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ASSESSMENT OF GREENHOUSE GASES ATTRIBUTABLE TO THE WASTE MANAGEMENT SECTOR IN URBAN PLANNING

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Abstract. Leading countries and especially the European Union are concerned with the threat that arises from the worming potential of greenhouse gases. The vast majority of greenhouse gases are produced due to anthropogenic actions, and the urban areas are the places where the biggest pressure on nature is made. According to the second European Common Indicator, it is necessary to assess each city's contribution to global climatic change. Thus, the possibility of forecasting, while urban planning is still on process, is a thing of great importance. The utmost input of greenhouse gases comes from the energy and waste management. An article presents a study how assessment of gases attributable to the waste management sector can be cooperated with urban planning on planning stage. The assessment is based on two variables: 1) population and 2) quantity of generated wastes. The first variable is to be taken from the prognostications of urban planners and the second one – from statistic data. To illustrate practical applying, city of Dubingiai in Molėtai district is taken as an example. The result of the study is a carbon dioxide equivalent that refers to waste management sector and possible measures of compensation. Substantial contribution of the study is a possibility to know the quantity of CO_2 equivalent in advance, i. e.; the planning stage.

Keywords: urban planning, ecology, municipal solid waste, greenhouse gases, assessment.

1. Introduction

Waste management tasks are important at political as well as scientific and social levels. Commonly scientific approach focuses on issues such as leachate effect on biogas production (Benbelkacem *et al.* 2010), gas permeability (Stoltz *et al.* 2010), which model determines landfill gas (LFG) emission rates more precise (Chalvatzaki and Lazaridis 2010, Thompson *et al.* 2009) etc. Although it is very specific and narrow problems subsequently political sector adopts those solutions. Problems that scientists have already examined help politicians to form appropriate guidelines. Waste management policy uses the same primary data, but assesses it in different context and scale. Furthermore, political waste management is implemented at local, national or even global level. On contrary to scientific world, political sector needs more broad-brush data, chiefly indirect problems are solved along with direct ones, and horizontal cooperation of different sectors is involved. For example, displacement of landfill common for few districts, questions of landfill closing and later treatment, waste source reduction possibilities and so forth.

Presently in Lithuania different pieces of national legislation starting with National Strategic Waste Management Plan and ending with concrete documents, e. g.; Construction and Demolition Waste Rules supervise waste management. Moreover, national agreements and requirements directly or indirectly oblige to take care about waste as well, for instance, Directive 2006/12/EC of the European Parliament and of the Council on waste or the Kyoto protocol.

According to Eurostat "in the European Union, 74% of the total population lives in cities and towns with more than 5000 inhabitants; in other words, only a quarter of all European citizens live in a rural environment" (Eurostat 2011a). In Lithuania in 2010 citizens amounted 67% of the total population (Statistikos departamentas 2010). Therefore, it matters very much to resolve waste management questions in cities, i.e.; the major sources of municipal solid waste (MSW). At the same time, cities are the most effective places to act. Apart from authority's incentives to promote changes in consumption, waste-related problems can find solutions in other areas. Scientific literature review shows that tackling of waste management problems needs interdisciplinary awareness and incorporation of other sectors.

This article analyses how questions related to MSW management could be resolved in urban planning. Problems linked with MSW are assessed in the context of global ecology, i. e.; in spite of local waste generation the impact of landfill gases is global. Therefore, article presents what are the quantities of green house gases (GHG) attributable to the waste management sector in Lithuania, and what means of compensation could be applied in urban planning. To illustrate how MSW treatment can be involved in urban planning, master plan of Dubingiai is presented.

2. Materials and Methods

2.1. Amount of MSW

Although the 20th article of Law on Waste Management tells that the Ministry of Environment regulates and administers the whole waste stream (LRS 1998), there are no official waste quotas in Lithuania, and thus each municipality sets its own quantum. This method is based on assumption, that local authority better understands local peculiarities and habits of consumption; therefore, can choose a more proper and effective solution. However, article studies problems of MSW in the context of global ecology; consequently, total national indices are more important than local individual index.

Despite the pressure of the European Landfill Directive (1999) for seeking alternative solutions in order to minimise disposal of biodegradable municipal waste, in Lithuania majority (90,6%) of the municipal waste stream still goes to landfills. The reason must be that landfills remain the cheapest and thus preferred disposal option. On contrary, for example, "Japan, Denmark, and Luxembourg treat >50% of the waste stream through incineration" (UNEP 2010). Presenting landfill as "the cheapest" solution is possible only then, when one speaks about instantaneous price, without paying much attention to associated long-term problems and necessary future investment. In Lithuania more than 800 landfills, which do no comply with requirements of environment protection and public safety, were on operation until 2000. Officially, all of them were closed on the 16th of July 2009 and from then waste stream goes to appropriately equipped 11 regional landfills. However, the question of old waste remains.

The classification of waste streams varies from country to country. In Lithuania, for example, MSW refers to household waste including similar waste from offices, small businesses etc. (LRV 2002). According to waste records, in 2006 5,7 million tonnes of waste were generated in Lithuania, 22,8% (1,3 million tonnes) of which were MSW (LRV 2002). Therefore, in 2006 per capita amount of MSW was 390kg, but in 2008 waste amount increased up to 407kg (Eurostat 2011b). Experts say that in 2010-2020 amount of MSW should reach 1,8 million tonnes. Although compared with European Union members per capita amount of MSW in Lithuania is quite moderate (see Fig1), it is difficult to decrease the amount to desirable European limit (300kg).

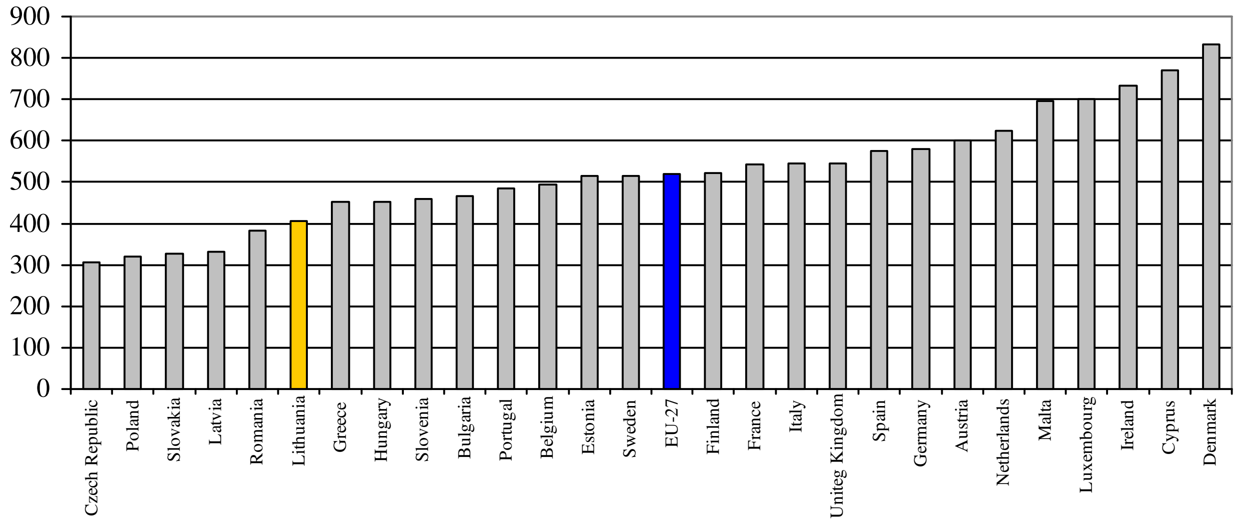

Fig 1. Municipal waste generation (kg per capita) in 2008 (source Eurostat 2011b)

Due to economic crisis, a significant decrease in consumption responded negatively waste generation, for instance, in 2009 Vilnius city generated nearly 13% and Vilnius district 12,4% less waste than in 2008 (VMST 2010). Although during economic crisis waste amount has decreased, it is forecasted that after economy recovers the consumption will grow, and respectively stream of waste will increase as well. Vilnius City Waste Management Plan prognosticates that in 2020 in Vilnius district waste amount will increase up to 350 thousand tonnes; however, Vilnius District Waste Management Centre expects the amount of waste per capita to increase 3% per year and in 2020 to reach 407 thousand tonnes (VAATC 2010).

Municipality of Vilnius is one of the best economically complying municipalities in Lithuania; nevertheless, in 2010 it had to admit that is unable to fulfil requirements of National Strategic Waste Management Plan. Separate collection of biodegradable waste is not to be expected for the next few years, and construction of incinerator has not been started yet (VMST 2010).

Although in recent years waste management in Lithuania is ruled better, waste collection, recycling and disposal are developed, but waste management issues are still essential. At a global scale, one of the most disturbing problems of the landfills is a landfill gas formation and greenhouse gas emissions.

2.2. Greenhouse gases attributable to MSW

In accordance with international environmental agreements and taking into account known ecological problems, it is purposive to link urban planning with global worming, or more specifically with greenhouse gas emission. At the Kyoto Conference, 38 industrialised countries agreed with GHG reduction, including carbon dioxide ("the most important greenhouse gas, contributing to 80% of total EU emissions" (EC 2010)) and methane. Moreover, "an indicator correlated with CO_2 emissions due to local energy consumption and CH_4 emissions due to local waste management activities, is likely to be the best way of measuring the greenhouse effect at a local level" (EC 2010).

Most of the waste, which now generates landfill gas, has been utilized previously, and thus it is hard to believe that data about its composition exist. Intergovernmental Panel on Climate Change proposes useful guidelines that allow calculation without concrete primary input; however, article analyzes only newly generated waste. In other words, it is assumed that waste composition is known.

Various studies show that LFG generation rate and gas composition depend upon various factors such as landfilling technology, waste composition, temperature, age of landfill, seasonal and diurnal variation (Manfredi *et al.* 2009, Park and Shin 2001, USEPA 2006) etc.; therefore, exact LFG composition and especially amount should be measured in a landfill (Jha *et al.* 2008). However, while accounting gas generation it should be kept in mind that urban planners need aggregated information plus in a short time. Therefore, computations could be based on average emission rates.

It is commonly agreed that LFG is mainly composed of 50-60% of methane and 40-50% of carbon dioxide (Manfredi 2009, Themelis and Ulloa 2007, USEPA 2000, Verma 2002). Typically, carbon dioxide emission is divided into two parts: biogenic and anthropogenic emission. Computations linked with global worming account only anthropogenic emission as biogenic carbon is considered to be "neutral" (USEPA 2008, Gentil *et al.* 2009, Scheutz *et al.* 2009). To put it another way, carbon dioxide that is emitted after final decomposition, for example, of paper, is the same carbon dioxide that was absorbed when a tree, from which paper was made, grew up. Consequently, biogenic carbon dioxide does not increase the net amount of carbon dioxide in atmosphere. On contrary, carbon dioxide that is emitted from rubber, plastics or fossil fuels is accounted as anthropogenic (or not biogenic), and results in global increase of carbon dioxide. LFG is the product of microbiological decomposition of waste (which is primarily from biogenic sources); therefore, carbon dioxide emission from MSW is not accounted. That means only methane emission remains.

Different calculation methodologies exist so accuracy needed while speaking about methane generation rates. The first approach presents methane generation rate during specific time interval, which in turn can be very different. Scientists speak about GHG flux in mg or g m^{-2} h^{-1} (Jha *et al.* 2008, Röver *et al.* 2010) or m^3 h^{-1} (Aronica *et al.* 2008) or L kg^{-1} (Barlaz *et al.* 1997). The second approach calculates the total flux irrespective of life or more precisely calculates the general emission until complete degradation of waste. In general, total amount of LFG varies from 100 to 200 Nm^2 per ton of MSW depending on waste composition and time limit (Manfredi 2009, Verma 2002). However, a more conservative estimate of methane emissions is about 50Nm^3 per ton of MSW (Themelis and Ulloa 2007) or 86Nm^3 per ton of MSW (Manfredi 2009).

When choosing the method of calculation, some general aspects must be taken into consideration. For instance, the generation of LFG does not start immediately after waste is placed in the landfill; the LFG peak is 5 to 7 years after disposal; LFG is produced at a stable rate for about 20 years, but will continue to be emitted for 50 or more years. Thus, it would be incorrect for urban planners to use LFG generation rates per year and simply multiply it 10 times (10 years is the expiry date of master plan in Lithuania). The result would include only a part of a threat that arises from MSW. Therefore, a more reasonable and fair solution is a calculation of the total flux until complete degradation of waste. Such approach does not allow offsetting of a problem, but shows the real threat's scale and insists on finding solutions within fixed time boundary. Lithuania does not have statistical data about average complete methane's rate from MSW sector; therefore, applicable number is to be taken from abroad. 86Nm^3 per ton is the number proposed in Manfredi's work (Manfredi 2009). Although Denmark has different waste management legislation it is in neighbourhood of Lithuania; therefore this number is believed to be appropriate. Nevertheless, if Lithuania presents lacking data in the future, it will be easy to change the numbers.

2.3. GHG from MSW

Before final calculation of methane attributable to MSW sector there are few things left to discuss.

Firstly, the amount of MSW. It is very important to use statistical data reported exclusively at national level. Although data from local administration of landfill may be more precise and new, it may be different in various cities. Therefore, a threat exists that, for example, city of Kaunas will use data from year 2010 and city of Alytus will use data from year 2008. This makes data incomparable and leaves an opportunity for speculation. Moreover, speaking in the context of global ecology, aggregate information is the one to be used. As mentioned before, in Lithuania per capita amount of MSW was 407kg in 2008 (Eurostat 2011b). It is easy to calculate amount of generated methane (expressed in m^3) until complete degradation of waste, using a simple formula (1).

$$Q_{person} = M * \frac{W}{1000} \quad (1)$$

Where M is the average methane rate (in our case $86Nm^3$ per tone) and W is the total amount of MSW per capita (in our case 407kg). Q_{person} indicates that one person in a given year generates such amount of MSW that finally equals to some cubic meters of methane.

Secondly, amount of GHG should be presented in globally comparable units. Each GHG has different lifetime and different ability of heat absorption; thus, gas that lasts longer and traps more heat is more damaging. An index that allows comparison is Global Worming Potential (GWP) index – a purely physical index. GWP index is "based on the time-integrated global mean radiative forcing of a pulse emission of 1kg of one compound relative to that of 1kg of the reference gas CO_2" (Forster *et al.* 2007). Due to its readiness, GWP is broadly used in scientific as well as political area. As science develops over time, there are slightly different values of GWP (see Table 1). It is interesting to note that despite short lifetime, methane enhances its own lifetime through changes in the OH concentration, and thus its indirect effect lasts much longer (Forster *et al.* 2007).

Table 1. Methane's GWP change and values (SAR - Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report; TAR – IPCC Third Assessment Report; AR4 – IPCC Fourth Assessment Report)

Common name	SAR 100-yr	TAR 100-yr	AR4		
			20-yr	100-yr	500-yr
Methane	21	23	72	25	7,6

Commonly GWP of a gas is calculated in 100 years horizon, but other periods are possible as well. Typical time frames are presented in Table 1 in column AR4, i. e.; 20 years, 100 years and 500 years. To come into contact with urban planning a link with corresponding legislation is needed. According to the 11th article of Law on Territorial Planning, the concept of master plan is valid 20 years and concrete solutions are valid 10 years (LRS 1995). Table 1 shows that GWP decrease is not linear, thus simple calculation of GWP of a gas in 10 years horizon would be incorrect. However, period of 20 years is quite near plus it correlates well with expiry date of the concept of master plan. Moreover, GWP value in 20 years is one of the default ones so is used very broadly. The European Common Indicators initiative suggests a set of environmental sustainability indicators and methodologies for collecting the data. The second indicator defined as "Local contribution to global climatic change" proposes measurement in CO_2 equivalent emissions (CO_2-eq) (EC 2010). Methane's GWP in 20 years is 72; therefore, 1 ton of methane corresponds 72 tons of CO_2-eq (in 20 years horizon). Equation (1) gives an answer in cubic meters so a conversion from cubic meters to tons is needed. Environmental Protection Agency of the United States (USEPA) has the Interactive Units Converter, according to it, $1m^3$ of methane has a weight of 0,6802kg (USEPA 2009). For fluent final calculation, equation (1) should be remodelled to equation (2).

$$Q_{person} = M * \frac{W}{1000} * \frac{T}{1000} * GWP_{time} \quad (2)$$

Where T is conversion coefficient that allows recalculation of methane amount into tons (in our case T is 0,6802kg), and GWP_{time} is methane's GWP value of selected time period. Q_{person} indicates that one person in a given year generates such amount of MSW that finally equals to come tons of CO_2-eq.

3. Results

Using equation (2) is easy to calculate that one statistical Lithuanian in 2008 generated such amount of MSW that is equal to 1,7 tons of CO_2-eq in 20 years horizon. As this number is universal, it can be used with any city in the territory of Lithuania. The number of citizens is easy to acquire and proposed method is simple; therefore, it deals great with the idea that urban planners need aggregated information plus need it quickly. Multiplication 1,7 by number of citizens shows total amount of CO_2-eq to be compensated each year. Nevertheless, three remarks must be taken into consideration. Firstly, per capita amount of MSW is a subject to change; therefore, updates must be made constantly. Periods of measurements must be set at national level as it guarantees comparability of data. Secondly, amount of waste generation is given per year and it means that the same amount is made every year. As concrete solutions of master plan are valid 10 years, the final MSW amount will be 10 times bigger. However, the concept of master plan is valid 20 years; thus, compensation measures can be proposed within 20 years time frame. Lastly, as methane's rates are taken from abroad, national study of gas rates in local landfills would increase accurateness of method.

4. Discussion

Most common compensation measure linked with global worming is a tree planting. One of the main reasons is that the Kyoto Protocol allows some remove of carbon by forests, plus planting efforts are quite simple and cheap to implement. However, it is compensation in the full sense of the word, i. e.; it has no effect on real decrease of MSW generation. Thus, if questions of areas needed for landfills were important, waste incineration would be a better and more effective way. In addition, this method can be considered within urban plan's possibilities. However, it is important not to mix waste incineration and the real reduce of MSW amount at its primary sources. Although primary decrease of MSW is undoubtedly the most effective option, it can not be solved in urban plan and thus is not discussed here.

Different researches show various carbon dioxide sequestration by trees, for example, between 2,2 and 9,5 tons per acre (1 acre = 4,047 ha) per year for afforestation and between 1,1 and 7,7 tons for reforestation (Gorte 2009a); but it is commonly agreed that one average tree absorbs 1 ton of carbon dioxide in its life (100 years). In 2009, Environmental Services, Inc. conducted an assessment of the carbon sequestration through Sustainable Harvest International planting efforts. Project reveals that each planting sequesters about 0,69 tons of carbon dioxide over its lifetime (50 years) (ESI 2009). If tree planting is selected as a compensation, considered lifetime of a tree is very important as due to it changes sequestered amount of carbon dioxide. Nevertheless, it is very hard to reassure that a tree will last for 100 years or that during this period it will not be cut down, or wildfire will not happen. Therefore, a 50 years life expectancy of a tree seems more adequate. To put it another way, it can be said that one statistical Lithuanian generates such amount of MSW per year that is equal to 1,7 tons of CO_2-eq in 20 years horizon, and to compensate that roughly 3 trees with expected lifetime of 50 years are needed.

Furthermore, during valid time of master plan's solutions, MSW amount finally increases 10 times, thus, one statistical Lithuanian produces 17 tons of CO_2-eq, what in turn demands about 30 trees. These trees should be planted in 10 years (solution's) time and must survive for at least 50 years. Another possibility is the tree planting in 20 years (concept's) time, but then two master plans overlap, thus, accuracy and succession are needed.

Law on Plantings (LRS 2007) and following acts describe different specifications such as classification of plantings, accessibility, required area etc. Although reasons of such specifications are not presented, acts could be easily improved with compensation mechanism. As demand of plantings is presented in m^2 per person, a conversion is needed. Tree density is different according to tree species, initial spacing or intent of the planting, thus, in Lithuania planting density varies from 1500 (asp) to 5000 (pine) trees per ha (LRS 2008). Here it was assumed that the planting density is 2000 trees per ha, consequently, $150m^2$ are needed to sequester CO_2-eq generated from MSW per person in 10 years or $15m^2$ per year.

This compensation method was experimented with master plan of Dubingiai. All statistical data and prognostications are taken from organizers of urban plan (Teritorijų planavimo mokslo institutas (TPMI)). Dubingiai is a small town in Molėtai district, located 20km south from Molėtai and 45km north-east from Vilnius. Current territory of city is about 90ha; 215 people lived in Dubingiai in 2009. TPMI estimated theoretical number of people for 20 years period, until 2030. Although population has decreased since 1989, decrease in absolute value is small - about 1,9 people per year. Since 2001 population has lost 24 habitants. Three scenarios have been developed, i. e.; pessimistic, realistic and optimistic. The second scenario is decided to be the most appropriate; it forecasts that after 5 years annual increase of 0,4 % is possible. In general, 213 habitants are expected in 2020; thus, for a period of 10 years an average mean of 214 habitants is chosen. According to above mentioned methods, one statistical Lithuanian produces 17 tons of CO_2-eq in 10 years what in turn demands about 30 trees; therefore, 214 habitants produce 3638 tons of CO_2-eq and demand roughly 6500 trees. Consequently, these trees require approximately 3,2ha area. Presently there are more than 12ha of forest in Dubingiai; thus, additional tree planting in 10 years time is considered as not necessary.

Although tree planting is attractive option, it remains temporal solution. "Eventually, trees die. They may be cut down, burned in a wildfire, blown over or snapped off in a wind or ice storm, or killed by insects or diseases" (Gorte 2009b). Therefore, trees act as a "sink" and allow "offsets" but do not solve a problem. Moreover, 30 trees or area of $150m^2$ per person is not a question in a small village, but is hard to find in a big city or, in fact, is impossible to find. Therefore, tree planting is feasible only in small cities and rural areas. Nevertheless, the big cities can find supplementary areas in its districts or anywhere else in a country. In this case, accurate national statistics of those plantings must be made, because exists possibility of overlapping or double counting. National data should be available to urban planners and constantly updated.

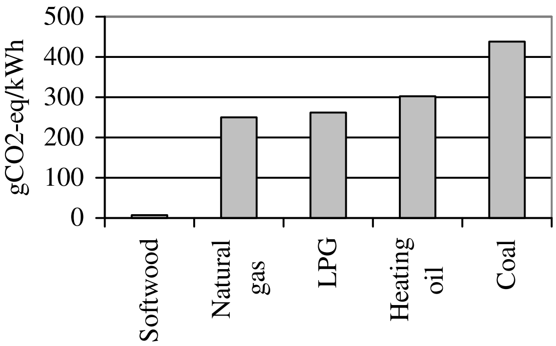

Fig 2. Environmental cost of an energy source (source Richarz *et al.* 2007)

Waste incineration is other option. Incineration releases carbon dioxide as well, but there are two differences. Firstly, waste incineration may significantly decrease demand of landfills or at least decrease waste storage area. Secondly, under controlled conditions generated energy can be used for electricity or heat. The efficiency for electricity production ranges between 18-26% (Fruergaard *et al.* 2009), however, it can reach 25-35% if landfill gas is combusted in gas engines that generate electricity and heat (Manfredi *et al.* 2009). The efficiency for conversion of biogas into heat is bigger and ranges between 40-50% (Fruergaard *et al.* 2009). Furthermore, waste incineration gives ecological benefit, but credits vary depending on the type of replaced initial heat source (see Fig 2). In Lithuania in 2009 lion's share of initial sources for district heating belonged to fossil fuels: 73,7% natural gas and 5,4% heating oil (LSTA 2010). Thus, it is obvious that waste incineration would be very favourable option. Although heat generation is almost twice effective compared to electricity production, it is not as widespread as electricity production. The problem is that commonly heat demand is low near plants. Nevertheless, part of the generated heat can be used within the plant or distributed through district heating pipes. A very successful example is famous Vienna's Spittelau thermal waste treatment plant. It was build in order to supply a new hospital that was two kilometres away, but today Spittelay is the second largest generator in Vienna's district heating network producing total output of 460MW (Wien Energie). As distance plays a major role, it must be considered on urban planning stage. In Lithuania there is no waste treatment plant at all; thus, international successful initiatives are to be followed. Richarz *et al.* states that district heating is a sensible solution but "is only viable within a radius of 5-10km of the respective power station". Furthermore, waste treatment plant location within the city is ideal from a logistic point of view, as it significantly reduces waste collection and delivery radius.

In summary it should be noted that from ecological point of view tree planting as well as waste incineration are far from perfect options. Primary decrease of MSW remains the most important task. However, discussed methods are useful solutions that allow "offsets" or possibility of reduction within urban plan's possibilities.

5. Conclusion

The review has found that compensation mechanism of GHG attributable to MSW sector can be implemented in urban planning. Currently one statistical Lithuanian produces 407kg of MSW per year that is equal to 1,7 tons of CO_2-eq in 20 years horizon. Therefore, if tree planting was chosen as compensation, roughly 3 trees per person are needed. As master plan's solutions are valid 10 years, the real amount will be 10 times bigger, i. e.; 17 tons of CO_2-eq and 30 trees. It was estimated that planting 30 trees requires 150m^2 in 10 years' time or 15m^2 per year. Therefore, tree planting is feasible only in small cities; nevertheless, big cities can find supplementary areas in its districts. In this case, accurate national statistics must be made. Waste incineration was discussed as more effective option that decreases landfill areas plus allows heat or electricity production. However, waste treatment plant should be allocated within a radius of 5-10km of the main heat source or more preferably within a city boundary.

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