Supplement to :

Potentials for future reductions of global GHG and air pollutant emissions from circular municipal waste management systems

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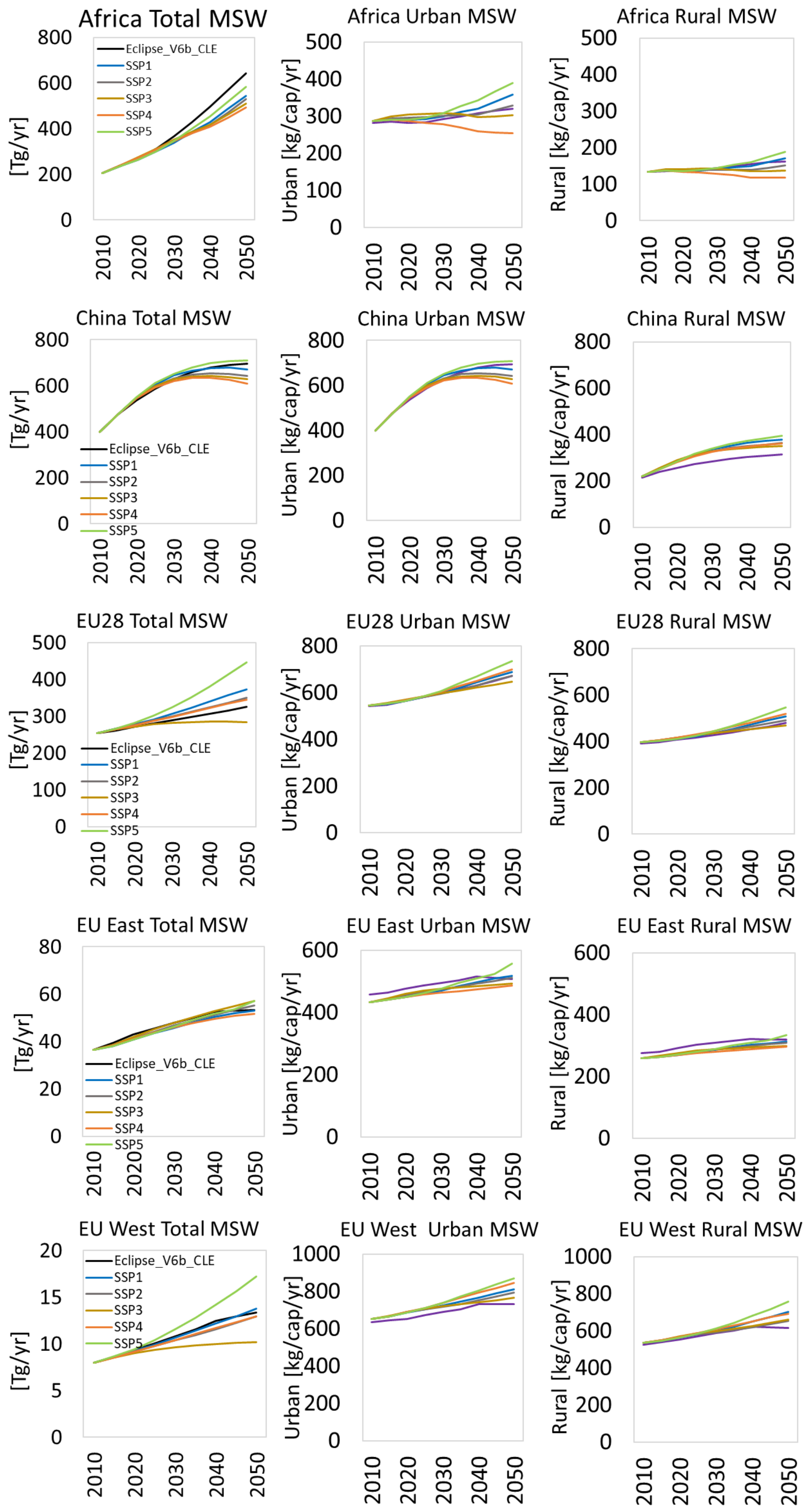

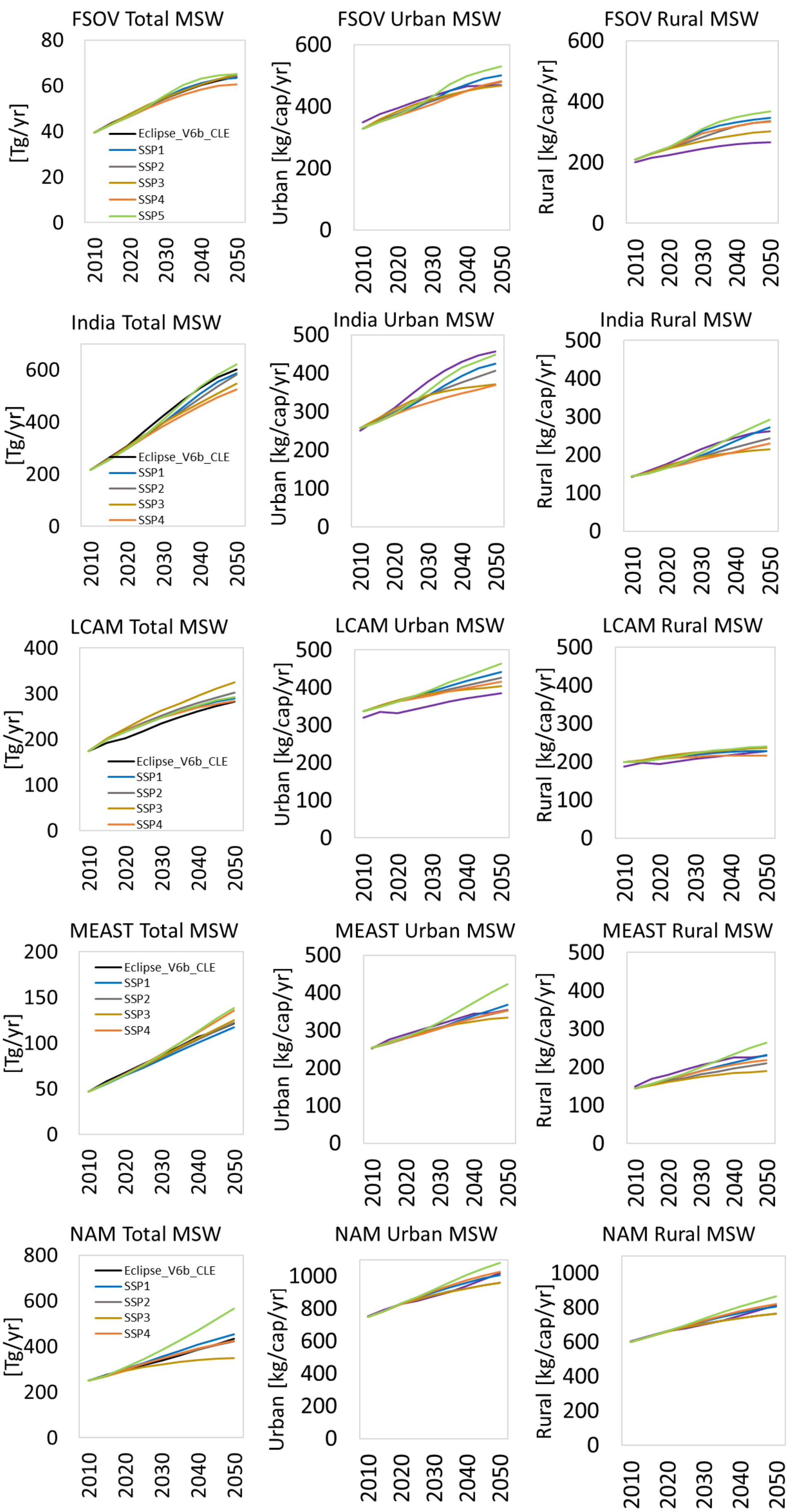
FSOV Total MSW
FSOV Urban MSW
FSOV Rural MSW
India Total MSW
India Urban MSW
India Rural MSW
LCAM Total MSW
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Eclipse_V6b_CLE
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SSP2
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2010
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2030
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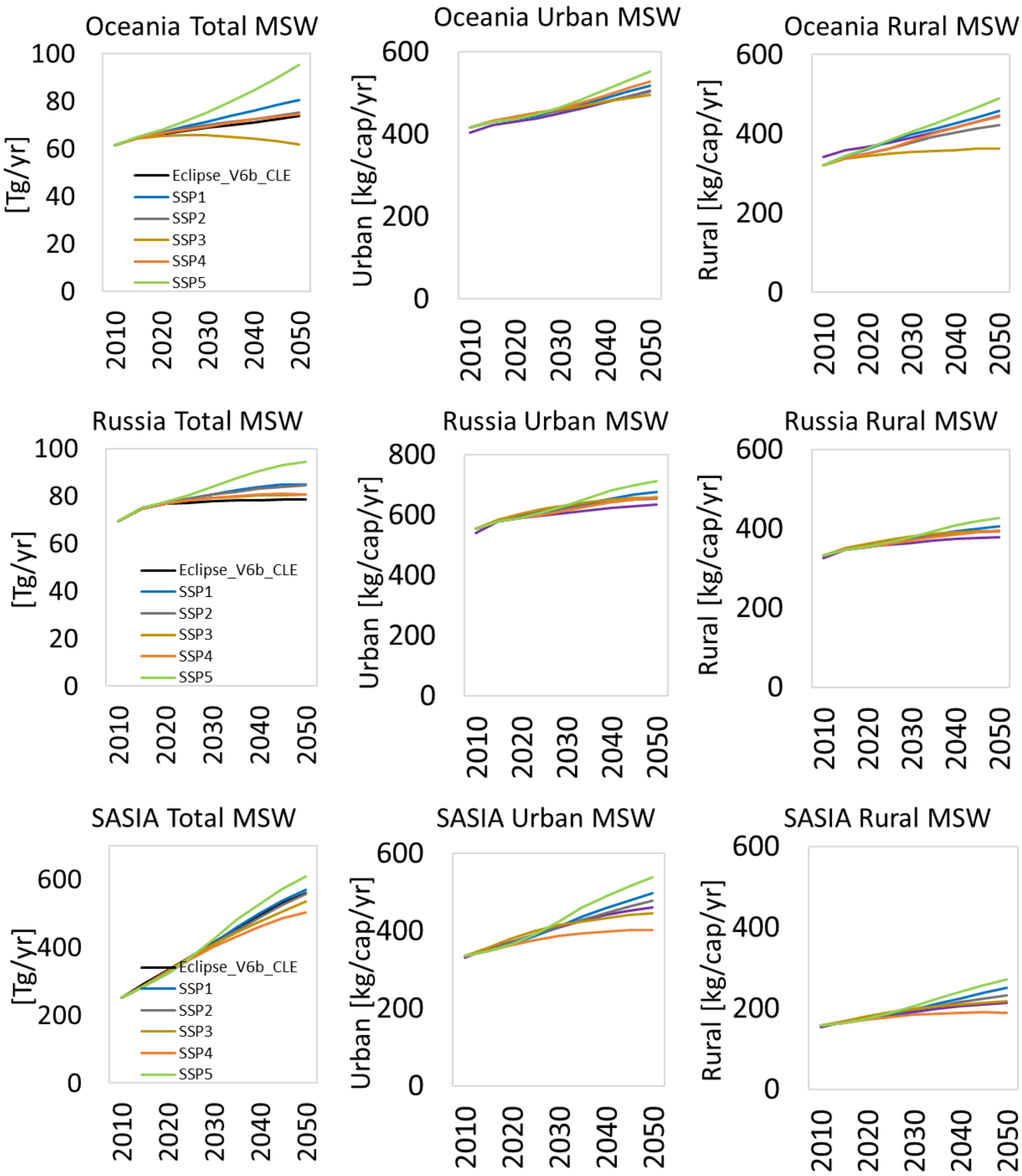

Fig. S1. MSW generation in urban and rural areas by region – scenario

S2. Scenario Analysis.

The following section presents an analysis of the mitigation scenarios along with regional figures. Furthermore, Table S1 presents a summary of MSW generation, management, and related emissions for 2030 and 2050.

Table S1. Global estimations of MSW, CH4, particulate matter and air pollutants for the baseline scenarios (CLE) and the mitigation scenarios (MFR).

	SSP1						**SSP2**					
	SSP1_CLE			**SSP1_MFR**			**SSP2_CLE**			**SSP2_MFR**		
	2030	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
MSW generation (Tg)	3048	3517	3901	2421	2771	3059	3025	3423	3801	3025	3423	3801
MSW dumpsites/non-sanitary landfills (Tg)	1144	1356	1523	60	0	0	1094	1265	1422	493	115	0
MSW openly burned (Tg)	566	680	779	21	0	0	568	666	767	292	43	0
CH4 (Gg)	35443	44739	53443	31473	16496	6502	35088	43859	51632	36544	37755	21893
CO (Gg)	23735	28522	32681	880	2	3	23844	27918	32171	12266	1818	4
CO2 (Gg)	109009	129723	149571	0	0.00	0.00	113406	130873	150656	47380	0	0.00
NOX (Gg)	3245	3900	4468	120	0.46	0.52	3260	3817	4398	1674	248	0.89
PM_2_5 (Gg)	4942	5938	6804	183	0.69	0.78	4964	5813	6698	2553	379	1.333
PM_BC (Gg)	373	448	514	14	0.54	0.61	375	439	505	191	29	1.04
PM_OC (Gg)	2976	3576	4098	110	0.11	0.12	2990	3501	4034	1539	228	0.21
SO2 (Gg)	128	154	176	5	0.03	0.03	128	150	173	66	10	0.06
VOC (Gg)	4776	5739	6576	177	0.02	0.03	4798	5618	6474	2470	365	0.04
	SSP3						**SSP4**					
	SSP3_CLE			**SSP3_MFR**			**SSP4_CLE**			**SSP4_MFR**		
	2030	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
MSW generation (Tg)	2994	3302	3579	2994	3302	3579	2990	3330	3602	2990	3330	3602
MSW dumpsites/non-sanitary landfills (Tg)	1041	1163	1271	495	125	0	1125	1291	1419	512	137	0
MSW openly burned (Tg)	576	659	742	394	104	0	554	633	706	350	82	0
CH4 (Gg)	34657	42730	49233	35784	37043	23065	35507	44555	52173	36643	36608	22125
CO (Gg)	24178	27640	31117	16546	4380	4	23252	26557	29629	14692	3424	3.77
CO2 (Gg)	120254	136166	152614	77266	19328	0.00	104467	113625	122238	58351	9649	0.00
NOX (Gg)	3305	3778	4253	2258	598	0.87	3179	3631	4051	2005	467	0.75
PM_2_5 (Gg)	5034	5754	6478	3443	912	1.31	4841	5529	6169	3058	713	1.13
PM_BC (Gg)	380	434	488	257	68	1.02	366	418	466	228	54	0.88
PM_OC (Gg)	3032	3466	3902	2076	549	0.20	2916	3330	3715	1843	429	0.18
SO2 (Gg)	130	149	167	89	23	0.06	125	143	160	79	18	0.05
VOC (Gg)	4866	5563	6263	3332	882	0.04	4679	5344	5962	2959	689	0.04
	SSP5						**ECLIPSE_V6b**					
	SSP5_CLE			**SSP5_MFR**			**ECLIPSE_V6b_CLE**			**ECLIPSE_V6b_MFR**		
	2030	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
MSW generation (Tg)	3144	3758	4296	3144	3758	4296	3043	3536	3948	3043	3536	3948
MSW dumpsites/non-sanitary landfills (Tg)	1173	1432	1650	119	0	0	1088	1292	1465	112	0	0
MSW openly burned (Tg)	579	717	832	40	0	0	577	705	811	38	0	0
CH4 (Gg)	35545	45373	55348	35324	22038	10339	35038	43579	51835	34805	21353	10238
CO (Gg)	24300	30068	34901	1674	4.22	5.03	24195	29573	34052	1577	3.96	4.51
CO2 (Gg)	113060	140681	166432	0	0.00	0.00	114513	138334	156987	0	0.00	0.00
NOX (Gg)	3323	4112	4774	229	0.84	1.01	3307	4042	4654	215	0.79	0.90
PM_2_5 (Gg)	5060	6260	7267	349	1.27	1.51	5037	6157	7089	329	1.19	1.35
PM_BC (Gg)	382	473	549	27	0.99	1.18	380	464	534	25	0.93	1.06
PM_OC (Gg)	3047	3770	4376	210	0.20	0.24	3034	3709	4270	198	0.19	0.21
SO2 (Gg)	131	162	188	9	0.06	0.07	130	159	183	8	0.05	0.06
VOC (Gg)	4890	6050	7022	336	0.04	0.05	4869	5952	6853	317	0.04	0.05

SSP1_MFR: The global adoption of the measure targeting the reduction of urban municipal food and plastic waste of 50% by 2030 reduces the global MSW generation by about 20% compared to the baseline (SSP1_CLE). Compared to SSP1_CLE, regions as Africa, China, SASIA, LCAM will experience a constant reduction of 30% per year on MSW generation between 2030 and 2050. India is expected to reduce MSW generation by 15% in 2030, reaching a maximum reduction of 18% in 2050. The rest of the world is expected to have a steady reduction of about 18% per year until 2050. Collection rates in developing regions will reach the levels of the EU in both, urban and rural areas achieving rates of >= 95% already in 2030. The reduction of MSW couple with the implementation of MSW management policies at a global level as a consequence of technology transfer and capacity building in less favored countries, including rural areas, will result in a global reduction of MSW openly burned of 96 % in 2030 and close to 100% in 2050. Consequently, same reduction percentage of particulate matter and air pollutants emissions will be observed. This reduction in emissions will have a notorious positive impact in air quality and can potentially bring some climate benefits [1–3]. Thus, it will be possible to avoid the release of 358 Gg/yr BC in 2030 and 538 Gg/yr BC in 2050. The speedy implementation of anaerobic digestion to treat organic waste and the establishment of source separated MSW collection to increase the recycling of materials achieves MSW landfill/dumpsite reduction of 92% in 2030 and 97% in 2050 compared to the same years in the SSP1_CLE. The uniform improvement of MSW management systems at a global level reduces CH_4 emissions by 11% in 2030 and 87% in 2050 compared to the same years in SSP1_CLE.

SSP2_MFR: MSW generation is expected to be the same as in SSP2_CLE due to the absence of measures targeting its reduction. There is an improvement in the global waste management system at a global level, however, inequalities are observed in the developing countries. Although those countries start taking MSW waste management as an important point in the political agenda, the implementation of the MSW management strategies, although possible, is challenging. After 2030, the implementation of the adopted measures shows an improvement. As a result, 55% less MSW, equivalent to 493 Tg/yr ends up in non-sanitary landfills/dumpsites in 2030 compared to the same year in SSP2_CLE. The quantities of MSW openly burned can be reduce by about 48% in 2030. While this pathway does not really affect developed regions such as Europe (EU28 and EU West), North America and Oceania due to the maturity of the management systems, it certainly makes more difficult for the rest of the world to cope with the increasing quantities of MSW generation. Thus, CH4 emissions will increase 4% in 2030 and a maximum reduction of 57% will be observed in 2050 compared to the same years in SSP2_CLE. A maximum emission reduction of particulate matter and air pollutants of 48% is observed in 2030.

SSP3_MFR: This scenario depicts the lowest MSW generation quantities within the modelled scenarios, due to the little economic growth and slow urbanization. The improvement of MSW management systems is rather slow resulting from the lack of investment, international support, and education. While the developed world can continue enhancing the MSW systems within the circular economy framework, developing countries really struggle with the quantities of MSW generation, thus, reaching the target of ~zero emissions from MSW management in 2050 is more than challenging. Particularly, rural areas start adopting strategies to improve MSW systems after 2030. Due to the slow adoption of measures, the maximum reduction of MSW ending in landfills/dumpsites and MSW open burned will be 55% and 32% in 2030, respectively. With the improvement of MSW management is still expected that 495 Tg/yr will end up in non-sanitary landfills/dumpsites in 2030. MSW openly burned will be reduced to 394 Tg/yr in 2030 and reach ~zero in 2050. Thus, generating 3% more of CH_4 emissions for the same year compare to the baseline. After 2030 developing countries start to replicate measures from the developed world thus there is a decline in emissions towards 2050. In this scenario, CH_4 emissions are estimated to be 23065 Tg/yr in 2050 being the highest in all MFR scenarios.

SSP4_MFR: Similarly, to SSP3_MFR, this scenario reflects the inequalities between the high- and middle-income countries and the low-income countries. This is reflected in the pace and level of the adopted measures to deal with the amounts of MSW generated. While this socio-economic development does not really affect industrialized regions, certainly is difficult for developing countries to improve MSW particularly in rural areas. The slow phase-in of circular MSW management still leaves 350 Tg/yr of MSW to end up in non-sanitary landfills/dumpsites in 2030. MSW openly burned will be reduced to 350 Tg/yr in 2030 and reach ~zero in 2050. CH_4 emissions will be rather the same in the SSP4_CLE and SSP4_MFR scenarios by 2030 while maximum reduction of particulate matter and air pollutants in the MFR will be 37% compared to their CLE counterparts. CH_4 emissions are expected to be reduced to 22125 Gg/yr in 2050. The reduction of particulate matter and air pollutants is proportional to the reduction of MSW openly burned.

SSP5_MFR: As a result of the increase in global income MSW generation reaches the highest quantities among the modelled scenarios. However, due to the MSW technology transfer and capacity building in the less favored countries, it is possible to drastically improve MSW systems, in both urban and rural areas, and hence reduce emissions. Still, solutions are focused only on technical approaches and end-of-pipe solutions and measures targeting reduction of MSW generation at source is lacking. Regions as Africa, India, South Asia and Latin America and the Caribbean quickly adopt anaerobic digestion to treat organic MSW and increase recycling rates of recyclables. Incineration plays an important role in the treatment of refuse. Even with the fast implementation of the circular MSW management systems, we estimate that 119 Tg/yr of MSW will still end up in non-sanitary landfills/dumpsites in 2030. 40 Tg/yr of MSW are expected to be open burned in 2030. CH_4 will be reduced to 79% in 2050 compared to SSP5_CLE, i.e., 10339 Gg/yr CH_4 will be emitted in 2050. As MSW open burned is estimated to be reduced by 93% in 2030 compared to SSP5_CLE, particulate matter and air pollutants from this source are reduced at the same level. We estimate that towards 2050 MSW open burned could be close to totally avoidable and therefore emissions associated to this practice as well.

ECLIPSE_V6b_MFR: The development of this scenario is quite similar to the SSP5_MFR in which the focus is technological solutions. As MSW generation is a bit lower than in the SSP5, baseline emissions are also correspondingly lower. We estimate that 112 Tg/yr of MSW will still end up in non-sanitary landfills/dumpsites in 2030. 38 Tg/yr of MSW are expected to be open burned in 2030. CH_4 will be reduced to 79% in 2050 compared to ECLIPSE_V6b_CLE, i.e., 10238 Gg CH_4 will be emitted in 2050. As MSW open burned is estimated to be reduced by 93% in 2030 compared to ECLIPSE_V6b_MFR, particulate matter and air pollutants from this source are reduced at the same level.

S3. Comparison of emissions from MSW

Table S2. Studies assessing Global CH_4 emissions from waste.

Study	Sector	2010	2011	2012	2013	2014	2015	2050	Notes
EDGARv 4.3.2 [4]	Waste	37	38	37	37	38	38		Includes industrial waste and MSW
CMIP6 [5,6]	Waste	33	33	33	34	34	34		Includes industrial waste and MSW
Wiedinmyer et al., 2014[7]	MSW	4							Open burning of MSW
Eclipse_V5a [2]	MSW	35					30	57	
This study	MSW	27					28	52-55	Min 52 Tg for SSP3 and Max 55 Tg for SSP5. All other Scenarios in between this range
CMIP6 [5,6]	Total	371		381		388	388		
Höglund-Isaksson, 2020[8]	Total						344	450	Total global anthropogenic CH_4

Table S3. Studies assessing Global CO_2 emissions from waste.

Study	Sector	2010	2011	2012	2013	2014	2015	2050	Notes
EDGARv 4.3.2 [4]	Waste	16	16	17	17	17	17		Includes industrial waste and MSW. Incineration and open burning
CMIP6[5,6]	Waste	112	116	120	124	129	130		Includes industrial waste and MSW
Wiedinmyer et al., 2014 [7]	MSW	1413							Open burning of MSW
This study	MSW	70					80	150-166	

Table S4. Studies assessing global emissions from waste.

Study	Sector	year	PM2.5	BC	OC	CO	SO2	NOx	VOCs	Notes
EDGARv 4.3.2 [4]	Waste	2012	0.107	0.006	0.010	0.040	0.040	0.090	0.030	Emissions from solid waste disposal sites and waste incineration
CMIP6[5,6]	Waste	2015		0.7	4	40	0.5	6	7	Includes industrial waste and MSW
Eclipse_V5a[2]	MSW	2015	2.5	0.4	1	10	0.1	0.3	1.4	
Wiedinmyer et al., 2014	MSW	2010	6	0.6	5	37	0.5	4	7	Emissions from open burning of MSW. VOC identified.
This study	MSW	2015	3.5	0.3	2.1	17	0.1	2	3	
Eclipse_V5a [2]	Total	2010	110	10	33	511	85	89	104	Estimates for PM2.5, BC, OC represent global total, whereof about 52% anthropogenic. Other pollutants refer to anthropogenic
CMIP6[5,6]	Total	2015		10	35	934	94	156	227	Total global emissions

Supplementary Methods

S4. Description of the SSPS.

The Shared Socioeconomic Pathways (SSPs) provide five plausible pathways about probable world's socioeconomic development. Each SSP is accompanied by a narrative and a quantification of development [9]. A short description of the narratives in terms of economic development and demographics for each SSPs is presented below (see ref[10]):

- SSP1 'Sustainability': Economic growth is moderately high in developing countries leading to a reduction of inequality within and between countries. Low material growth and resource use. Current high fertility countries move towards low population while in low fertility countries there is an increase of fertility rates. Urbanization is still high in developing countries, the negative effects associated with it are limited.
- SSP2 'Middle of the road': Moderate economic growth. Income distribution shows an improvement but still inequalities are observed. Population growth is moderate, and urbanization is consistent with the historical trend.
- SSP3 'Regional Rivalry': Little economic growth due to lack of investment in education and technology. High inequalities within and between countries. Population growth is high, and urbanization slow.
- SSP4 'Inequality': Medium economic growth in high- and middle-income countries while low-income countries are far left behind. Thus, reflected in the high and low consumption patterns of the respective economies. Industrialized countries depict low fertility rates and population growth. In low-income countries urbanization is high forming urban-slums.
- SSP5 'Fossil Fueled Development': Income inequality decreases within regions and per capita income increases at a global level. Global population declines. Regions reach high level of urbanization.

S5. GDP per capita and share of urban population.

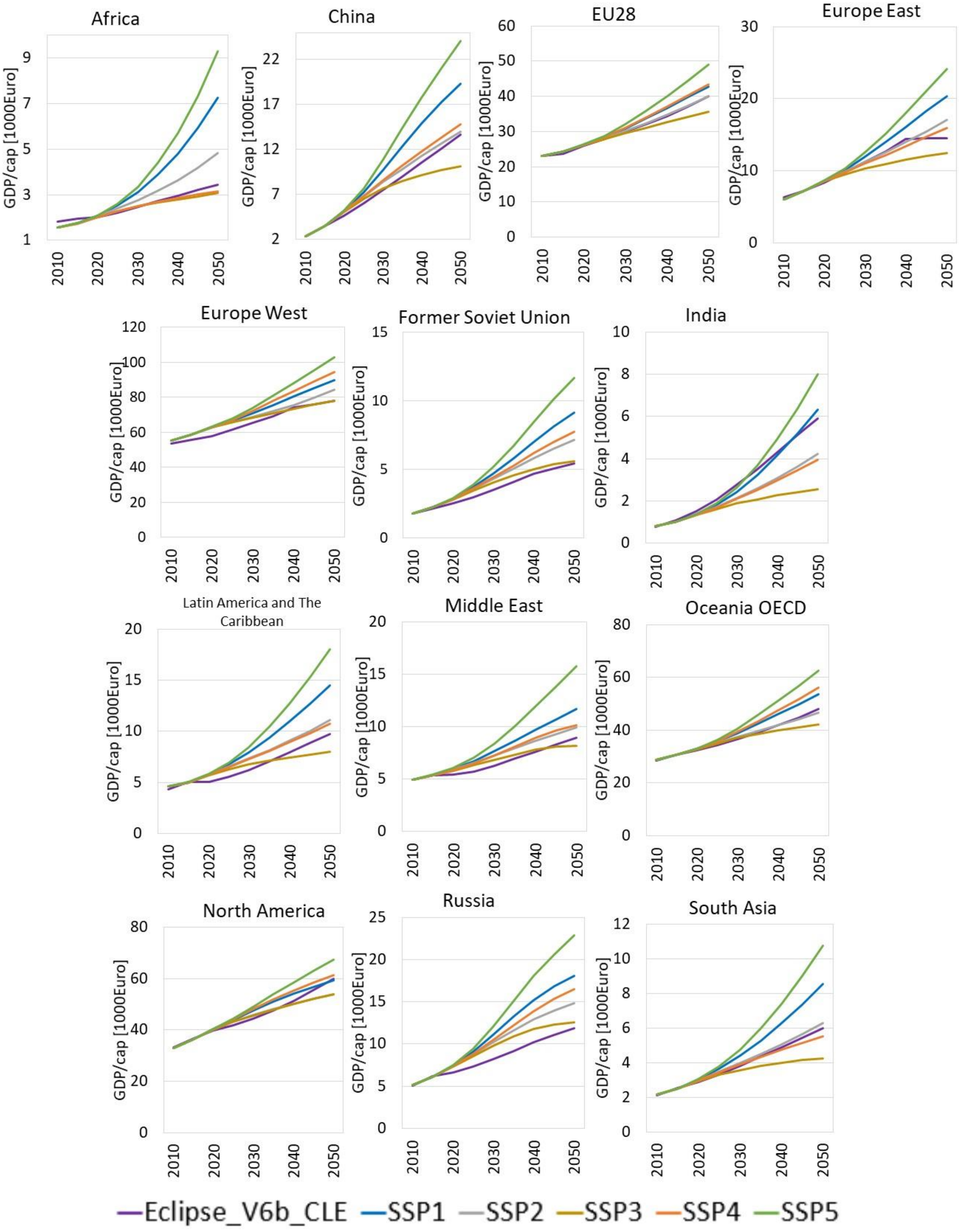

Fig. S2 . GDP per capita by region

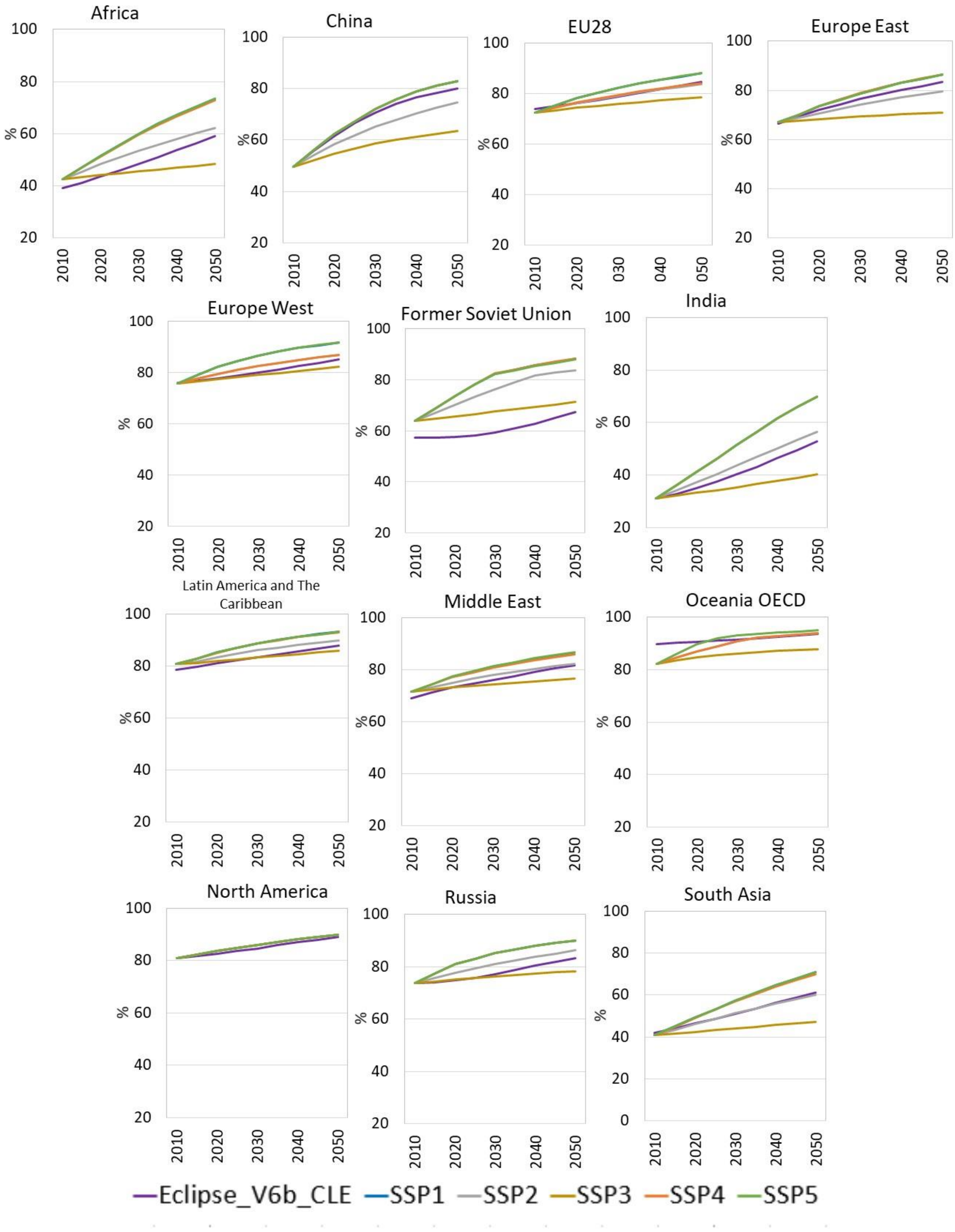

Fig. S3. Share of urban population by region.

S6. Description of the methodology to project municipal solid waste generation and composition.

A new methodology to project municipal solid waste generation and waste composition by income group was developed based on the assumption that average national waste generation rate and composition vary depending on the average national income level ref[11–13] [12]. Numerous studies [12,14–16] indicate that composition of municipal solid waste depends on socio-economic characteristics, geographical location and environmental features. Paper and plastic wastes are the main fractions of MSW in high-income countries, while food waste dominates in low income countries [12]. A panel data analysis is performed to determine the elasticity of the different variables on the generation of municipal solid waste per capita. The drivers used here to project future municipal solid waste generation are GDP per capita and urbanization rate. Furthermore, since waste composition influences the carbon content and hence the material and energy recovery potential, projections of waste composition are needed. For future years, the composition of waste is recalculated based on an estimated elasticity of per capita food waste to GDP per capita. After projecting the future generation of food waste per capita, other types of waste are projected to make up the rest of total per capita MSW generated with the relative contribution of non-food waste in 2015 kept constant in future years.

Description of the variables and data to estimate MSW generation elasticities: Three different variables are used to run the panel analysis, namely, historical municipal solid waste generation per capita, gross domestic product per capita and urbanization rates. All variables are specified in logarithmic form in order to provide parameter estimates that can be directly interpreted as elasticity values. In total, the unbalanced panel data set comprises 1006 observations. In order to control for the influence of population growth, waste generation per capita is chosen instead of total waste generation as dependent variable in elasticity estimations [17]. Data on historical municipal solid waste generation in kilogram per capita are obtained from different sources (Table 1). The dataset for EU28 countries covers from 1995 to 2017, for some OECD countries the data covers between 5 and 31 years (e.g., Japan and South Korea).

Table S5. Urban-rural MSW generation per capita ratio

Country	Years	Waste generation data - Source
EU 28 countries	1995-2017	Eurostat (retrieved 2020) Table [env_wasmun]. Ireland: Environmental protection Ireland https://www.epa.ie/nationalwastestatistics/irelandswastestory/ Finland: Statistics Finland/Waste statistics, Finnish Environment Institute (SYKE)
Norway	1995-2017	Waste statistics from statistics Norway https://www.ssb.no/en/avfkomm
Switzerland	1995-2013	Eurostat (retrieved 2020) Table [env_wasmun]
Australia	2006-2015	OECD (retrieved 2020) Table [Municipal waste] and Australian Bureau of Statistics -waste accounts https://www.abs.gov.au/statistics/environment/environmental-management/waste-account-australia-experimental-estimates/2018-19
Japan	1985-2016	OECD (retrieved 2020) Table [Municipal waste]
South Korea	1985-2016	OECD (retrieved 2020) Table [Municipal waste]
Mexico	1991-2012	OECD (retrieved 2020) Table [Municipal waste]
New Zealand	2002-2017	OECD (retrieved 2020) Table [Municipal waste]
United States of America	1990- 2015	Advancing Sustainable Materials Management: 2018 Tables and Figures Assessing Trends in Materials Generation and Management in the United States November 2020. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancing-sustainable-materials-management
Brazil	2000-2012	OECD (retrieved 2020) Table [Municipal waste]
Chile	2000-2016	OECD (retrieved 2020) Table [Municipal waste]
Israel	2000-2017	OECD (retrieved 2020) Table [Municipal waste]
Colombia	2003-2011	SSPD 2011, OECD (retrieved 2020) Table [Municipal waste]
Russia	1999-2011	OECD (retrieved 2020) Table [Municipal waste]
Turkey	1995-2017	Eurostat (retrieved 2020) Table [env_wasmun]
Serbia	2006-2017	Eurostat (retrieved 2020) Table [env_wasmun]
Macedonia	2008-2017	Eurostat (retrieved 2020) Table [env_wasmun]
Malaysia	1996-2000	Department of statistics Malaysia (accessed 2016)
Kenya	1998-2009	
Montenegro	2008-2017	Eurostat (retrieved 2020) Table [env_wasmun]
Bosnia and Herzegovina	2008-2017	Eurostat (retrieved 2020) Table [env_wasmun]
Kosovo	2015-2017	Eurostat (retrieved 2020) Table [env_wasmun]
Peru	2012-2015	Municipalidad Metropolitana de Lima (MML) 2015

Data on Gross Domestic Product per capita in constant 2010 US dollars was obtained from the World development Indicators (World Bank, retrieved 2020). Urban population information was obtained from EUROSTAT Table [EU-SILC survey [ilc_lvho01]] for EU28 and from the World Development

Indicators (retrieved 2020) for the other countries. To get an agreement between the dataset and guarantee consistency some adjustments on the information were needed due to the different definition of urbanization.

Elasticity estimation models: Historical data on municipal solid waste generation per capita (dependent variable) are plotted against GDP per capita (independent variable) in order to visualize the relationship between the two variables and to identify possible clusters of municipal waste generation (Fig. S4).

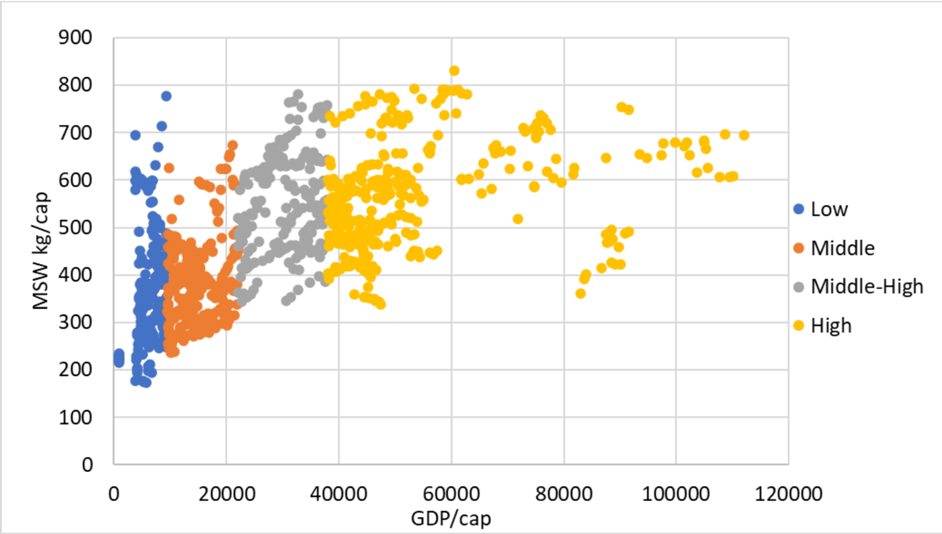

Fig. S4. Municipal solid waste vs GDP per capita.

The definition of the different income groups was carried out based on the distribution of the scatterplot. Note that in the subsequent projections, countries may over time move out of their initial income group into a higher income group following an increase in the GDP per capita. Hence, the group distribution of the municipal solid waste generation is dynamic over time. It is important to notice that this income group definition is independent than that of the World Bank or any other income classification. The income group definition here is specifically related to MSW generation.

The different income groups are classified as follows (GDP in constant 2010 US$): Low-income group is formed by countries/regions with GDP per capita lower than 9500 US$/year, middle-income group represents countries/regions with GDP per capita higher-equal than 9500 US$/year and lower than 22000 US$/year; middle-high income group represents countries/regions with GDP per capita higher-equal than 22000 US$/year and lower than 38000 US$/year and high-income group is formed by countries/regions with GDP per capita higher equal than 38000 US$/year. The latter group was then carefully revised as evidence has shown that some countries have already implemented some waste prevention programs. Fact that could interfere in the relationship between the variables. Therefore, a subgroup of countries with GDP per capita higher-equal than 38000 US$/year and years before implementation of any waste prevention program was selected. At EU level, the Waste Framework

Directive[1] requires Members States to adopt waste prevention programmes by December 2013. Therefore, the selection of the observations was done after reviewing the reported information in terms on MSW generation to EUROSTAT but also official national sources, together with a careful revision of the annual review progress in the completion and implementation of the programmes carried out by the European Environment Agency (EEA) in 2019[2]. For countries outside the EU (i.e., Japan), a similar process was carried out in which reported values were contrasted to the implementation of strategies and regulations to reduce MSW generation.

Furthermore, since waste composition influences on the one hand emissions of air pollutants and greenhouse gases and on the other hand, the circularity of resources, projections of waste composition are relevant. In particular, low-income countries tend to have a considerably higher fraction of food waste in the total municipal waste generated than high income countries. Therefore, changes in the future composition of waste are projected by income group based on an estimated elasticity of food waste generation to GDP per capita. Historical data on food waste generation is taken from ref[18]. The dataset comprises 882 observations in total. The elasticity is estimated for the same income groups as MSW in unbalanced panels. The panel data analysis is performed to determine the elasticity of the different variables on the generation of municipal solid waste per capita. Pooled OLS, fixed effects and random effects estimator models are run to test the effects of the explanatory variables on municipal waste generation per capita. In the pooled models a single slope is calculated for all countries and the between (cross-sectional) and within (time) variances are bluntly added up. When the cross-sectional variance is eliminated and the slopes are based on time variance only, the model is denoted a within estimator whereas in between models the time variance is eliminated and only cross-sectional variance is considered in the elasticity parameter. In fixed effect models, the within estimator is describing the slope while the country-specific effects are captured as country-specific constants. Finally, random effect model treats the individual effects as random variables and the variance is a weighted average of within and between variance [19]. Three different tests are applied to select the appropriate model. A Lagrange Multiplier (LM) test is applied to test for the cross-sectional dependence in heterogeneous panels (test random effects vs pooling). An F test is used to test for individual effects based on the comparison between the within and the pooling model and a Hausman test is used to evaluate the difference in vector coefficients between the fixed and random effects models. The results of the elasticity estimations of municipal solid waste generation to GDP per capita and urbanization rate and elasticity estimations of food waste generation (fraction in MSW) to GDP per capita are presented in Table S6

[1] Directive 2008/98/EC, Article 29.

[2] https://www.eea.europa.eu/themes/waste/waste-prevention/countries/folder_contents?pagenumber=2&pagesize=20

Table S6. MSW generation elasticities to GDP per capita and urbanization rate

Variable kg/cap	Income group USD2010/cap	n	Number of observations	Explanatory variable	OLS	Fixed Effect	Random Effect	LM - test	Hausman - test
MSW	<9500	23	166	Constant	0.001		0.015	8.835	23.012
				GDP per capita	0.000	0.375***	0.008		
				Urbanization rate	0.013	0.003	0.011		
				R-square	-0.010	-0.001	-0.008		
	<9500	23	166	Constant	-0.001		0.013	8.923	23.643
				GDP per capita	0.000	**0.375*** **	0.007		
				Urbanization rate					
				R-square	-0.006	**0.006**	0.446		
	<9500	23	166	Constant	0.001		0.010	6.692	0.063
				GDP per capita					
				Urbanization rate	0.013	0.009	0.011		
				R-square	-0.004	-0.161	-0.004		
FW	<9500	23	166	Constant	-0.023***		5.033***	25.425	55.065
				GDP per capita	-0.002	**0.176*** **	0.161***		
				Urbanization rate					
				R-square	0.006	**0.473**	0.681		
MSW	>=9500 - <22000	18	253	Constant	-0.024**		-0.023~	2.351	2.438
				GDP per capita	0.250***	0.175**	0.224***		
				Urbanization rate	-0.504~	-0.127	-0.357		
				R-square	0.080	-0.032	0.060		
	>=9500 - <22000	18	253	Constant	-0.046***		**-0.022**	34.273	1.818
				GDP per capita	0.364***	0.160**	**0.183*** **		
				Urbanization rate					
				R-square	0.085	-0.028	**0.058**		
	>=9500 - <22000	18	253	Constant	-0.016*		-0.015	3.286	1.054
				GDP per capita					
				Urbanization rate	0.291	0.551*	0.437~		
				R-square	0.002	-0.059	0.008		
FW	>=9500 - <22000	18	253	Constant	**0.004*** **		5.052***	1.002	0.001
				GDP per capita	**0.133*** **	0.130***	0.130***		
				Urbanization rate					
				R-square	**0.628**	0.521			
MSW	>=22000 - <38000	22	201	Constant	-0.011		-0.021	8.378	0.368
				GDP per capita	0.204***	0.258**	0.241***		
				Urbanization rate	-0.263	-0.042	-0.104		
				R-square	0.096	-0.061	0.078		
	>=22000 - <38000	22	201	Constant	-0.011		**-0.021**	8.616	0.174
				GDP per capita	0.186***	0.254***	**0.233*** **		
				Urbanization rate					
				R-square	0.090	-0.055	**0.081**		
	>=22000 - <38000	22	201	Constant	-0.007		-0.022	7.436	9.389
				GDP per capita					
				Urbanization rate	-0.027	0.312	0.088		
				R-square	-0.005	-0.115	0.006		
FW	>=22000 - <38000	22	201	Constant	-0.023*		5.164***	4.513	0.108
				GDP per capita	-0.232***	-0.023	-0.036		
				Urbanization rate					
				R-square	0.083	-0.123	0.826		

Variable kg/cap	Income group USD2010/cap	n	Number of observations	Explanatory variable	OLS	Fixed Effect	Random Effect	LM - test	Hausman - test
MSW	>=38000*	16	230	Constant	-0.001		-0.001	0.051	0.024
				GDP per capita	0.536***	0.537 ***	0.536***		
				Urbanization rate	0.027	0.019	0.027		
				R-square	0.8971	0.256	0.303		
	>=38000*	16	230	Constant	-0.001		-0.001	0.051	0.002
				GDP per capita	0.539***	0.539***	**0.539*** **		
				Urbanization rate					
				R-square	0.307	0.259	**0.307**		
	>=38000*	16	230	Constant	-0.003		-0.003	0.043	0.068
				GDP per capita					
				Urbanization rate	0.473**	0.488**	0.473**		
				R-square	0.027	-0.041	0.027		
FW	>=38000	16	230	Constant	0.000		5.120***	6.681	3.611
				GDP per capita	-0.365***	0.056	**0.051**		
				Urbanization rate					
				R-square	0.182	-0.054	0.298		
MSW	All income groups	50	892	Constant	-0.004		-0.001	0.046	0.051
				GDP per capita	0.100***	0.099***	0.100***		
				Urbanization rate	0.016	0.016	0.016		
				R-square	0.025	-0.033	0.025		
	All income groups	50	892	Constant	-0.004		**-0.004**	0.046	0.048
				GDP per capita	0.103***	0.101***	**0.103*** **		
				Urbanization rate					
				R-square	0.001	-0.032	**0.025**		
	All income groups	50	892	Constant	-0.006		-0.006	0.061	0.010
				GDP per capita					
				Urbanization rate	0.042	0.002	0.042		
				R-square	0.001	-0.057	0.010		
FW	All income groups	46	927	Constant	-0.002		5.102***	13.507	5.999
				GDP per capita	0.099***	**0.101*** **	0.085***		
				Urbanization rate					
				R-square	0.033	**-0.013**	0.249		

Where:, $\varepsilon_{it}=u_i+v_{it}$ *is an error term which is separated into an individual effects term and a residual omitted variables term, and* ε_{it}*~IID* $\left(0,\sigma_{\varepsilon}^{2}\right)$ *is an error term which are assumed to be normally distributed with mean zero and constant variance. * before implementation of waste prevention programmes or policies to reduce MSW generation.*

S7. Rural-urban waste generation ratio

Table S7. Urban-rural MSW generation per capita ratio

Region	Rural Urban ratio	Comments	Source
Africa	0.53	Ratio between average kg/cap/year between North Africa (442) and Sub-Saharan Africa (237)	[20]
China	0.8/0.55	Based on average rural waste generation rate of 0.95 kg/cap/day for the year 2010 for provinces with high urban areas and 0.55 for provinces with lower urban areas.	[21]
Latin America and the Caribbean	0.56	Urban solid waste generation in LAC reaches between 0.6 to 0.93 kg/cap/day. Ratio between countries highly urbanized and less urbanized in Latin America.	[22]
EU15	0.8		
EU13	0.6	Based on a study carried out in Romania in which average waste generation rate of 0.4 kg/cap/day is stipulated. However, in peri urban areas waste generation rates are close to the ones in urban areas.	[23,24]
North America	0.8	Based on economic differences between urban and rural areas in the US.	[25]
Europe West	0.8	Assumed to similar to EU15	
Russia	0.6	Assumed to be similar to EU13	
Former Soviet Union	0.6	Assumed to be similar to EU13	
Middle East	0.6	Based on the reported MSW generation rates per capita for countries such as Mauritania, Morocco, Algeria, Tunisia, Egypt, Lebanon, Syria, Jordan, and Yemen.	[26]
Oceania	0.8		
India	0.55	Value based on MSW generation rates for different income levels, and specific reported data on urban/rural generation in Andhara Pradesh, Chandigarh, Kerala and Tamil Nadu.	[27–30]
South Asia	0.5	Value based on a study carried out in Thailand on the different MSW generation rates in different household types.	[31]

S8. Waste matrix in GAINS.

Table S8. Solid waste management technologies

Solid waste management technology	Municipal solid waste							
	Food	**Glass**	**Metal**	**Other**	**Paper**	**Plastic**	**Textile**	**Wood**
Open burned	X			X	X	X	X	X
Scattered and/or disposed to water-courses	X	X	X	X	X	X	X	X
Unmanaged solid waste disposal site - low humidity - < 5m deep	X			X	X		X	X
Unmanaged solid waste disposal site - high humidity - > 5m deep	X			X	X		X	X
Compacted landfill	X	X	X	X	X	X	X	X
Covered landfill	X			X	X		X	X
Landfill gas recovery and flaring	X			X	X		X	X
Landfill gas recovery and used	X			X	X		X	X
Low quality burning of waste	X			X	X	X	X	X
Incineration (poor air quality controls)	X			X	X	X	X	X
Incineration (high quality air pollution controls - energy recovery)	X			X	X	X	X	X
Anaerobic digestion	X							
Composting	X							
Recycling		X	X		X	X	X	X

S9. MSW management narratives and regional aggregation.

Table S9. MSW management narratives

Scenario	Description
SSP1_MFR	Maximum municipal food waste reduction of 50% by the year 2030 based on Lipinski et al., 2013 and based on the target adopted by the United Nations Assembly in 2015 of halving per capita food waste at the retail and consumer level as a part of the 2030 Sustainable Development Goals. A maximum municipal plastic waste rate reduction of 50% by the year 2030 as a part of the 2030 Sustainable Development Goals. Waste management policies are implemented at a global level resulting in an improvement of waste management systems. Waste technology transfer and capacity building is facilitated allowing the less favored countries to improve and develop appropriate waste management systems in both urban and rural areas. Hence, environmental impacts such as air pollution and GHGs emissions caused by inappropriate waste management are avoided.
SSP2_MFR	EU28, EU West, EU East, Oceania and North America regions continue developing and implementing policies to meet the proposed environmental targets related to waste. Russia and the Former Soviet Union countries also implement similar policies but a slower pace. All other countries either continue or start developing strategies to improve their waste management systems but are still left behind in terms of implementation.
SSP3_MFR	EU28, EU West, EU East, Oceania, and North America countries continue developing and implementing policies to meet the proposed environmental targets related to waste. Russia and The Former Soviet Union countries also implement similar policies but a slower pace. All other countries are left far behind due to a lack of international support in terms of technology transfer and capacity building. Environmental concerns related to waste are not a priority in these countries. Disparities between waste management in urban and rural areas are notorious.
SSP4_MFR	EU28, EU West, EU East, Oceania, and North America and Russia and The Former Soviet Union countries continue developing and implementing policies to meet the proposed environmental targets related to waste. Russia and The Former Soviet Union countries catch up with European countries in terms of waste management. All other countries continue struggling to cope with the large quantities of waste generated.

SSP5_MFR	Waste technology transfer and capacity building is facilitated allowing the less favored countries to improve and develop appropriate waste management systems in both urban and rural areas. However, policies targeted to waste reduction are still missing.
Eclipse_V6b_MFR	Waste management systems are improved at a global level. There is collaboration between and within nations. Reduction of environmental impacts caused by waste management are successfully implemented.

Table S10. Regional Aggregation

Income group	**Country/region**
Africa	South Africa, Tanzania, Egypt, Kenya, Nigeria, North Africa (includes Algeria, Morocco, Libya, Tunisia, Sudan), East Africa, Western Africa, Rest Africa
China	Anhui, Beijing, Chongqing, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hainan, Hebei, Heilongjiang, Henan, Hong Kong and Macau, Hubei, Hunan, Jilin, Jiangsu, Jiangxi, Liaoning, Inner Mongolia, Ningxia, Qinghai, Shaanxi, Shanghai, Sichuan, Tianjin, Tibet, Xinjiang, Yunnan and Zhejiang
EU28	Austria, Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden, Greece, Malta, Portugal, Slovenia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, Italy, Spain, United Kingdom.
EU-East	Albania, Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro, Serbia, Turkey.
EU-West	Norway, Iceland, Switzerland
Former Soviet Union (FSOV)	Armenia, Former Soviet Union States (includes Tajikistan, Turkmenistan, and Uzbekistan), Georgia, Azerbaijan, Kazakhstan, Belarus, Moldova, Kyrgyzstan
India	Andhra Pradesh, Assam, West Bengal, Bihar, Chhattisgarh, Delhi, North East (excl Assam), Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Maharashtra, Manipur, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttarakhand, Uttar Pradesh, Jammu Kashmir
Latin America and The Caribbean	Argentina, Caribbean (includes countries in the Caribbean region), Chile, Brazil, Mexico, Central America, Colombia, Ecuador, Bolivia, Paraguay, Perú, Uruguay, Venezuela, and Other Latin America.
Middle East	Middle East, Iran, Israel, Saudi Arabia
North America	United States and Canada.
Oceania	Australia, New Zealand, Japan
Russia	Russia (Europe – Asia)
South Asia	Afghanistan, Bangladesh (Dhaka and rest of Bangladesh), Cambodia, North Korea, South Korea, Myanmar, Taiwan, Nepal, Pakistan (Karachi, NW frontier provinces Baluchistan, Punjab and Sindh), Philippines (Bicol, Luzol and Manila), Sri Lanka, Thailand (Bangkok, Central Valley, North Eastern Plateau, Northern Highlands and Southern Peninsula), Vietnam (North and South).

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