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ELIMINATION OF GREENHOUSE GAS EMISSION DUE TO IMPROVEMENT OF BIODEGRADABLE WASTE MANAGEMENT SYSTEM

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Abstract

In order to reduce the emissions of greenhouse gasses (GHG) from landfills, European Union (EU) Landfill Directive 1999/31/EC requires a progressive reduction of the municipal biodegradable waste disposal. The main problem of the waste management system in Latvia is a heavy dependence from the waste disposal at landfills. An insufficient separate waste collection system and a promotion of the landfilling as a major treatment option, leaded to the disposal of 84% of the total collected municipal waste in 2012 with a high share of the biodegradable waste. Therefore, in Latvia, the volume of emissions due to the activities of the waste management branch was 5.23% (632.6 CO_2 eq.) of the total GHG emissions produced in the national economy in 2010 (12 097 Gg CO_2 eq., except the land use, land-use change and forestry). The aim of this research is to revise the current situation of the management of biodegradable waste in Latvia, and to propose the future activities for the practical improvements dealing with biodegradable waste. The Waste Management Planning System (WAMPS) software has been used as an environmental impact analysis tool for the modelling waste management scenarios. The WAMPS software calculates emissions, energy and turnover of waste streams for processes within the waste management system, e.g., waste collection and transportation, composting, anaerobic digestion, and final disposal – landfilling or incineration. The obtained results are presented in four environmental impact categories: acidification, global warming, eutrophication and photo-oxidant formation, which are characterised by a certain emission. It covers an integrated waste management system starting with the activities where products become waste and have been put into the waste bin at waste generation source to the last point, where the waste becomes either useful material (recycled material, biogas or compost) or becomes part of emissions in the environment after its final disposal at landfill or incineration plant.

KEYWORDS

Biodegradable waste, Mathematic modelling, Waste management

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1. INTRODUCTION

The aim of this paper is to find improvements of waste management system in Latvia, in order to reduce disposal of biodegradable waste and to eliminate GHG generation at landfills.

As one of the main problems indicated is that of strong dependence of the Latvian solid waste management (SWM) system on the landfills, which, in turn, entails a number of other problems: a large amount of the disposed waste; not fulfilled targets as to decreasing the disposal of biodegradable waste; as yet a high proportion of biodegradable waste in the total disposed municipal waste; and a low proportion of the recycled household waste (BiPRO, 2012). Also, the non-optimal organisation and performance of the SWM system has given rise to unjustifiably large amounts of GHG emissions, and, consequently, to global environmental impact (Eurostat, 2012; UNFCCC, 2012).

The total yearly production of bio-waste in the EU amounts to 118 to 138 Mt of which around 88 Mt originate from municipal waste and between 30 to 50 Mt from industrial sources such as food processing, and on average, 40% of EU bio-waste is still landfilled in 2010, but up to 100% in some Members States (BIO Intelligence, 2011; JRC, 2014). The average structure of deposited waste material at the landfills in Latvia has been estimated in a research project, *The Assessments of Dissolved Organic Carbon Parameters in the Landfill Waste Material* (2011). The estimated results show that a lot of waste material in general has been disposed at landfills. According the provided measurement the content of disposed waste contains - bio-waste from 50.3 % to 51.7%; plastic 10.3% - 11.8 %; paper / cardboard 5.7% - 8 %, glass 10.9% - 19 %, textile, rubber and leather 3% - 8.6 %; and metal 2% - 4.6% (Virsma, 2011).

The EC investigations show that the main food waste producers are households – 42% and food manufacturing industry – 39%, but the third bigger producer are named food service and catering sector – 14% (BIO Intelligence, 2011). The main municipal biodegradable waste streams that generate bio-waste related to European Waste Codes (EWC) are listed as follow:

1) Kitchen and canteen waste (food waste) (20 01 08 EWC code);
2) Garden and park waste (20 02 01 EWC code);
3) Mixed municipal waste (20 03 01 EWC code);
4) Waste from public market (20 03 02 EWC code) which includes biodegradable materials equivalent to codes 20 01 08 EWC and 20 02 01 EWC.

2. STATISTIC DATA ON COLLECTION OF THE MAIN MUNICIPAL BIODEGRADABLE WASTE STREAM

Officially obtained statistic data on collection of the main municipal biodegradable waste streams in Latvia, mentioned before, are shown in Table 1 (LEGMC, 2014)

Main municipal bio-waste streams and their treatment in Latvia, 2005 -2013, Table 1

	Food waste (20 01 08 EWC code)				Garden and park waste (20 02 01 EWC code)			
	Produced	Collected	Recycled	Landfilled	Produced	Collected	Recycled	Landfilled
2005	28	-	-	85	-	-	-	12 604
2006	91	50	-	50	-	13 010	4131	17 695
2007	93	94	-	94	1926	14 666	7 562	7 446
2008	38	50	-	50	935	15 526	7 763	7 544
2009	33	11	-	11	1 156	5 127	3 169	11 654
2010	44	-	-	-	996	5 348	4 139	8 257
2011	32	888	-	-	4 126	20 818	10 508	1 799
2012	5 090	36	10	-	2 381	35 857	13 180	1 320
2013	54	33	11	-	27 818	29 874	48 808	1 702
	Mixed municipal waste (20 03 01 EWC code)				Waste from public market (20 03 02 EWC code)			
	Produced	Collected	Recycled	Landfilled	Produced	Collected	Recycled	Landfilled
2005	539 614	-	3 246	539 614	363	-	-	363
2006	138 563	884 691	99 752	586 829	-	546	-	376
2007	160 891	745 787	42 015	710 997	-	235	-	297
2008	152 254	670 448	39 698	627 142	-	600	-	2
2009	148 602	533 865	5	594 217	-	647	-	-
2010	138 173	512 987	5	568 517	-	654	-	-
2011	162 675	412 157	10 828	509 751	-	593	-	-
2012	108 340	495 959	35 388	502 206	-	-	-	-
2013	100 899	510 109	56 469	503 733	-	-	-	-

The represented data show great discrepancy between different waste streams and the treatment methods. Interpretation of statistic data is characterized by a peculiarity that produced waste amount consist only from reports given by facilities and institutions, and do not include produced waste in households listed in the amount of collected waste. The reports of official data base show, that food waste (20 01 08 EWC code) management is not stated as obligatory demand in practice in the country, and a legal possibility to interpret waste codes allows to treat food waste as mixed municipal waste. Nevertheless, significant improvements have been observed for green waste (20 02 01 EWC code) management - a total recycled amount grows to 48 808 tonnes in 2013, as treatment method mainly is used open windrow composting. Majority of mixed municipal waste (20 03 01 EWC code) is recycled in MBT at landfills. Starting with the year 2009 when the demands how to handle waste from catering were stated this stream in Latvia municipal waste data bases was disappearing.

3. BIO-WASTE TREATMENT OPTIONS

In order to elaborate the National Waste Management (WM) system for the first WM planning stage (2006-2012), the Latvian territory was divided into ten WM planning regions, in each of them one landfill for solid waste disposal being organised in compliance with the

EU sanitary requirements. Mainly it was chosen as a low-cost option for final solid waste disposal compared to waste incineration due to a low inhabitant density at territory. Landfilling, also, allows for disposal all materials in the solid waste stream, for any WM system and technology processes (Mc Dougall, et al., 2003; Tchobanoglous, et al., 1993).
Presented data in Table 2 show a WM performance of each WM planning region. Overall, 583 069 tonnes of municipal waste have been collected in 2013; in this total amount excluded waste amounts from class septic tank sludge (20 03 04 EWC code), waste from sewage cleaning (20 03 06 EWC code), bulky waste (20 03 07 EWC code), and has been made correction in metal (20 01 40 EWC code), where was included amount not corresponding to produced household waste.

According to the statistical data, a large discrepancy is observed between collected and disposed waste amount within regions, and it indicates that waste from industry have been treated as municipal waste, also significant diversion of recycled waste material is noted among regions. As it is shown by the table 2, collected mixed municipal waste was 219 kg per capita; recycled 30 kg per capita, and landfilled – 185 kg per capita.

Municipal waste treatment by MWP regions in 2013, Table 2

WMP region	Number of inhabitants (on 2013)	Collected mixed MW	kg capita^{-1}	Recycled	kg capita^{-1}	Landfilled	kg capita^{-1}
Austrumlatgale	94 257	3 419	36	400	4	16 792	178
Dienvidlatgale	179 336	47 789	266	470	3	52 830	295
Liepāja	147 274	38 522	262	558	4	31 743	216
Maliena	70 349	5 737	82	1 529	22	7 715	110
Piejūra	138 959	62 725	451	4 429	32	28 821	207
Pierīga	883 228	249 799	283	35 664	40	300 266	340
Ventspils	75 421	19 393	257	733	10	7 255	96
Vidusdaugava	114 723	14 588	127	584	5	18 418	161
Zemgale	161 784	38 313	237	2 405	15	27 735	171
Ziemeļvidzeme	158 494	29 823	188	26 190	165	12 158	77
Total / average	2 023 825	510 106	219	72 962	30	503 733	185

Kļavenieks reported (Kļavenieks, 2014) that today less than half of disposed mixed waste could be pre–treated before landfilling (see Table 3). There is planned that waste pre-treatment capacity in Latvia, after new infrastructure establishment will reach to 701 380 tonnes per year in 2016. Landfilling of mixed MSW without pre-treatment or separation out the biological fraction is common practice in Latvia. Nowadays, this option is reasonably considered as bad practice because associated with environmental and safety risks related to landfill gas collection (Arina, et al., 2012) with a methane (GHG) generation potential, also treatment of leachate and worthless land usage. But the problems arise with a material after pre-treatment process at landfills - it further application and use (see figure 1).

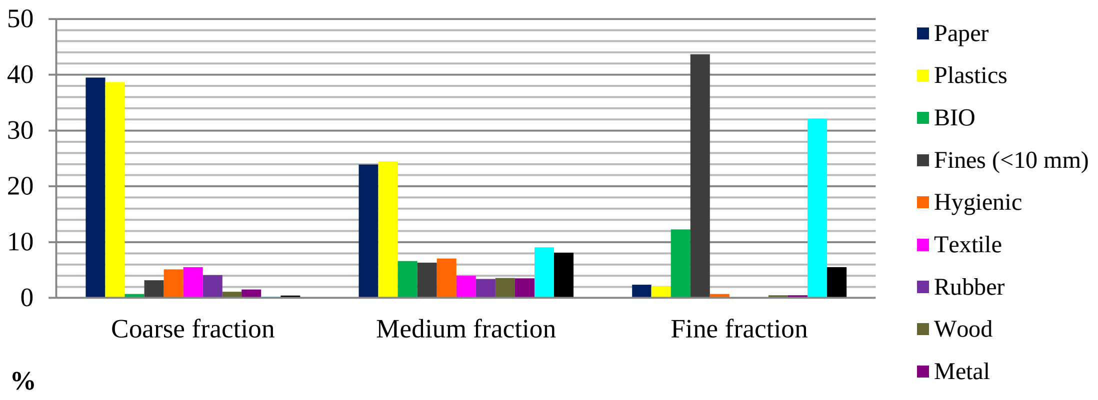

Fig. 1: The average composition of waste fractions after waste pre-treatment by the disc screener (%, for dry waste)

The results of mechanical sorting of mixed waste show that the coarse fraction, mostly complies with the standard of RDF material of the local cement kiln, content of moisture in all fractions is too high for RDF production, and separated organic fraction is with high pollution level to be used as a compost (Kalnacs, et al., 2013). Therefore, the separation of kitchen and garden waste at source must be a high-priority issue in municipal waste management.

The total compost plants capacity at landfills are 29 720 m^2, they are designed for composting of small fraction which consists of polluted bio mass. However, a number of municipalities have their own green waste repository, where green waste is stored, managed and used for landscaping, but this amount is not listed in the state report.

Mixed waste pre-treatment capacity in Latvia, Table 3

WMPR / Operator	Location	Capacity, tonnes	Year established	Compost plant, m^2
Ziemeļvidzeme / ZAAO	Daibe, MBT landfill	30 000	2011	5 632
Vidusdaugava / Vidusdaugavas SPAAO	Dziļā vāda, MBT landfill	80 000	2012	14 000
Liepāja / VAAO	Vibsteri , MBT	40 000	2012	
Pierīga / Ķilupe	Ķilupe, MSF	14 000	2012	
Zemgale / Jelgavas komunālie pakalpojumi	Brakšķi, MBT landfill	30 000	2013	
Ventspils / Ventspils labiekārtošanas kombināts	Pentuļi, MBT landfill	22 380	2013	
Dienvidlatgale / AADSO	Cinīši, MBT landfill	60 000	2015	1 050
Piejūra / AAS Piejūra	Janvāri, MBT landfill	40 000	2015	5 038
Austrumlatgale / ALAAS	Križevņiki, MBT landfill	20 000	2015	2 000
Piejūra / AAS Piejūra	Jūrmala, MSF	20 000	2015	
Alba 5 (AP Kaudzītes)	Kaudzītes, MBT landfill	15 000	2015	2 000
Pierīga / Vides pakalpojumu grupa/Getliņi EKO	Getliņi, MBT landfill	300 000	2016	
Liepāja / EKO Kurzeme/Liepājas RAS	Ķīvītes, landfill	30 000	2016	
Total mixed waste pre-treatment / compost capacity, tonnes:				29 720
	January, 2014	216 380		
	January, 2016	701 380		

Dubrovkis et al pointed that 34 biogas plants worked in Latvia in 2012 with a total installed capacity of around 39 MW, including 3 biogas plants at landfills – Daibe, Ķīvītes and Getliņi; 1 biogas plant of urban sewage sludge; 2 biogas plants of food industry (biogas is used directly combustion boiler); 1 wood biomass gasification facility, and 27 biogas plants in agriculture (Dubrovskis, et al., 2013).

4. MATERIALS AND METHODS

The Waste Management Planning System (WAMPS) software has been used as the environmental impact analysis tool for modelling waste management scenarios. The new version of WAMPS (see Fig. 2) offers the user to create more scenarios for waste management development, as it has been improved with a mechanical pre- treatment process, where new fractions – metal, fine and RDF – are produced. The new waste material technology – incineration in a cement kiln – is also one of the solutions how to use waste as burning material and replace the fossil resources.

The WAMPS software calculates emissions, energy and turnover of waste streams for processes within the waste management system, e.g., waste collection and transportation, composting, anaerobic digestion, and final disposal – landfilling or incineration (IVL, 2013).

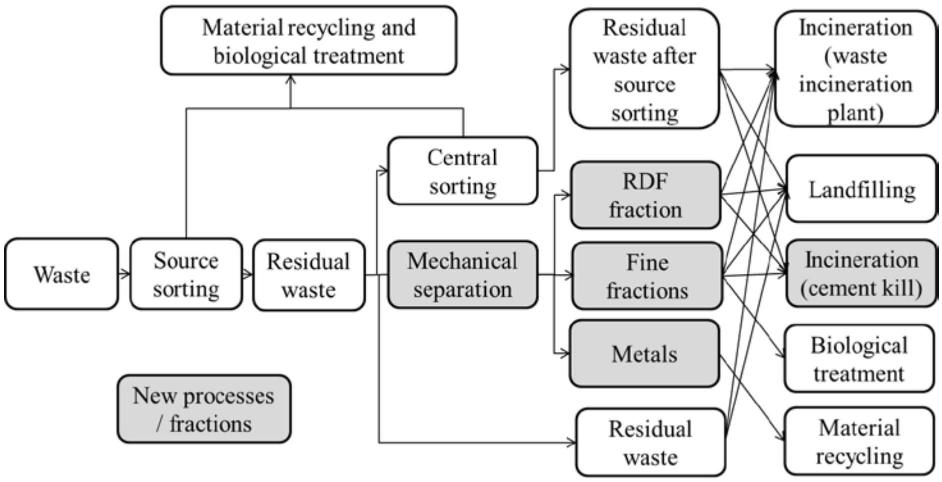

Fig. 2: Overview of WAMPS modelling possibilities

WAMPS software based on the Life Cycle Assessment approach, and the results are presented in four environmental impact categories: acidification, global warming, eutrophication and photo-oxidant formation, which are characterised by a certain emission. This paper focuses only on the global warming category.

WAMPS covers an integrated waste management system starting with the activities where products become waste and have been put into the waste bin at waste generation source to the last point, where the waste becomes either useful material (recycled material, biogas or compost) or becomes part of emissions in the environment after its final disposal at a landfill or incineration plant. The calculation can give also negative net emissions, as an example WM with incineration could give lower emissions than the corresponding energy production in the background system (fossil resource). The net emissions from each of waste management scenarios are calculated after equation (1) (Moora, 2009):

$$E_{net} = E_{waste} – E_{background} \quad (1)$$

where,

E_{net} – Net emissions (tonnes year^{-1});

E_{waste} – Emission from waste process that produce a certain amount of product / energy (tonnes year^{-1});

$E_{background}$ – Emission from the same amount of alternative virgin production in the background system (tonnes year^{-1}).

Also, in the development of the WAMPS software, a number of limitations have been acknowledged.

4.1. Waste amount and composition

For the modelling purpose, it is assumed that total collected municipal waste amount correspond to produced amount listed in the public officially available data of municipal waste management form "No. 3-Waste Report", it is 583 068 tonnes year^{-1} (see Table 4). The waste from source institutions and small enterprises - consists of amount in a section "Produced waste" of statistic data, and it is 185 624 tonnes year^{-1} (LEGMC, 2014). The Eurostat report (Eurostat, 2014) indicats that 64% of total population live in multi-storey buildings in Latvia. Therefore, rest of total collected municipal waste is shared following: 64% or 254 364 tonnes year^{-1} from multi-storey buildings and 36% or 143 080 tonnes year^{-1} from private houses.

In this case study, it is assumed that waste composition in the country conforms to assessed municipal waste composition of Ogre municipality (39 233 inhabitants). There were sorted and measured 28 tonnes of waste with the waste composition characteristic of the summer season (Bendere, et al., 2014).

Municipal waste composition (tonnes year^{-1} and % by weight), Table 4

	Institutions and small enterprises	Multi-storey buildings	Private houses
Waste amount, tonnes	185 624	254 364	143 080
Waste fraction, % by weight			
Paper and cardboard	32%	10%	11%
Newspaper, magazines ect.	7%	3%	3%
Plastic	27%	28%	21%
Metal packaging (aluminium and steel)	1%	2%	2%
Glass	4%	8%	8%
Rubber, incl. tyres	-	-	-
Clothes, shoes, textiles and leather	-	-	-
Wood	-	-	-
Biodegradable material (mixed	-	13%	1%
Organic degradable kitchen waste	10%	29%	19%
Garden Waste	14%	-	20%
Hazardous waste	1%	2%	-
Electric and electronic wastes (WEEE)	-	-	3%
Inert wastes	3%	5%	4%
Non-hazardous batteries	-	-	5%
Steel and metal scrap (mixed)	-	-	-

Others	1%	-	3%
Total	100%	100%	100%

1) sorting at source (see Table 5) and mechanical sorting.

The provided inhabitants survey in Marupe municipality (Riga suburb with 10 000 inhabitants, of whom 5 000 live in private houses) in 2014 shows that two thirds of 171 respondents confirm - they already organizing green waste backyard composting. This aspect is taken in account in order to fulfil Landfill Directives target and requirements on biodegradable waste. It is assumed that all private houses reduce green waste amount at source gradually: 50% of weight in Scenarios 1 and 100% - in Scenarios 2 and 3 by home composting.

After estimated statistic data and waste composition, the institutions can fulfil green waste treatment targets and start to separate 100 % of produced green waste. The treatment can be done using open windrow composting. The third largest producer of food waste - food service and catering sector is taken into account in Scenario 2, but households living in multi-storey buildings are added in Scenario 3.

Currently, the Waste Framework Directive objectives are very ambitious for Latvia, so it is chosen less ambitious goal - 25% source sorting of waste materials: paper / cardboard, glass, plastic and metal in the Scenarios 1 to 3 (see Table 5).

Waste sorting at source of studied waste management scenarios, Table 5

Scenario	Paper / cardboard	Glass	Plastic	Metal	Food waste		Green waste	
					Institutions	Multi-storey buildings	Institutions	Private houses
Base	4%	1%	1%	1%	<1%		100%	-
Scenario 1	25%	25%	25%	25%	-	-	100%	50%
Scenario 2	25%	25%	25%	25%	100%	-	100%	100%
Scenario 3	25%	25%	25%	25%	100%	100%	100%	100%

After source sorting of waste material (paper, plastics, glass, metallic packages and bio-waste) rest of waste - mixed waste is transported to landfill equipped with mechanical sorting line for pre-treatment process. After results of investigation (Kalnacs, et al., 2013), the four fractions are separated from the total mixed household waste mass, i.e.:

~35 % – fine fraction mainly composed of organic waste;

~40 % – medium fraction of diversified waste;

~22 % – coarse fraction (RDF) containing waste of high calorific value (plastics, paper, textile, rubber);

~3 % – iron-containing.

This percentage was used in mechanical sorting calculations of calculated waste management scenarios.

4.2. Waste management scenarios and used technologies

A base scenario and three alternative scenarios is developed for Latvian waste management system. The studied scenarios are hypothetical and characterise possible food waste and green waste management development trends in Latvia, in order to reduce GHG emissions. Base scenario conforms to existing situation in the country.

Main characteristics of studied waste management scenarios, Table 6

Scenario	Mechanical sorting	Biodegradable organic waste (after source sorting)			Fine fraction (after mechanical sorting) Composted and used as covering material for disposal site	RDF fraction (after mechanical sorting			Landfill
		Home composting	Open windrow composting	Anaerobic digestion		Landfill	Incineration	Incineration (Cement kiln)	
Base	+		100 %		100 %	100 %			100%
Scenario 1	+	35 %	65 %		100 %	80 %	10 %	10 %	100 %
Scenario 2	+	52% of 75%*	48% of 75%*	25 %	100 %	80 %	10 %	10 %	100 %
Scenario 3	+	53% of 30%*	47 % of 30%*	70 %	100 %	80 %	10	11	100

*were 100% - total composted fraction

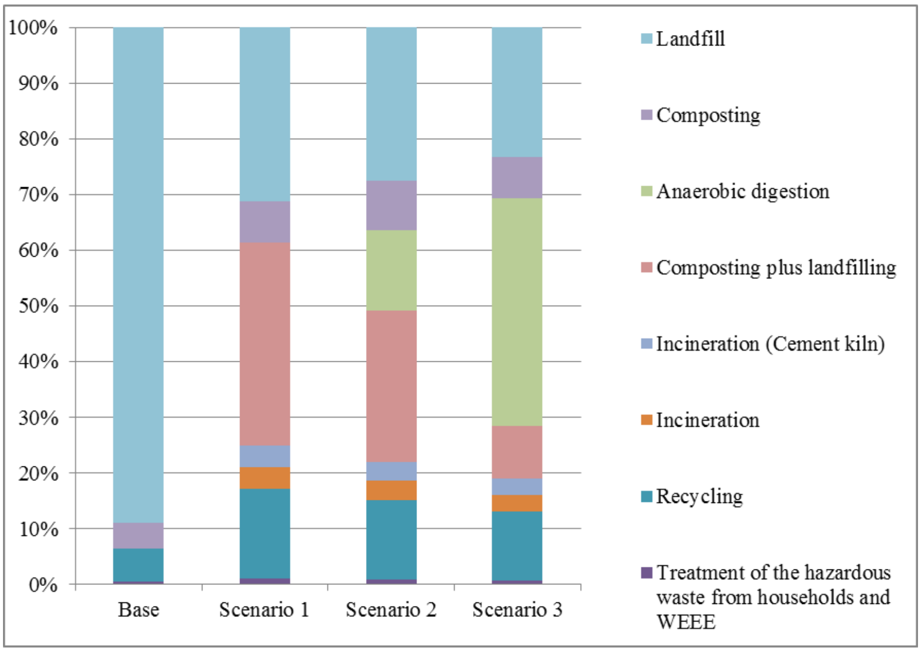

Fig. 3: Projection of treatment of studied waste management scenarios (% by weigh)

The assumptions taken in the mathematic design of the models are (see Table 6 above):

a) it is assumed that biodegradable waste composting produce the compost that is 60% from the total mass, and it is used as fertiliser for landscaping, agricultural or local consumption at home;
b) in all scenarios it is assumed that energy produced from landfill gas and waste incineration replaces fossil fuel in a background system - natural gas;
c) in all scenarios it is assumed that landfill gas is recovered and combusted with 35% efficiency (Arina, et al., 2012; Sonesson, et al., 1997) – 50% of district heating and 40% of electricity;
d) the incineration complies with EU requirements, and it is assumed that energy recovery from incineration process is 20% of electricity and 80 % district heating.

5. RESULTS

The LCA modelling results of studied scenarios show that biodegradable waste avoiding from disposal in landfills leads to significant reduction of GHG. The global warming of analysed scenarios is shown in Figure 4 and Table 7.

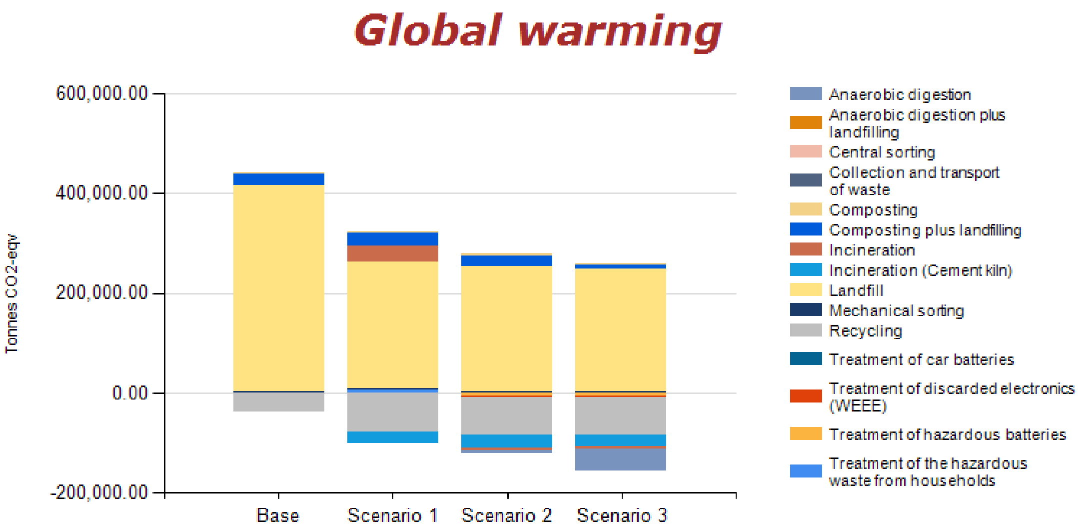

Fig.4: Overview of global warming from studied waste management scenarios (tonnes CO_2 eqv)

The diagrams show net emissions from each waste management technology minus saved emissions in the background system. Negative results show avoided impacts and saving of fossil fuel.

Total designed GHG emission shows reduction from 404 700 tonnes CO_2 eqv (Base scenario); 222 127 tonnes CO_2 eqv (Scenario 1); 158 526 tonnes CO_2 eqv (Scenario 2) to 92 333 tonnes CO_2 eqv (Scenario 3).

Global warming emissions by each waste treatment technology (tonnes CO_2 eqv.), Table 7

	Anaerobic digestion	Composting	Composting plus landfilling	Incineration	Incineration (Cement kiln)	Landfill
Base	-	2 981	23 159	-	-	415 037
Scenario 1	-	4 526	24 569	-32 346	-24 497	255 230
Scenario 2	-6 836	5 891	20 746	-7 152	-24 104	252 958
Scenario 3	-43 162	5 422	8 301	-6 284	-22 853	246 070

	Mechanical sorting	Recycling	Treatment of discarded electronics (WEEE)	Treatment of hazardous batteries	Treatment of the hazardous waste from households
Base	1 619	-36 533	-1 548	-109	95
Scenario 1	1 485	-76 897	-1 998	-4 842	-1 662
Scenario 2	1 372	-76 897	-1 998	-4 842	-1 662
Scenario 3	1 016	-76 897	-1 998	-4 842	-1 662

CONCLUSIONS

Landfill (Base Scenario), as final disposal waste treatment method, is a major source of GHG emissions, mainly CH_4, despite of the fact assumed that all landfills gas is collected and recovered.

A significant net impact give material recycling and incineration, especially an incineration in cement kiln, when materials are recycled and produced heat and electricity that allows to save virgin materials and fossil fuels. It also reduce disposed amount in landfills.

The sorting of food waste at source and reduction of its content in the fine fraction for composting and landfilling – increase options to use food waste as valuable material and reduce significantly disposed waste amount in landfills. Also the food waste separated at source presents significant input material for energy recovery and energy production from biogas which displaces energy largely based on fossil fuels (coal, oil, gas).

Composting may results in CO_2 emission from organic matter decomposition process, also after the compost is added to the soil and from mechanical turning of the compost pile. If composting process is managed properly, then CH_4 emission does not appear from anaerobic decomposition.

Current statistic data show insufficiency of reliable data of produced food waste amount and its content which reduce the effectiveness of waste treatment planning. Therefore pilot research results are extremely necessary.

In a system perspective, it is essential requirement to prepare food waste for anaerobic digestion in planned capacity and constant quality, therefore food waste thermal stabilisation is desirable.

In order to manage food waste anaerobic digestion feasible (composting only food waste without any other organic material will be extremely difficult), establishment of new or integration in existing alternative systems for energy and digest consumption is necessary. The rationale is to combine production with agriculture, transport or other utilities.

The green waste composting is rational option, if the produced compost is valuable and is needed as soil improver. Therefore government has to create legislative and economical instruments how to adequately stimulated compost market and use produced material for landscaping, road construction projects or others.

Home composting in private houses, in case of Latvia, is very feasible and it allows reduce significantly treated municipal waste amount. Therefore local municipal support and campaigns of home composting awareness arising is extremely necessary.

REFERENCES

Arina, D., Bendere, R. & Teibe, I., 2012. *Pre-treatment Processes of Waste Reducing the Disposed Amount of Organic Waste and Greenhouse Gas Emission.* Florence, The ISWA World Solid Waste Congress 2012, p. 517 pdf.

Barton, R., Dalley, D. & Patel, V., 1996. Life Cycle Assessment for Waste Management. *Waste Management*, 16(Nos 1-3), pp. 35-50.

Bendere, R., Teibe, I. & Arina, D., 2014. *Finding sound bio-waste treatment solutions in the Baltic states.* Athens, National Technical University of Athens.

BIO Intelligence, S., 2011. *Preparatory Study on Food Waste Across EU 27,* bez viet.: European Communities.

BiPRO, 2012. *Screening of Waste Management Performance of EU Member States,* Brisele: European Commission.

Boer, E., Boer, J. & Jager, J., 2005. *Waste management planning and optimisation. Handbook for municipal prognosis and sustainability assessment of aste managemnt systems.* 1st red. Stuttgart: Ibidem- Verlag.

Dubrovskis, V., Niklass, M., Emsis, I. & Kārkliņš, A., 2013. *Biogāzes ražošana un efektīva izmantošana,* Rīga: Latvijas Biogāzes asociācija.

Eurostat, 2012. *Greenhouse gas emissions by sector,* Luxemburg: Eurostat.

IVL, 2013. *Joint Baltic Sea Region Strategy for Municipal Waste Management,* s.l.: s.n.

JRC, 2014. *End-of-waste criteria for biodegradable waste subjected to biological treatment (compost & digestate): Technical proposals,* Luxembourg: bez nos.

Kalnacs, J., Arina, D. & Murashov, V., 2013. Content and Properties of Mechanically Sorted Municipal Wastes and Their Suitability for Production of Alternative Fuel. *Renewable Energy & Power Quality Journal,* pp. pp 1-4.

Kļavenieks, K., 2014. *Eiropas Savienības fondu 2014. - 2020. gada finanšu plānošanas perioda potenciāli atbalstāmo vides aizsardzības aktivitāšu ekonomisko ieguvumu novērtējums,* Riga: Geo Consultants, SIA.

LEGMC, 2014. *Valsts statistisko pārskats "3-Atkritumi" (State Statistical Review "3-Waste"),* Riga: bez nos.

Mc Dougall, F., White, P., Franke, M. & Hindle, P., 2003. Integrated Solid Waste Management: a Life Cycle Inventory. In: *Integrated Solid Waste Management: a Life Cycle Inventory.* Oxford: Blackwell Science, p. 513.

Moora, H., 2009. *Life Cycle Assesment as a Decision Support Tool for System Optimisation - the Case of Waste Management in Estonia.* Tallinn: Tallinn Iniversity of Technology.

Sonesson, U., Jonsson, H., Mingarini, K. & Dalemo, M., 1997. ORWARE – A simulation model for organic waste handling systems. Part 2: Case study and simulation results. *Resources, Conservation & Recycling,* Sep, 21(1), pp. 39-54.

Tchobanoglous, G., Theisen, H. & S, V., 1993. *Integrated Solid Waste Management. Engineering Principles and Management Issues.* Singapore: McGraw-Hill Book Co.

UNFCCC, 2012. *National Inventory Submissions*, bez viet.: United Nations Framework Contention on Climate Change.

Verghese, K. L., 2009. Life cycle assessment and waste management. %1*Life Cycle Assessment: Principles, Practice, and Prospects.* bez viet.:CSIRO, pp. 51-68.

Virsma, 2011. *Degradējamā organiskā oglekļa daļas noteikšana apglabātos atkritumos,* Rīga: Ziņojums.

Housing statistics, 2014.
Http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/housing_statistics