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USE OF RECREATIONAL PARK BIO-WASTE AS LOCALLY AVAILABLE ENERGY RESOURCE

BIOODPADY PARKÓW WYPOCZYNKOWYCH JAKO MIEJSCOWY SUROWIEC DO WYTWARZANIA ENERGII

Abstract: Biomass is the oldest and third in terms of volume renewable energy source. Biomass produced by recreational parks is organic matter (fresh of dry) produced by plants as a consequence of their normal growth. Plant waste (bio-waste) produced mainly due to leaf abscission in autumn and during maintenance works are generally transported outside park area. This results in a loss of potential profit for the manager/owner of the site. Bio-waste may be stored in composting plants or incinerated in on-site incineration plants producing energy for the park (and its environs) and thus contributing to energetic self-sufficiency of the park. The aim of this article is to estimate biomass volume available in selected Lodz city parks for use in energy production.

Keywords: Park bio-waste, recreational park, Lodz city

Introduction

Improper and uncontrolled collection as well as incineration of waste contributes to global greenhouse effect. Poland by singing the Kyoto Treaty [1] agreed to decrease greenhouse gas emissions [2]. As a consequence state policy is evolving towards gradual increase of biomass share among resources used for production of energy. At present nearly 92% of renewable energy produced in Poland derives from biomass (forestry 85.5% and agriculture 6.3%) [3]. Use of biomass as a fuel for energy production is a complex issue which requires an analysis of resources available in a given area. Currently, numerous large plantations of energy crops are set up (*eg* willow, miscanthus, ...), usually at a certain distance from urbanised areas. Such crops are characterised by rapid biomass growth in comparison to traditional crops. Crops such as these are used at an industrial scale where land conditions allow [4–9]. In cities park bio-waste may constitute an alternative source of energetic materials. Bio-waste

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such as shed leaves are a serious problem in cities. Such leaves are most often removed to city dumps, stored and sometimes composted. Removal of bio-waste from green areas in cities is associated with transportation costs (in this case: cost of service, fuel, amortization, ...). Since bio-waste produced by city green areas requires regular disposal, alternative means of its utilization should be considered [10, 11]. Parks located in city downtown zone can be thought of as reservoirs of resources which can be converted to biofuel or energy, as shown in Fig. 1. Selective waste collection (such as waste paper, glass, plastics and other) practiced in cities can be complemented with collection of bio-waste, *eg* leaves collected during autumn park maintenance. It thus seems reasonable to collect energy resources directly from urban parks.

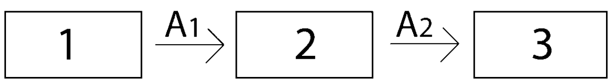

Fig. 1. An outline of energy production using bio-waste (1 – bio-waste; 2 – biofuel; 3 – electric and thermal energy; A1 – processing; A2 – converting)

Subject, goal and scope

The topic of this article is bio-waste produced in recreational parks.

The goal of this article is identification of bio-waste in recreational parks.

This article covers quantity, weight and calorific value of bio-waste from recreational parks.

Selected terminology

Park biomass – organic matter (either fresh of dry) produced by park plants as a consequence of their normal growth.

Park bio-waste – plant waste produced during vegetative period (especially leaf abscission in autumn, mowed grass as well as organic waste left behind by visitors), which are subject to natural decay.

Recreational park – a functional unit of green spaces in city serving a recreational purpose which is covered mainly in plants.

Bio-waste calorific value – 1. thermal energy produced by incineration of biofuel produced from park bio-waste (expressed most frequently as $MJ \cdot kg^{-1}$ or $kJ \cdot g^{-1}$); 2. calorific value of incinerated tree leaves (own definition based on: Dziewanowska and Dobek [10]).

Bio-waste incineration – one of three methods of of bio-waste management (aside from dumping and composting), involving acquisition of electric or/and thermal energy.

Research site

This article covers data collected while researching all downtown Lodz recreational parks. This area was selected due to the fact that bio-waste from those parks is transported outside of the city. The research site is shown in Fig. 2.

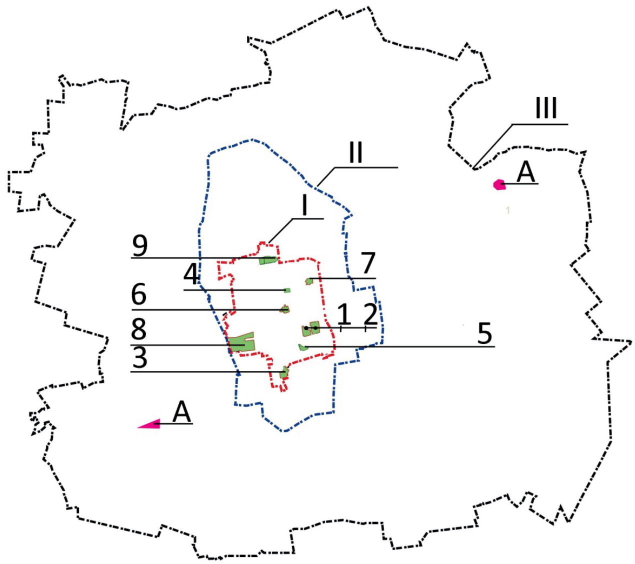

Fig. 2. Research site – recreational parks located in downtown Lodz (1–9 downtown Lodz parks' ordinal numbers, A – potential disposal destination for downtown Lodz recreational parks' bio-waste, I – boundary of downtown zone, II – boundary of residential zone, III – boundary of suburban zone / Lodz city limits

Research methods

Materials

This article is based on the following materials:

– own research and analyses conducted in downtown Lodz recreational parks (in the period between 2012–2014),

– domain literature (books and articles) on: bio-waste management, using biomass in production processes, calculating calorific value of tree leaves in green areas,

– selected legal acts.

Methods

Method used for evaluation of recreational park bio-waste volume and calorific value of deciduous trees' leaves shed in autumn is based on research, data and estimations acc. to: Dziewanowska and Dobek [10].

Arguments for use of recreational park bio-waste (current state of research)

Literature on use of biomass/ bio-waste [4–9] is mainly focused on agricultural (cultivation of energy crops) and industrial aspects rather than on studying selected problems of bio-waste management – in this case estimation of calorific value of incinerated leaves collected in city green areas [10, 11].

Waste (including bio-waste) management defined in accordance with act on waste of 2012 [12] as „collection, transportation, processing of waste including supervision of those operations...” may also include estimation/ determination of its characteristics / properties (in this case volume and calorific value of bio-waste) as well as establishing means of its disposal (such as incineration). Research by Dziewanowska and Dobek [10], Arodudu et al. [13], Lin and Cao [14] and other authors confirm this view.

It should be noted that park bio-waste (*eg* leaf abscission) is a resource which may be used to produce biofuel [11]. However, leaves may be used as fuel only after drying rather than when fresh.

What does collection and processing of waste depend on?

During routine park maintenance of urban green areas there comes a time (in Poland this is autumn) when bio-waste, including shed leaves, is collected and transported outside of the park. It may be stored and then dried. There are however other means of disposing of such bio-waste. Leaves do not need to be transported to a drying room, but may be left to dry on their own within the park (*eg* in a spot designated for storing such bio-waste). They can then be collected after reaching sufficiently low humidity.

In order to achieve the highest calorific value, bio-wastes need to be dried and comminuted after collecting. Based on domain literature leaves may be processed after they reach humidity of 15–20% in a drying process lasting 1 to 2 weeks at 293 K [10]. It’s worth noting that those values are mirrored for example in forest cover humidity parameters. Forest cover with 0–20% humidity is classified as 3rd fire danger class and as such is most susceptible to ignition.

According to research conducted by Dziewanowska and Dobek [10] dried leaves nearly double their calorific value and lose half their weight compared to when fresh. They may be used directly as fuel (after comminuting) or converted to briquette. Comminuting leaves seems more beneficial than converting them into briquette, since comminuted leaves have higher calorific value compared to briquette. For example of 1 gram of comminuted dry leaves has a mean calorific value of 15.4 kJ, while the same amount of briquette less than – 14.0 kJ. Additionally comminution process seems to be more cost effective.

Means of evaluation of park biomass volume and its calorific value

According to field research a single 100-year old common beech tree (*Fagus sylvatica*) has 800,000 leaves with a total surface area of 1600 m^2 [15]. Based on in-house studies of downtown Lodz recreational parks one leaf of common beech (*Fagus sylvatica*) with typical dimensions of 0.03 x 0.04 m weights 1 g (0.000001 Mg) fresh biomass on an average. This allows to estimate the biomass of shed leaves of a 100 year old tree at 800 kg (0.8 Mg), and the calculated mass may be considered standard. These two values along with number of trees in a park allow calculating an approximate/ estimated bio-waste volume (of fresh matter) for a given park.

Volume of bio-waste for autumn leaf abscission can be calculated using the following formula:

Number of deciduous trees in a park × standard biomass volume for one deciduous tree (fresh matter) = bio-waste volume after autumn leaf abscission.

Example: if in a given park there are 100 deciduous trees aged approx. 100 years, the biomass produced during autumn leaf abscission can be estimated at 80,000 kg (80 Mg).

When determining the calorific value of shed leaves it is necessary to consider that dry matter weight will be half that of fresh matter before drying [10]. Results of research by Dziewanowska and Dobek [10] show that leaves collected for measurement, dried and then comminuted has a calorific value of 15 $MJ \cdot g^{-1}$. Based on this it can be calculated that 1 Mg of dry matter of bio-waste (leaves) has an approximate calorific value of 15 GJ. Calculation should include biomass volume produced by one tree and number of trees in a park.

Total calorific value of bio-waste produced by trees growing in a park during autumn leaf abscission can be calculated using this formula:

Number of deciduous trees in a park · volume of biomass produced by one tree (fresh matter) expressed in Mg $\cdot$ 1/2 $\cdot$ 15 $GJ \cdot Mg^{-1}$ = calorific value of bio-waste produced during autumn leaf abscission of park deciduous trees expressed in GJ.

Example: given there are 100 deciduous trees in a park, each producing 0.8 Mg of leaves (fresh matter), or 0.4 Mg of dry biomass (considering that drying halves the initial leaf weight) and assuming that 1 Mg of dry matter has an approximate calorific value of 15 GJ, then total dry leaves calorific value may be estimated at 600 GJ.

Is incineration of leaves collected from urban parks practiced?

Practice of incineration of green area bio-waste is currently at a pilot stage, nevertheless it seems to gain in popularity in Poland but also abroad. Polish examples include green area bio-waste management system introduced in Otwock, where leaves are collected and transported to a warehouse, dried and finally incinerated in a bio-waste incineration plant. Abroad initiatives include a still unfinished park bio-waste management project with the use of an on-site bio-waste incineration plant in a park in Uppsala in Sweden. The project envisages converting incinerated bio-waste to electric power for use in the park as well as neighbouring residential estates [16].

Results and discussion

Studied literature allows to treat recreational park bio-waste as a locally available resource for production of energy. Available volume of this resource was estimated for downtown Lodz recreational parks. Calorific value for the resource was also calculated.

Resources available in downtown Lodz parks are presented in the Table 1.

The method described above was used to evaluate the volume of bio-mass produced in nine downtown Lodz recreational parks during autumn leaf abscission. Out of the nine downtown zone parks the greatest biomass volume can be obtained from Poniatowski Park. This park produces 3,299.2 Mg of bio-waste leaves (fresh matter). Moniuszko Park produces the least leaves by weight. This park produces 199.2 Mg of bio-waste leaves (fresh matter) – which is 16 times less than site with the largest area.

Table 1

Bio-waste volume in downtown Lodz recreational parks

No. (See Fig. 1)	Park proper name	Park area $[m^2 \cdot 10^4]$	Number of trees in park [pc]	Park biomass volume [Mg]	Park bio-waste ratio $[Mg/m^2 \cdot 10^4]$
1	Zrodliska I Park	10.6	965	772.0	72.83
2	ZrodliskaII Park	6.6	579	463.2	70.18
3	Reymont Park	6.3	562	449.6	71.37
4	Moniuszko Park	2.3	249	199.2	86.61
5	Kilinski Park	2.9	349	279.2	96.28
6	Sienkiewicz Park	4.6	464	371.2	80.70
7	Staszic Park	3.9	504	403.2	103.38
8	Poniatowski Park	41.7	4,124	3,299.2	79.12
9	Staromiejski Park	17.0	940	752.0	44.24
TOTAL		95.9	8,736	6,988.8	78.30*

* Mean average bio-waste ratio in downtown Lodz recreational parks $[Mg/m^2 \cdot 10^4]$.

By summing up bio-waste volume produced by downtown Lodz parks it can be estimated that all downtown zone parks may produce 6,988.8 Mg of leaves during autumn abscission (fresh matter). It should be noted that this biomass is currently being removed from those sites.

It can be observed that biomass volume in a given site is directly related to the number of deciduous trees and park surface area. As noted by Dziewanowska and Dobek [10] and Herezniak [15] the older the tree the more leaves it produces. However, calorific value of leaves of various tree species may differ significantly [11,14], and this requires further studies.

Estimations for nine downtown zone parks show that Staszic Park has the highest bio-waste ratio. Bio-waste ratio of this park is 103.3 $Mg/m^2 \cdot 10^4$. The lowest bio-waste ratio was found for Staromiejski Park. This ratio was equal to 70.18 $Mg/m^2 \cdot 10^4$, which is approximately 2.3 times less than on site with the highest ratio. On an average 1 hectare produces approximately 78.30 Mg of biomass.

Summing up, biomass ratio for individual downtown zone parks is not proportional to their area. Parks with small area but a large number of trees have higher bio-waste ratio.

Potential calorific value of biomass collected from recreational parks is given in table below (Table 2).

Calorific value of leaves shed during autumn leaf abscission in nine downtown Lodz parks was estimated using the method described above. Out of the nine downtown parks the biomass from Poniatowski Park has the highest calorific value. Calorific value of biomass for this park was calculated at 24,744 GJ. Biomass which can be collected in the Moniuszko Park has lowest calorific value. The calorific value of the biomass from this park was calculated at 1,494 GJ – which is over 16 times less than for the largest park. Summing up calorific value of biomass from each of the downtown Lodz parks, it

Table 2

Potential calorific value of biomass collected from downtown Lodz recreational parks

No. (See Fig. 1)	Park proper name	Park area [$m^2 \cdot 10^4$]	Number of trees in park [pc]	Park biomass volume [Mg]	Park biomass calorific value [GJ]	Biomass calorific value ratio [GJ /$m^2 \cdot 10^4$]
1	Zrodliska I Park	10.6	965	772.0	5,790	546
2	Zrodliska II Park	6.6	579	463.2	3,474	526
3	Reymont Park	6.3	562	449.6	3,372	535
4	Moniuszko Park	2.3	249	199.2	1,494	650
5	Kilinski Park	2.9	349	279.2	2,094	722
6	Sienkiewicz Park	4.6	464	371.2	2,784	605
7	Staszic Park	3.9	504	403.2	3,024	775
8	Poniatowski Park	41.7	4,124	3299.2	24,744	593
9	Staromiejski Park	17.0	940	752.0	5,640	332
TOTAL		95.9	8,736	6988.8	52,416	587*

* Mean average calorific value ratio of biomass collected in downtown Lodz recreational parks [GJ/$m^2 \cdot 10^4$].

can be estimated that the total energy which can be produced from leaves shed in autumn in downtown zone parks equals 52,416 GJ. It should be noted that this energy may be used outside of these parks.

Calculations done for nine downtown zone parks show that Staszic Park has the highest calorific value ratio. Biomass calorific value ratio of this park equals 775 GJ/$m^2 \cdot 10^4$. Staromiejski Park proved to have the lowest biomass calorific value ratio. It was calculated at 332 GJ/$m^2 \cdot 10^4$, which is less than half compared to the site with the highest biomass calorific value ratio. On an average, approximately 587 GJ of energy can be produced from 1 ha of park.

Summing up, biomass calorific ratio for individual downtown zone parks is not directly proportional to their area. The smaller the park area with greater number of trees, and the greater volume of biomass, the higher biomass calorific value ratio.

Analysis of literature and calculations confirm the need for management of recreational park bio-waste.

The results as well as literature provide data suggest that parks may become a source of fuel, provided that during autumn maintenance works leaves are dried to proper humidity and incinerated in specified conditions.

Incineration process should be subject to constant improvement and have smallest possible impact on the park and its visitors. This should be a topic of separate studies with a goal of minimising or eliminating environmental impact of an incineration plant. Research so far indicates that biofuel which can be produced from park bio-waste may be converted to electric or thermal energy or both.

The supply of resource for production of biofuel in downtown Lodz seems to be guaranteed. Parks produce bio-waste yearly. Collecting this material does not require separate plantations or cultivation (tilling, fertilization, regular watering, etc.). Use of bio-waste produced by parks plants helps to realize the full potential of urban parks, by complementing ecological and recreational functionality of parks with an economical function. Done calculations prove that green areas in cities can provide raw material for producing energy on site.

It should be noted that the raw material produced by the recreational parks is first and foremost beneficial to park's direct environs, providing health benefits for denizens, but is also a production site allowing yearly collection of shed leaves and using them for production of biofuels and energy for the environs.

The strategy of using biomass to produce biofuel should cover a few parks and rely on transporting collected bio-waste to an incineration plant located in the vicinity or in the largest of the parks. According to authors the minimum park area where setting up an incineration plant would be feasible is 40 ha. This requirement is met by Poniatowski Park in Lodz.

The key issue is cost-effectiveness of bio-waste incineration. This requires further research and calculations. Research in this field should be correlated with refinement of ecosystem services discussed by Bolund and Hunhammer [17], Constanza et al. [18] and Fisher et al. [19].

Conclusions

1. Parks can be treated as production site of energetic materials within cities. In this certain dualism in park functionality can be seen – on one hand they should service daily and weekly recreational traffic, and on the other hand – produce raw materials for production of biofuel.

2. Studies prove that parks do provide raw materials for production of energy in the form of tree leaves collected during autumn maintenance jobs.

3. Results show that the nine downtown Lodz parks produce approximately 6,988.8 Mg of fresh biomass (leaves alone) a year which when processed can provide energy equal to approximately 52,416 GJ enough to heat approx. 52,416 m^2 of a flat = one thousand 3-room flats for a year.

4. One hectar of park grounds produces approximately 78.3 Mg of bio-waste with the calorific value of 587 GJ, which can later be converted to electricity or thermal energy allowing to heat approx. 587 m^2 of a flat = ten 3-room flats for a year.

5. The idea of collecting bio-waste from recreational parks and using them to produce energy should become an incentive to broaden the list of ecosystem services provided by recreational parks.

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BIOODPADY PARKÓW WYPOCZYNKOWYCH JAKO MIEJSCOWY SUROWIEC DO WYTWARZANIA ENERGII

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Abstrakt: Biomasa to najstarsze i trzecie co do wielkości na świecie naturalne odnawialne źródło energii. Biomasę parków wypoczynkowych stanowi substancja organiczna (w postaci świeżej lub suchej) powstająca podczas naturalnego rozwoju roślin na obszarze parku. Pozostałości roślinne (bioodpady) nagromadzone głównie podczas jesiennego opadu liści i prowadzonych zabiegów pielęgnacyjnych w parku są przeważnie wywożone poza jego teren. Taka sytuacja wiąże się utratą potencjalnych dóbr dla zarządcy/właściciela terenu. Bioodpady mogą być magazynowane w kompostownikach lub spalane w spalarniach na miejscu, wytwarzając energię dla parku (jak i otoczenia) i przyczyniając się w ten sposób do samowystarczalności parku pod względem energetycznym. Artykuł zawiera szacunkowe obliczenia dotyczące możliwości pozyskania biomasy na cele energetyczne na przykładzie wybranych parków Łodzi.

Słowa kluczowe: bioodpady, spalarnie bioodpadów, wytwarzanie energii, park wypoczynkowy