**Development of the Waste Sector GHG emissions Projections Model: Final report - August 2020**

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1. **Description of the GHG emissions projections model**

The GHG emissions for the waste sector were modelled using the methodology given by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The Excel spreadsheet is set-up with various tabs summarising the input data for the GHG emissions; these are given by the ‘Input data’, ‘Parameters’, ‘MSW characteristics’ and ‘Waste Summary 2017 SASOW’ tabs. The tab ‘Baseline data (from input)’ summarises the input data for the baseline GHG emissions calculations in terms of waste generated, composition of the MSW and the waste treatment pathway. The tabs ‘Recycling - Case 1’ to ‘Recycling - Case 3’ include the calculations for the input data for the GHG emissions after the implementation of the different policies. The tabs ‘4A SWD Case 1’ to ‘4D Wastewater and dis’ include the calculations for the GHG emissions based on the methodology given by 2006 IPCC Guidelines and the final results are given in the tab ‘Output data (results)’ and ‘results (plots)’.

1. **Methodology** 
   1. **Calculation of GHG emissions**

**4A Solid Waste Disposal**

The GHG emissions for the Solid Waste Disposal of MSW and industry waste was calculated using the First Order Decay (FOD) method given by the 2006 IPCC Guidelines. The key assumption of this method is that it assumes that the degradable organic carbon (DOC) in waste decays slowly over a few decades.

**4B Biological treatment of solid waste**

The GHG emissions from the biological treatment of solid waste were calculated using the 2006 IPCC Guidelines. The 2006 IPCC Guidelines provides default methane and nitrous oxide emission factors that were used in conjunction with the mass of waste estimated and projected to be treated by composting or anaerobic digestion.

**4C Incineration and open burning of waste**

The GHG emissions from the open burning of solid waste were calculated using the 2006 IPCC Guidelines. The 2006 IPCC Guidelines provides default methane, carbon dioxide and nitrous oxide emission factors that were used in conjunction with the mass of that was waste treated.  The carbon dioxide and nitrous oxide emission calculations also required the dry matter content, carbon content and fossil fraction for the different waste types and the default values given by the 2006 IPCC Guidelines were used.

**4D Wastewater treatment and discharge**

The GHG emissions from the treatment and discharge of wastewater were calculated using the 2006 IPCC Guidelines. The methane emissions were calculated based on the different wastewater treatment pathways default values given by the 2006 IPCC for South Africa for the respective population groups (rural, urban-low and urban-high), per capita degradable organic component (BOD) and the default methane emission factors. The nitrous oxide emissions were calculated from the per capita protein consumption and the corresponding default emission factors given by the 2006 IPCC Guidelines.

* 1. **Waste input data**

The GHG emissions are calculated from an estimated historical inventory of disposed waste, the waste generation rates, the population, the GDP and the relevant emission factors. The population and GDP data for each scenario modelled are read in from SATIM. However, the GDP data sourced from SATIM is generated for the years 2010 to 2050. Therefore, for the historical GDP data (pre-2010), nominal GDP values in the World Bank time series were corrected using CPI and/or real annual growth rates to real GDP numbers (same base year, i.e. 2012), which were then multiplied by the industrial waste intensity factor for each year to get the industrial waste quantity in each year back to 1989.

A summary of the waste generation rates input data for solid waste and wastewater is given in Table 1.

Table 1: Summary of waste generation input data for the baseline (2017)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Units | Value | Source |
| MSW generation rate | kg/cap/yr | 424 | Calculated from the draft SASoW report (2018) and Rodseth, Notten and von Blottnitz (2020) |
| Industrial waste generation rate | ton industrial waste/Rmill GDP | 28.0 | Calculated from the draft SASoW report (2018) and using the real TVA for the year 2017 (with a base year of 2012) from SATIM |
| Industrial waste generation rate (excl. coal ash generated) | ton industrial waste/Rmill GDP | 12.0 | Calculated from the draft SASoW report (2018) and using the real TVA for the year 2017 (with a base year of 2012) from SATIM |
| Per capita degradable organic component (BOD) | kg/capita/yr | 13.5 | Default value for SA - 2006 IPCC Guidelines |
| Per capita protein consumption (Protein) | kg protein/capita/yr | 29.2 | Averaged from 2000 to 2013 FAO Statistics (FAO, 2019) |
| Amount of sludge deposited per person connected to a sewer | kg/capita/yr | 30.6 | Calculated from 2017 NIR and cross-checked with literature |

A summary of the distribution of the solid waste treatment methods for both MSW and industrial waste for the baseline case (2017) are given in Table 2. This distribution data was calculated from the draft SASoW report (2018) and a paper published by Rodseth, Notten and von Blottnitz (2020).

Table 2: Distribution of solid waste treatment methods for MSW and industrial waste for the baseline (2017)

|  |  |  |
| --- | --- | --- |
|  | MSW | Industrial waste |
| Solid waste disposal | 46.5% | 78.2% |
| Overall recycling[[1]](#footnote-1) | 41.4% | 8.9% |
| Open burning | 12.1% | 0% |
| Waste Incineration | 0% | 12.9% |
| Total | 100% | 100% |

The updated MSW generation rate and distribution of solid waste treatment methods are calculated from the waste generation data given in the draft SASoW (2018) for the year 2017. The recycling rate is considerably higher than the one given in the 2017 NIR (41% vs 11%). In addition to this, the solid waste disposal emissions are dependent on historical data, therefore prior to the 2017 baseline data, an adjusted MSW generation rate and distribution of solid waste treatment was used based on the assumptions/data given by the 2017 NIR (see Key Assumptions for more details).

In the 2017 NIR, no emissions are calculated from the biological treatment of waste, however, it was reported in the draft SASoW (2018) that 13.9% of the total MSW waste is recycled through biological treatment in 2017 (which is 34% of the total mass of recycled waste). Therefore, it was assumed that the 2017 NIR recycling rate also includes the recycling of organics (see Section 3. Baseline model - Key Assumptions for more details).

1. **Baseline model** 
   1. **Model choices**

* For MSW, the first-order decay model was applied using the disaggregated approach, i.e. separately to the key organic fractions rather than to the MSW in bulk.
* For industrial waste, the first-order decay model was applied only to the biomass waste disposed of in landfill and it was assumed that the remaining industrial waste disposed of in SWD had a degradable organic carbon (DOC) content of zero.
  1. **Key assumptions for the modelling of the GHG emissions in the waste sector (for the baseline)**
* The baseline MSW generation and distribution of solid waste treatment data was used from the year 2017 onwards. Prior to 2010, the MSW generation (578kg/cap/yr) and distribution of solid waste (SWD 80%, recycling 11% and open burning 9%) were taken from the 2017 NIR. For the years 2010 to 2017, the waste generation data was linearly ramped down and the recycling linearly ramped up. This linear increase also was used for the recycling of organic waste (which accounts for 34% of the total waste recycled).
* The baseline industrial distribution of solid waste treatment data was used from the year 2012 onwards. Prior to 2002, the distribution of industrial solid waste was assumed to be 88% SWD, 9% recycling and 3% incineration as it was assumed that historically a higher fraction of the biomass was disposed of in SWD sites instead of incinerated, with an ecological modernisation of South Africa’s industries commencing around the time of the 2002 WSSD in Johannesburg. The distribution of industrial solid waste was adjusted linearly to reach the baseline distribution by the year 2012.
* For the SWD of industrial waste, the degradable organic carbon (DOC) content of the biomass waste was assumed to be 0.4 (using IPCC default factors, and based on this waste originating from sugar mills, saw mills and pulp and paper industry)(Department of Environmental Affairs, 2018).
* Per capita degradable organic component (BOD) and protein consumption were assumed to be constant over the time series.
* Based on the draft SASoW (2018), 13.9% of the total MSW waste recycled in 2017 is organic waste. It was assumed that this MSW organic waste is treated through composting and anaerobic digestion. From the year 2000 to 2010 it was assumed that the split was 100:0, from 2010 to 2017 it was assumed that the split was 95:5 and from 2017 onwards that the split will be 90:10 for composting and anaerobic digestion respectively.
* For the recycling of organic industrial waste, it was assumed that the biological treatment is assumed to have a composting/anaerobic digestion split of 90:10 from 2010 to 2017.
* Composition of municipal waste generated is assumed to be constant throughout the time series and was calculated to be 19.9% food, 26.6% garden waste, 8.9% paper waste and 44.6% inert waste (Calculated from the draft SASoW report (2018) and Rodseth, Notten and von Blottnitz (2020)).
* The percentage of waste being treated through open burning is assumed to be 50% of the unmanaged waste and 10% of the managed disposal waste (by mass) which equates to 12% of the MSW generated and is assumed to be constant over the time series (Calculated from the draft SASoW report (2018) and Rodseth, Notten and von Blottnitz (2020)). This results in the composition of municipal waste being treated through open burning being 29.0% food, 30.3% garden waste, 8.3% paper waste and 32.4% inert waste.
* For methane recovery, it was assumed that 10 Gg/yr of methane are recovered from the SWDS for the years 2000 to 2050 (Department of Environmental Affairs, 2017).
* The amount of sludge deposited in the SWDS is assumed to be 501 Gg/yr for the duration of the timeseries up to 2017, from 2017 onwards the amount of sludge deposited will be taken as 30.6 kg/cap/yr (this is based on the percentage of the population being serviced by a sewer system, which was 29% of the population for the year 2017 (IPCC, 2006; Department of Environmental Affairs, 2017).
* For the solid waste disposal sites, it was assumed that 40% of the MSW landfill sites are well-managed (managed-anaerobic), 30% are assumed to be mostly compliant (managed – aerobic), 30% are informal dumpsites (uncategorised) (baseline) (von Blottnitz, Chitaka and Rodseth, 2018). The methane correction factor for MSW was calculated based on this categorisation. For industry waste, the default values for the categorisation of SWD sites from the 2006 IPCC Guidelines were used.
* For the wastewater sector, it was assumed that the income distribution of the population will remain constant throughout the time series and the default values from the 2006 IPCC Guidelines can be used.

1. **GHG Projections Model - year 2017 to 2050**

There are various policies that aim to improve waste management in South Africa, aiming to affect the amount of waste generated, the waste treatment pathway and the compliance of the treatment pathway. Therefore, the input data needs to be adjusted in scenarios modelling if these policies are partially or fully met, and this is calculated in tabs ‘Recycling - Case 1’ to ‘Recycling - Case 3’. Case 1 represents policy targets only partially or not achieved, Case 2 represents policy targets achieved as stated and Case 3 represents policy targets exceeded (where applicable). For each case there are two scenarios in terms of generation of wastes from coal combustion, these are namely: ‘B’ – IRP Realistic and ‘G’ – No new coal. (With coal wastes making up 47 Mt of the total landfilled waste of 79 Mt in 2017, it is important to reflect the wastes from coal combustion separately, and in relation to the situation in the energy sector, as modelled.) A summary of the policy targets used for the 3 cases is given in Table 3.

Table 3: Summary of policies applied in the Waste Sector for the years 2018 to 2050 (reference year: 2017)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Strategic Objective | Case 1: Policy targets only partially or not achieved | Case 2: Policy targets achieved as stated | Case 3: Policy targets are exceeded |
| M1.1 | Prevent waste through cleaner production, industrial symbiosis, and extended producer responsibility | Reduction in waste disposed to landfill   * 50% within 10 years * 65% within 20 years * At least 80% within 30 years | Reduction in waste disposed to landfill   * 50% within 5 years * 65% within 10 years * At least 80% within 15 years | NA |
| M1.2 | Increase reuse, recycling and recovery rates | Assume no further gains to 2030 except for fly ash   * 58% of paper recycled * 43.7% of plastic recycled * 71.2% of glass recycled * 80% of metals recycled * 20% of fly -ash recycled | Achieve the following recycling rates by 2030   * 70% of paper recycled * 60% of plastic recycled * 90% of glass recycled * 90% of metals recycled * 40% of fly -ash recycled | NA |
| M1.3 | Divert organic waste from landfill through composting and the recovery of energy | 25% reduction in volume of organic waste disposed to landfill within 5 years and 50% in 10 years. Composting/anaerobic digestion split 90:10 by 2022 | 50% reduction in volume of organic waste disposed to landfill within 5 years. Composting/anaerobic digestion split 90:10 by 2022 | Growth of the energy recovery industry higher than anticipated – composting/anaerobic digestion split is 50:50 by 2022 |
| M1.4 | Ensure municipal landfill sites and waste management facilities comply with licensing requirements (not part of waste minimisation) | 50% conversion from unmanaged to managed MSW landfill sites by 2030 and 100% by 2050 | All municipal landfill sites are converted from unmanaged to managed (by 2030) | NA |
| M2 | Achieve universal, sustainable sanitation provision | Provide 48% of the rural population and 20% of the urban low-income previously not receiving sanitation treatment with adequate sanitation (based on IPCC default values) by 2050 | Provide 48% of the rural population and 20% of the urban low-income previously not receiving sanitation treatment with adequate sanitation (based on IPCC default values) by 2030 | NA |

* 1. **Modelling of the policy targets**
     1. **Modelling of M1.1, M1.2 and M1.3**

A key objective of the national waste management strategy (M1.1) is to prevent waste through cleaner production, industrial symbiosis, and extended producer responsibility and (together with more recycling) aims to reduce waste to landfill by at least 80% in the next 15 years. The diversion of waste from landfill can be achieved by either increased recycling (of both inert and organic waste) or by decreasing the amount of waste generated. There are two policy measures that aim to increase recycling rates of inert material (M1.2) and divert organic waste (M1.3). These two measures in conjunction with a source reduction fraction (SRF) were used to determine the mass of waste generated and waste treatment pathway for both MSW and industrial waste.

***Calculation of the Source Reduction Factor (SRF)***

The source reduction factor (SRF) is defined as the percentage by which the mass of waste disposed of to SWD (and open-burning for MSW) needs to be reduced by in order to achieve the objective of reducing waste to landfill (M1.1) after the implementation of increased recycling rates (M1.2) and diversion of organic waste (M1.3). Therefore, to calculate the SRF, first the mass of waste that needs to be diverted to achieve the reduction in landfill waste was calculated based on the SWD targets in M.1.1. This was calculated separately for MSW and industrial. Thereafter, the mass of additional waste that is recycled (both inert and organic) as a result of M1.2 and M1.3 was subtracted from the total mass of waste that needs to be diverted to calculate the remaining mass of waste that is then reduced through the implementation of the SRF. Finally, the SRF was calculated from the ratio of this ‘remaining mass of waste’ that needs to be diverted and the total mass of waste disposed of in SWD after the implementation of M1.2 and M1.3. The SRF only targets the remaining mass of waste that is sent to SWD and open burning for MSW and only SWD for industrial waste after achieving the targets of M1.2 and M1.3. For the calculation of the SRF for industrial waste, the mass of fly ash waste generated was excluded as the generation of this waste is dependent on the energy sector.

An upper limit of 100% was set for the SRF; for the situation where the SRF was higher than 100%, the SRF was corrected and the policy goals stated as “not met”. An overall SRF was calculated based on by how much the total mass of waste generated was reduced by to achieve the targets of the M1.1 for MSW and industrial waste individually.

***Composition of MSW and industrial waste disposed of in SWD sites***

As a result of policy measures M1.1 to M1.3, the composition of waste disposed of to SWD sites varies depending on the measures. The composition of MSW and industrial waste disposed of in SWD post the implementation M1.1 to M1.3 was calculated based on how much waste was diverted through increased recycling rates (M1.2) and diversion of organic waste (M1.3).

* + 1. **Modelling of M1.4 – Compliance of municipal landfill sites and waste management facilities**

To model the target of converting municipal landfill sites from unmanaged to managed landfill sites, the categorisation for the calculation of the MCF was adjusted linearly to convert all non-compliant municipal landfill sites (managed – aerobic and uncategorised) to managed-anaerobic landfill sites (i.e 100% managed-anaerobic landfill sites).

* + 1. **Modelling of M2 - Universal, sustainable sanitation provisions**

To model the target of providing safe access to sanitation to 100% of the population, the fraction of each income group that did not receive adequate sanitation treatment (as given by the default values in the 2006 IPCC Guidelines) was reduced to zero linearly and redistributed proportionally amongst the other sanitation treatment options (for each income group).

As a result of providing safe access to sanitation to 100%, the percentage of the population being serviced by a sewer system increased based on this redistribution and was calculated accordingly.

1. **References**

von Blottnitz, H., Chitaka, T. and Rodseth, C. (2018) ‘South Africa beats Europe at plastics recycling, but also is a top 20 ocean polluter. Really?’ Cape Town, South Africa.

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Department of Environmental Affairs (2018) *South Africa State of Waste. A report on the state of the environment. Draft report.* Pretoria: Department of Environmental Affairs. Available at: www.environment.gov.za.

FAO (2019) *FAOSTAT Statistical Database: Food Supply - Livestock and Fish Primary Equivalent*. Food and Agriculture Organization of the United Nations (FAO). Available at: http://www.fao.org/faostat/en/#data/CL (Accessed: 20 May 2020).

IPCC (2006) *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme*. Edited by N. T. and T. K. Eggleston H.S., Buendia L., Miwa K. IGES, Japan.

1. The overall percentage of the waste sent to recycling for treatment includes recycling of inert material such as glass, plastic, metals etc. as well as the organic waste sent to recycling [↑](#footnote-ref-1)