainty of the method. Since global mitigation strategies aims to the reduction and control of CO_2 emission it is therefore necessary to choose fuel with the lowest primary energy intake for the whole preparation cycle. In the case of hard coal, it aims to search for new resource fields, excavation process, preparation of different assortments and complicated transportation. Moreover, there are high additional costs and energy demand spent on environment and infrastructure reparations (e.g., mining damages removal). In order to prepare fuel out of weeds no pre-treatment is necessary, except for biomass harvesting (in February or March, depending on weather conditions) and, ash sowing (as mineral fertiliser). This "fuel field" is close to final place of use (furnace in a farmer's house), so weed biomass could be perceived as sustainable energy source. With respect to climate change mitigation it is a 'win–win' situation for both sides – man and environment.

Using weed species for energy purposes is strictly dependent on the on-site climate-soil conditions. Cultivated weeds are resistant to drought and do not require irrigation. This is in line with the guidelines of The Worldwide Hydrogeological Mapping and Assessment Programme (WHYMAP), because on many areas were found an excessive depletion of groundwater, which affects not only their availability, but also lowers their quality. This forces the accurate planning of weed "crops" in order to reduce the use of groundwater for irrigation, irrigation pumps and also reduce additional CO_2 emissions (Zou et al., 2015; WHYMAP, 2008).

However, it is not the final CO_2 emission factor. There are other factors, which are presented in Table 6 influencing CO_2 emission, such as grinding, transport and burning. Table 6 shows all of the precise information.

Table 6 CO_2 emission from anthropogenic sources is also affected by environmental policy of many countries, but a major factor influencing emission level is economic growth. Raising economic growth by 1% results in increasing of CO_2 emissions by 0.94%. Much weaker correlation was found for Gross Domestic Product (GDP), where the 1% growth rate results in the decrease of CO_2 emissions by 0.002% (Mercan and Karakaya, 2015). The most effective and cost-free process of reducing global CO_2 emissions is the slowing economy process. This is confirmed according to the energy-growth-environment (EGE) studies. If China, which generates 10.5 bln Mg of CO_2, had slowed the economy by only 3%, the CO_2 emission would have reduced by more than 300 million Mg/year. This quantity is equal to the annual CO_2 emission in

Poland. Taking into account period from January 2010 to December 2015 (6 years) the economy in China (GDP) was reduced from 12.2 to 6.8 percent. It means that over 540mln Mg of CO_2 was not emitted. Therefore, the key to a global low-cost CO_2 reduction is a change of "high-consumption" lifestyles to another trend called "slow-live" philosophy. Decentralisation of fuel (and food) sources is the first step to obtain this goal. One of examples are the areas covered with fast and extensively growing weeds. They can influence the reduction of GHG gases, since they do not require organic fertilization (lack of extra CO_2 from the soil as a result of organic matter decomposition) and additional irrigation (energy consumption by the pumps, emissions of methane (CH_4) from flooded soils) etc. (Kollah et al., 2015; Zou et al., 2015).

Self fuel production in the vicinity to the house, in addition to saving fossil fuel consumption will also intensify the trend to save energy (Lin, 2013).

4. Conclusions

High prices of fossil fuels and unfavourable changes in climate conditions forces the necessity to find new and cheap fuels for wide use in individual furnaces. At the moment, the use of renewable energy is an important topic worldwide. Analysed weed plants characterised by high calorific value and could be harvested by popular agriculture machines—or even using hand tools, such as a scythe—and used in typical or retort furnaces. Moreover, these plants are entirely frost-resistant, they are free of natural pests, are resistant to diseases and they do not require complicated energy crop cultivation technology. All above mentioned properties greatly contributes to the reduction of biomass cost. Lack of competition with other crops as well as lack of long distance transport of plants and easy processing for the collected biomass (e.g., pelletising and briquetting) are additional factors in favour of the analysed plants over other species. This biomass source could also be a way for biomass ash or overproduced manure use to prevent a drop in yield amount. The use of the proposed weed species is a realisation of a global mitigation strategy due to the reduction of CO_2 emission. Energy from weeds is really renewable due to yield obtained each year. However, term "renewable" should not apply for energy derived from trees which grows at lasts 20–50 years. More favourable solution is the use of crop weeds, which are local, do not require large investments and help save trees, which additionally absorb CO_2, thus purifying the earth's atmosphere.

A considerable acreage of fallow land that could be sown with tansy would not only decrease the use of solid fuel such as coal but also will led to the minimisation of the still-widespread phenomenon of the thermal utilization of waste for energy purposes.

Despite the fact that this type of biomass is a source of fine particulate dust, which could be the main factor limiting the wide use of these plants as energy source, incineration of weeds could in fact lead to cheap, short-term environmental and development benefits to nations.

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