MSc Program
Renewable Energy in Central & Eastern Europe

Reduction potentials of GHG in solid waste management in the Republic of Serbia

A Master Thesis submitted for the degree of
"Master of Science"

supervised by
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Affidavit

I, **Slavko Dvoršak**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Reduction potentials of GHG in solid waste management in the Republic of Serbia", 80 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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ABSTRACT

This master thesis describes the current status of waste management in the Republic of Serbia and includes the quantities of waste that is generated, collected and landfilled, and the emissions of GHG that are emitted by landfilling of municipal solid waste. Presented are also different phases in the process of degradation of the waste in the landfills and different conditions affecting the process of methane formation and the possible reductions of methane emissions.

In the master thesis three different future projections are presented for the waste quantities generated, collected and landfilled. The base year for all scenarios is the year 2002 for which the quantities and the structure of the waste is quite known. In all scenarios an increase in waste quantities for 3% per year is foreseen and it is also projected that in the year 2020 there will be generated 493 kg of municipal solid waste per person.

The emissions of methane from the landfills are also calculated for each projection for waste quantities. Methane emissions from waste disposal are thus of anthropogenic origin and, consenquently, a constituent part of national GHG inventories in accordance with IPCC methodology. For the calculation of GHG mass balance method was used in accordance with The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

Further more European and Serbian legislation frameworks are also described and rules of procedure for CDM projects and foreseen CDM projects in the Republic of Serbia. The Clean Development Mechanism (CDM) was introduced by the Kyoto Protocol to provide a financial incentive to establish project activities in developing countries for reducing greenhouse gas emissions while also fostering sustainable development. The CDM is project-based mechanism which enables the sale and purchase of Certified Emission Reductions that are generated by projects in developing countries. The CDM projects increase the flexibility and cost-effectiveness of meeting Kyoto targets.

I. Table of Content:

II. List of figures:

III. List of tables:

IV. List of Equations

V. List of Abbreviations

BOD – Biochemical Oxygen Demand
CDM – Clean Development Mechanism
CER – Certified Emission Reductions
CH_4 - Methane
CO_2 – Carbon Dioxide
COD – Chemical Oxygen Demand
FOD – First Order Decay
GDP – Gross Domestic Product
GHG – Green House Gases
IPCC – Intergovernmental Panel on Climate Change
JI – Joint Implementation
KOMDEL – Professional Association of Communal Companies
MCF – Methane Correction Factor
MSW – Municipal Solid Waste
NATO – North Atlantic Treaty Organization
NMOC – Non-Methane Organic Compound
PAH – Polycyclic Aromatic Hydrocarbon
PCB – Polychlorinated Biphenyls
SWDS – Solid Waste Disposal Site
UN - United Nations

1. INTRODUCTION

Climate change is already happening and represents one of the greatest environmental, social and economic threats facing the planet.

The warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level. The Earth's average surface temperature has risen by 0.76° C since 1850. Most of the warming that has occurred over the last 50 years is very likely to have been caused by human activities. [1]

The dominant factor in the radiative forcing of climate in the industrial era is the increasing concentration of various greenhouse gases in the atmosphere. Several of the major greenhouse gases occur naturally but increases in their atmospheric concentrations over the last 250 years are largely due to human activities.[2]
One of the most important GHG is methane (CH_4). It is a more potent greenhouse gas than carbon dioxide, with a global warming potential (over a 100 year time horizon) 21 times greater than carbon dioxide.[3] Greenhouse gas emissions are often calculated in terms of how much CO_2 would be needed to produce a similar warming effect. This is called CO_2 equivalent. For example, 5 tonnes of methane would have a CO_2 equivalent of 5 x 21 = 105 tonnes CO_2 eq[4]
The CH_4 sources, combined with the small natural range of CH_4 concentrations over the past 650,000 years and their dramatic increase since 1750 make it *very likely* that the observed long-term changes in CH_4 are due to anthropogenic activity.[5]
Climate change demands all efforts to reduce CO_2 emissions as soon as possible.[6]
Landfills are the largest human-related source of methane in Europe, accounting for 34% of all methane emissions. Methane is generated in landfills and open dumps as waste decomposes under anaerobic (without oxygen) conditions. The amount of

[1] http://ec.europa.eu/environment/climat/home_en.htm/ accessed December 15th , 2008
[2] Solomon. et. al. (2007) p. 26
[3] European Commission (1998)
[4] http://www.climnet.org/publicawareness/wasteCC.htm/ accessed December 15th , 2008
[5] Solomon. et. al. (2007) p. 27
[6] Prognos (2008) p. 12-13

methane created depends on the quantity and moisture content of the waste and the design and management practices at the site.[7]

1.1 Demographic data about the Republic of Serbia

The Republic of Serbia is located in the southeastern Europe, in the heart of the Balkan Peninsula, and covers the area of 88,361 km^2. Within Serbia there is one autonomous province Vojvodina (21,506 km^2).

Serbia borders on seven countries: Albania, Bosnia and Herzegovina, Croatia, Hungary, Romania, Bulgaria, Macedonia and Montenegro. The main rivers in Serbia include the Danube, Sava, Drina, Morava and Tisa.

The population of Serbia is 7.5 million according to the 2002 Census. In 2000, 52% of the population lived in urban areas. The main cities are Belgrade, the capital of Serbia (pop. 1,280,639), Novi Sad (234,151), Nis (177,823), and Kragujevac (145,890).[8]

The main contribution to Serbian GDP in 2002 was provided by industry (30.3%), agriculture, forestry and fishing (19.2%), wholesale and retail trade (18.6%), transport and telecommunication (12.4%), construction (5.7%), and electricity, gas and water supply (5.7%).

The most important agricultural areas are located in Vojvodina. Cattle, sheep, and pigs are intensively reared. Serbia's large and heavy industries are primarily linked with mining. Consequently, there was a considerable development of industries such as melting, refining, metallurgical industries, chemical industries, machinery and vehicle production. Other important industrial production include cement and other building materials, fertilizers, electrical equipment, sawmills, wooden furniture, paper products, leather and fur products, yarns and fabrics, rubber, textiles, food products and beverages.

[7] http://www.epa.gov/methane/sources.html/ accessed May 10th, 2009
[8] National Environmental Strategy, Government of Republic of Serbia (2007) p. 1-3

The major decline in production and the gross domestic product occurred in 1990s due to market disintegration, economic sanctions, impoverishment of the population, high unemployment, bombing of some major infrastructure and industrial facilities to name just a few. The GDP per capita in the year 2000 was only about 50 % of its 1989 level. The economy of the Republic of Serbia has showed positive results since 2000. GDP rose by 5.5% in 2001, 4 % in 2002, 3% in 2003, and 8.6% in 2004 in real terms. In 2001, this was achieved primarily by a rise in agricultural output (18%), after the dry year 2000, while since 2002 a rise in the service sector was also pronounced.[9]

Climate in the Republic of Serbia is in the north, continental climate (cold winters and hot, humid summers with well distributed rainfall); in other parts, continental and Mediterranean climate (relatively cold winters with heavy snowfall and hot, dry summers and autumns).[10]

Figure 1: Map of the Republic of Serbia

[9] National Environmental Strategy, Government of Republic of Serbia (2007) p. 10
[10] https://www.cia.gov/library/publications/the-world-factbook/geos/ri.html/ accessed June 10th, 2009

3.1.1.1.1.1. Districts in Central Serbia

District	Capital	Area in km²	Population in 2002 (rank)	Population per km²
City of Belgrade	Belgrade	3,222.68	1,576,124	488
Bor District	Bor	3,507	146,551	41.8
Braničevo District	Požarevac	3,865	200,503	51.9
Jablanica District	Leskovac	2,769	240,923	87
Kolubara District	Valjevo	2,474	192,204	77.7
Mačva District	Šabac	3,268	329,625	100.9
Moravica District	Čačak	3,016	224,772	74.5
Nišava District	Niš	2,729	381,757	139.9
Pčinja District	Vranje	3,520	227,690	64.7
Pirot District	Pirot	2,761	105,654	38.3
Podunavlje District	Smederevo	1,248	210,290	168.5
Pomoravlje District	Jagodina	2,614	227,435	87
Rasina District	Kruševac	2,667	259,441	96
Raška District	Kraljevo	3,918	291,230	74.3
Šumadija District	Kragujevac	2,387	298,778	125.2
Toplica District	Prokuplje	2,231	102,075	45.7
Zaječar District	Zaječar	3,623	137,561	37.7
Zlatibor District	Užice	6,140	313,396	51

Table 1: Districts in Central Serbia[11]

3.1.2. Districts in Vojvodina

District	*Capital*	*Area in km²*	*Population in 2002 (rank)*	*Population per km²*
Central Banat District	Zrenjanin	3,256	208,456	$ 64.00
North Bačka District	Subotica	1,784	200,140	112.20
North Banat District	Kikinda	2,329	165,881	71.20
South Bačka District	Novi Sad	4,016	593,666	147.80
South Banat District	Pančevo	4,245	313,937	73.60
Srem District	Sremska Mitrovica	3,486	335,901	96.40
West Bačka District	Sombor	2,420	214,011	88.40

Table 2: Districts in Vojvodina[12]

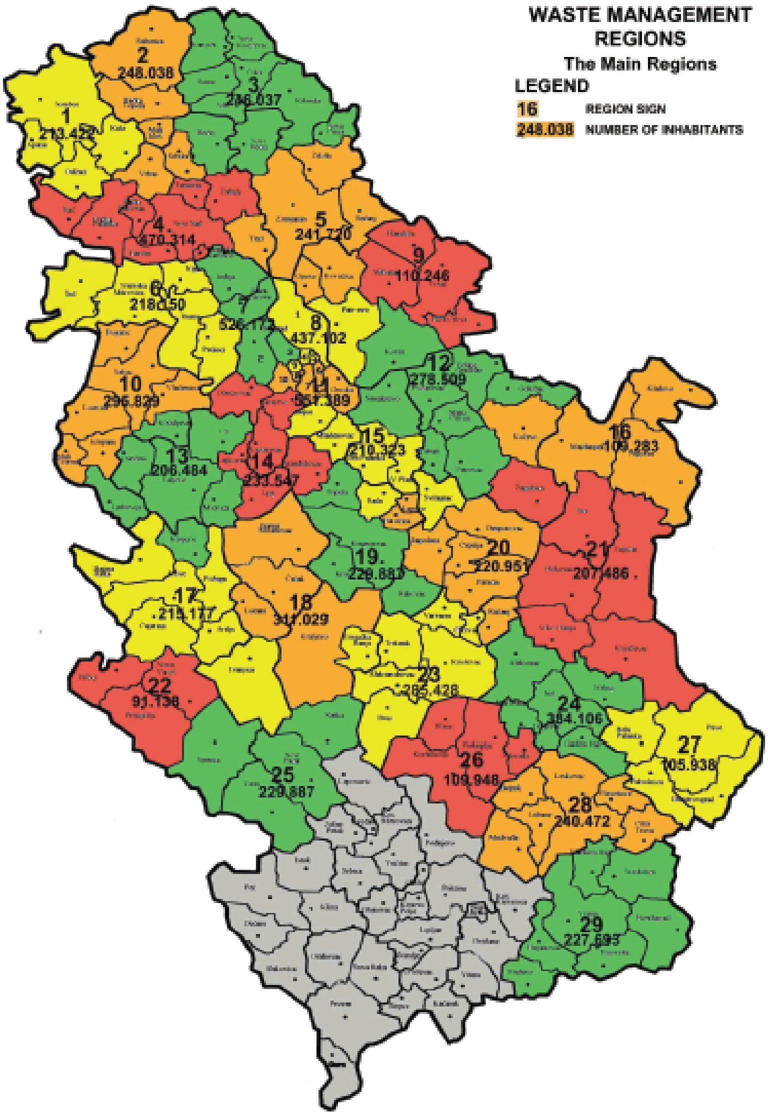
[11] http://en.wikipedia.org/wiki/Districts_of_Serbia/ accessed June 10th, 2009
[12] http://en.wikipedia.org/wiki/Districts_of_Serbia/ accessed 10th June, 2009

1. WASTE GENERATION

Inadequate waste management is a significant ecological problem in the Republic of Serbia. This is the conclusion of numerous environmental analyses on the territory of the Republic, done in the previous few years (the Ministry of Health and Environmental Protection of Serbia, Directorate of Environmental Protection 2001; the Ministry of Natural Resources and Environmental Protection, 2002-2003; World Bank 2002; UN European Economic Commission, 2002; etc).[13]

Waste volume in the Republic of Serbia, as in numerous transitional countries, is hard to estimate. The main reason is lack of information on waste qualitative and quantitative analysis, i.e. filing system of quantities, characteristics, especially content, and classification of waste. Data on waste origin and methods of disposal are incomplete. According to the data provided by the professional association KOMDEL, total waste collected by the 90% communal companies in Serbia is estimated at 2.200.000 t/year. The above number includes household, commercial and non-hazardous industrial waste, but not waste from hospital and other health institutions, clinic waste, and also construction waste. As indicated by the data collected for 160 municipalities from Central Serbia and Vojvodina, (data from Kosovo unavailable) it may be estimated that communal companies collect waste from 60-70 % of population, i.e. 5 million inhabitants. Waste produced by 2,5 million inhabitants is not included in the collection system. Such waste is disposed of without control, to illegal landfills in villages, or by rivers, and is incinerated without any control. Average communal waste mass in the Republic of Serbia is estimated to 0,80 kg/cap./day, a little less than in the Central and east European countries. Social and economic environmental changes in the previous few years have brought certain reduction of the waste production, together with waste structure changes.[14]

[13] The National Waste Management Strategy, Government of Republic of Serbia (2003), p. 23-31
[14] The National Waste Management Strategy, Government of Republic of Serbia (2003) p. 23-31



Picture 1: Waste management regions in the Republic of Serbia

An average person generates approximately 290 kg of waste per annum. Households generate the majority of municipal waste (about 63 %), and 20 % is generated by businesses. At present there are 180 officially registered landfills for disposal of municipal waste in Serbia. The disposal sites generally do not meet the technical requirements of sanitary landfills. There are also hundreds of illegal dumpsites of different size in rural areas. Dumpsites are subject to uncontrolled burning producing harmful emissions of particulate matter, dioxins and PAH. Degradation of bio-degradable waste in dumpsites results in the emissions of landfill gas, containing CO_2 and methane, which may, due to inadequate handling, lead to explosions. The leachate from dumpsites pose a threat to groundwater, surface waters and soil due to the high organic and heavy metals content.[15]

Packaging waste is classified as household and commercial waste. Though there are no official data on packaging waste volume, it is estimated that it covers 40% i.e. 550.000 t/y. There are no reliable data on the quantity of used batteries, as well as of unusable vehicles located mostly in registered junks. Quantities of old tires and waste oils are also hard to estimate. Collected data on oil quantities containing PCB show that there are about 200 tons of similar oils in Serbian power plant systems, still in use. Certain volume of waste polluted by PCB oils was produced during the NATO bombing in 1999, due to PCB leaking from the bombed transformer stations. There are no reliable data on waste produced by electric and electronic instruments, since this category of waste is not specifically classified.[16]

There is also no reliable data on the volumes of hazardous waste generated by industry. It is estimated that 460,000 t/year of hazardous industrial and medical waste is generated in Serbia including: waste motor oils 106,000 t/y, mixed organics/water emulsions 257,000 t/y, other hazardous waste (medical waste, organic and inorganic hazardous waste from industry, PCB waste etc.) 97,000 t/y. Vojvodina faces a problem with waste from oil rigs (the quantity is estimated to be about 600,000 m^3). There are neither facilities for hazardous waste treatment and disposal (destruction or incineration), nor proper storage facilities for hazardous waste. Hazardous waste is disposed temporarily in inadequate storages (some of which operate for several decades).[17]

Most of it is generated during mining and energy-production activities. Large quantities of hazardous waste are generated in mining industry, and when ores are technologically prepared for metallurgic and chemical processing. Surface coal and mineral mining excavation sites, together with disposal sites of various materials cover large areas of degraded and contaminated soil. Extremely ecologically hazardous are inadequately protected flotation of slag and waste generated in chemical industry mud, located in particularly insufficient locations (usually near water-courses). There are pyrite burnouts and phosphor-plaster disposal sites in

[15] National Environmental Strategy, Government of Republic of Serbia (2007) p. 27
[16] The National Waste Management Strategy, Government of Republic of Serbia, (2003) p.23-31
[17] National Environmental Strategy, Government of Republic of Serbia (2007) p. 28

Serbia with annual volumes of 300-500.000 tons. Cement factories use 100.000 tons of this waste annually in their production processes. Another by-product may be found on disposal sites, nitro-plaster (around 300.000 tons), generated in the process of nitro-cellulose production.

Large quantities of ash (about 6-7 million t/y)are generated by thermoelectric plants.

Total annual medical waste volume in all health institutions in Serbia is estimated to 70.000 tons, i.e.1,8 kg/bed of medical waste/day, of which 9.600 tons are hazardous waste, an East European average. The mentioned waste is produced in hospitals, health centres, other health facilities and health protection institutes. In most health care facilities, infectious waste is not typically segregated (used needles, syringes, dressing, infusions etc.), but mixed with originally communal waste, and thrown into plastic baskets and/or solid polyethylene bags. Bio hazardous waste produced in veterinary and health care facilities is thrown into pits, or burnt without any control.[18]

Definition of waste according to the EU waste Directive 'waste' shall mean any substance or object, which the holder discards or intends or is required to discard.[19]

2.1. Sources and methods of data collection

Data about waste quantities used in the calculations are obtained from public utility enterprises in urban localities and on the basis of the available records.

2.2. Definitions

Landfill is defined as deposit of waste into or onto land, including specially engineered landfill, and temporary storage of over one year on permanent sites.

Municipal waste includes waste originating from: households, commerce and trade, small businesses, office buildings and institutions (schools, hospitals, government buildings). It also includes bulky waste (e.g. white goods, old furniture, mattresses) and waste from selected municipal services, e.g. waste from park and garden

[18] The National Waste Management Strategy, Government of Republic of Serbia (2003) p.23-31
[19] Directive 2006/12/ec of the european parliament and of the council of 5 April 2006 on waste

maintenance, waste from street cleaning services (street sweepings, the content of litter containers, market cleaning waste), if managed as waste.

Industrial waste - Wastes may be generated during the extraction of raw materials during the processing of raw materials to intermediate and final products, during the consumption of final products, and during any other human activity. Industrial waste comprises waste from mining and quarrying, manufacturing industries, energy production and construction.

Hazardous waste refers to the categories of waste to be controlled according to the Basel Convention on the control of transboundary movements of hazardous waste and their disposal. 'Hazardous waste' means waste which displays one or more of the hazardous properties.[20]

Recycling is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Treatment means the physical, thermal, chemical or biological processes that change the characteristics of the waste in order to reduce its volume or hazardous nature facilitate its handling or enhance recovery.[21]

Disposal means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy.[22]

[20] Directive 2008/98/EC
[21] http://webrzs.stat.gov.rs/axd/godisnjak/god2007pog02.pdf/ accessed August 20th, 2009
[22] Directive 2008/98/EC

2.3. Waste treatment technologies in the Republic of Serbia

Landfills are the primary waste disposal method. Municipal waste, including hazardous waste generated by households, is usually disposed directly to landfills. Serbia currently has 180 registered landfills for municipal waste. These disposal sites generally do not meet the technical requirements of sanitary landfills. In addition to the registered landfills, there are hundreds of illegal dumpsites of various sizes in rural areas.[23]

Figure 2: Distribution of landfills in Serbia[24]

[23] United Nations; Economic commission for Europe; Committee on environmental policy; Environmental performance reviews Republic of Serbia (2007)
[24] Republic of Serbia; Ministry of Science and environmental protection, Environmental Protection Agency; Environment in Serbia an indicator based review (2007), p.121-131

The only method of managing waste that is currently practiced in Serbia is disposal in landfills, which mostly fails to meet the most basic requirements of hygiene, as well as technical and technological standards, and some of them are already filled to full capacity.[25]

Analysing the data on amounts and types of waste discharged in landfills, it is readily apparent that very little care is currently taken of this issue. The fact that only 30 landfills (18.3%) have records of the types and quantities of waste is suggestive enough.[26]

Communal waste is deposited to sites without any previous treatment. In spite of an option of composting (large percent of organic waste), it is not done. There is no single waste-incinerating device in Serbia, nor is it used as an alternative fuel in cement-factories or iron-factories. Despite the fact that primary recycling (waste separation at the source) is regulated by law in the Republic of Serbia, anticipating deposition of paper, glass and metal containers into specially marked trashcans, the system is not practically used. Communal waste recycling is not organized either. There is only industrial waste recycling, mostly privately initiated.[27]

2. THE PROCESS OF FORMING METHANE IN THE LANDFILLS

The organic components of the waste are degraded by micro-organisms in the landfill. The organic materials occuring in waste can be classified into broad biological groups represented by proteins, carbohydrates and lipids or fats. Carbohydrates are by far the major component of biodegradable wastes and include cellulose, starch and sugars. Proteins are large complex organic materials composed of hundreds or thousand of amino acids groups. Lipids or fats are materials containing fatty acids.[28]

[25] Republic of Serbia; Ministry of Science and environmental protection, Environmental Protection Agency; Environment in Serbia an indicator based review (2007), p.121-131
[26] Republic of Serbia; Ministry of Science and environmental protection, Environmental Protection Agency; Environment in Serbia an indicator based review (2007) p.121-131
[27] The National Waste Management Strategy, Government of Republic of Serbia, 2003
[28] Williams (2005) p. 200-206

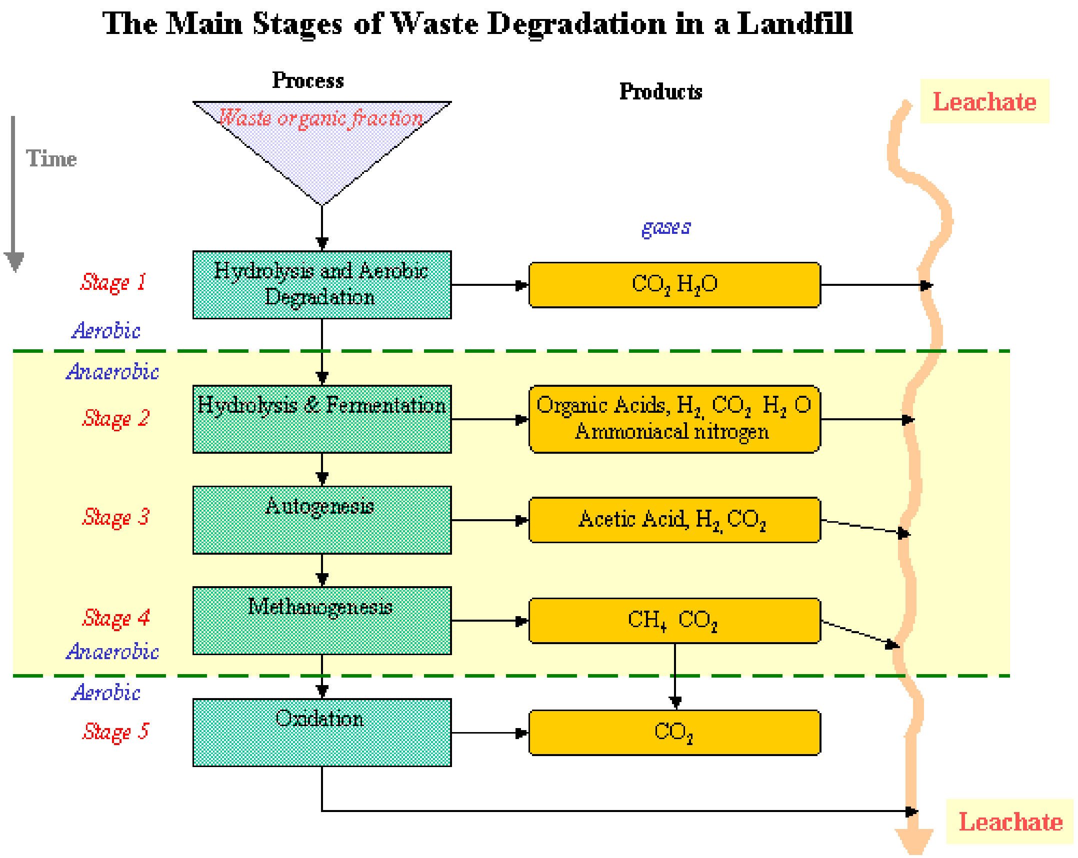


Figure 3: **Major phases of waste degradation in landfills**[29]

Landfills often accept waste over a 20- to 30-year period, so waste in a landfill may be undergoing several phases of decomposition at once. This means that older waste in one area might be in a different phase of decomposition than more recently buried waste in another area.[30]

3.1. Phase I. Hydrolysis/aerobic degradation

The hydrolysis/aerobic degradation stage occurs under aerobic (in the presence of oxygen) conditions. This occurs during the emplacement of the waste and for a period thereafter which depends on the availability of oxygen. The micro-organisms are of the aerobic type and they require oxygen for their metabolise. The heat generated from the exothermic degradation reaction can raise the temperature of the waste up to 70-90 °C. However, compacted waste achieves lower temperatures due

[29] http://www.landfill-site.com/assets/images/autogen/a_Waste-Degradation_Flowchart02.gif/ accessed September 10th, 2009
[30] http://www.atsdr.cdc.gov/hac/landfill/html/ch2.html/ accessed September 10th, 2009

to the lower availability of oxygen.[31] Common products of Phase I include CO_2, H_2O, NO_3, and other oxygenated compounds. Oxygen is rapidly depleted in the covered landfill cell by the action of heterotrophic aerobic microorganisms. Diffusion of oxygen into the void spaces is negligible; once the O_2 level drops below 10 to 15%, anaerobic microorganisms are activated.[32]

The aerobic stage lasts for only a matter of days or weeks depending on the availability of oxygen for the process, which in turn depends on the amount of air trapped in the waste, the degree of waste compaction and how quickly the waste is covered.

3.2. Phase II. Hydrolysis and Fermentation

Microorganisms which can tolerate reduced oxgen conditions become dominant. Carbohydrates, proteins and lipids are hydrolysed to sugars, which are then furter decomposed to carbon dioxide, hydrogen, ammonia, and organic acids. Proteins decompose via deaminisation to form ammonia and also carboxylic acids and carbon dioxide. The ammonia is derived largely from the deaminisation of protein, which also form carboxylic acids and carbon dioxide. The derived leachate contains ammoniacal nitrogen in high concentration. The organic acids are mainly acetic acid, but also propionic, butyric, lactic and formic acids and acid derivative products, and their formation depends on the composition of initial waste material. The temperature in the landfill drops to between 30 and 50°C during this stage. Gas concentration in the waste undergoing phase II decomposition may rise to levels of up to 80% carbon dioxide and 20% hydrogen.[33]

In the phase II, the pH of landfill liquids decreases due to the formation of organic acids and the effect of the elevated concentrations of CO_2 within the voids, which may partly dissolve and form carbonic acid, H_2CO_3.

[31] Williams (2005) p. 200-206
[32] Pichtel (2005) p. 310-315
[33] Williams (2005) p. 200-206

$CO_2 + H_2O \rightarrow H_2CO_3$

Equation 1: Formation of carbonic acid[34]

3.3. Phase III Acetogenesis

The organic acids formed in phase II are converted by acetogen microorganisms to acetic acid, acetic acid derivatives, carbon dioxide and hydrogen under anaerobic conditions. Other organisms convert carbohydrates directly to acetic acid in the presence of carbon dioxide and hydrogen. Hydrogen and carbon dioxide levels begin to decrease throughout of phase III. Low hydrogen levels promote the methane generating microorganisms, the methanogens, which generate methane and carbon dioxide from the organic acids and their derivatives generated in earlier phases. The acidic conditions of the acetogenic phase increase the solubility of metal ions and thus increase their concentration in leachate. In addition, organic acids, chloride ions, ammonium ions and phosphate ions, all in high concentration in the leachate, readily forms complexes with metal ions, causing further increases in solubilisation of metal ions. Hydrogen sulphide may also be produced throughout the anaerobic phases as the sulphate compounds in the waste are reduced to hydrogen sulphide by sulphate reducing microorganisms. Metal sulphides may be reaction product of the hydrogen sulphide and metal ions in solution.[35]

The pH of landfill liquids drops to 5 or even less due to the presence of the organic acids and the relatively high concentrations of CO_2 within the void spaces. There is no methane production during this phase, as methanogenic bacteria cannot tolerate acidic conditions. The biochemical oxygen demand (BOD), the chemical oxygen demand (COD), and the conductivity of the leachate increase significantly during phase III due to dissolution of the organic acids in the leachate. Also, because of the low pH values, metals and other inorganic constituents are solubilized during this phase.[36]

[34] Pichtel (2005) p. 310-315
[35] Williams (2005) p. 200-206
[36] Pichtel (2005) p. 310-315

3.4. Phase IV Methanogenesis

The methanogenesis phase is the main landfill gas generation phase, with the gas composition of typical landfill gas generated at approximately 60% methane and 40% carbon dioxide. The reactions are relatively slow and take many years for completion. The conditions maintain the anaerobic, oxygen-depleted environment of phase II and III. Low levels of hydrogen are required to promote organisms, the methanogens, which generate carbon dioxide and methane from organic acids, and their derivatives such as acetates and formates, both generated in the earlier phases. Methane may also form from the direct microorganism conversion of hydrogen and carbon dioxide to form methane and water. Hydrogen concentrations produced during phase II and III therefore fall to low levels during this IV phase. There are two classes of microorganisms which are active in methanogenic phase, the mesophilic bacteria which are active in the temperature range 30-35°C and the thermophilic bacteria active in the range of 45-65°C. Therefore, landfill gas can be generated during the methanogenic phase over a temperature range of 30-65°C, with an optimum temperature range of gas generation between 30 and 45°C. Where temperatures in the mass of waste drop below 15°C in cold weather conditions or in shallow sites, then the rate of biological degradation falls off.[37]

Many organic acids have already decomposed in the phase IV, so the pH rises and stabilizes at about 6,8 to 8. Consequently, metals which were previously soluble now precipitate. The concentration of BOD, the COD, and the conductivity also decline.[38]

Phase IV is the longest phase of the waste degradation, but may not commence until 6 months to several years after the waste is placed in the landfill, depending on the level of water content and water circulation. Significant concentration of methane is generated after 3 and 12 months, depending of the development of the anaerobic microorganisms and waste degradation products. Landfill gas will continue to be generated for periods of between 15 years and 30 years after final deposition of

[37] Williams (2005) p. 200-206
[38] Pichtel (2005) p. 310-315

waste, depending on waste and site characteristics. However, low levels of landfill gas may be generated up to 100 years after waste emplacement.[39]

3.5. Phase V Oxidation

The final stage of waste degradation results from the end of the degradation reactions, as the acids are used up in the production of the landfill gas methane and carbon dioxide. New aerobic microorganisms slowly replace the anaerobic forms and reestablished aerobic conditions. Aerobic microorganisms which convert residual methane to carbon dioxide and water may become established.[40]

[39] Williams (2005) p. 200-206
[40] Williams (2005) p. 199

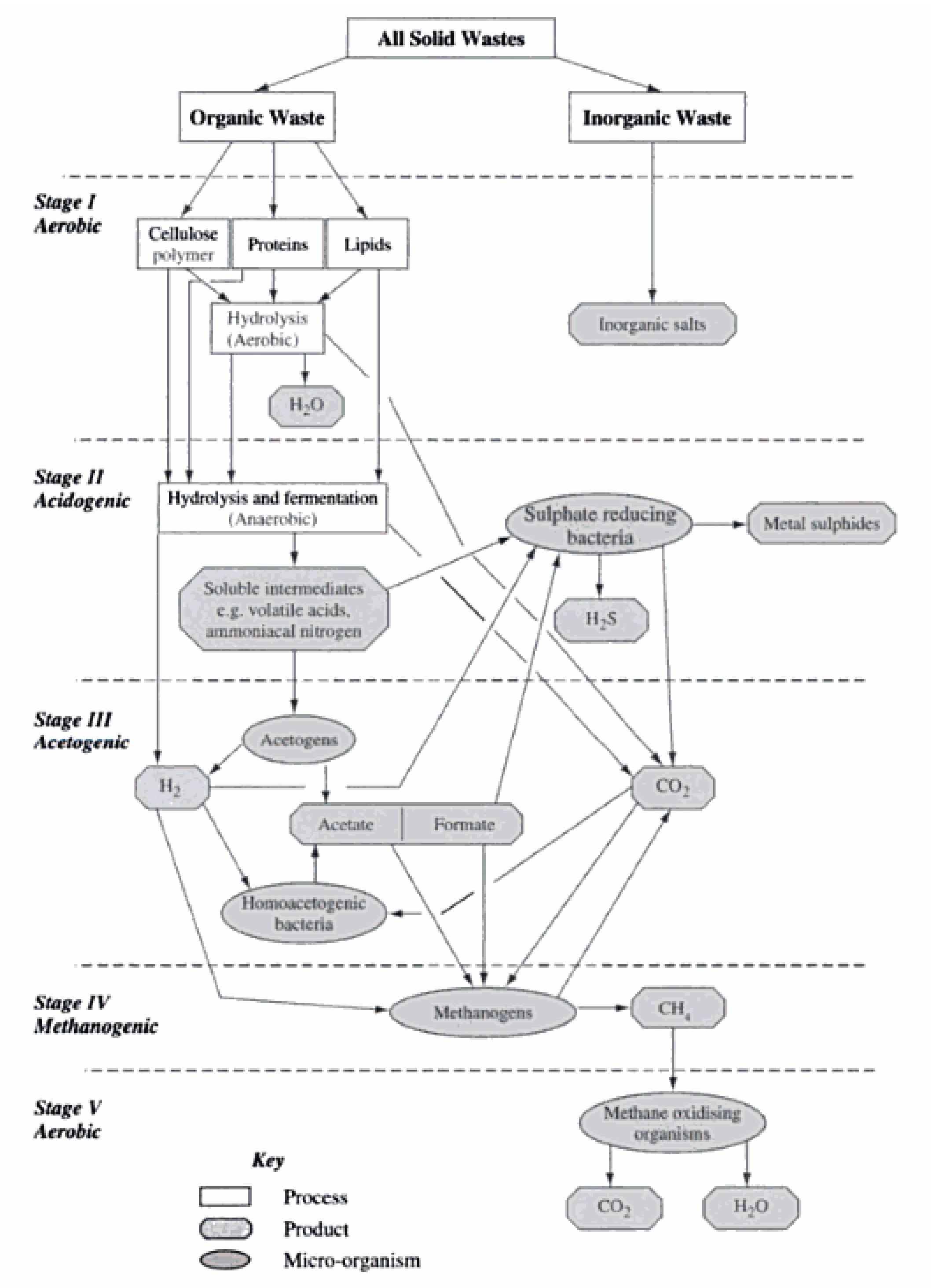


Figure 4: Details of the phases of waste degradation in landfills[41]

[41] Williams (2005) p. 200

3.6. Conditions for methane production

The rate and volume of landfill gas produced at a specific site depend on the characteristics of the waste (e.g., composition and age of the refuse) and a number of environmental factors (e.g., the presence of oxygen in the landfill, moisture content, and temperature).[42]

3.6.1. Site characteristics

Landfill sites with waste depth exceeding 5m tend to develop anaerobic conditions and greater quantities of landfill gas. Shallower sites allow air interchange and lower anaerobic activity and consequently lower landfill gas production.

3.6.2. Waste composition

The more organic waste present in a landfill, the more landfill gas (e.g., carbon dioxide, methane, nitrogen, and hydrogen sulfide) is produced by the bacteria during decomposition. The more chemicals disposed of in the landfill, the more likely NMOCs and other gases will be produced either through volatilization or chemical reactions.

3.6.3. Age of refuse

Generally, more recently buried waste (i.e., waste buried less than 10 years) produces more landfill gas through bacterial decomposition, volatilization, and chemical reactions than does older waste (buried more than 10 years). Peak gas production usually occurs from 5 to 7 years after the waste is buried.

3.6.4. Presence of oxygen in the landfill

Only when oxygen is used up bacteria will begin to produce methane. The more oxygen present in a landfill, the longer aerobic bacteria can decompose waste in Phase I. If waste is loosely buried or frequently disturbed, more oxygen is available, so that oxygen-dependent bacteria live longer and produce carbon dioxide and water for longer periods. If the waste is highly compacted, however, methane production will begin earlier as the aerobic bacteria are replaced by methane-producing

[42] Cheremisinoff (2003) p.103

anaerobic bacteria. Methane gas starts to be produced by the anaerobic bacteria only when the oxygen in the landfill is used up by the aerobic bacteria; therefore, any oxygen remaining in the landfill will slow methane production. Barometric highs will tend to introduce atmospheric oxygen into surface soils in shallow portions of a landfill, possibly altering bacterial activity. In this scenario, waste in Phase IV, for example, might briefly revert to Phase I until all the oxygen is used up again.[43]

3.6.5. Moisture content

Moisture content is the factor which most often limits methane production. This is to be expected in dry climates and where there is little opportunity for infiltration, and in wet climates where biological activity may be limited because landfills are typically designed to minimize the water infiltration.[44]

Lysimeter studies of the effect of moisture content on waste degradation recommend a minimum of 25 percent (wet basis) and 40 to 70 percent for optimum degradation. However, operating landfills greater than 35 percent moisture content can cause problems with equipment moving over the refuse.[45]

3.6.6. Temperature

The rate of methane generation can be increased, up to 100 times, when the temperature raises from 20 to 40 ºC. Moreover, in a deep landfill with a moderate water flux, landfill temperature of 30 to 45 ºC can be expected. The heat is a result of anaerobic decomposition process that can result in a temperature rise within the landfill environment. The heat flux from the landfill to the surroundings can also be resulted from the insulating effect of the solid waste.[46]

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[43] http://www.atsdr.cdc.gov/hac/landfill/html/ch2.html/ accessed June 10th, 2009
[44] Daniel (1993) p. 129
[45] Shearer (2001) p. 10
[46] Warith (2003) p. 69

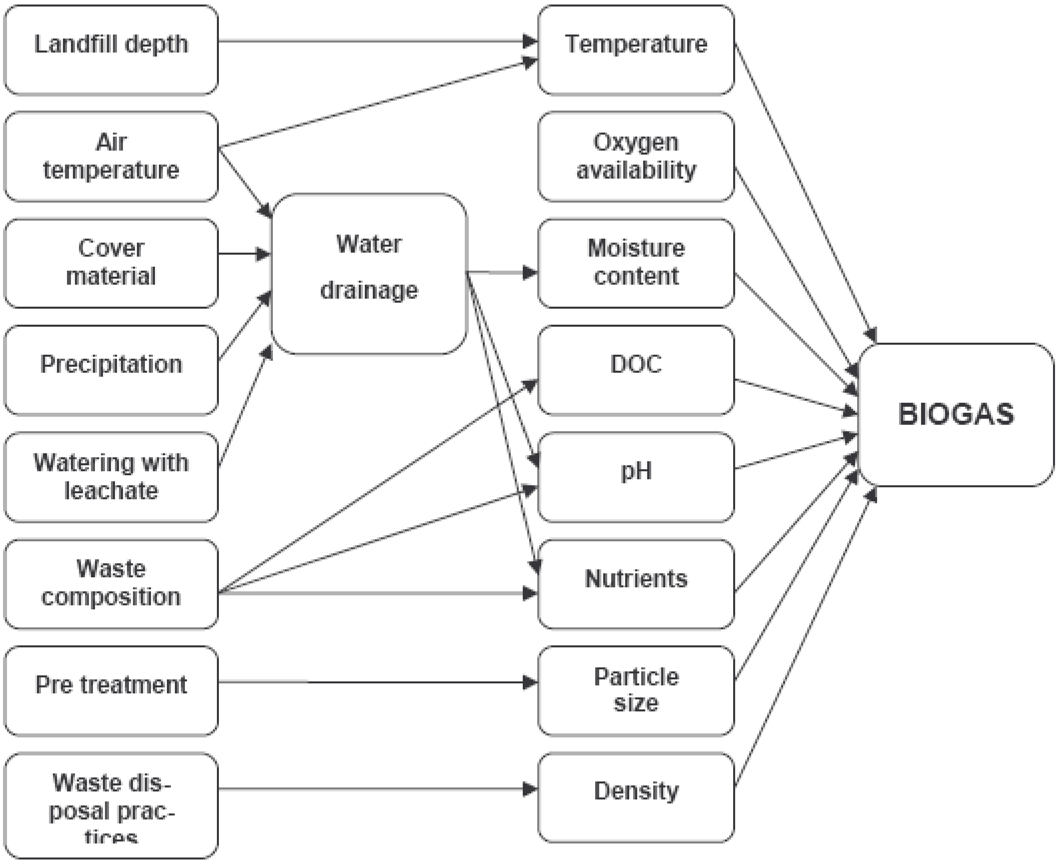

Figure 5: Parameters influencing bigas generation[47]

4. FUTURE PROJECTIONS REGARDING COMMUNAL WASTE QUANTITIES

In the thesis are described three different scenarios for the waste quantities generated, collected and landfilled. The base year for all scenarios is the year 2002 for which the quantities are quite known and were 290 kg per person in 2002. In all scenarios an increase in waste quantities for 3% per year is foreseen. It is also projected that in the year 2020 there will be generated 493 kg of municipal solid waste per person. On average, each European citizen generated 460 kg municipal waste in 1995. This amount rose to 520 kg per person in 2004, and a further increase to 680 kg per person is projected by 2020. The quantities of generated waste depends on the GDP and the consumption patterns, due to the fact that the GDP in 2020 will still be significantly lower in the Republic of Serbia than in the EU member states the lower

[47] European Environmental Agency, Waste management in Europe and Landfill Directive (2005) p. 5

value for the generated waste was used in the calculation. In total, this corresponds to an increase of almost 50 % in 25 years. This projected continuing increase in waste volumes is primarily due to an assumed sustained growth in private final consumption (i.e. an average growth in the EU 15 and EU 12 respectively of 2 % and 4 % per year by 2020) and a continuation of current trends in consumption patterns.[48]

In the figure 6 generated waste in the Republic of Serbia is shown.

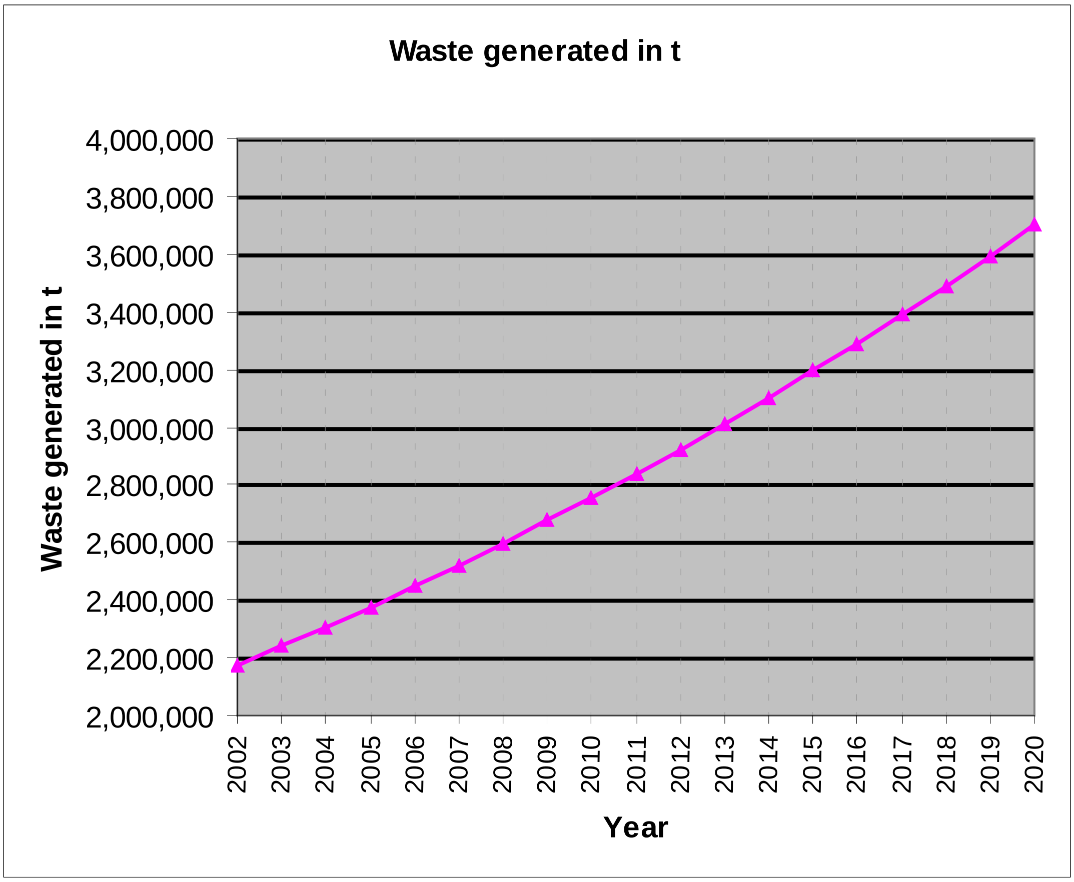

Figure 6: Waste generated in the Republic of Serbia

The difference in generated waste per person in Serbia and Europe is shown in figure 7.

[48] EEA Briefing (2008/1) p. 1

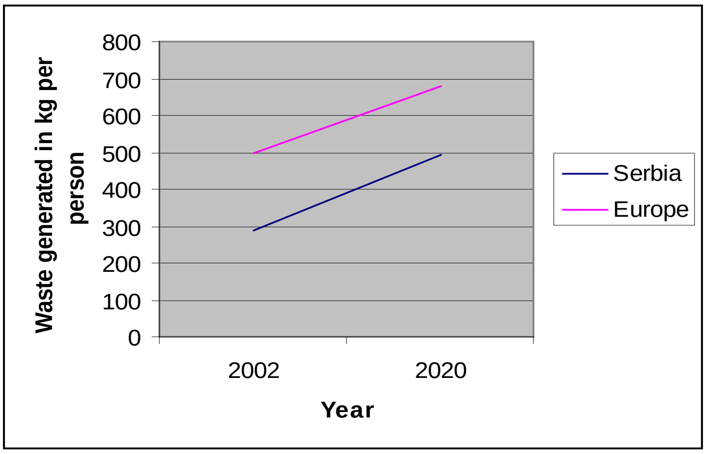

Figure 7: Waste generated in Serbia and Europe in year 2002 and 2020

4.1. The pessimistic scenario for waste volume

In the pessimistic scenario the waste management situation is shown as it is today and the data about waste volume is based on the year 2002 and is 290 kg per year. The waste volume increases for 3% per year and is 357 kg per person in the year 2010 and 494 kg per year in 2020.

The population included in the collection of waste is 60% in the year 2002. In the thesis an increase for 2% per year for the population is foreseen included in the collection of waste. In the year 2010 76% of population is included in the waste collection and in the year 2020 is 96%.

The pessimistic scenario is based on the assumption that all the collected waste goes to the landfill without any previous treatment. The landfills do not meet the minimal technical requirements. On the web page of the United Nations[49] the projections for the population growth for all countries can be found, including the Republic of Serbia with the population of Kosovo. In the UN projection there are only minor changes of the population, due to this reason in all scenarios the population is projected to 7.500.000 for all the years.

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[49] http://data.un.org/ accessed November 10th, 2008

Year	Total waste generated in t	Waste collected in t	Waste landfilled in t
2002	2,175,000	1,305,000	1,305,000
2003	2,240,250	1,388,955	1,388,955
2004	2,307,458	1,476,773	1,476,773
2005	2,376,681	1,568,610	1,568,610
2006	2,447,982	1,664,628	1,664,628
2007	2,521,421	1,764,995	1,764,995
2008	2,597,064	1,869,886	1,869,886
2009	2,674,976	1,979,482	1,979,482
2010	2,755,225	2,093,971	2,093,971
2011	2,837,882	2,213,548	2,213,548
2012	2,923,018	2,338,415	2,338,415
2013	3,010,709	2,468,781	2,468,781
2014	3,101,030	2,604,865	2,604,865
2015	3,194,061	2,746,892	2,746,892
2016	3,289,883	2,895,097	2,895,097
2017	3,388,579	3,049,721	3,049,721
2018	3,490,237	3,211,018	3,211,018
2019	3,594,944	3,379,247	3,379,247
2020	3,702,792	3,554,680	3,554,680

Table 3: Pessimistic scenario for generated waste

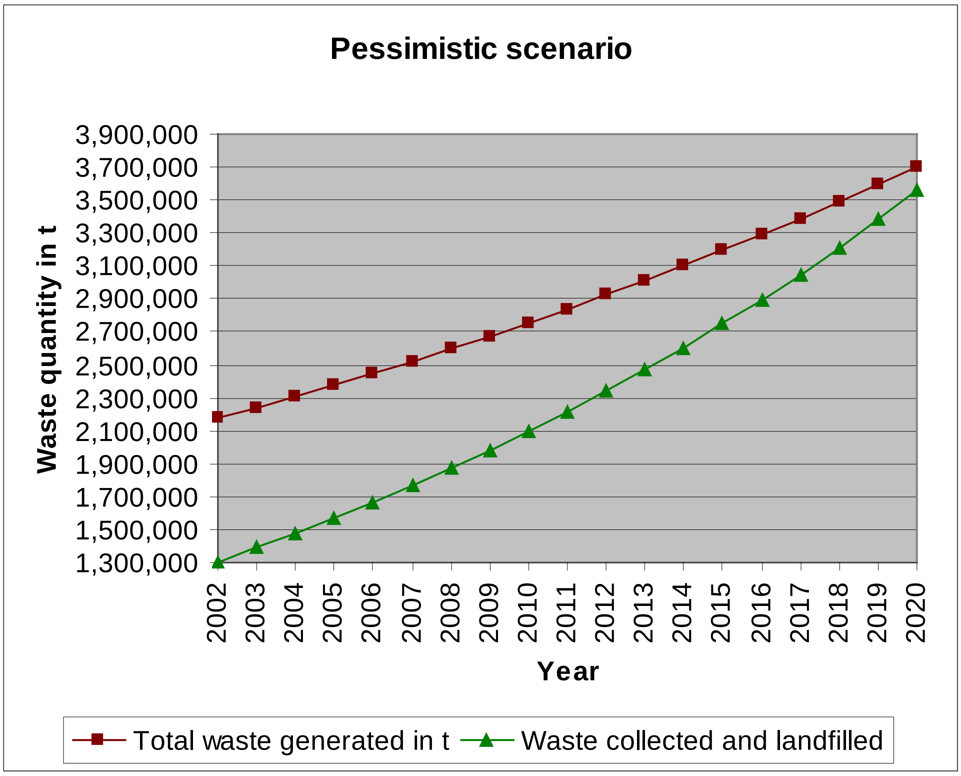

Figure 8: Waste generated in Gg – pessimistic scenario

4.2. The realistic scenario for waste volume

The realistic scenario is based on the data from the year 2002 and has the same assumptions as the pessimistic scenario. The difference between the pessimistic and realistic scenario is that not all the waste goes to the landfill. To the landfill goes all the waste until the year 2008. After the year 2008 the waste volume that goes to the landfill decreases for 3% per year. The diversion from the landfill in the year 2015 is 24% and in the year 2020 is 39%. That means the procentage of the total waste going to the lanfill in the year 2015 is 76% and in the year 2020 is 61%. The landfills partly meet the minimal technical requirements. The waste that is diverted from the landfills is recycled, used in biogas facilities, mechanical-biological treatment plants, composting plants or incineration plants. Emissions from these activities are not included in the presented calculations due to the fact that they have only minor emissions of GHG. For example composting contributes very little to national GHG inventories generating only 0.01–0.06% of global emissions.[50]

Year	Total waste generated in t	Collected waste in t	Landfilled waste in t
2002	2,175,000	1,305,000	1,305,000
2003	2,240,250	1,388,955	1,388,955
2004	2,307,458	1,476,773	1,476,773
2005	2,376,681	1,568,610	1,568,610
2006	2,447,982	1,664,628	1,664,628
2007	2,521,421	1,764,995	1,764,995
2008	2,597,064	1,869,886	1,813,789
2009	2,674,976	1,979,482	1,860,713
2010	2,755,225	2,093,971	1,905,514
2011	2,837,882	2,213,548	1,947,922
2012	2,923,018	2,338,415	1,987,652
2013	3,010,709	2,468,781	2,024,401
2014	3,101,030	2,604,865	2,057,843
2015	3,194,061	2,746,892	2,087,638
2016	3,289,883	2,895,097	2,113,421
2017	3,388,579	3,049,721	2,134,805
2018	3,490,237	3,211,018	2,151,382
2019	3,594,944	3,379,247	2,162,718
2020	3,702,792	3,554,680	2,168,355

Table 4: Projection of waste quantities

[50] Amlinger (2008), pg. 47

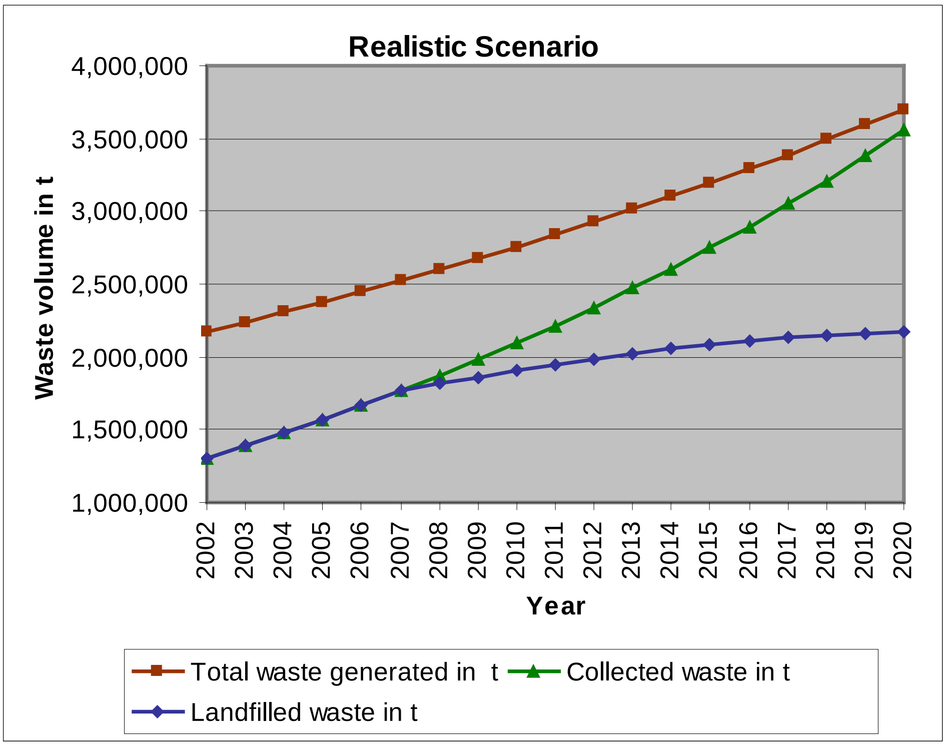

Figure 9: Waste volume

4.3. The optimistic scenario for waste volume

The optimistic scenario is based on the data from the year 2002 and has the same assumptions as the realistic scenario. The difference between the optimistic and realistic scenario is that after the year 2008 the waste volume that goes to the landfill decreases for 4% per year. The diversion from the landfill in the year 2015 is 32% and in the year 2020 is 52%. That means the percentage of the total waste going to the landfill in the year 2015 is 68% and in the year 2020 is 48%. The landfills fully meet all technical requirements.

The general requirements that should be considered for all classes of landfills according to the EU landfill Directive are:

- Requiremnts regarding location
- Water control and leachate management
- Protection of soil and water
- Gas control

- Nuisances and hazards
- Stability
- Barriers
- Waste acceptance

Year	Total waste generated in t	Collected waste in t	Landfilled waste in t
2002	2,175,000	1,305,000	1,305,000
2003	2,240,250	1,388,955	1,388,955
2004	2,307,458	1,476,773	1,476,773
2005	2,376,681	1,568,610	1,568,610
2006	2,447,982	1,664,628	1,664,628
2007	2,521,421	1,764,995	1,764,995
2008	2,597,064	1,869,886	1,795,090
2009	2,674,976	1,979,482	1,821,123
2010	2,755,225	2,093,971	1,842,694
2011	2,837,882	2,213,548	1,859,380
2012	2,923,018	2,338,415	1,870,732
2013	3,010,709	2,468,781	1,876,274
2014	3,101,030	2,604,865	1,875,503
2015	3,194,061	2,746,892	1,867,887
2016	3,289,883	2,895,097	1,852,862
2017	3,388,579	3,049,721	1,829,833
2018	3,490,237	3,211,018	1,798,170
2019	3,594,944	3,379,247	1,757,208
2020	3,702,792	3,554,680	1,706,247

Table 5: Projection of waste quantities

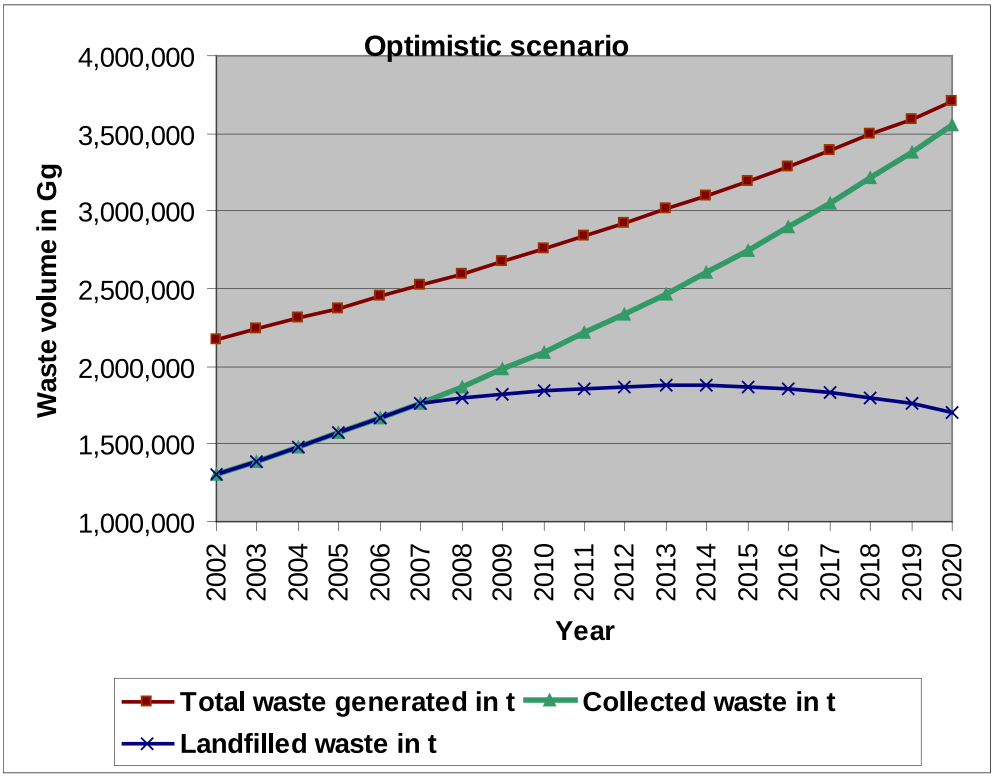

Figure 10: Waste volume – optimistic scenario

The figure 11 shows the comparison of quantities of waste according to different scenarios.

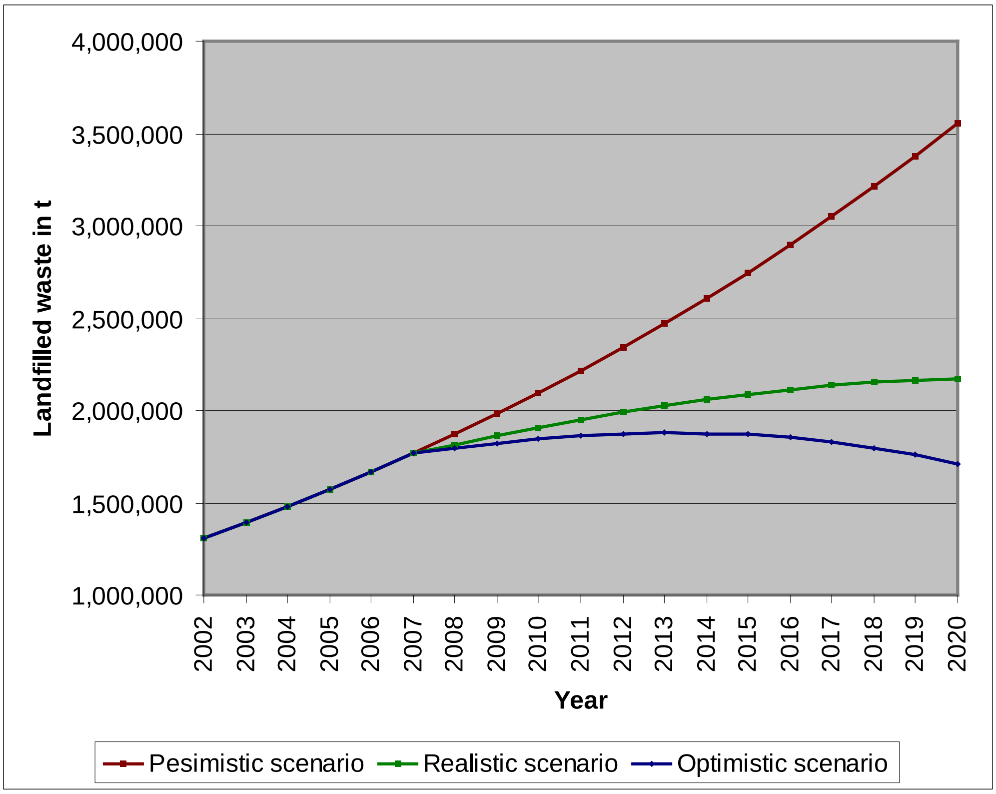

Figure 11: Comparison of different scenarios

5. CALCULATION OF METHANE EMISSIONS FROM WASTE

Waste management and treatment of industrial and municipal waste are sources of GHGs emissions. The inventory covers CH_4 emissions resulting from solid waste disposal on land. This section does not include estimates of emission of N_2O from wastewater handling and municipal sewage.

The figure 12 shows how the global anthropogenic methane emissions are allocated by source.

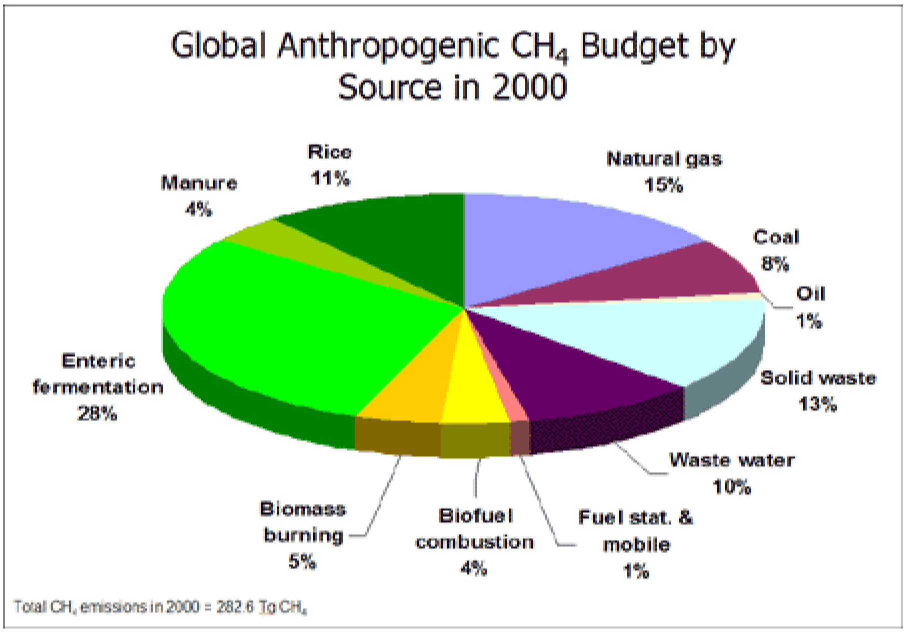

Figure 12: Global anthropogenic CH_4 budget by source in 2000[51]

5.1. Source category description

Methane is emitted during anaerobic fermentation of degradable organic substances in solid waste disposal sites in processes, which may last several decades. If waste were not disposed of on solid waste disposal sites, the degradation would take place in aerobic conditions without methane formation. Methane emissions from waste disposal are thus of anthropogenic origin and, consequently, a constituent part of national GHG inventories in accordance to IPCC methodology.

[51] EPA; Compilation 2002/ accessed November 12th, 2008

5.2. Methodological issues

To ensure accuracy and comparability between inventories from different countries, the Intergovernmental Panel on Climate Change (IPCC) developed methodologies to estimate greenhouse gases from the most important anthropogenic sources of greenhouse gases within the categories of energy, industrial processes and product use, agriculture, forestry and other land use, and waste.

The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories[52] and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories[53] described two methods for estimating CH_4 emissions from SWDS: the mass balance method and the First Order Decay (FOD) method.[54]

The default method for CH_4 emissions from solid waste disposal sites estimates these emissions with a simple equation requiring waste disposal data only for the inventory year. An assumption of this method is that all CH_4 emissions are generated in the year in which the waste is disposed.

IPCC guidelines 2006[55] describe a more precise method, which considers that methane emissions from disposed-of waste are released over a longer period of time. The so-called First Order Decay (FOD) method is based on the assumption of an exponential time-dependent decline of emissions. Annual emissions are thus partial sums of emissions from waste disposed of in previous periods. The FOD method is more precise, but requires data on quantity, composition and disposal conditions for a period of 20 to 30 years prior to the year for which emissions are determined. At the same time, it is necessary to know the half-life of methane generation.[56]

The essential difference between the results obtained by these two methods is in emissions of the reference year and in the response of certain emissions to waste-management measures. The quantities of disposed of waste have been rising in the

[52] 1996 Guidelines, IPCC (1997) p. 3
[53] GPG2000, IPCC (2000) p. 5
[54] 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006) p.5
[55] 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006) p.6
[56]Weitz (2008) p. 636-40

last 30 years and therefore emissions calculated according to the first order decay method for the reference year are, as a rule, lower. The first order decay method takes into account also the contribution of waste disposed of in the past, therefore the reduction of quantity of disposed of biodegradable waste in certain emissions shows only after a certain time delay. However, it needs to be stressed that emissions that are cumulatively determined according to both methods in the limit of a long period of time do not differ, assuming the oxidation factor remains unchanged.

Consistent time-series data on waste disposal in the Republic of Serbia are much too short for satisfactory determination of emissions in accordance with the first order decay method for the basis year. Since the method applied must be the same for all years, the for the calculations in this thesis the default method for estimating emissions has been applied.

The default IPCC methodology applies the following equation for determining the emission of methane:

$$E_{CH_4} = (MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12 - R) \times (1 - OX)$$

Equation 2: Calculation of emissions of CH_4 [57]

where:

E_{CH_4} = Annual emission of CH_4

MSW_T = total MSW generated (Gg/yr)

MSW_F = fraction of MSW disposed to solid waste disposal sites

MCF = methane correction factor (fraction)

DOC = degradable organic carbon (fraction)

DOC_F = fraction DOC dissimilated

F = fraction of CH4 in landfill gas (default is 0.5)

$\frac{M_{CH_4}}{M_C}$ = Ratio of molecular weights of methane and carbon (16/12)

R = recovered CH4 (Gg/yr)

OX = oxidation factor (fraction - default is 0)

[57] 1996 Guidelines (1997) p. 5

The basic parameter for determining methane emissions is the total amount of waste disposed of at solid waste disposal sites and fraction of DOC. The methane conversion factor *MCF* defines the dependence of methane release on the degree of anaerobic conditions on solid waste disposal sites. IPCC methodology suggests different factors depending on how solid waste disposal sites are managed.

5.2.1. Type of Site Methane Correction Factor (MCF) Default Values

Type of site	Methane Correction Factor (MCF) Default Values
Managed – anaerobic	1,0
Managed – semi-aerobic	0,5
Unmanaged 3 – deep (>5 m waste) and /or high water table	0,8
Unmanaged 4 – shallow (<5 m waste)	0,4
Uncategorised SWDS	0,6

Table 6: Methane Correction Factors

In the calculation the methane correction factor for uncategorized SWDS is used.

5.2.1.1 Anaerobic managed solid waste disposal sites:

These must have controlled placement of waste (i.e., waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include at least one of the following:

- cover material;
- mechanical compacting;
- levelling of the waste.

5.2.1.2 Semi-aerobic managed solid waste disposal sites:

These must have controlled placement of waste and will include all of the following structures for introducing air to waste layer:

- permeable cover material;
- leachate drainage system;
- regulating pondage;
- gas ventilation system.

5.2.1.3. Unmanaged solid waste disposal sites – deep and/or with high water table:

All SWDS not meeting the criteria of managed SWDS and which have depths of greater than or equal to 5 metres and/or high water table at near ground level. Latter situation corresponds to filling inland water, such as pond, river or wetland, by waste.

5.2.1.4. Unmanaged shallow solid waste disposal sites;

All SWDS not meeting the criteria of managed SWDS and which have depths of less than 5 metres.

Uncategorised solid waste disposal sites:

Only if countries cannot categorise their SWDS into one of the above four categories of managed and unmanaged SWDS, the MCF for this category can be used.[58]

5.3. Calculation of GHG in pessimistic scenario

The pessimistic scenario for the calculation GHG is based on the pessimistic scenario for the waste volume. In the Republic of Serbia the landfills do not meet the minimal technical requirements and the covering of the disposed waste is used only in a few landfills. The quantities of the disposed waste that is covered are not known, due to this reason in the calculation MCF factor 0.6 for the uncategorized SWDS is used.
In the IPCC 1996 guidelines[59] there is no default value for DOC content in MSW for the Republic of Serbia, but for the Eastern Europe it is between 0.15-0.17. In the calculation value 0.17 for a DOC in the MSW is used.

Degradable organic carbon is the organic carbon that is accessible in biochemical decomposition, and should be expressed as Gg C per Gg waste. It is based on the composition of waste and can be calculated from a weighted average of the carbon content of various components of the waste stream. The following equation, as presented[60]:

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[58] 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006) p. 8
[59] IPCC 1996 guidelines p. 6
[60] 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006) p. 9

$$DOC = (0.4 \bullet A) + (0.17 \bullet B) + (0.15 \bullet C) + (0.3 \bullet D)$$

Equation 3: Calculation of DOC in municipal solid waste

where:

A = Fraction of MSW that is paper and textiles

B = Fraction of MSW that is garden waste, park waste or other non-food organic putrescibles

C = Fraction of MSW that is food waste

D = Fraction of MSW that is wood or straw

The use of national values is encouraged if data is available. National values can be obtained by performing waste generation studies and sampling of different SWDS within a country. In the Republic of Serbia there is no reliable data on the fraction of DOC in MSW, also in the IPCC 1996 guidelines[61] there is no default value for DOC content in MSW for the Republic of Serbia, but for the Eastern Europe it is between 0.15-0.17. In the calculation value 0.17 for a DOC in the MSW is used.

DOCF is an estimate of the fraction of carbon that is ultimately degraded and released from SWDS, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in SWDS. Fraction dissimilated DOC (DOCF) is the portion of DOC that is converted to landfill gas. To date, estimates of how much carbon may be dissimilated have relied on a theoretical model that varies only with the temperature in the anaerobic zone of a landfill:

$0.014T + 0.28$, where T = temperature. If one assumes that the temperature in the anaerobic zone of a SWDS remains constant at about 35^o C, regardless of ambient temperature, this method yields a figure of 0.77 dissimilated DOC, due this fact in the calculation default value 0.77 is used.[62]

Landfill gas consists mainly of CH_4 and carbon dioxide (CO_2). The CH_4 fraction F is usually taken to be 0.5, but can vary between 0.4 and 0.6, depending on several factors including waste composition (e.g. carbohydrate and cellulose). The

[61] IPCC 1996 guidelines p. 7

[62] IPCC 1996 guidelines p. 8

concentration of CH_4 in recovered landfill gas may be lower than the actual value because of potential dilution by air, so F values estimated in this way will not necessarily be representative. The default value used for the fraction of carbon released as methane is 0.5.[63]

Conversion ratio which converts carbon to methane is 16/12.

Potential Methane Generation Rate per Unit of waste '(Gg CH_4/Gg MSW) = Fraction of DOC in 'MSW X Fraction of DOC in 'MSW X Fraction of DOC which actually 'Degrades X Fraction of Carbon Released as Methane X Conversion Ratio.
Potential Methane generation per unit of waste in the pessimistic scenario is 0.09.

Methane recovery is the amount of CH_4 generated at SWDS that is recovered and burned in a flare or energy recovery device. CH_4 recovered and subsequently vented should not be subtracted from gross emissions. The default value for methane recovery is zero. This default should only be changed when references documenting the amount of methane recovery are available. Recovered gas volumes should be reported as CH_4 not as landfill gas, as landfill gas contains only a fraction of CH_4. Reporting based on metering of all gas recovered for energy utilisation and flaring is consistent with *good practice*.
In the pessimistic scenario it is foreseen that in the Republic of Serbia there is no landfill gas recovery.

The oxidation factor (OX) reflects the amount of CH_4 from SWDS that is oxidised in the soil or other material covering the waste. If the oxidation factor is zero, no oxidation takes place, and if OX is 1 then 100% of CH_4 is oxidised. Studies show that sanitary landfills tend to have higher oxidation results than unmanaged dump sites. For example, the oxidation factor at sites covered with thick and well-aerated material may differ significantly from sites with no cover or where large amounts of CH_4 can escape through cracks in the cover.[64]

[63] 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006) p. 10
[64] 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006) p. 12

CH_4 generated at SWDS can be recovered and combusted in a flare or energy device. The amount of CH_4 which is recovered is expressed as R in Equation 2. If the recovered gas is used for energy production, then the resulting greenhouse gas emissions should be reported under the Energy Sector. Emissions from flaring are however not significant, as the CO_2 emissions are of biogenic origin and the CH_4 and N_2O emissions are very small, so *good practice* in the waste sector does not require their estimation. However, if it is wished to do so these emissions should be reported under the waste sector.

The default value for CH_4 recovery is zero. CH_4 recovery should be reported only when references documenting the amount of CH_4 recovery are available[65]. In the Republic of Serbia the systems for the landfill gas recovery are not installed. In the pessimistic scenario it is assumed that, there will be no system for landfill gas recovery until the year 2020.

The gross annual methane generation is 68.33 Gg in the year 2002, 109.64 Gg in 2010, 143.83 Gg in 2015 and 186.12 Gg in the year 2020.

[65] 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006) p. 12

According to the pessimistic scenario the increasee of the landfill gas is illustrated in figure13.

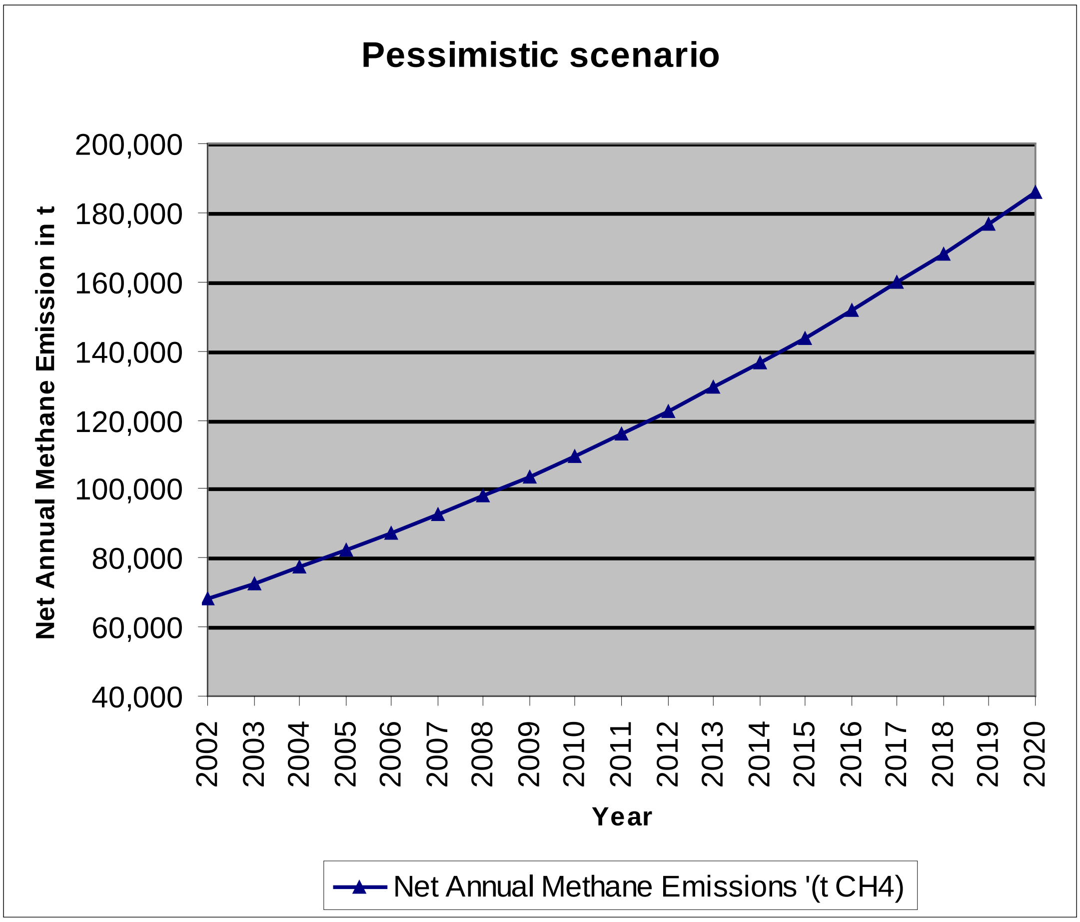

Figure 13: Net Annual Methane Emissions in Gg in pessimistic scenario

	A	B	C	D	E	F	G	H	J	K	L	M	N
Year	A total Annual MSW Disposed 'to SWDSs(Gg MSW)	Methane Correction Factor'(MCF)	Fraction of DOC in 'MSW	Fraction of DOC which actually 'Degrades	Fraction of Carbon Released as Methane	Conversion Ratio	Potential Methane Generation Rate per Unit of waste '(Gg CH_4/Gg MSW)	Realised (Country specific Methane Generation Rate per Unit of (Gg CH4/ 'Gg MSW)	Gross Annual Methane Generation '(Gg CH_4)	Recovered Methane per Year '(Gg CH_4)	Net Annual Methane Generation '(Gg CH_4)	One Minus Methane Oxidation Correction 'Factor	Net Annual Methane Emissions '(Gg CH_4)
							G= (C x D x E x F)	H= (B x G)	J= (H x A)		L= (J - K)		N= (L x M)
2002	1,305	0.6	0.17	0.77	0.5	16/12	0.09	0.05	68.33	0	68.33	1	68.33
2003	1,389	0.6	0.17	0.77	0.5	16/12	0.09	0.05	72.73	0	72.73	1	72.73
2004	1,477	0.6	0.17	0.77	0.5	16/12	0.09	0.05	77.32	0	77.32	1	77.32
2005	1,569	0.6	0.17	0.77	0.5	16/12	0.09	0.05	82.13	0	82.13	1	82.13
2006	1,665	0.6	0.17	0.77	0.5	16/12	0.09	0.05	87.16	0	87.16	1	87.16
2007	1,765	0.6	0.17	0.77	0.5	16/12	0.09	0.05	92.42	0	92.42	1	92.42
2008	1,870	0.6	0.17	0.77	0.5	16/12	0.09	0.05	97.91	0	97.91	1	97.91
2009	1,979	0.6	0.17	0.77	0.5	16/12	0.09	0.05	103.65	0	103.65	1	103.65
2010	2,094	0.6	0.17	0.77	0.5	16/12	0.09	0.05	109.64	0	109.64	1	109.64
2011	2,214	0.6	0.17	0.77	0.5	16/12	0.09	0.05	115.90	0	115.90	1	115.90
2012	2,338	0.6	0.17	0.77	0.5	16/12	0.09	0.05	122.44	0	122.44	1	122.44
2013	2,469	0.6	0.17	0.77	0.5	16/12	0.09	0.05	129.27	0	129.27	1	129.27
2014	2,605	0.6	0.17	0.77	0.5	16/12	0.09	0.05	136.39	0	136.39	1	136.39
2015	2,747	0.6	0.17	0.77	0.5	16/12	0.09	0.05	143.83	0	143.83	1	143.83
2016	2,895	0.6	0.17	0.77	0.5	16/12	0.09	0.05	151.59	0	151.59	1	151.59
2017	3,050	0.6	0.17	0.77	0.5	16/12	0.09	0.05	159.68	0	159.68	1	159.68
2018	3,211	0.6	0.17	0.77	0.5	16/12	0.09	0.05	168.13	0	168.13	1	168.13
2019	3,379	0.6	0.17	0.77	0.5	16/12	0.09	0.05	176.94	0	176.94	1	176.94
2020	3,555	0.6	0.17	0.77	0.5	16/12	0.09	0.05	186.12	0	186.12	1	186.12

Table 7: Net Annual Methane Emissions

5.4. Emissions of methane in realistic scenario

The realistic scenario is based on the realistic scenario for waste volume.
The methane correction factor is 0,6 from the year 2002 until the year 2012. This correction factor is for uncategorized landfills and increased in 2013 and 2014 to 0,8 and 0,9 respectively. From the year 2015 the value for methane correction factor is 1 as is for the managed landfills.

The fraction of DOC in MSW is 0,17 from the year 2002 until the year 2009, later starts to slowly decrease and is 0,10 beyond the year 2015. The fraction of DOC is decreasing, due to the reason that organic part in MSW is diverted from the landfills to the composting plants and biogas plants.

The recovery of landfill gas starts in the year 2010 with recovery of 10 Gg of methane. After the year 2010 the systems for recovery of landfill gas will be applied in more landfills and the recovered landfill gas will increase to 60 Gg of methane in the year 2020.

In figure 14 the realistic scenario is shown for the methane emissions from the MSW. The emissions are increasing until the year 2009, mainly because the volume of the landfilled waste is increasing. The landfill gas starts to decrease until the year 2010, because the fraction of DOC in MSW is decreasing and later because the systems for the landfill gas recovery are applied.

The increase of net annual emissions of methane in the year 2013 and 2014 is because the landfills are better managed and the generation of methane is higher, but the systems for recovery of the landfill gas are not in operation yet. After the year 2015 all landfills are managed and also the systems for recovery of the landfill gas are already in use and this results in a decrease of the net annual emission of methane.

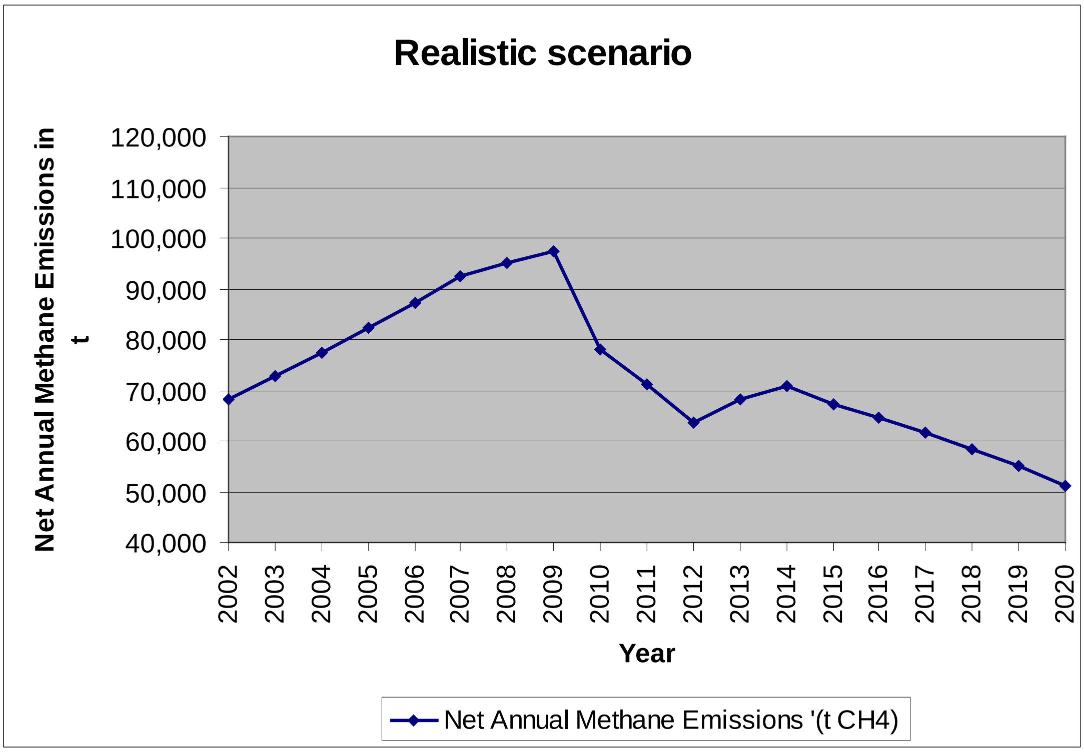

Figure 14: Net Annual Methane Emissions in Gg in realistic scenario

5.5. Emissions of methane in the optimistic scenario

The main difference between the realistic scenario and optimistic scenario is in the volume of landfilled waste and in the fraction of DOC in MSW.

The methane correction factor is the same as in the realistic scenario and is 0,6 from the year 2002 until the year 2012. This correction factor is for uncategorized landfills and increases in 2013 and 2014 to 0,8 and 0,9 respectively. From the year 2015 the value for methane correction factor is 1 as is for managed landfills.

The fraction of DOC in MSW is 0,17 from the year 2002 until the year 2008, later starts to slowly decrease and is 0,10 beyond the year 2014. The fraction of DOC is decreasing, due to the reason that organic part in MSW is diverted from the landfills to the composting plants and biogas plants.

Also the quantity of the recovery of landfill gas is the same as in the realistic scenario. The difference between realistic scenario and optimistic scenario is in the procentage of the recovery of the landfill gas. In realistic scenario percentage of recovered gas is 11,4% in the year 2010 and 53,9% in the year 2020. In optimistic scenario percentage of recovered gas is 12,6% in the year 2010 and 68,5% in the year 2020.

According to the optimistic scenario figure 15 shows the methane emissions from municipal solid waste. The emissions are increasing until the year 2009, mainly because the volume of the landfilled waste is increasing. The landfill gas starts to decrease until the year 2010, because the fraction of DOC in MSW is decreasing and later because the systems for the landfill gas recovery are applied.

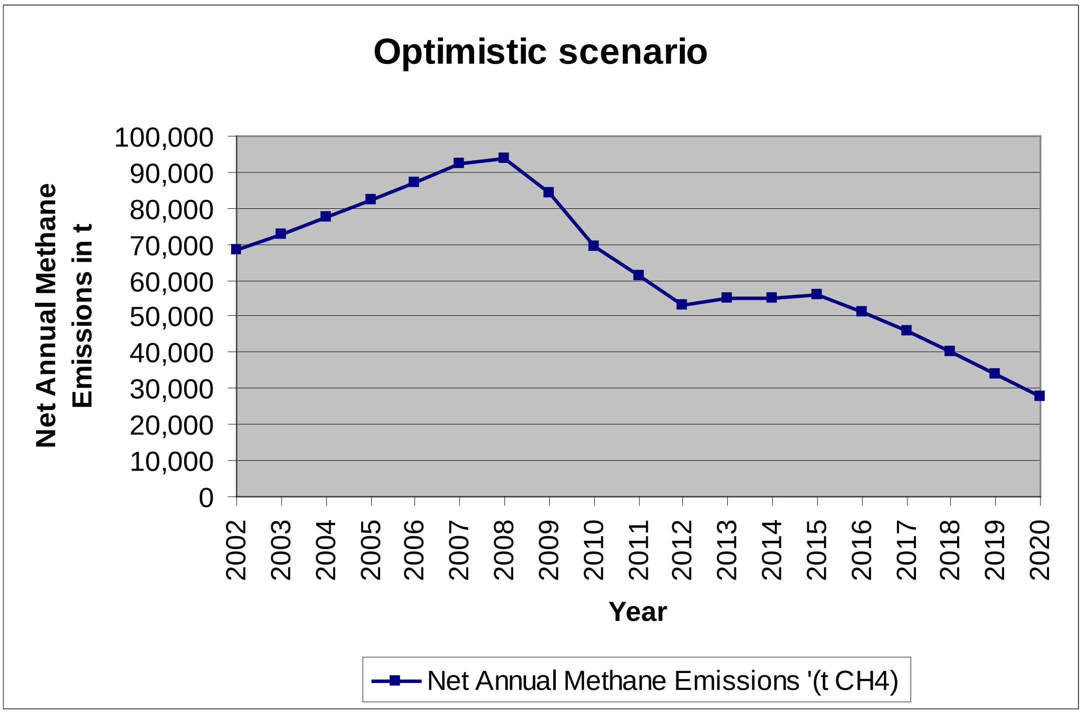

Figure 15: Net Annual Methane Emissions – optimistic scenario

5.6. Uncertainties and time-series consistency

Parameters affecting key uncertainties:[66]

- Quantity and composition of landfilled waste
  - waste composition may change over time
  - actual emission estimates are still dependent on data extrapolations from earlier years which are in general of lower quality
  - Data of industrial waste is often of lower quality

- Quantity of CH_4 that is actually generated
  - Small changes in the assumed DOC value can result in large variations.
  - DOC values are widely differing among the countries (as different waste compositions)
  - DOCf - Fraction of DOC actually dissimilated to landfill gas

- Quantity of CH_4 that is actually emitted
  - Degree of oxidation that occurs as the gas diffuses through the landfill cover material (presence, thickness and other characteristics of SWDS cover material).
  - Methane recovery

The uncertainty in the calculation is estimated to:
Uncertainty of activity data amounts to 40%.
Uncertainty of emission factor amounts to 70%

[66] Deuber (2005) pg. 5

6. LEGISLATION FRAMEWORK IN THE EUROPEAN COMMUNITY

The waste management policy of the European Union set out in the various Environment Action Programmes is implemented through the Waste Management Strategy and subsequent legislative measures such as Directives, Regulations and Decisions of the European Union on specific waste management issues.[67]

The Member States began taking national measures to control and manage waste, which then led to the Waste Framework Directive and the Hazardous Waste Directive, both adopted in 1975, and later to the Waste Shipment Regulation. These three pieces of legislation put in place the basis of the regulatory structure on waste. They define waste and other key concepts, ensure waste is handled without causing damage to the environment or human health, and impose controlled conditions for moving waste throughout the EU.[68]

The EU strategy on waste has developed into the concept of the »hierarchy of waste management«. The hierarchy was originally developed through the aims of the original 1975 Waste Framework Directive which encouraged waste reduction, re-use and recovery with disposal as the least desirable option. The hierachy was formally adopted in the 1989 EU Community Strategy for Waste Management.[69]

[67] Williams (2005) p. 8
[68] European Commision: EU Waste Policy – The Story behind the Strategy (2005) p. 8
[69] Williams (2005) p. 9

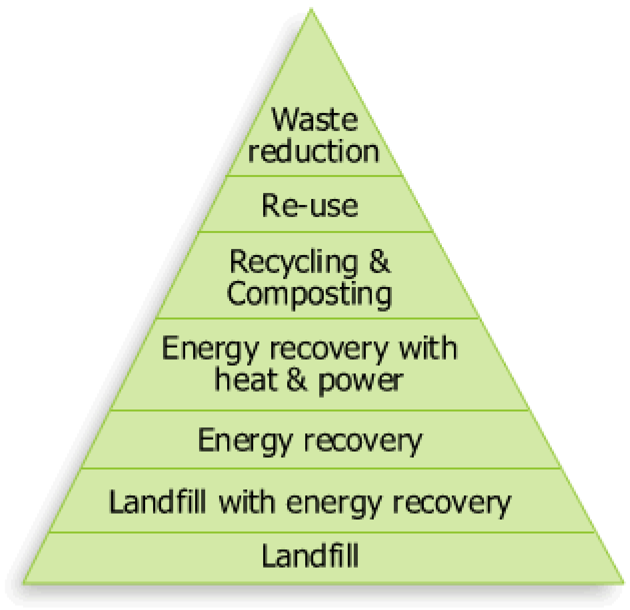

Figure 16: Waste Hierarchy[70]

6.1. European Waste Legislation

The aims of the EU Strategy on sustainable waste management and the objective of moving waste management options up the waste hierarchy may be achieved by a range of policy instruments. One of the most important is regulatory policy and is based on the extensive EU legislative and regulatory provisions covering the management of waste. A number of key European Community Directives, Regulations and Decisions influence the management of waste across the EU including:[71]

- Directive 2008/98/EC of the European Parliament and of the Council of 5 April 2006 on waste
- Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste
- Council Directive 2000/76/EC on incineration of waste
- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste
- European Parliament and Council Directive 94/62/EC - Packaging and packaging waste

[70] http://www.surreywaste.info/images/instances/0000466E7B35.C0A801BA.00007CC0.0030.gif /accessed September 20th, 2009
[71] Williams (2005) p. 13

- Directive 2006/66/EC of the European Parliament and of the Council - Disposal of spent batteries and accumulators
- Directive 2000/53/EC of the European Parliament and of the Council - End-of-life vehicles
- Directive 2002/96/EC of the European Parliament and of the Council - Waste electrical and electronic equipment (WEEE)

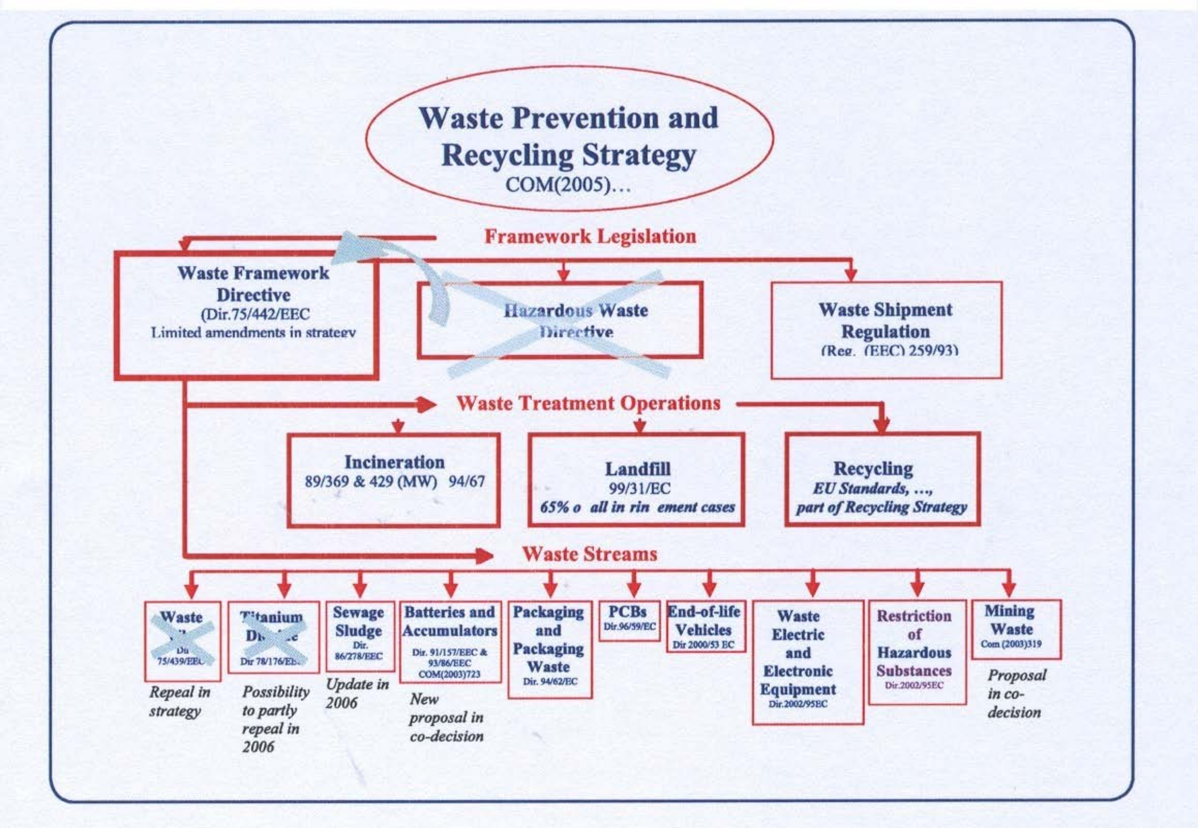

Figure 17: Waste legislation framework[72]

7. LEGISLATION FRAMEWORK IN THE REPUBLIC OF SERBIA

The legal/legislative and institutional framework is founded in the Constitution of the Republic of Serbia adopted in September 2006, which proclaims that every citizen has the right to a healthy environment and the right to timely and full information about the state of the environment. Everyone is accountable for the protection of the

[72] http://www.etrma.org/images/EU_Waste_legislation.jpg/ accessed September 20th, 2009

environment, and is obliged to preserve and improve it and to protect natural rarities and scientific, cultural and historical heritage, as well as goods of public interest. stipulating the right to a healthy environment and the duty of all, in line with the law, to protect and enhance the environment.[73]

Environmental legislation in Serbia consists of large number of laws and regulations (approximately 100). Legislative, executive and judicial powers are mostly practiced through the legally prescribed scope of competences of republic authorities. According to the law, certain competences are delegated to the autonomous province and the local government.

The new legal framework for environmental protection was introduced in 2004 in the Republic of Serbia by the Law on Environmental Protection, the Law on Strategic Environmental Assessment, the Law on Environmental Impact Assessment, and the Law on Integrated Prevention and Pollution Control.

The most significant issues covered by the Law on Environmental Protection include fundamental principles of environmental protection; management and protection of natural resources; measures and conditions of environmental protection; environmental programmes and plans; industrial accidents; public participation; a monitoring and information system; clearly identified competences of the Environmental Protection Agency; reporting; financing environmental protection; and inspection services and fines. The new laws are harmonised with the EU Directives on Environmental Impact Assessment (85/337/EEC), Strategic Impact Assessment (2001/43/EC), IPPC (96/61/EC) and Public Participation (2003/35/EC). The Ministry of Science and Environmental Protection Directorate for Environmental Protection (DEP) has the key responsibility in environmental protection.[74]

[73] Economic Commission for Europe: Environmental Performance Reviews: Republic of Serbia, (2007) p. 19
[74] Dedijer at. et. (2007) p. 3-5

The Law on Environmental Protection includes several articles regarding waste management. Article No.3 defines that waste management is also between activities affecting the environment.[75]

Article No. 9 is important because it introduces the integration principle - state authorities, those of the autonomous province and local self-governance unit shall provide the integration of environmental protection and enhancement into all sector policies by implementing mutually harmonized plans and programs and by implementing regulations through permit system, technical and other standards and norms, by financing, through incentive and other measures of environmental protection.

Article No. 10 defines the need to implement special Law regarding Waste Management, while Article No. 30 defines that Waste management shall be enforced according to regulated conditions and measures of waste treatment through system of collecting, transport, treatment and disposal, including supervision over those activities and concern for the facilities for waste treatment after their closure and that the owner of the waste is obliged to undertake measures of waste management in order to prevent or reduce waste generation, reuse and recycle; separation of secondary raw materials and use of waste as energents, i.e. waste disposal.

In addition Article No.57 is also very important. It is related to import, export and transport of waste and defines that:

- The import of hazardous waste shall be prohibited.
- The waste may be imported only if not available in the Republic, but is necessary in production as a secondary raw material.
- Permit for import, export and transit of waste shall be issued by the Ministry in compliance with law and other regulations.

[75] Ristić et. al. (2006), p. 32-35

- When applying for permit for import, export and transit from paragraph 1 of this Article, the applicant shall submit the documentation whose contents shall be prescribed by the Ministry.

- The Minister shall regulate the conditions which are to be fulfilled by professional organizations for waste research.

- The Minister shall determine professional organizations from paragraph 5 of this Article.[76]

The obligation from The Basel Convention is fulfilled with Article No. 57 which define the conditions for import, export and transport of waste.

In Serbia a number of laws in line with EU practices were adopted, such as the Environment, Integrated Pollution Prevention and Control (IPPC), Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) laws. However, these new laws generally lack fundamental elements such as definitions compliant with EC requirements, precise rights and obligations for legal and civil entity, clear legal competences of authorities, standards to be achieved and thresholds to be complied with. They fall short of determining procedural stages and are sometimes vague and inconsistent.[77]

A number of key Laws, Regulations and Decisions influence the management of waste across the EU. They include:[78]
- Law on Integrated environmental pollution prevention and control ("Official Gazette of the Republic of Serbia", No. 135/04)
- Law on environmental impact assessment ("Official Gazette of the Republic of Serbia", No. 135/04)
- Law on strategic environmental impact assessment ("Official Gazette of the Republic of Serbia", No. 135/04)

[76] Republic of Serbia. Law on Environmental Protection (2004) Article No. 3, 9, 10, 30 and 57
[77] Environment for Europe: Critical Issues in Implementation Environmental Policies, (2007) p. 5
[78] Williams (2005) p. 13

- Law on Waste Management ("Official Gazette of the Republic of Serbia", No. 36/09)
- Law on Packaging and Packaging Waste ("Official Gazette of the Republic of Serbia", No. 36/09)

In Annex 1 all relevant environmental legislations are stated.

7.1. Ministry of Environmental protection and other environmental institutions

In 2003, the Ministry of Natural Resources and Environmental Protection (MNREP) was established. The responsibilities in the field of water protection were shared between the MNREP and the Ministry for Agriculture and Water Management (MAFWM). In 2004, the institutional framework was modified and key environmental responsibilities were divided between two ministries: the Ministry of Science and Environmental Protection (MSEP) and the MAFWM. In May 2007, a new Government was put in place and the Ministry of Environmental Protection (MEP) set up on the basis of the former Directorate for Environmental Protection (DEP) of the MSEP.

The Environmental Protection Agency (EPA), established in 2004, is an institute under the MEP. Its main functions include:

- Developing, harmonizing and managing the national environmental information system (especially regarding the status of environmental media) and developing a register of polluters;
- Collecting environmental data and reporting on environmental conditions and environmental policy implementation;
- Developing procedures for processing and assessing environmental data;
- Updating data on the Best Available Techniques and practices to support IPPC; and
- Cooperating with and reporting to the European Environmental Agency (EEA) and the European Environment Information and Observation Network (EIONET).

The EPA has only a small budget and staff. It has been built on former institutional structures (e.g. monitoring institutes, which will continue to perform monitoring, collect and process data). Its limited number of staff, 22 people, does not enable the EPA to fulfil all of its functions. The Institute for Nature Protection, also under the MEP, is responsible for protection of nature, especially protection of protected areas, such as parks, nature reserves, wild flora and fauna habitats, and is also responsible for overseeing the use of these natural resources.[79]

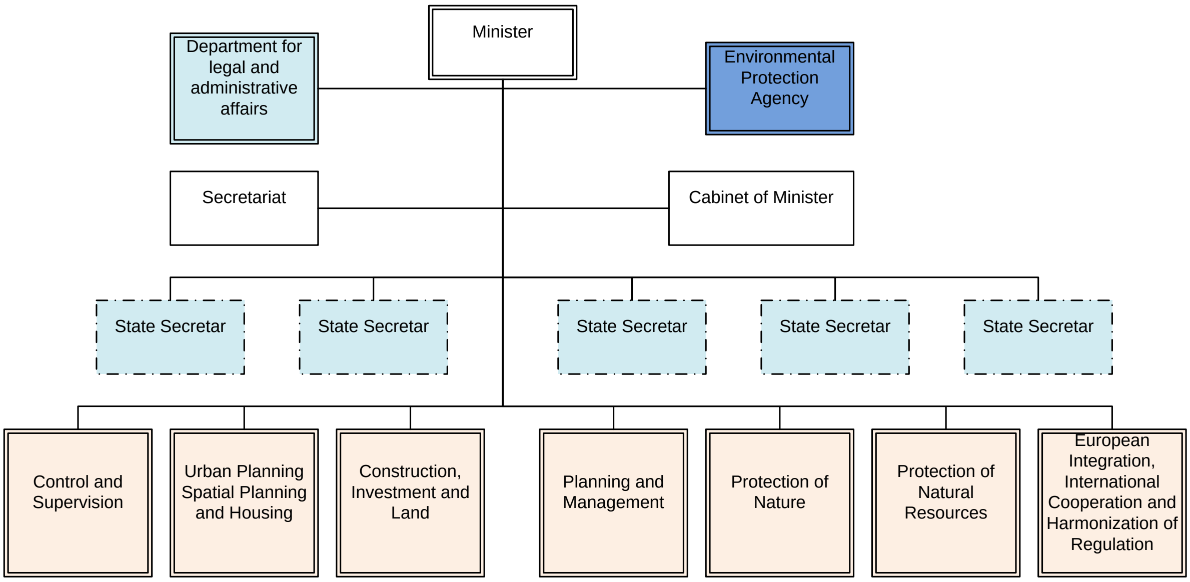

Figure 18: Organizational Structure of the Ministry of Environmental Protection[80]

[79] Economic Commission for Europe: Envieronmental Performance Reviews: Republic of Serbia, (2007), p. 19-22
[80] http://www.ekoplan.gov.rs/en/Organizational-scheme-of-Ministry-of-Environment-and-Spatial-Planning-1-c26-content.htm/ accessed September 25th, 2009

8. KYOTO PROTOCOL

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty, adopted by more than 150 countries in Kyoto, Japan, on December 11th, 1997 and entered into force by the Russian Federation's ratification on February 16th, 2005. It contains binding constraints on the main greenhouse gas emissions (GHG) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Under the Kyoto Protocol, industrialized countries and countries with economies in transition (Annex I countries) have to reduce their combined GHG emissions by 5.2 % on average below their 1990 levels in the first commitment period from 2008 to 2012. In order to reach these commitments, under the Kyoto Protocol have been established three flexible instruments, among them is the Clean Development Mechanism (CDM). It allows governments or private entities in industrialized countries to implement GHG emission reduction projects in developing countries (non-Annex I countries), like Serbia and accomplish their commitment, receiving the certificates known as the "Certified Emission Reductions" – CERs or carbon credits, where each of this unit is equal to one tone of carbon dioxide equivalent. The purpose of the CDM is to assist developing countries in achieving sustainable development and the ultimate objective of the UNFCCC, and to assist developed countries to achieve compliance with their quantified emission limitation and reduction commitments.

The Serbian Parliament ratified the Kyoto Protocol on September 24th, 2007 and thereby confirmed interest of Serbia in its implementation, particularly by the establishment of the Designated National Authority (national body in charge for the CDM project approval), as well as the definition of the rules and procedures for the CDM projects approval in accordance with the national sustainable development criteria.[81]

The Republic of Serbia, The Ministry of Environment and Spatial Planning adopted on 21st of November 2008 the Rules of procedure on the working methodology,

[81] http://www.global-issues-rtd.info/programmes/133.html/ accessed September 26th, 2009

criteria and deadlines for assessment and approval of proposed Clean Development Mechanism (CDM) projects by the Designated National Authority for the implementation of CDM projects under the Kyoto Protocol. The rules of procedure are based on the Government Decision No: 02-2099/2008-1 dated 5th June 2008, and the Agreement on Establishment of the National Authority for Implementation of Projects under the Clean Development Mechanism of the Kyoto Protocol, dated 30th July.

8.1. Definitions in the Rules of Procedure

"***Serbian National Authority***" consists of the Expert Group and the Secretariat, the head of the National Authority is the minister in charge of environmental issues. The National Authority verifies and approves CDM projects under the Kyoto Protocol at the national level (DNA);

"***CDM project***" means Clean Development Mechanism project under the Kyoto Protocol;

"***Project Design Document (PDD)***" means project description in standard form approved by the Executive Board of the CDM under the Kyoto Protocol;

"***Project Idea Note (PIN)***" means project idea description in the form given in Annex 6 which is an integral part of these Rules of Procedure. In the project development process the PIN submission is voluntary and non obligatory;

"***Project participants***" means the project owner and investors;

"***The Expert Group***" consists of nominated representatives of the ministry in charge of water management, construction, economy, energy, environment, agriculture, regional development, mining, transportation, finance and forestry. The Expert Group provides opinion on submitted CDM projects, that is, checks compliance of these projects with the provisions of the Kyoto Protocol, national CDM indicators of sustainable development and with relevant positive laws of the Republic of Serbia. If necessary, activities of the Expert Group may be supported by explicitly invited experts as well as by representatives of institutions in charge of matters relevant to certain CDM projects without a nominated representative in the Expert Group;

“***The Secretariat***“ means an organizational unit within the ministry in charge of environmental issues which is performing technical and administrative work for DNA, primarily including: reception of CDM project proposals, communication with stakeholders, coordination of DNA activities, checking if the project proponent has fulfilled his commitments under the Law on Environmental Impact Assessment, submission of CDM project proposals to the Expert Group, preparation of the draft Letter of Approval/Rejection and submission for approval of these letters to the ministries responsible for the proposed CDM project, preparation of the final Letter of Approval/Rejection, submission of the Letter of Approval/Rejection to the project proponent and performing other administrative work of the DNA;

”***The Interested Ministries***” means the ministries responsible for sectors in which CDM projects may be implemented without nominated representatives in the Expert Group;

”***The Public***” means one or more natural or legal bodies, their associations, organizations or groups;

“The Interested Public“ means the public which is influenced or likely to be influenced by the CDM project, including non-governmental organizations dealing with environmental protection which are registered with the responsible authority.

8.1.1. Submission of CDM project proposals[82]

For purposes of verification and approval of CDM project proposals, project participants have to submit to the Secretariat an application containing the following documentation:

1) Request for approval with the project title and name/names of project participants (Annex 2 which is an integral part of these Rules of Procedure);

2) Project Design Document (PDD);

3) Justification of the contribution of the proposed project to sustainable development of the Republic of Serbia, that is, listing which national CDM indicators of sustainable development stipulated in Annex 1 of these Rules of Procedure have been fulfilled, with a short explanation;

4) Preliminary Final Validation Report prepared in accordance with procedures prescribed by the CDM Executive Board;

5) Decision on Approval of Environmental Impact Assessment of a particular project, if mandatory, or a Decision stating that, according to the law, that particular project is not subject to mandatory environmental impact assessment;

6) Contract, describing the relations between the parties participating in project preparation.

8.1.2. Process of handling the request for the approval of a project proposal

Within the period of a maximum of 3 days after receiving the request for approval of project proposal the DNA Secretariat has to verify that the documentation is complete. If the documentation is not complete, the Secretariat will send, without delay, request to project participants to submit the missing documentation.

If a project participant does not submit the missing documentation within a maximum of 10 days, his request will be considered rejected, and in case of further interest, the project participant must submit a new request.

When the documentation is complete, the Secretariat has to, for public consultation purposes, publish the Project Design Document (PDD) on the official DNA website.

[82] Rules of Procedure CDM (2008)

The deadline for submission of public comments on PDD is 7 days after the publication of the PDD on the official DNA website.
Upon expiration of the period the Secretariat will forward the received documentation to the Expert Group members for providing opinion including the competent authority’s explanation on the approval/rejection of the proposed project.
Within the period, the Secretariat will, in consultation with the Expert Group members, determine a list of interested ministries, that is, the ministries of Serbian Government which are competent for certain CDM projects and which do not have representatives involved in activities of the Expert Group, and will submit the received documentation to the interested ministries for opinion.

8.1.3. CDM project assessment

The Ministries which have nominated representatives in the Expert Group have to, within the period of 15 days upon receiving the documentation, submit their opinion on the proposed project, including an explanation for such opinion.
In case of a negative opinion, it is necessary that the explanation contains reference to elements in which the proposed project is contrary to the provisions of the Kyoto Protocol, national CDM indicators of sustainable development and relevant positive laws of the Republic of Serbia, with reference to certain provisions.
If within the prescribed period, the ministry which has nominated representative in the Expert Group, that is, the interested ministry, does not submit its opinion, that is, does not explain its position, the Secretariat will infer that the interested ministry has raised no objection and will continue the procedure.

8.1.4. Meeting of the Expert Group

A meeting of the Expert Group may be held in order to discuss all issues related to the work of the National Authority, that is, to enable consultation between Expert Group members in the process of assessment of the proposed projects.
An Expert Group member has a right to call for organization of a meeting of the Expert Group for evaluation of the proposed projects at any time within the period of

8 days after receiving the documentation and with the aim of discussing other issues related to the work of the National Authority, at any time.

In these cases, the Secretariat will call a meeting within the period of 15 days.

During the meeting the Expert Group will, through consensus, decide on matters related to the work of the National Authority.

Beside the invitation to the meeting of the Expert Group, the Secretariat will also submit a draft agenda.

If a project proposal has been submitted to an interested ministry for opinion, the Secretariat will invite that ministry to attend the meeting called for evaluation of the proposed project.

The meeting will be chaired either by the head of the DNA or a person authorized to represent him at the meeting.

If an Expert Group member is unable to attend the meeting, the Ministry has to send other nominated representatives of that Ministry as delegate for that specific meeting.

8.1.5. Decision-making method and the final decision of the DNA

Based on the opinion of the Expert Group, the Secretariat will, within the period of 3 days after the expiration of the period, prepare a Draft Letter of Approval or a Draft Letter of Rejection.

If the Ministry which has nominated representatives in the Expert Group does not submit an opinion with explanation within the period specified, it will be inferred that the ministry’s opinion is positive.

If any of the ministries with a representative in the Expert Group, that is, an interested ministry has submitted a negative opinion with explanation, the Secretariat will make a Draft Letter of Rejection using the prescribed standard form.

If all ministries with representatives in the Expert Group, that is, the interested ministries have submitted a positive opinion, the Secretariat will make a Draft Letter of Approval using the prescribed standard form.

The minister in charge of environmental issues will submit the Draft Letter of Approval/Rejection to the ministry in charge of that particular CDM project for giving consent.

The competent ministry is obliged to submit their consent to the Draft Letter of Approval or the Draft Letter of Rejection within the period of 3 days upon receiving it.

If the competent does not submit the approval within the period specified, it will be inferred that the ministry gave its approval.

After receiving the approval, the minister in charge of environmental issues will sign the Letter of Approval, that is the Letter of Rejection and submit it to project participants within the period of 3 days.

If the competent ministry referred submits a negative opinion on the Draft Letter of Approval/Rejection, the Secretariat will call a meeting for reevaluation of the proposed project.

In this case the ministries which have nominated representatives in the Expert Group are obliged to submit a new opinion on project proposal within the period of 3 days after the meeting.

8.1.6. Submission of the Project Idea Note (PIN)

For the purpose of gaining Letter of support for the Project Idea Note *(PIN)*, project participants shall submit to the Secretariat an application containing the following documentation:

1) Project Idea Note (PIN) in the prescribed form;

2) Justification of the contribution of the foreseen project to the sustainable development of the Republic of Serbia, that is, listing which national CDM indicators of sustainable development have been fulfilled, with a short explanation.

On decision-making process for supporting the PIN, the provisions concerning the decision-making process for approving CDM projects will apply, with exception of the provision on the deadline for submitting an opinion on PIN. Deadline for submitting an opinion on PIN by the ministry with a nominated representative in the Expert Group is 8 days after receiving the PIN.

9. FORESEEN CDM PROJECTS IN WASTE SECTOR IN THE REPUBLIC OF SERBIA

Serbia has ratified the Kyoto Protocol and become, as a non-Annex I country, a host country for CDM projects. Serbia has stabilised its political system and is beginning to modernise its economy. The CDM may contribute to attracting foreign investors implementing new and sustainable technologies in Serbia.[83]

There are several benefits of implementing waste related CDM projects:[84]
Environmental benefits:

- Reduced GHG emissions generation
- Reduced environmental degradation from uncontrolled waste disposal
- Material recovery enables natural resource and energy conservation
- Energy recovery helps to reduce demand on limited natural resources

Economical benefits

- Revenues from CER sales allow for implementation of project
- Foreign expertise and training received to facilitate smooth technology transfer

Social benefits

- Improved sanitary and health conditions
- New facilities / projects create local job opportunities
- Staff training to improve skills of locals.

The possible buyers of Certified Emission Reductions are:[85]

- Annex I –governments to meet their Kyoto targets, some countries have special purchase programmes
- European companies for compliance in the EU ETS
- Non-European companies for Kyoto compliance
- Financial institutes for trading purposes

[83] Stankovic (2007), p. 3
[84] Crawford (2009), p. 22
[85] Tuerk (2006), p. 6

Two examples of foreseen CDM projects in waste sector in the Republic of Serbia:[86]

1. **Project title: Kragujevac – Landfill site LFG recovery and flaring**

Location: Municapality of Kragujevac

Project description: Landfill site Jovanovac has been operational since 1963 and receives all collected MSW of the Kragujevac Municipality, serving of population of of about 129.00 inhabitants. The amount of MSW carried into landfill is estimated at 96t/day. Until today, over 2 millions tons have been disposed at this landfill site. This landfill site has no system to protect groundwater against leaching and it is without gas collection and flaring system.

GHG offset: approx 110.000 t CO2e for 2009-2013

Investment costs: 500.000€

Project partners: Municipality of Kragujevac and Public Utility Company

2. **Project title: Bundled project activity – GHG emissions reduction through LFG Flaring**

Location: Municipalities of Uzice, Cacak and Pozega

Project description: Bundled project landfill sites are located in Central Serbia, of which Uzice and Pozega in Zlatibor District and Cacak in Morava District. These landfill sites do not meet technical requirements of sanitary landfills. There is no previous treatment of MSW or implemented measures for the protection of environment.

GHG offset: 140.000 tCO2e in total

Investment cost: approx. 1 million €

Project partner: Municipalities of Uzice,Pozega, Cacak and Local Public Utility Companies

[86] Ministry of Environmental Protection of the Republic of Serbia: CDM opportunities in the Republic of Serbia (2007), p. 30-31

It is difficult to estimate the potential environmental benefits of an improved waste management because of the lack of data. The potential carbon savings from this sector could be estimated at 410 ktCO2/ per year.[87]

10. CONCLUSION

The projections for the quantities of generated waste in the Republic of Serbia are showing great increase from 290 kg per person in the year 2002 to the 493 kg per person in the year 2020. This projected continuing increase in waste volumes is primarily due to an assumed sustained growth in private final consumption and a continuation of current trends in consumption patterns.

The decrease of the future quantities of waste and that optimistic scenario could become the following framework conditions are necessary:

- implementation of more strictly legislation regarding environmental protection
- divert waste from the landfills
- only pre-treated waste should be landfilled
- biological fraction of MSW should be treated in biogas plants or compost plants
- landfills should be designed according the technical requirements defined in the EU Landfill Directive
- energy recovery of the landfill gas
- investments in modern technologies for the waste management
- increase the environmental awareness of the population

For the calculation of the emissions of the GHG from the MSW the mass balance method was used in accordance with The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

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[87] Stankovic (2007) p. 3

All future projections regarding methane emissions from MSW are based on the year 2002 and were 68,33 Gg of methane. If we calculate also the global warming potential that is 21 the result is 1434,93 Gg of CO2e in the base year.

The projected quantities of the methane in pessimistic scenario in the year 2020 are 186,12 Gg of CH4 or 3.908,52 Gg of CO2e.

The projected quantities of the methane in realistic scenario in the year 2020 are 51,31 Gg of CH4 or 1.077,51 Gg of CO2e.

The projected quantities of the methane in optimistic scenario in the year 2020 are 27,59 Gg of CH4 or 579,39 Gg of CO2e.

The difference between the pessimistic and optimistic scenario in the year 2020 is 158,53 Gg of methane or 3329 Gg of CO2e. This is also the potential reduction of GHG in the year 2020, but it has to be pointed out that this is possible only, if all the presuppositions are fulfilled.

It should be mentioned also that where data was not available or was very poor quality a default values were used. Due to this fact the uncertainty in the calculation is estimated to:
Uncertainty of activity data amounts to 40%.
Uncertainty of emission factor amounts to 70%.

Recommendations to improve the GHG inventory in waste sector are:

- First order decay models should preferably be used for the estimation of CH_4 emissions from solid waste disposal, but for this more precise data are necessary.
- The parameters used in calculation should be obtained through studies and direct measurements of emissions at waste disposal sites.
- More clearly should be described which waste types are included in their estimation of emissions from solid waste disposal, and in particular whether

industrial waste, sludge and biodegradable construction and demolition waste are also included.

- The consistency of definitions used for municipal solid waste and other waste types for the GHG inventory with the definitions used under the Waste Statistics Regulation should be checked.
- More measurements should be performed in order to validate the models and parameters used for CH_4 emissions from individual landfills with typical characteristics.

In Kyoto protocol Article 12.2. it is stated that the purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.

Due to the fact that the Republic of Serbia is the country not included in Annex 1 it has possibility to be the host country for the CDM projects. The Republic of Serbia has already established Designated National Authority to review and give national approval for CDM projects.

The CDM projects in the Republic of Serbia must meet the criteria stated in The Sustainable Development Strategy of the Republic of Serbia. The criteria are economic (involvement oflocal partner, best available technology…), social (increased employment, improvement of living conditions…) and environmental (reduction of energy dependence, reduction of GHG…).

The benefits from CDM projects for the Republic of Serbia are not only financial benefits, but also environmental, social and technological.

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ANNEX 1: List of relevant legislation in the Republic of Serbia:

Legislation

2001

• Law on Ratification on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (OG SUSM No. 11/2001)

• Law on Ratification on the Convention on biodiversity (OGSUSM No. 11/2001 and OGSUSM No. 16/2005)

• Law on Genetically Modified Organisms (OG FRY No. 21/2001)

• Regulation on conditions and the manner of selection, packaging and storing of secondary substances (OG RS, No. 55/2001)

• Regulation on method of destroying plants for which measures of destroying are ordered (OG FRY No. 67/2001)

• Regulation on types of packaging for pesticides and fertilisers and on destroying pesticides and fertilisers (OG FRY No. 35/99, No. 63/2001)

• Regulation on trade, import and sampling of fertilisers (OG FRY No. 59/2001)

• Regulation on trade, import and sampling of pesticides (OG FRY No. 59/2001)

• Regulation on methods of organic plant production and on collecting forest fruits and curative plants as products of organic agriculture (OG FRY No. 51/2001)

• Decree on Specific Conditions for the Importation and Processing of Crude Oil and Oil Derivates in 2001 (OG RS No. 16/2001, 23/2001, 28/2002, 54/2002, 37/2003, 90/2003, 56/2005, 76/2005 and 8/2005)

• Excise tax law (OG RS Nos. 22/2001, 73/2001, and 80/2002)

2002

• Law on Local Self-government (OG RS No. 9/2002, 33/2004, 135/2004, 62/2006)

• Law on Determination of Certain Competencies for the Autonomous Province (OG RS No. 6/2002)

• Decree on road and railroad transport of dangerous substances (OG RS No. 53/2002)

• Regulation on detailed conditions which must be fulfilled by professional organizations which perform emissions and imissions measurement (OG RS No. 5/2002)

• Regulation on methods of organic livestock production (OG FRY No. 51/2002)

• Regulation on conditions which must be fulfilled by legal persons performing examination of methods of organic production process (OG FRY No. 67/2002)

• Regulation on restricted use of genetically modified organisms (OG FRY No. 62/2002)

• Regulation on content and data of register of genetically modified organisms and products from genetically modified organisms (OG FRY No. 66/2002)

• Regulation on trading with genetically modified organisms and products from genetically modified organisms (OG FRY No. 62/2002)

• Regulation on introducing into production genetically modified organisms and products from genetically modified organisms (OG FRY No. 62/2002)

• Water Master Plan of the Republic of Serbia (OG RS No. 7/2002)

• Regulation on the requirements that legal persons must fulfil for conducting systematic examination of the contents of radionuclides in the environment (OG FRY 32/98, 67/2002 and 70/2002)

2003

• Law on Planning and Construction (OG RS No. 47/2003 and 34/2006)

• Law on the Customs Service (OG RS No. 73/2003).

• Law on Ratification of Convention on Cooperation for the Sustainable Use of Danube River, (OGSUSM No. 2-2/2003).

2004

• Law on Environmental Protection (OG RS No. 135/2004)

• Law on Strategic Environmental Impact Assessment (OG RS No. 135/2004)

• Law on Environmental Impact Assessment (OG RS No. 135/2004)

• Law on Integrated Environmental Pollution Prevention and Control (OG RS No. 135/2004)

• Law on the free access to information(OG RS No 120/2004)

• Law on Energy (OG RS No. 84/2004)

• Draft Law on Ratification on Amendments to the Montreal Protocol on Substances Depleting Ozone Layer (OG SUSM No. 2/2004)

• Decree on the Establishment of the Air Quality Control Programme in 2004 and 2005 (OG RS No. 48/2004)

• Resolution on Accession to the EU (OG RS No. 48/2004)

2005

• Law on State Administration (OG RS No. 79/2005)

• Law on Ministries (OG RS No. 19/2004, 84/2004 and 79/2005)

• Law on standardization (OG SUSM 44/2005)

• Law on technical requirements for products and their harmonization with legislative requirements (OG FRY No. 44/2005)

• Law on accreditation (OG FRY No., 44/2005)

• Law on metrology (OG FRY No. 44/2005)

• Decree on validation of projects for which impact assessment is obligatory and list of projects for which environmental impact assessment could be requested (OG RS No. 84/2005)

• Regulation on the content of the request for decision making on the need for the impact assessment completion, and the content of the request for definition of the extent and content of the environmental impact assessment study (OG RS No. 69/2005)

• Regulation on the content of the environmental impact assessment study (OG RS No. 69/2005)

• Regulation on the content, appearance and the way of keeping official book on managed procedures and
decisions made regarding environmental impact assessment (OG RS No. 69/2005)

• Regulation on activities of the technical commission for evaluation of the environmental impact assessment study (OG RS No. 69/2005)

• Regulation on the public access, presentation and public discussion of the environmental impact assessment study (OG RS No. 69/2005)

• Decree on type of activities and facilities for which integrated permit is issued (OG RS No. 84/2005)

• Decree on the contents of programmes of measures for bringing of operation of the existing installation and activities with prescribed conditions for activities (OG RS No. 84/2005)

• Decree on the criteria for determining of the best available techniques, environmental quality standards and of emission limits values in the integrated permit (OG RS No. 84/2005)

• Regulation on the content and the way of administration of the register of issued integrated permits (OG RS No. 69/2005)

• Decree type of pollution, criteria for calculation of charges, polluters, the amount and manner of calculation and payment of charges (OG RS No. 113/2005)

• Decree on criteria and conditions for refund, waiving or reduction of charges for environmental pollution (OG RS No. 113/2005)

• Regulation on control of use and trade of wild flora and fauna (OG RS No. 31/2005 and 45/2005)

• Regulation on type of equipment, content and mark/badge of inspector for environment protection (OG RS No. 35/2005)

• Regulation on the form of the legal identification card of inspector for environment protection (OG RS No. 35/2005)

• The Decree on Importation of Motor Vehicles (OG RS No. 106/2005)

• Decree on oil derivatives price (OG RS No. 42/2005 and 111/2005)

2006

• Law on Agricultural Land (OG RS No. 62/2006)

• Law on Amendment of the Law on Mining (OG RS No. 44/1995, 85/2005, 101/2005 and 34/2006)

• Decree on the Establishment of the Air Quality Control Programme in 2006 and 2007 (OG RS No 23/2006)

• Regulation on the Conditions Which are to be fulfilled by professional organization for waste research (OG RS No 53/2006)

• Regulation on the technical and other requirements for liquid fuels originated from oil derivates (OG FRY No 51/2004,54/2005 and 18/2006)

• Regulation on criteria for issuing energy permits, content of the request and the method of issuing energy permits (OG RS No 23/2006)

• Regulation on limit values, imission measuring methods, criteria for establishing measuring sites and data evidence (OG RS No. 54/92, 30/99, 19/2006)

• Regulation on content and method of filling of the integrated permit issuing (OG RS No. 30/2006)

• Regulation on content and format of integrated permit (OG RS No. 30/2006)

• Council Decision of 30 January 2006 on the principles, priorities and conditions contained in the European Partnership with Serbia and Montenegro including Kosovo as defined by the United Nations Security Council Resolution 1244 of 10 June 1999 and repealing Decision 2004/520/EC, Official Journal of the European Union L25/32 7.2.2006

2007

• Law on Nature Protection
• Law on ratifying the Kyoto protocol (OG RS No. 88/07)
• Law on ratifying Convention on cross border impacts on the environment(OG RS No. 102/07)

2009

• Law on genetic modified organisms (OG RS No. 41/09)
• Law on ratifying Stockholm Convention (OG RS No. 42/09)
• Law on ratifying Annex B of Kyoto Protocol (OG RS No. 38/09)
• Law on Chemicals (OG RS No. 36/09)
• Law on packaging and packaging waste (OG RS No. 36/09)
• Law on environmental protection (OG RS No. 36/09)
• Law on air protection (OG RS No. 36/09)
• Law on noice protection (OG RS No. 36/09)
• Law on waste management (OG RS No. 36/09)

Plans, Programmes, and Strategies

2002

• Study of Sustainable Development of the Water Sector in the Republic of Serbia

2003

• Water Master plan of Serbia 2002-2012.

• Poverty Reduction Strategy

• National Waste Management Strategy

• General Flood Defence Plan for 2003-2008 (OG RS No.34/2003)

2004

• European Partnership

• Energy Development Strategy of the Republic of Serbia by 2015

2005

• National Environmental Strategy (adopted by Government 2006)

• National Strategy of the Republic of Serbia for Serbia and Montenegro's EU Accession, 2005

• Food Safety Strategy, 2005

• National Action Plan for Gasification of the Republic of Serbia, 2005

• National Strategy for Development of Agriculture

2006

• Forestry Development Strategy, (adopted by Government 2006)

• Strategy for Development of Tourism, 2006

• Study of Sustainable Development of the Water Sector of Serbia (2006)

• National Strategy for Economic Development of Serbia until the 2012.

• Strategy for Official Statistics (2006)

2007

• National Sustainable Strategy

• National Environmental Strategy

ANNEX 2: Application for letter of approval

APPLICATION FOR LETTER OF APPROVAL

Project participants

[names]

[address]

On [date], project participants apply for issuance of Letter of Approval [project name].

Project participants have to submit the following documentation to DNA of the Republic of Serbia in written and electronic form, in Serbian and English language:

1) Project Design Document (PDD);

2) Justification of the contribution of the proposed project to sustainable development of the Republic of Serbia, that is, listing which national CDM indicators of sustainable development stipulated in Annex 1 of these Rules of Procedure have been fulfilled, with a short explanation;

3) Preliminary Final Validation Report, prepared in accordance with procedures prescribed by CDM Executive Board and which can be submitted only in English;

4) Decision on Approval of Environmental Impact Assessment of a particular project, if mandatory, or a Decision stating that, according to the law, that particular project is not subject to mandatory environmental impact assessment;

5) Contract, describing the relations between the parties participating in project preparation.

[date]

[project participants' names]

ANNEX 3: Letter of support

MEMORANDUM

Government of the Republic of Serbia

MINISTRY OF ENVIRONMENT

AND SPATIAL PLANNING

Date

LETTER OF SUPPORT

for (project name)

(number of the LoS)

[recipient address]

Designated National Authority of the Republic of Serbia is compliant to submitted Project Idea Note (PIN) for the [project name].

This Letter shall not obligate DNA of the Republic of Serbia to issue Latter of Approval once Project Design Document has been submitted for assessment and approval.

[Minister,

Chair of DNA]

ANNEX 4: Letter of approval

MEMORANDUM

Government of the Republic of Serbia

MINISTRY OF ENVIRONMENT

AND SPATIAL PLANNING

Date

LETTER OF APPROVAL

for (project name)

(number of the LoA)

[recipient address]

DNA of the Republic of Serbia has approved (project name) as CDM project and shall state the following:

1. The Letter confirms that Republic of Serbia has ratified Kyoto Protocol on 24 September 2007 and that it is a Party to the Kyoto Protocol.

2. The Letter confirms voluntary participation in proposed CDM project.

3. The Letter confirms that project contributes to the achievement of sustainable development aims of the Republic of Serbia.

[Minister,

Chair of DNA]

ANNEX 5: Letter of rejection

MEMORANDUM

Government of the Republic of Serbia

MINISTRY OF ENVIRONMENT

AND SPATIAL PLANNING

Date

LETTER OF REJECTION

for (project name)

(number of the LoR)

[recipient address]

DNA of the Republic of Serbia has rejected (project name) as a CDM project.

Reasons for rejection of (project name) have been appended to this Letter.

[Minister,

Chair of DNA]

ANNEX 6: Project Idea Note form

Project Idea Note form (PIN)	
1. Project name and submission date	
2. Project proponent's name/title:	Institution/entity: Public/private: Main business activity:
3. Contact information	Contact person: Address: Phone: Fax: E-mail:
4. Project activity location	Region: City/town: Municipality:
5. Project description (Describe project activity, main technical parameters, that is technology which will be used, expected results in accordance to GHG emission reduction, contribution to sustainable development on the basis of sustainable development criteria and indicators) (two pages maximum)	
6. Current project status (Pre-feasibility study, feasibility study, project idea only, project concept, main project in construction phase etc.)	
7. Additionality (What would happen in case of absence of project activity?)	
8. Funding Assessment of investment costs and available funds	
9. Timeframe Estimation of timeframe for implementation of proposed project	