CITIES AND CIRCULAR ECONOMY FOR FOOD

TECHNICAL APPENDIX: GLOBAL MODELLING

0 GENERAL METHODOLOGICAL NOTES

1. The analysis provides a high-level estimate of the food system in its material flows and associated effects on matters of environment and health. The analysis also estimates the economic potential contained in those flows. In estimating the effect on the food system, the report team analysed a set of interventions ('levers') associated with the circular economy which we identified from our desk research and interviews with experts in the relevant fields as having the potential to make substantial impacts; potential annual impacts were estimated for today (based on 2013 data) and 2050.

2. Estimates selected were the ones identified as the most comprehensive, reasonably well quantifiable due to existing global data. Wherever possible, we built on existing work that provided a consistent and established approach. It should be noted that most issues differ strongly in scope and effect in different regions of the world; as such, inference to local conditions should be made with caution.

3. Wherever possible, conservative assumptions were taken in estimating the scale of costs and potential benefits.

4. Given the limitations stated above, the estimation of the potential cost benefits of transitioning to a circular economy for food stated in this report can be considered at the lower end of what might be achievable if a full circular economy for food was implemented.

5. The base year of the analysis is generally 2013, the latest year for which data from the UN Food and Agricultural Association's (FAO) Food Balance Sheets (FBS) is available at the time of writing of this report. Selected data that was from several years prior to 2013 was adjusted to the 2013 base year.

6. Future costs are shown in USD using the 2018 exchange rate and dollar value.

7. Extrapolations to 2050 were made in a simplified fashion: either projecting forward past developments or modelling issues based on their underlying drivers. E.g. In our model, human waste increases in line with the United Nations' projecting increases in human population. Unless stated otherwise, we have worked on business-as-usual (BAU) assumptions, i.e. current trends are generally projected into the future and we have not taken into account any additional measures that would create efficiency improvements.

8. Some projections (e.g. greenhouse gas (GHG) and water withdrawal increases per ton of food produced) are slightly higher than in other studies. This is in part due to simplified assumptions taken for the projections. However, significantly, this can be considered plausible as in most studies climate effects are not taken into account. Already, the effects of climate change (e.g. on agricultural yields, water efficiency) are visible – both on the long term and through shocks. Recent studies that include climate change effects typically find significant losses of agronomic efficiency. We have therefore hypothesised that until 2050, no additional efficiency gains can be realised.

9. Where available, all today's and projected data were triangulated with third-party sources and several dozen experts were engaged to validate our approaches and key metrics, as well as to scope the field.

10. Notwithstanding all diligence that was taken to reach the estimates presented in this report, these estimates remain high-level estimates based on the best available data and knowledge. The limitations of this approach are fully acknowledged. For deeper insights into the distinct topics discussed here we refer the reader to the scientific sources underpinning the analysis.

1 DISCUSSION OF APPROACH IN CONTEXT OF COMPARABLE STUDIES

Recent scientific advances are increasingly leading to sophisticated, integrated models concerning global systems of natural resources and human health. Some of these are based on multi-year efforts of large groups of renowned experts, taking into account the latest tools available to science. Rather than claiming to compare to such research, this analysis attempts to position its estimates in range of what is derived from such scientifically sound approaches.

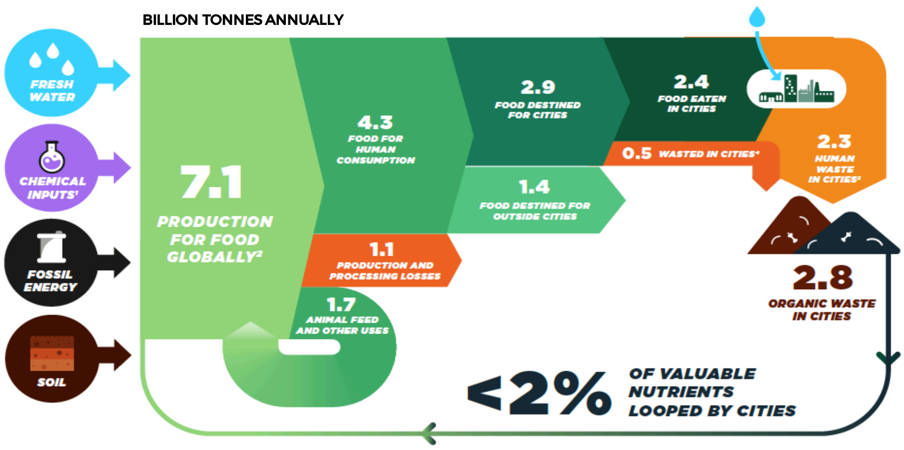
Of particular relevance to this report are two authoritative studies that were published towards the end of the analysis. These provide comprehensive future projections of global agriculture and its environmental and societal impacts:

- *The future of food and agriculture: alternative pathways to 2050* by FAO (2018), which constitutes the first time that a comprehensive set of projections of the global food system and its impacts on a wide range of ecological and societal factors has been provided by the Food and Agricultural Organization (FAO).
- *Options for keeping the food system within environmental limits* by Springmann *et al.* (2018), which takes a planetary boundary perspective, i.e. focussing on the impacts of human activities on a set of environmental resources that are critical to a 'safe operating space' , such as fresh water, soil, phosphorus, and greenhouse gases.

Both studies differ from most previous studies by taking into consideration the effects of climate change in their calculations.

For this present analysis, both studies were used to triangulate and fine-tune our projections and assumptions herein. While direct comparisons are possible only to a limited extent due to different baselines and methodological scopes and approaches, the high-level estimations made here are thought to be directionally in line with the findings of the two studies and other similarly comprehensive studies. We hope that the results of this report's analysis can contribute fruitfully to the debate about how to shape a food system that is

2 CURRENT FOOD MATERIAL FLOWS AND NEGATIVE EXTERNALITIES



1. Such as fertilisers or pesticides; 2. As per FAOSTAT 'Production' definition, i.e. typically reported at the first production stage (farm level for crops and animal products; live weight for seafood) 3. Human waste includes solid and liquid waste, expressed in wet mass; 4. Food wasted in cities includes distribution and consumption stages

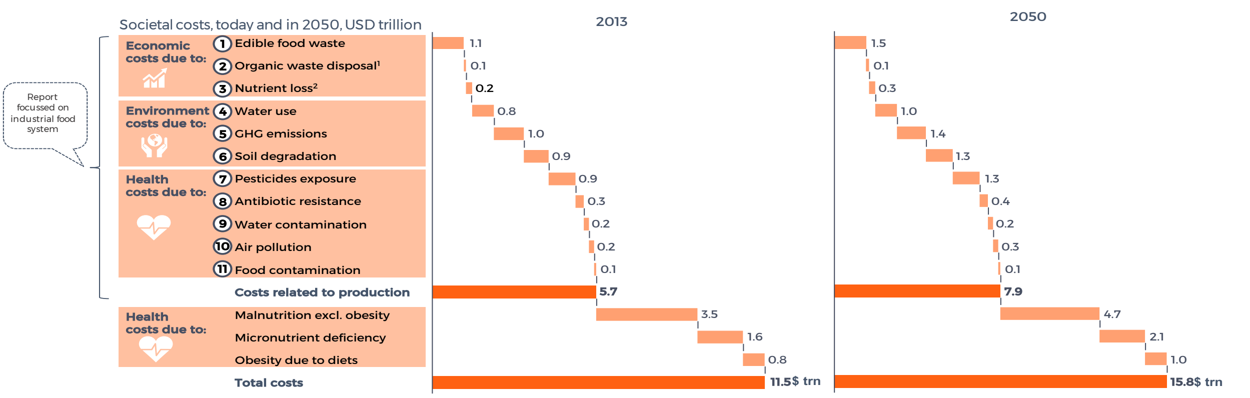
Source: FAOSTAT, *Food Balance Sheets* (2013); FAOSTAT, livestock manure (2013); WBA, Global Bioenergy Statistics (2017); The World Bank, *What a Waste* (2012); Scialabba, N., *et al.*, *Food wastage footprint: impacts on natural resources* (2013), United Nations University, *Valuing human waste as an energy resource* (2015), Cities and the Circular Economy for Food analysis

		METRIC	VALUE	UNIT	COMMENT	SOURCE
	GLOBAL	Global food production	7.1	billion tonnes	Based on the latest food production data outlined in FAOSTAT's Food Balance Sheets (FBS): food as per FAOSTAT 'Production' definition is 7.1 billion tonnes, i.e. typically reported at the first production level (farm level for crops and animal products; live weight for seafood).	FAO, FAOSTAT, Cities and Circular Economy for Food team calculations
		Total food waste and losses	1.8	billion tonnes	Including all losses from production to consumption, including crops not used for food. Closely replicating the methodology of FAO (2011) for estimating food waste and losses along the food value chain based on detailed loss and waste factors provided by FAO. Some deviation due to methodological simplification regarding processed / fresh foods.	FAO, FAOSTAT, Cities and Circular Economy for Food team calculations
		Share of total food waste and losses at production stage	25%		= 1.8 billion tonnes / 7.1 billion tonnes	
		Edible food waste and losses	1.5	billion tonnes	= Food losses and waste x Edible shares by commodity	FAO, FAOSTAT, Cities and Circular Economy for Food team calculations
		Share of edible food waste and losses at production stage	21%		= 1.5 billion tonnes / 7.1 billion tonnes	
		Share of edible food waste and losses within total food waste and losses	82%		= 1.5 billion tonnes / 1.8 billion tonnes	
		Edible food losses in food production	1.1	billion tonnes	Food losses occur upstream in food value chain: inefficiencies in agricultural production, harvesting, post-harvest handling, transportation and storage of crops.	
		Edible food waste at consumer stage	0.7	billion tonnes	Food waste including distribution and consumption stages	
		Inedible food waste and losses	0.3	billion tonnes	= Food losses and waste x Inedible shares by commodity	FAO, FAOSTAT, Cities and Circular Economy for Food team calculations
		Food for human consumption	4.3	billion tonnes		FAO, FAOSTAT, Cities and Circular Economy for Food team calculations
		Animal feed and other uses	1.7	billion tonnes	Including food processing, feed, seeds, and other uses	FAO, FAOSTAT, Cities and Circular Economy for Food team calculations
		Inedible food waste and losses	0.3	billion tonnes		FAO, FAOSTAT, Cities and Circular Economy for Food team calculations
		+				
		Currently composted other organic waste (excluding food waste)	0.05	billion tonnes	See below. Note that while there is a wide range of treatment methods for solid organic waste, we have chosen composting as a reasonable baseline proxy for the 'looping' of organic nutrients because it is a) comparatively low cost and – in principle – low-tech and therefore the most universally applicable approach across the globe; and b) it is the only method with significant global scale and information today, allowing for reasonable estimates regarding its scaling potential. We fully recognise that more advanced technologies, such as anaerobic digestion or pyrolytic processes, have enormously beneficial potential and consider them as potential building blocks in the circular economy for food.	World Bank, EPA, European Compost Network, Cities and Circular Economy for Food team calculations
		+				
		Human waste	4.3	billion tonnes	Human waste includes liquid and solid waste	UNU-INWEH, UN, Cities and Circular Economy for Food team calculations
		x				
		% of mass that is N (nitrogen) or P (phosphorus)	0.9%	of NP	Weighted average of nitrogen (N) and phosphorus (P) content in different organic waste types.	WRAP, UNU-INWEH
		=				
		NP waste	53.0	million tonnes		Cities and Circular Economy for Food team calculations

	Human waste	4.3	billion tonnes	= World population x Human waste per person. Triangulated with information from the European Sustainable Phosphorus Platform and expert inputs.	UNU-INWEH, UN, Cities and Circular Economy for Food team calculations
	Share of untreated wastewater	80%		Globally, it is estimated that only 20% of all wastewater is collected.	UNESCO
	Tonnes of manure	21	billion tonnes	Based on nitrogen from manure as per FAOSTAT	FAOSTAT, World Bank, Cities and Circular Economy for Food team calculations
CITIES' SHARE	Share of food for human consumption destined for cities	68%		= Share of today's population living in cities (54%), adjusted for higher GDP (leading to greater amounts of food produced and increased consumption per capita in cities). Triangulated with data from Eurostat, OECDstat and national statistics, and updated data from What a Waste 2.0 (2018).	FAOSTAT, Cities and Circular Economy for Food team calculations
	Food for human consumption destined for cities	2.9	billion tonnes	=68% x Global food for human consumption	Cities and Circular Economy for Food team calculations
	Share of global food waste at consumer stage that occurs in cities	66%		= Share of today's population living in cities (54%), adjusted for higher GDP (leading to greater amounts of food produced and increased consumption per capita in cities). Triangulated with data from Eurostat, OECDstat and national statistics, and updated data from What a Waste 2.0 (2018).	FAOSTAT, Cities and Circular Economy for Food team calculations
	Food waste at consumer stage that occurs in cities	0.5	billion tonnes	= 66% x Global food waste at consumer stage	Cities and Circular Economy for Food team calculations
	Food eaten in cities	2.4	billion tonnes	= Food for human consumption destined for cities - Food waste at consumer stage that occurs in cities	Cities and Circular Economy for Food team calculations
	Share of human waste in cities	54%		= Urban share: assuming that excretion in cities and rural areas is the same. Triangulated with data from Eurostat, OECDstat and national statistics, and updated data from What a Waste 2.0 (2018).	FAOSTAT, Cities and Circular Economy for Food team calculations
	Human waste in cities	2.3	billion tonnes	= 54% x Global human waste	Cities and Circular Economy for Food team calculations
	Total organic waste in cities	2.8	billion tonnes	= Food waste in cities + Human waste in cities	Cities and Circular Economy for Food team calculations
	Share of organic waste in cities looped	2%		= Current cities' share (54% as per global urbanization rate) of share of solid organic waste composted (69 Mt of 585 Mt) and share of human waste treated and reapplied in safe and productive fashion (45 Mt of 4335 Mt). Note that 'safe and productive' is defined here as treated by advanced treatment and reapplied as fertiliser. A much bigger share of human waste is applied to soils around the world; however, typically at low efficiency and often untreated, thus putting local population at risk and contributing to food- and waterborne diseases. Such practices are therefore not included in the definition used here.	Cities and Circular Economy for Food team calculations
OUTSIDE CITIES' SHARE	Share of food for human consumption destined for outside cities	32%		= Global food for human consumption - 68% share for cities. Triangulated with data from Eurostat, OECDstat and national statistics, and updated data from What a Waste 2.0 (2018).	Cities and Circular Economy for Food team calculations
	Food for human consumption destined for outside cities	1.4	billion tonnes	=32% x Global food for human consumption	Cities and Circular Economy for Food team calculations
WASTE TYPES	2013 Food waste in collected municipal organic waste	0.3	billion tonnes	= Total municipal organic waste x 53% share of food waste in collected organic waste according to EPA. Triangulated with data from Eurostat, OECDstat and national statistics, and updated data from What a Waste 2.0 (2018).	World Bank, EPA, Cities and Circular Economy for Food team calculations
	2013 Total other municipal organic waste	0.3	billion tonnes	= Total municipal organic waste x 47% share of food waste in collected organic waste according to EPA. Triangulated with data from EURSTAT, OECDstat and national statistics, and updated data from What a Waste 2.0 (2018).	World Bank (2012), Cities and Circular Economy for Food team calculations
	2013 Currently composted other organic waste (excluding food waste)	0.05	billion tonnes	= Total organic waste x 12% composted - food waste composted. Validated through expert inputs	World Bank, EPA, European Compost Network, Cities and Circular Economy for Food team calculations

EXTERNALITIES	Food produced	7.1	billion tonnes		See above
	x				
	Blue water intensity of food production	193	km^3 / billion tonnes	Following FAO (2013) methodology, this only includes consumptive water use, i.e. what is evapotranspirated by or contained in plants. Therefore, it covers only the share of total irrigation water that is not returning to water catchments through run-off. As such, it is lower than water 'withdrawal', which is typically reported by major databases (~2.700 km^3).	FAO (2013), Cities and Circular Economy for Food team calculations
	=				
	Blue water usage of food production	1,371	km^3		
	Food production GHG (greenhouse) emissions	5.2	billion tonnes CO_2e	Biochemical GHG emissions from farm operations as per FAOSTAT. Assuming all emissions are due to food production. GHG for food production: based on FAOSTAT 'Agricultural Emissions'. Since emissions are based on agricultural primary commodity, a direct link to the amounts of food produced as per FBS is not possible. Since most of the emission categories can be associated with the production of foodstuffs, it was assumed that all emissions are due to food production.	FAOSTAT
	+				
	Food value chain GHG emissions	2.5	billion tonnes CO_2e	Energy use in food processing, distribution, storing, etc.. FVC (FAO): GHG emissions associated with the handling, packaging, processing, and preparation of food along the entire value chain were included following the method of FAO. For 2050: adjusted by increase in food produced	FAO (2013), FAOSTAT
	+				
	End-of-life GHG emissions	0.8	billion tonnes CO_2e	GHG from decomposition of food waste, particularly methane. End-of-life treatment (FAO, UNEP): total emissions of food waste as per FAO 2013, adjusted for increased food volumes (2007 -> 2013). Relative emission savings potential was calculated based on UNEP. For 2050 projections, no changes in those reduction factors were assumed	FAO (2013), FAOSTAT
	+				
	Human waste GHG emissions	0.6	billion tonnes CO_2e	Methane and nitrous oxide in human waste. Human waste (EPA, UNU-IWEH): includes only GHG emissions from CH_4 and N_2O, based on 2010 global estimates of EPA adjusted to our base year. Emissions from process energy consumption were not considered. For 2050 projections: adjusted by increase in global population	EPA, UNESCO
	=				
	GHG emissions of food production	9.1	billion tonnes CO_2e		
	Degradation rate of cropland (at various degrees)	16.64	mn ha p.a.	Note that other reported numbers, ranging from 3 to 10 million hectares per year (IPBES, 2018), refer to land abandoned due to severe land degradation; consistent with our economic valuation of land / soil erosion based on Pimentel (1995), our values encompass a wider range of degrees of degradation as estimated in the 1990 GLASOD project	GLASOD, Pimentel *et al*., Cities and Circular Economy for Food team calculations
	+				
	Degradation rate of pastureland (at various degrees)	22.82	mn ha p.a.	See above	GLASOD, Pimentel *et al*., Cities and Circular Economy for Food team calculations
	=				
	Soil degradation	39.46	mn ha p.a.		
	Pesticide exposure costs due to food production	0.9	USD trillion p.a.	See below	See C2 Cost chart below
	Share of antimicrobial resistance attributable to food system	22%		Based on multiple data points estimating the total contribution of the food system to the issue of antimicrobial resistance, including from untreated human waste, active pharmaceutical ingredients in water bodies and foods, and over- and misuse of antibiotics in animal husbandry (improvement of which was recently estimated to reduce risk of AMR prevalence in humans by on average by 24% (Tang *et al.* (2017))	iPES Food, expert input
	Manure leaked / applied not in line with best practice	54	million tonnes		FAOSTAT, Cities and Circular Economy for Food team calculations
	Share of global air pollution due to agriculture	20%		Due to the significant role of (agricultural) ammonia air emissions in the formation of harmful PM2.5 fine particles	Bauer *et al*.

3 SOCIETAL COSTS AND PROJECTIONS: 2013 and 2050



1 Organic waste management fees; 2 From inedible food waste, other organic waste, and sewage, and from N and P run-off from fertilisers and manure

		METRIC	VALUE	UNIT	COMMENT	SOURCE
FOOD EXPENDITURE COSTS		Food expenditure of 95 countries, including BRICS	3.77	USD trillion p.a.	Food expenditure includes eating in and out, excludes alcohol	World Bank: Global consumption database
		+				
		Food expenditure of Australia	0.07	USD trillion p.a.		OECDstat
		+				
		Food expenditure of the US	0.93	USD trillion p.a.		OECDstat
		+				
		Food expenditure of the EU	1.37	USD trillion p.a.		OECDstat
		+				
		Food expenditure of Japan	0.47	USD trillion p.a.		OECDstat
		+				
		Food expenditure of Canada	0.09	USD trillion p.a.		OECDstat
		=				
		2013 TOTAL FOOD EXPENDITURE	**6.71**	**USD trillion p.a.**		
		2050 TOTAL FOOD EXPENDITURE	**9.52**	**USD trillion p.a.**	**Increased by 42% proportionate to food production**	
2050 PROJECTION ASSUMPTIONS	PROJECTIONS	Food production increase 2013 to 2050	42%		Growth rate of food (tonnes) derived from FAO food basket development estimation, adjusted for base year. Simplified assumption that food basket develops uniformly, i.e. no dietary shifts included. Among various projections of global food consumption, our projection is at the lower end of the range (e.g. compared to FAO FOFA 2018, finding a 40-53% increase in gross agricultural output). In part this is due to the fact that many projections select a lower base year, leading to a higher relative change; partly this can be attributed to the simplified mode of projection applied. We consider the results sufficiently accurate for the purpose of this study. Note that most recent recognised projections of FAO FOFA (2018) find no net changes in the share of animal products on global average (with an increase in meat consumption in emerging economies being compensated for by a decrease in developed economies). Among various projections of global food consumption, our projection is at the lower end of the range (e.g. compared to FAO FOFA 2018, finding a 40-53% increase in gross agricultural output). In part this is due to the fact that many projections select a lower base year, leading to a higher relative change; partly this can be attributed to the simplified mode of projection applied. We consider the results sufficiently accurate for the purpose of this study. Note that most recent recognised projections of FAO FOFA (2018) find no net changes in the share of animal products on global average (with an increase in meat consumption in emerging economies being compensated for by a decrease in developed economies)	FAO, Cities and Circular Economy for Food team calculations
		Population growth 2013 to 2050	35%			UN
		GHG emissions increase as part of whole food value chain increase 2013 to 2050	35%		Development proportionate to projected food production, including improvements in CO_2e intensity of food production and population growth for GHG from human waste. Note: mixed effect from sub-components (GHG from food production, value chain and end-of-life, as well as human waste), thus no detailed description possible. Note: mixed effect from sub-components (GHG from food production, value chain and end-of-life, as well as human waste), thus no detailed description possible.	FAO, Cities and Circular Economy for Food team calculations
		GHG emissions increase of food production 2013 to 2050	30%		Value based on FAO, 2018: ratio of increase of GHG emissions in food production compared to increase in food production (0.7) Note: component of 'GHG emissions increase of whole food value chain increase'. For 2050 projections, an increase in emissions relative to food production increase is assumed in accordance to the FOFA stratified societies scenario. Note: higher than baseline FAO FOFA (2018) scenarios; lower than Springmann et al. (2018) scenarios. For 2050 projections, an increase in emissions relative to food production increase is assumed in accordance to the FOFA stratified societies scenario. Note: higher than baseline FAO FOFA (2018) scenarios; lower than Springmann *et al.* (2018) scenarios.	FAO

		Water demand increase 2013 to 2050	33%		Increase based on Burek *et al.*, taking into account rising pressures on land and climate change effects leading to increased demand for irrigation. We base our water projection on a scenario with climate change effects and limited efficiency gains (Burek *et al.*, 2016); with this our estimation falls in the upper range of estimates. However, most past projections have not taken into account climate change effects. As UNESCO (2018) acknowledges, 'Best estimates of future global agricultural water consumption (including both rainfed and irrigated agriculture), are of an increase of about 19% by 2050, but this could be much higher if crop yields and the efficiency of agricultural production do not improve dramatically'. We have therefore chosen to select a water use scenario at the upper end of the range.	Burek *et al*., Cities and Circular Economy for Food team calculations
		Organic waste increase 2013 to 2050	102%		Based on annual growth rates by country income level derived from World Bank 2012–2025 projections. Based on cumulative annual growth rates derived from World Bank (2012), adjusted down for periods 2025–2050. triangulated with projections from What a Waste 2.0 and OECDstat. Based on cumulative annual growth rates derived from World Bank (2012), adjusted down for periods 2025–2050. Triangulated with projections from What a Waste 2.0 and OECDstat.	World Bank, Cities and Circular Economy for Food team calculations
	IMPROVED PARAMETERS	2050 Improved Nitrogen Use Efficiency (NUE)	75%		Achievable NUE based on multiple values and triangulation through expert inputs; compared to current NUE of 50%.	OECD and Yara, expert input
		2050 Improved Phosphorus Use Efficiency (PUE)	52%		Achievable PUE based on expert inputs and market evidence; compared to current PUE of 19%	Yara, expert input

		METRIC	VALUE	UNIT	COMMENT	SOURCE
ECONOMIC COSTS	1. EDIBLE FOOD WASTE AND LOSSES	Edible food waste and losses	1.5	billion tonnes		See C1 Main metrics chart above
		x				
		Cost per tonne edible food waste and losses	742	USD / tonne	Economic value per tonne food lost and wasted derived from FAO estimates; expressed in 2013 USD	FAO, Cities and Circular Economy for Food team calculations
		=				
		2013 Edible food waste costs	**1.1**	**USD trillion p.a.**		
		2050 Edible food waste costs	**1.5**	**USD trillion p.a.**	**Increased by 42% proportionate to food production**	**See C1 Projection assumptions above**
	2. ORGANIC WASTE DISPOSAL	2013 tonnes considered in organic waste disposal	0.6	billion tonnes	= 0.3 billion tonnes 2013 Food waste in collected municipal organic waste + 0.3 billion tonnes 2013 Total other municipal organic waste	See C1 Main metrics chart above
		x				
		Costs per tonne for waste collection and disposal	126.7	USD / tonne	Global average costs for collection and disposal across country income groups. 95 USD / tonne (collection costs) + 32 USD / tonne (weighted average of costs for 5% of the waste being composted and of respective 95% / 2 of dumping and landfill costs)	World Bank
		+				
		Human waste	4.3	billion tonnes		See C1 Main metrics chart above
		x				
		Share of treated wastewater	20%		= 1 - Share of untreated wastewater	UNESCO
		x				
		Costs per tonne for human waste disposal	1.3	USD / tonne	Based on proxy of average US wastewater disposal costs per m^3 of wastewater, covering collection, treatment, and disposal. Triangulated and validated with expert inputs; given the wide range of levels of US wastewater treatment facilities, this is a legitimate proxy for worldwide wastewater treatment costs.	Black & Veatch Corporation, expert input, Cities and Circular Economy for Food team calculations
		=				
		2013 Organic waste disposal costs	**0.08**	**USD trillion p.a.**		
		2050 Organic waste disposal costs	**0.13**	**USD trillion p.a.**	**Edible food waste Increased by 42% proportionate to food production; other municipal organic waste increased by 102% proportionate to increase of organic waste; tonnes of human waste increased by 35% proportionate to population growth**	**See C1 Projection assumptions above**
	3. NUTRIENT LOSS	2013 Nitrogen (N) in fertilisers	0.1	billion tonnes		FAO
		x				
		(1 - NUE)	50%		i.e. 50% of applied N is lost, while 50% is taken up by crops	OECD and Yara, Hirel *et al*.
		x				
		Price per tonne of N	739	USD / tonne of N		FAO, Cities and Circular Economy for Food team calculations
		+				
		2013 Phosphorus (P) in fertilisers	0.02	billion tonnes		FAO
		x				
		(1 - PUE)	81%		i.e. 81% of applied P is lost, while 19% is taken up by crops	FAO, Rouached, Roberts and Johnston, Neto *et al*.
		x				
		Price per tonne of P	2,225	USD / tonne of P		FAO, Cities and Circular Economy for Food team calculations
		=				
		2013 NP run-off from virgin fertilisers	**0.07**	**USD trillion p.a.**		
		+				
		(Inedible food waste and losses	0.3	billion tonnes		See C1 Main metrics chart above
		+				
		2013 Currently composted other organic waste (excluding food waste)	0.05	billion tonnes		See C1 Main metrics chart above
		+				
		Human waste)	4.3	billion tonnes	For the sake of N and P valuation, it is assumed that only a marginal amount of human waste (from wastewater, sewage, and other sourcecs) is reused worldwide. While already human waste is being used for fertilisation, rarely is this carried out in a safe and productive fashion – two preconditions for 'nutrient looping' in circular economy scenario	See C1 Main metrics chart above
		x				
		Share of mass that is N or P	0.9%		Weighted average of shares N and P content in waste types. Triangulated and validated data from the European Sustainable Phosphorus Platform, various other sources, and expert input	WRAP, UNU-INWEH
		x				
		Price per tonne of N or P	899	USD / tonne of NP	Weighted average of prices for N (739 USD / tonne) and P (2,225 USD / tonne)	FAO
		=				
		2013 NP waste from organic waste	**0.04**	**USD trillion p.a.**		
		+				
		(2013 N lost from manure at pasture	0.04	billion tonnes		FAOSTAT, Cities and Circular Economy for Food team calculations
		+				
		2013 N lost from manure at fields)	0.01	billion tonnes		FAOSTAT, Cities and Circular Economy for Food team calculations
		x				
		Price per tonne of N	739	USD / tonne of N		FAO, Cities and Circular Economy for Food team calculations

		+				
		2013 P in manure	24.1	billion tonnes	Triangulated with empirical data from US farming operations N:P ratios	Lun *et al*.
		x				
		(1 - PUE)	81%		i.e. 81% of applied P is lost, while 19% are taken up by crops	Journal of Crop Research and fertilisers, Resources, Conservation and Recycling, Neto *et al*.
		x				
		Price per tonne of P	2,225	USD / tonne of P		FAO, Cities and Circular Economy for Food team calculations
		2013 NP run-off from manure	**0.08**	**USD trillion p.a.**		**Cities and Circular Economy for Food team calculations**
		=				
		2013 Nutrient loss costs	**0.19**	**USD trillion p.a.**		**Cities and Circular Economy for Food team calculations**
		2050 Nutrient loss costs	**0.28**	**USD trillion p.a.**	**N and P in fertilisers, inedible food waste and losses, and manure increased by 42% proportionate to food production; composted other organic waste increased by 102%, tonnes of human waste increased by 35% proportionate to population growth.**	**See C1 Projection assumptions above**
		TOTAL ECONOMIC COSTS 2013	**1.4**	**USD trillion p.a.**		
		TOTAL ECONOMIC COSTS 2050	**1.9**	**USD trillion p.a.**		
ENVIRONMENTAL COSTS	4. WATER USE	Blue water usage of food production	1,371	km³		See C1 Main metrics chart above
		x				
		Social costs of water use in agriculture	0.6	USD / m³	= Costs for water use and water scarcity / water footprint of food waste	FAO
		=				
		2013 Water use costs due to food production	**0.8**	**USD trillion p.a.**		
		2050 Water use costs due to food production	**1.0**	**USD trillion p.a.**	**Increased by 33% (see C1 Main metrics chart above)**	**See C1 Projection assumptions above**
	5. GHG EMISSIONS	GHG emissions of food production	9.1	billion tonnes CO_2e		See C1 Main metrics chart above
		x				
		Societal costs of carbon	113	USD / tonne CO_2e	Following FAO, the societal cost of carbon from the Stern review is applied	FAO, Stern
		=				
		2013 GHG emission costs due to food production	**1.0**	**USD trillion p.a.**		Cities and Circular Economy for Food team calculations
		2050 GHG emission costs due to food production	**1.4**	**USD trillion p.a.**	**Increased by 35% (see C1 Main metrics chart above)**	**See C1 Projection assumptions above**
	6. SOIL DEGRADATION					
		2013 Soil degradation costs due to food production	**0.9**	**USD trillion p.a.**		Pimentel *et al*.
		2050 Soil degradation costs due to food production	**1.3**	**USD trillion p.a.**	Assuming that at near-constant total available arable land and rates of soil degradation, rising land pressure from increased agricultural outputs will lead to increased farming intensity and corresponding costs of soil degradation.	**See C1 Projection assumptions above**
		TOTAL ENVIRONMENTAL COSTS 2013	**2.7**	**USD trillion p.a.**		
		TOTAL ENVIRONMENTAL COSTS 2050	**3.7**	**USD trillion p.a.**		
	7. PESTICIDE EXPOSURE	2013 EU health costs due to pesticide exposure	0.17	USD trillion p.a.	Average of best and worst case scenario. There is a very wide range of health cost estimates of pesticides, ranging from few billion USD US estimates to multiple times that. These estimates are often based on substantially different approaches and different technical and geographical scopes. Given the broad range of active ingredients in pesticides and the young and emerging science around their longer term and complex interactive effects, we have chosen to select one comparatively high but selective approach of one subset of active ingredients. Other studies with different scopes, e.g. Tresande *et al*., (2016) have found similarly high costs from pesticide exposure through additional pathways. We therefore consider our approach to be in range for a realistic estimate of overall global pesticide health	iPES Food
		+				
		2013 EU health costs due to pesticide exposure	0.17	USD trillion p.a.	Average of best and worst case scenario. Extrapolating from EU to global population taking into account relative population size, pesticide use per capita, and healthcare expenditure per capita. Approach validated with health expert	iPES Food
		x				
		Extrapolation on population share of rest of world	1402%	0.053256	RoW has 1402% of EU population	UN
		x				
		Higher per capita pesticide usage factor in rest of world	133%	0.746641	Higher per capita pesticide usage in RoW, thus assumed higher share of health costs	FAOSTAT: Pesticides
		x				
		Extrapolation on lower health costs per capita in rest of world	23%		Per capita health costs on average are lower in RoW than Europe	WHO: Global health expenditure database
		=				
		2013 Pesticide exposure (health) costs due to agriculture	**0.9**	**USD trillion p.a.**		
		2050 Pesticide exposure (health) costs due to agriculture	**1.3**	**USD trillion p.a.**	**Increased by 42% proportionate to food production**	

HEALTH COSTS	8. ANTIMICROBIAL RESISTANCE (AMR)	Average global costs of antimicrobial resistance due to productivity loss	1.35	USD trillion p.a.	Costs due to reduced labour force (i.e. productivity loss to the global economy). Based on average annual costs of USD 0.04 trillion to USD 3.3 trillion until 2050, rebalanced to account for higher annual costs in 2050 than in 2018. We base our cost estimates on a study conducted by RAND which was commissioned in the context of an independent review of the total global issue led by economist Jim O'Neill; the final outcomes of which resulted in this paper. We base our estimates on the average annual costs 2015-2050 reported by the RAND study, recalculating them to account for an increase of cost proportionate to population increase while maintaining the same total cumulative costs estimated by RAND. Therefore, our base year estimate (USD 300 billion p.a. for the food system) is likely high comparing with other estimates: e.g. US costs from AMR were USD 20 billion p.a. (2013) and USD 2 billion in the EU (2009). However, with this methodological choice we aim to avoid an overstatement of the issue in 2050 while applying a simple and straightforward way of	RAND corporation
		x				
		Share of antimicrobial resistance attributable to food system	22%		Of the range of the estimated contribution of the 'food system' to antimicrobial resistance of 5%-22% the upper end of the range was chosen given the larger scope of our definition of the 'food system'	iPES Food, expert input
		=				
		2013 AMR costs due to food system	**0.3**	**USD trillion p.a.**		
		2050 AMR costs due to food system	**0.4**	**USD trillion p.a.**	**Increased by 35% proportionate to world population growth**	
	9. WATER CONTAMINATION	2013 Cost of lacking universal access to improved water and sanitation services	0.26	USD trillion p.a.	Based on benefit analysis of universal access to improved water and sanitation services. Attribution of health costs due to waterborne diseases to particular sources is challenging due to complex and overlapping disease pathways and lack of consistent, global data. However, attributing the vast majority of these issues (mostly due to diarrhoeal diseases) to untreated human waste and mismanaged animal waste as key sources was considered appropriate. Of those two sources, human waste can be considered the main contributor.	WHO
		x				
		Share of waterborne disease spread by agriculture and human waste	95%		Higher-end scenario based on expert input and analysis that untreated human waste is a main contributor to the overall burden of disease from waterborne diseases	Expert input
		+				
		2013 Health costs of poor water and sanitation	0.10	USD trillion p.a.	Including lost productivity due to disability and death, direct cost, e.g. for healthcare, and direct investment to mitigate. Aiming for conservative estimates, we have included two different costing scenarios into our cost estimates.. Aiming for conservative estimates, we have included two different costing scenarios into our cost estimates.	McKinsey
		x				
		Share attributed to sanitation	62%		Lower-end scenario taking into account that only a share of the health burden from poor water and sanitation is due to lacking sanitation services.	WHO
		x				
		Share of waterborne disease spread by agriculture and human waste	95%			Expert input
		/				
		Average of both estimates	2			
		=				
		2013 Water contamination costs due to food system	**0.2**	**USD trillion p.a.**		
		2050 Water contamination costs due to food system	**0.2**	**USD trillion p.a.**	**Increased by 35% proportionate to world population growth**	
	10. AIR POLLUTION	2013 Costs for total outdoor air pollution	0.9	USD trillion p.a.	Costs due to reduced labour force: including lost productivity due to disability and death, direct cost, e.g. for healthcare, and direct investment to mitigate	McKinsey
		x				
		Share of global air pollution due to agriculture	20%		In combination with industrial and transport air pollution (particularly NOx), ammonia from agriculture (1/3 fertiliser volatisation; 2/3 manure production, management, and application) constitutes the most significant precursor to anthropogenic fine particular matter (PM2.5). This in turn is responsible for the vast majority of health burden from ambient air pollution. Consequently, and particularly in densely populated areas like the EU, China, and North America, ammonia turns out to be one of the most harmful air pollutants.	Bauer
		=				
		2013 Air pollution costs due to agriculture	**0.2**	**USD trillion p.a.**		
		2050 Air pollution costs due to agriculture	**0.3**	**USD trillion p.a.**	**Increased by 42% proportionate to food production**	
	11. FOOD CONTAMINATION	Costs per DALY (according to water contamination calculation)	2,542	USD	= 0.2 USD trillion / 60.7 mn DALYs DALY (disability-adjusted life year, see glossary for further information) Assuming similar diseases as waterborne diseases. Lacking better cost data on distinct burden of disease from foodborne diseases, it was assumed that similar pathogens as those from waterborne diseases – mostly diarrhoeal diseases – are contributing to the distinct impact of foodborne diseases. Therefore costs were estimated on ratios of DALYs and associated costs from waterborne compared to foodborne diseases. This approach was validated with experts.	WHO
		x				
		2013 DALYs from foodborne diseases	33	millions p.a.	Assuming that the majority of diarrhoeal foodborne diseases are due to initial contamination of food with unsafely handled human waste and manure.	WHO
		=				
		2013 Food contamination costs due to agriculture	**0.1**	**USD trillion p.a.**		
		2050 Food contamination costs due to agriculture	**0.1**	**USD trillion p.a.**	**Increased by 42% proportionate to food production**	

	MALNUTRITION (EXCLUDING OBESITY)					
		2013 Costs of malnutrition	**3.5**	**USD trillion p.a.**		**UK Sustainable Food Trust**
		2050 Costs of malnutrition	**4.7**	**USD trillion p.a.**	**Increased by 35% proportionate to world population growth**	**UK Sustainable Food Trust, Cities and Circular Economy for Food team calculations**
	MICRONUTRIENT DEFICIENCY	2013 Total global costs of micronutrient deficiencies	2.1	USD trillion p.a.		UK Sustainable Food Trust
		x				
		Conservative adjustment	75%			Expert input
		=				
		2013 Costs of micronutrient deficiencies	**1.6**	**USD trillion p.a.**		
		2050 Costs of micronutrient deficiencies	**2.1**	**USD trillion p.a.**	**Increased by 35% proportionate to world population growth**	
	OBESITY DUE TO UNHEALTHY DIETS	2013 Average economic impact of obesity	1.7	USD trillion p.a.	Average of two estimates: including lost productivity due to disability and death, direct cost, e.g. for healthcare, and direct investment to mitigate	McKinsey, FAO
		x				
		Share of obesity-related costs attributable to diet vs. lack of physical activity	45%		Based on relative size of health costs due to obesity from lack of physical activity and poor diets. Since obesity is caused by multiple factors this represents a rough estimation of the share associated with unhealthy diets	WHO
		=				
		2013 Costs of obesity due to unhealthy diets	**0.8**	**USD trillion p.a.**		
		2050 Costs of obesity due to unhealthy diets	**1.0**	**USD trillion p.a.**	**Increased by 35% proportionate to world population growth**	
		TOTAL HEALTH COSTS 2013	7.5	USD trillion p.a.		
		TOTAL HEALTH COSTS 2050	10.2	USD trillion p.a.		

		METRIC	VALUE	UNIT	COMMENT	
SUMMARY OF SOCIETAL COSTS	2013 COSTS OF FOOD SYSTEM	**TOTAL COSTS 2013**	**11.50**	**USD trillion p.a.**		
		ECONOMICAL COSTS PER USD SPENT ON FOOD	0.20	USD / USD		
		HEALTH COSTS PER USD SPENT ON FOOD	1.11	USD / USD		
		USD ENVIRONMENTAL COSTS PER USD SPENT ON FOOD	0.40	USD / USD		
		TOTAL COSTS PER USD SPENT ON FOOD	**1.71**	**USD / USD**		
	2050 COSTS OF FOOD SYSTEM, 'BUSINESS AS USUAL' (BAU) SCENARIO	**TOTAL COSTS 2050**	**15.77**	**USD trillion p.a.**		
		ECONOMICAL COSTS PER USD SPENT ON FOOD	0.20	USD / USD		
		HEALTH COSTS PER USD SPENT ON FOOD	1.07	USD / USD		
		ENVIRONMENTAL COSTS PER USD SPENT ON FOOD	0.39	USD / USD		
		TOTAL COSTS PER USD SPENT ON FOOD	**1.66**	**USD / USD**		

4 CIRCULAR ECONOMY SCENARIO IN 2050

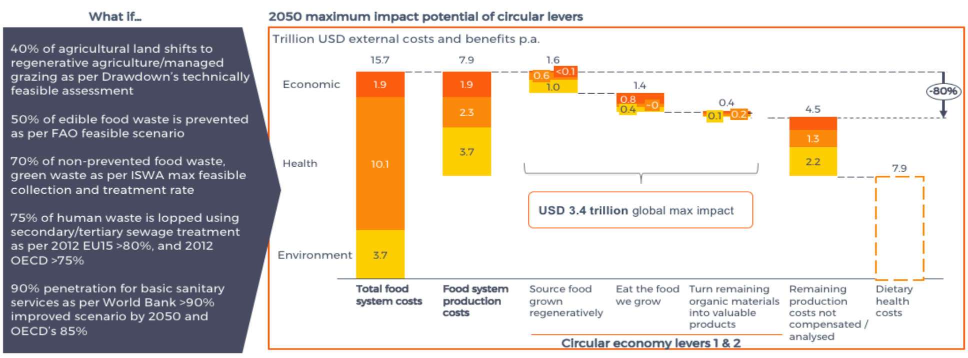
Circular economy levers considered for this scenario:

A. Prevent edible food waste
B. Grow food regeneratively (cropland; assuming best practice manure application)
C. Managed grazing (pasture-kept animal product production)
D. Composting from inedible food waste (including the prevented food waste, then substracted by applying the penetration rate)
E. Composting from other organic MSW (green waste)
F. Wastewater treatment

These circular economy levers directly address costs from linearity. They are linked to the two broader ambitions cities can achieve: 'Source food grown regeneratively, and locally where appropriate' and 'Make the most of food'. Levers that are related to diets (not considered for this analysis) could directly address the other half of the food system societal costs. When applied at the same time, these levers can indirectly support one another and multiply impact.

Benefits that the scenario leads to:
- economic value creation
- avoided waste disposal costs
- avoided GHG emissions
- saved water use
- soil improvement
- air quality improvement

Deploying a circular urban food system could potentially generate societal benefits worth USD 3.4 trillion, USD 2.7 trillion of which can be driven by cities



*GHG impact does not avoid all food production emissions but rather compensates these

	LEVER	RATE		COMMENT	SOURCE
TECHNICALLY FEASIBLE PENETRATION RATES vs. 100% THEORETICAL	A. Food waste prevention	50%		Share of food waste prevented according to feasible scenario by FAO by 2050. Following assumption of FAO (2018) as well as AgriTEEB (2018) that a 50% reduction of all food waste and losses per capita across the value chain is possible until 2050. Note that this is goes beyond the ambition of SDG 6.2 which names concrete goals only for distribution and consumption steps of the food value chain.	FAO
	B. Regenerative agriculture on cropland	47%		Remaining share of global cropland that can shift to crop regenerative agriculture in Drawdown's technically feasible assessment. Taking into account already existing areas under regenerative agriculture (as per Drawdown definition), and technically feasible area for regenerative agriculture for crops (including soil and crop types, slope angles, and climate conditions, as well as competition from other types of agriculture. We apply a slightly wider definition of regenerative agricultural practices than Drawdown, containing the following required practices: no synthetic pesticides; no or best practice synthetic fertilisers; organic fertilisation prioritising on-farm inputs and following best practices particularly regarding manure; minimal soil disturbance (no-till or reduced tillage); diversified crop rotation; and permanent soil cover. Further optional practices can encompass: permaculture; no use of GMOs; mechanical weed control; keyline land preparation.	Drawdown
	C. Managed grazing (animal product production)	37%		Remaining share of global grazing area that can shift to managed grazing in Drawdown's technically feasible assessment. Taking into account already existing areas under managed grazing (as per Drawdown definition), and technically feasible area for regenerative agriculture for crops (including soil and crop types, slope angles, and climate conditions, as well as competition from other types of agriculture).	Drawdown
	D. Composting from inedible food waste	70%		70% of inedible (and thus not preventable) food waste, based on maximum feasible collection and treatment rate. The most successful organic waste collection and treatment systems can reach up to 85%-90% collection and treatment rates.	ISWA
	E. Composting from other organic waste (green waste)	70%		Assuming similar feasibility as for inedible food waste	Based on ISWA
	F. Wastewater treatment (basic sanitary services part)	90%		Considering near 100% is possible; World Bank improvements of 0.8% p.a. would reach >90% by 2050; and OECD projects 85% as BAU/100% as 'improved' scenario. Higher penetration scenario since basic sanitary services are more likely to achieve wider adoption until 2050 given lower costs and complexity. The penetration rate for wastewater treatment differs depending on the regarded issues: 1) Health issues: we assume a near 100% risk reduction from pathogens is possible through best practice low-tech solutions – effectively collecting, containing, and neutralising relevant pathogens. Therefore, we assume a high feasible penetration rate of 90%, based e.g. on scenarios by OECD. These methods, while potentially allowing for safe reapplication of human biosolids to agricultural soils, would not however allow for energy recovery or advanced nutrient recovery for best practice application. 2) GHG emissions and nutrient looping: process emissions from CH_4, N_2O cannot be fully removed; however, by means of energy recovery from biodigestation those emissions can be partly captured and used as carbon neutral energy source. Further assuming carbon neutral energy sources for the operation of wastewater treatment production by 2050, we perdeict that an effective climate neutrality of wastewater treatment is feasible. Since these are more advanced approaches than those needed	OECD
	F. Wastewater treatment (environmental part)	75%		Considering near 100% is possible, EU15 is >80%, and OECD >75% (2012 data)	OECD

Important note: The levers below are analysed independently from each other.

	METRIC	VALUE	UNIT	COMMENT	SOURCE
SAVED EDIBLE FOOD WASTE VALUE	2050 Edible food waste costs	1.5	USD trillion p.a.	Caveat: While we assume 1 tonne of food waste avoidance reduces impact proportionately, in fact this will depend on what tonne of food waste is avoided. Some types of food, e.g. meat, have a higher footprint and thus higher mitigation potential when such food waste is avoided. Since high-impact foods like meat are only a small share, their avoidance weighs less heavily in per tonne avoided food waste. This high-level assumption could lead to an inflated impact estimation	See C2 Costs chart above
	2050 Theoretical direct economic benefits of edible food waste prevention	1.5	USD trillion p.a.	Assuming a 100% penetration rate	
	2050 Potential direct economic benefits of edible food waste prevention	**0.77**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above
OSAL COSTS	2050 Total food waste in collected municipal organic waste	0.4	billion tonnes	= 2013 Total food waste in collected municipal organic waste increased by 42% proportionate to food production	See C1 Main metrics chart above
	x				
	Share of edible food waste and losses within total food waste and losses	82%			See C1 Main metrics chart above
	x				

	SAVED DISPO	Waste collection and disposal costs	126.7	USD / tonne	Global average costs for collection and disposal across country income groups. 95 USD / tonne (collection costs) + 32 USD / tonne (weighted average of costs for 5% of the waste being composted and of respective 95% / 2 of dumping and landfill costs)	World Bank
		2050 Theoretical waste management costs benefits through food waste prevention	0.05	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential waste management costs benefits through food waste prevention	**0.02**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above

A. DESIGN OUT EDIBLE FOOD WASTE	SAVED WATER USE	2050 Water footprint of food production	1818	km^3	= 2013 Water footprint of food production increased by 33%	FAO, see C1 Main metrics chart and projection values above
		x				
		Share of edible food waste and losses at production stage	21%			See C1 Main metrics chart above
		=				
		2050 Theoretical water use benefit through food waste prevention	373	km^3	Assuming a 100% penetration rate	
		2050 Theoretical water use benefit through food waste prevention	187	km^3	Assuming a 50% penetration rate	See penetration rates above
		x				
		Societal costs of water use in agriculture	0.6	USD / m^3	= Costs for water use and water scarcity / water footprint of food waste	FAO
		=				
		2050 Theoretical water use benefits through food waste prevention	0.21	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential water use benefits through food waste prevention	**0.11**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above
	SAVED GHG EMISSIONS	2050 Total GHG emissions of food wastage	3.5	billion tonnes CO_2e	= 2013 Total GHG emissions of food wastage increased by GHG emission of food production increase from 2013 to 2050. Note that these include full life cycle emissions of food waste as per FAO (2013), including impacts from agricultural production. These emissions are therefore not directly comparable with GHG emissions from food produced	FAO
		x				
		Share of edible food waste and losses within total food waste and losses	82%			See C1 Main metrics chart above
		=				
		2050 Theoretical GHG emission benefits through food waste prevention	2.9	billion tonnes CO_2e	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits through food waste prevention	1.4	billion tonnes CO_2e	Assuming a 50% penetration rate	See penetration rates above
		x				
		Societal costs of carbon	113	USD / tonne CO_2e	Following FAO, the societal cost of carbon from the Stern review is applied	FAO, Stern
		=				
		2050 Theoretical GHG emission benefits through food waste prevention	0.32	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits through food waste prevention	**0.16**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above
	PREVENTED SOIL DEGRADATION	2050 Soil degradation costs due to food production	1.3	USD trillion p.a.		See C2 Costs chart above
		x				
		Share of edible food waste and losses at production stage	21%			See C1 Main metric chart above
		=				
		2050 Theoretical soil degradation benefits through food waste prevention	0.26	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential soil degradation benefits through food waste prevention	**0.13**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above
	REDUCED PESTICIDE EXPOSURE	2050 Pesticide exposure (health) costs due to agriculture	1.31	USD trillion p.a.		See C2 Costs chart above
		x				
		Share of edible food waste and losses at production stage	21%			See C1 Main metrics chart above
		=				
		2050 Theoretical pesticide exposure benefits through food waste prevention	0.27	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential pesticide exposure benefits through food waste prevention	**0.13**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above
	REDUCED ANTIMICROBIAL RESISTANCE	2050 AMR costs due to food system	0.39	USD trillion p.a.		See C2 Costs chart above
		x				
		Share of antimicrobial resistance due to food system attributable to animal production	50%		Based on expert inputs and review, stipulating that shares of contribution to AMR from animal husbandry and untreated sewage may be of similar size	Expert input
		x				
		Share of edible food waste and losses at production stage	21%		Assumption of a linear 21% reduction of meat production	See C1 Main metrics chart above
		=				
		2050 Theoretical AMR benefits through food waste prevention	0.04	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential AMR benefits through food waste prevention	**0.02**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above
	REDUCED AIR POLLUTION	2050 Air pollution costs due to agriculture	0.26	USD trillion p.a.		See C2 Costs chart above
		x				
		Share of edible food waste and losses at production stage	21%			See C1 Main metrics chart above
		=				
		2050 Theoretical air pollution benefits through food waste prevention	0.05	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential air pollution benefits through food waste prevention	**0.03**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above
	TOTAL	2050 Total theoretical benefits through food waste prevention	2.74	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Total potential benefits through food waste prevention	**1.37**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See above

B. GROW FOOD REGENERATIVELY	REDUCED FERTILISER LEAKAGE	(2050 N and P fertiliser leakage with current NUE and PUE	0.1	billion tonnes	= Fertiliser demand 2013 x 142% growth of food production * (1 - NUE / PUE)	FAO, Cities and Circular Economy for Food team calculations
		-				
		N and P fertiliser leakage 2050 with improved NUE and PUE)	0.03	billion tonnes	Value calculated with improved NUE and PUE (see 2050 factors) based on the demand of N and P actually reaching the crops in BAU	FAO, see C1 Main metrics chart above, Cities and Circular Economy for Food team calculations
		x				
		Value of N / P	1086	USD / tonne	Weighted average of prices for N (739 USD / tonne) and P (2,225 USD / tonne)	FAO, Cities and Circular Economy for Food team calculations
		=				
		2050 Theoretical fertiliser leakage benefits through regenerative agriculture on cropland	0.08	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential fertiliser leakage benefits through regenerative agriculture on cropland	**0.04**	**USD trillion p.a.**	**Assuming a 50% penetration rate**	See penetration rates above
	SAVED WATER USE	2050 Water footprint of food production	1,818	km^3	= 2013 Water footprint of food production increased by 33%	FAO, see C1 Main metrics chart and projection values above
		x				
		Reduction potential of water efficiency through regenerative agriculture on cropland	60%		Water use efficiency increase potential from no-till agricultural practices, as proxy for effects of regenerative agriculture on cropland	Kassam and Friedrich, Peiretti, Cities and Circular Economy for Food team calculations
		x				
		Share of food excluding animal produce	81%			FAOSTAT: *Food Balance Sheets*
		=				
		2050 Theoretical waster use benefit through regenerative agriculture on cropland	885	km^3	Assuming a 100% penetration rate	
		2050 Potential waster use benefit through regenerative agriculture on cropland	413.3	km^3	Assuming a 47% penetration rate	See penetration rates above
		x				
		Societal costs of water use in agriculture	0.6	USD / m^3	= Costs for water use and water scarcity / water footprint of food waste	FAO
		=				
		2050 Theoretical water use benefits through regenerative agriculture on cropland	0.51	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential water use benefits through regenerative agriculture on cropland	**0.24**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See penetration rates above
	SAVED GHG EMISSIONS	2050 Total cropland	1,664	mn ha	2013 Total cropland x 4% increase total cropland 2013 to 2050	Niggli *et al*., FAOSTAT: FAO land data
		x				
		GHG emissions mitigation potential of regenerative agriculture on cropland compared to conventional methods	0.84	tonnes CO_2e / y / ha	= 0.23 tonnes Ce / y / ha * 3.67 tonne CO_2 / tonne CO_2 / tC	Drawdown
		=				
		2050 Theoretical GHG emission benefits through regenerative agriculture on cropland	1.4	billion tonnes CO_2e	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits through regenerative agriculture on cropland	0.7	billion tonnes CO_2e	Assuming a 47% penetration rate	See penetration rates above
		x				
		Societal costs of carbon	113	USD / tonne CO_2e		FAO, Stern
		=				
		2050 Theoretical GHG emission benefits through regenerative agriculture on cropland	0.16	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits through regenerative agriculture on cropland	**0.07**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See penetration rates above
	PREVENTED SOIL DEGRADATION	2050 Soil degradation costs due to food production	1.2	USD trillion p.a.		See C2 Costs chart above
		x				
		2013 Share of degraded area due to agriculture on cropland	42%		Other part of degraded area due to agriculture on pastureland; assuming regenerative agriculture on cropland is able to fully halt, if not reverse, soil erosion and subsequent land degradation	GLASOD
		=				
		2050 Theoretical soil degradation benefits through regenerative agriculture on cropland	0.53	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential soil degradation benefits through regenerative agriculture on cropland	**0.25**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See penetration rates above
	REDUCED PESTICIDE EXPOSURE	2050 Pesticide exposure costs due to food production	1.31	USD trillion p.a.	Avoidance of health burden by terminating use of synthetic pesticides	See C2 Costs chart above
		2050 Theoretical pesticide exposure benefits through regenerative agriculture on cropland	1.31	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential pesticide exposure benefits through regenerative agriculture on cropland	**0.61**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See penetration rates above
	REDUCED AIR POLLUTION	2050 Air pollution costs due to agriculture	0.26	USD trillion p.a.		See C2 Costs chart above
		x				
		(Share of air pollution due to agriculture that is attributable to manure	66%			Bauer *et al*.
		x				
		Share of manure utilised as fertiliser)	22%		Effectiveness of lever limited to applying manure as fertiliser; other zoogenic ammonia sources not considered	FAOSTAT
		+				
		(Share of air pollution due to agriculture that is attributable to N fertiliser use)	33%			Bauer *et al*.
		x				
		Share of air pollution from fertiliser avoidable)	67%		Based on nutrient-looping calculations: share of avoidable N fertiliser volatisation	Cities and Circular Economy for Food team calculations
		=				
		2050 Theoretical air pollution benefits through regenerative agriculture on cropland	0.09	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential air pollution benefits through regenerative agriculture on cropland	**0.04**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See penetration rates above

	REDUCED FOOD CONTAMINATION	2050 Food contamination costs due to agriculture	0.12	USD trillion p.a.		See C2 Costs chart above
		x				
		Share of food contamination disease costs caused by manure	50%		Assumption: 50% sewage treatment, 50% manure; cost reduction due to minimised manure run-off from pastures under managed grazing, which improves soil health and manure uptake, and thereby mitigates the contamination of water bodies with manure	Expert input
		x				
		Share of manure utilised as fertiliser	22%			FAOSTAT
		=				
		2050 Theoretical food contamination benefits (excluding pesticides) through regenerative agriculture on cropland	0.013	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential food contamination benefits (excluding pesticides) through regenerative agriculture on cropland	**0.006**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See penetration rates above
	TOTAL	2050 Total theoretical benefit of regenerative agriculture on cropland	2.68	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Total potential benefit of regenerative agriculture on cropland	**1.25**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See above
C. MANAGED GRAZING	SAVED GHG EMISSIONS	2050 Total pastureland and grazing	3,345	million ha	2013 Total pastureland and grazing x 102% increase total pastureland and grazing 2013 to 2050	FAOSTAT: Emissions – Land Use, Cities and Circular Economy for Food team calculation based on FAO
		x				
		GHG emissions mitigation potential of managed grazing compared to conventional methods	2.3	tonnes CO_2e / y / ha	= 0.63 t Ce/y/ha * 3.67 tonne CO_2 / tC	Drawdown
		=				
		2050 Theoretical GHG emission benefits through managed grazing	7.7	billion tonnes CO_2e	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits through managed grazing	2.9	billion tonnes CO_2e	Assuming a 37% penetration rate	See penetration rates above
		x				
		Societal cost of carbon	113	USD / tonnes CO_2e		FAO
		=				
		2050 Theoretical GHG emission benefits through managed grazing	0.87	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits through managed grazing	**0.33**	**USD trillion p.a.**	**Assuming a 37% penetration rate**	See penetration rates above
	PREVENTED SOIL DEGRADATION	2050 Soil degradation costs due to food production	1.2	USD trillion p.a.		See C2 Costs chart above
		x				
		Share of degraded area due to agriculture on pasture land	58%		Other part of degraded area due to agriculture on cropland; assuming managed grazing practices are able to fully halt, if not reverse, soil erosion and subsequent land degradation.	GLASOD
		=				
		2050 Theoretical soil degradation benefits through managed grazing	0.72	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential soil degradation benefits through managed grazing	**0.27**	**USD trillion p.a.**	**Assuming a 37% penetration rate**	See penetration rates above
	REDUCED AIR POLLUTION	2050 Air pollution costs due to agriculture	0.26	USD trillion p.a.	It is assumed that due to improved nutrient uptake of pastures from better soil health and immediate 'tilling' of manures from animal hooves, ammonia creation is mitigated	See C2 Costs chart above
		x				
		(Share of air pollution due to agriculture that is attributable to manure	66%			Bauer *et al*.
		x				
		Share of manure not utilised as fertiliser	78%			FAOSTAT
		x				
		Share of grazing animal food from total amount of animal food	8%		Effects only applicable to that share of animals that are kept outdoors	FAOSTAT, FAO, Cities and Circular Economy for Food team calculations
		=				
		2050 Theoretical air pollution benefits through managed grazing	0.01	USD trillion p.a.	Assuming a 100% penetration rate	Cities and Circular Economy for Food team calculation
		2050 Potential air pollution benefits through managed grazing	**0.004**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See penetration rates above
	REDUCED FOOD CONTAMINATION	2050 Food contamination costs due to agriculture	0.12	USD trillion p.a.		See C2 Costs chart above
		x				
		Share of food contamination disease costs caused by manure	50%		Assumption: 50% sewage treatment, 50% manure; cost reduction due to minimised manure run-off from pastures under managed grazing, which improves soil health and manure uptake, and thereby mitigates the contamination of water bodies with manure.	Expert input
		x				
		Share of manure not utilized as fertiliser	78%			FAOSTAT
		x				
		Share of grazing-animal food from total amount of animal food	8%			FAOSTAT, FAO, Cities and Circular Economy for Food team calculations
		=				
		2050 Theoretical food contamination benefits (excluding pesticides) through managed grazing	0.004	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential food contamination benefits (excluding pesticides) through managed grazing	**0.001**	**USD trillion p.a.**	**Assuming a 47% penetration rate**	See penetration rates above
	TOTAL	2050 Total theoretical benefit of managed grazing	1.61	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Total potential benefit of managed grazing	**0.60**	**USD trillion p.a.**	**Assuming a 37% penetration rate**	See above

D. COMPOSTING FROM INEDIBLE FOOD WASTE	SAVED NUTRIENT LOSS	2050 Inedible food waste and losses	0.5	billion tonnes	= 2013 Inedible food waste and losses increased by 42% proportionate to food production	See C1 Main metrics chart above
		x				
		Share that is N or P	0.8%	of NP	Weighted average of shares N and P content in waste types. Simplified assumption that average N and P values of average food and green waste are constant	WRAP, UNU-INWEH
		x				
		Price of N and P	901	USD / tonne of NP	Weighted average of prices for N (739 USD / tonne) and P (2,225 USD / tonne)	FAO
		=				
		2050 Theoretical benefits of prevented nutrient loss from composting inedible food waste and losses	0.00334	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential benefits of prevented nutrient loss from composting inedible food waste and losses	**0.002**	**USD trillion p.a.**	**Assuming a 70% penetration rate**	See penetration rates above
	ADDITIONAL COMPOST VALUE	2050 Inedible food waste and losses	0.5	billion tonnes	= 2013 Inedible food waste and losses increased by 42% proportionate to food production	See C1 Main metrics chart above
		x				
		Share of food waste that is not currently composted	96%		Potential for 2050	World Bank, Cities and Circular Economy for Food team calculations
		x				
		Mass reduction during composting	50%			Expert input
		x				
		Value per tonne compost	70	USD / tonne	From a wide range of possible prices for high quality and minerally enhanced composts, a conservative average value was derived. The value of minerally enhanced or fortified composts ('organo-mineral fertilisers' / 'enhanced soil improvers') can differ substantially from near nil as a mere sink for surplus minerals to several hundreds of dollars for specialty soils. Based on expert interviews and market research we derived a price point we believe is realistic and conservative	Expert input, market data points
		=				
		2050 Theoretical benefits from composting inedible food waste and losses	0.02	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential benefits from composting inedible food waste and losses	**0.01**	**USD trillion p.a.**	**Assuming a 70% penetration rate**	See penetration rates above
	SAVED GHG EMISSIONS	2050 Inedible food waste and losses	0.5	billion tonnes	= 2013 Inedible food waste and losses increased by 42% proportionate to food production	See C1 Main metrics chart above
		x				
		Share of food waste that is not currently composted	96%		Potential for 2050	World Bank, Cities and Circular Economy for Food team calculations
		x				
		CO_2 emission for food waste	0.43	tonnes CO_2e / tonne	= 668 Mtonnes CO_2e end-of-life GHG of food waste / 1,555 Mtonnes total food wasted	FAO
		x				
		CO_2e mitigation potential through composting in comparison to dumping	88%		= (1- 0.08 kg CO_2e composting / 0.67 kg CO_2e dumping)	UNEP
		=				
		2050 Theoretical GHG emission benefits from composting inedible food waste and losses	0.2	billion tonnes CO_2e	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits from composting inedible food waste and losses	0.1	billion tonnes CO_2e	Assuming a 70% penetration rate	See penetration rates above
		x				
		Societal cost of carbon	113	USD / tonne CO_2e		FAO
		=				
		2050 Theoretical GHG emissions benefits from composting inedible food waste and losses	0.02	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential GHG emissions benefits from composting inedible food waste and losses	**0.01**	**USD trillion p.a.**	**Assuming a 70% penetration rate**	See penetration rates above
	TOTAL	2050 Total theoretical benefit of composting of inedible food waste	0.04	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Total potential benefit of composting of inedible food waste	**0.03**	**USD trillion p.a.**	**Assuming a 37% penetration rate**	See above

E. COMPOSTING FROM OTHER ORGANIC WASTE	SAVED NUTRIENT LOSS	2050 Total other municipal organic waste	0.6	billion tonnes	2013 Total other municipal organic waste increased proportionate to increase of organic waste 2013 to 2050	See C1 Main metrics chart above
		x				
		Share that is N or P	0.8%	of NP	Weighted average of shares N and P content in waste types. Simplified assumption that average N and P values of average food and green waste are constant.	WRAP, UNU-INWEH
		x				
		Price of N and P	901	USD / tonne of NP	Weighted average of prices for N (739 USD / tonne) and P (2,225 USD / tonne)	FAO
		=				
		2050 Theoretical benefits of prevented nutrient loss from composting other organic waste	0.004	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential benefits of prevented nutrient loss from composting other organic waste	**0.003**	**USD trillion p.a.**	**Assuming a 70% penetration rate**	See penetration rates above
	ADDITIONAL COMPOST VALUE	2050 Total other municipal organic waste	0.6	billion tonnes	2013 Total other municipal organic waste increased proportionate to increase of organic waste 2013 to 2050	See C1 Main metrics chart above
		x				
		Mass reduction during composting	50%			Expert input
		x				
		Value per tonne compost	70	USD / tonne	The value of minerally enhanced or fortified composts ('organo-mineral fertilisers' / 'enhanced soil improvers') can differ substantially from near nil as a mere sink for surplus minerals to several hundreds of dollars for specialty soils. Based on expert interviews and market research we derived a price point we believe is realistic and conservative.	Expert input
		=				
		2050 Theoretical benefits from composting other organic waste	0.02	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential benefits from composting other organic waste	**0.01**	**USD trillion p.a.**	**Assuming a 70% penetration rate**	See penetration rates above
	SAVED GHG EMISSIONS	(2050 Total other municipal organic waste	0.6	billion tonnes	2013 Total other municipal organic waste increased proportionate to increase of organic waste 2013 to 2050	See C1 Main metrics chart above
		-				
		2050 Currently composted other organic waste excluding food waste)	0.1	billion tonnes	2013 Currently composted other organic waste (excluding food waste) increased proportionately to the increase of organic waste 2013 to 2050	See C1 Main metrics chart above
		x				
		CO_2 emission of dumping per tonne	0.67	tonnes CO_2e / tonne		UNEP
		x				
		CO_2e mitigation potential through composting in comparison to dumping	88%		= (1- 0.08 kg CO_2e composting / 0.67 kg CO_2e dumping). Note that the climate mitigation potential of applying compost to soils (including by offsetting peat use) is not considered due to potential double-counting with crop regenerative agriculture and for the purpose of making conservative assumptions	UNEP, Cities and Circular Economy for Food team calculations
		=				
		2050 Theoretical GHG emission benefits from composting other organic waste	0.27	billion tonnes CO_2e	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits from composting other organic waste	0.19	billion tonnes CO_2e	Assuming a 70% penetration rate	See above
		x				
		Societal cost of carbon	113	USD / tonnes CO_2e		FAO
		=				
		2050 Theoretical GHG emission benefits from composting other organic waste	0.03	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits from composting other organic waste	**0.02**	**USD trillion p.a.**	**Assuming a 70% penetration rate**	See penetration rates above
	TOTAL	2050 Total theoretical benefit of composting of other organic (green) waste	0.05	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Total potential benefit of composting of other organic (green) waste	**0.04**	**USD trillion p.a.**	**Assuming a 37% penetration rate**	See penetration rates above
F. WASTEWATER TREATMENT	SAVED NUTRIENT LOSS	2050 tonnes of human waste	5.8	billion tonnes	= 2013 value increased proportionate to world population growth	See C1 Main metrics chart above
		x				
		Share that is N or P	0.8%	of NP	Weighted average of shares N and P content in human waste	UNU-INWEH
		x				
		Price of N and P	899	USD / tonne of NP	Weighted average of prices for N (739 USD / tonne) and P (2,225 USD / tonne)	FAO
		=				
		2050 Theoretical benefits of prevented nutrient loss through wastewater treatment	0.04	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential benefits of prevented nutrient loss through wastewater treatment	**0.03**	**USD trillion p.a.**	**Assuming a 75% penetration rate**	See penetration rates above
	SAVED GHG EMISSIONS	CO_2e from CH_4 & N_2O from wastewater	0.8	billion tonnes	2005 data adjusted with population growth from 2005 to 2013; then increased by 135% proportionate to population growth	EPA, see C1 Main metrics chart above
		x				
		CO_2e mitigation potential from tertiary wastewater treatment	95%		Weighted average for mitigation potentials for CH_4 and N_2O	UNEP, EPA
		=				
		2050 Theoretical GHG emissions benefits through wastewater treatment	0.75	billion tonnes CO_2e	Assuming a 100% penetration rate	
		2050 Potential GHG emissions benefits through wastewater treatment	0.57	billion tonnes CO_2e	Assuming a 75% penetration rate	See above
		x				
		Societal cost of carbon	113	USD / tonnes of CO_2e		FAO
		=				
		2050 Theoretical GHG emission benefits through wastewater treatment	0.09	USD trillion p.a.	Assuming a 100% penetration rate	
		2050 Potential GHG emission benefits through wastewater treatment	**0.06**	**USD trillion p.a.**	**Assuming a 75% penetration rate**	See above

REDUCED ANTIMICROBIAL RESISTANCE	2050 Costs of antimicrobial resistance (AMR) due to food system	0.39	USD trillion p.a.		See C1 Main metrics chart above
	x				
	Share of antimicrobial resistance due to food system attributable to leaked human waste	50%			Expert input
	x				
	Share of AMR due to dissemination of AMR pathogen strains vs. active pharmaceuticals remaining in treated sludge	95%		Due to spread of resistant pathogens; remaining active pharmaceutical ingredients in treated sewage sludge is considered marginal based on expert interviews.	Expert input
	x				
	Effectiveness of sewage treatment in reducing pathogen strains	99.5%		High-level assumption that occurrence of AMR is reduced proportionally with pathogen loading.	Reinthaler *et al*.
	=				
	2050 Theoretical AMR benefits through wastewater treatment	0.19	USD trillion p.a.	Assuming a 100% penetration rate	
	2050 Potential AMR benefits through wastewater treatment	**0.14**	**USD trillion p.a.**	**Assuming a 75% penetration rate**	See penetration rates above
REDUCED WATER CONTAMINATION	2050 Costs for water contamination	0.21	USD trillion p.a.		See C2 Costs chart above
	x				
	Share of waterborne disease costs from the food system attributable to sewage	100%		Including contamination from manure and untreated human waste	Expert input
	x				
	Theoretical reduction of diarrhoeal disease through wastewater treatment	32%		Even at theoretical 100% effectiveness, other and interlinked pathogen pathways remain, decreasing maximum feasibility to reduce the burden of disease	WHO
	=				
	2050 Theoretical water contamination benefits through wastewater treatment	0.07	USD trillion p.a.	Assuming a 100% penetration rate	
	2050 Potential water contamination benefits through wastewater treatment	**0.06**	**USD trillion p.a.**	**Assuming a 75% penetration rate**	See penetration rates above
REDUCED FOOD CONTAMINATION	2050 Foodborne disease costs due to agriculture	0.12	USD trillion p.a.		See C2 Costs chart above
	x				
	Share of foodborne disease costs from agriculture due to untreated wastewater	50%		Assumption: 50% due to sewage treatment, 50% due to manure	Expert input
	x				
	Theoretical reduction of diarrhoeal disease through wastewater treatment	32%		Even at theoretical 100% effectiveness, other and interlinked pathogen pathways remain, decreasing maximum feasibility to reduce the burden of disease.	WHO
	=				
	2050 Theoretical food contamination benefits (excluding pesticides) through wastewater treatment	0.02	USD trillion p.a.	Assuming a 100% penetration rate	
	2050 Potential food contamination benefits (excluding pesticides) through wastewater treatment	**0.017**	**USD trillion p.a.**	**Assuming a 75% penetration rate**	See penetration rates above
TOTAL	2050 Total theoretical benefit of wastewater treatment	0.40	USD trillion p.a.	Assuming a 100% penetration rate	
	2050 Total potential benefit of wastewater treatment	**0.27**	**USD trillion p.a.**	**Assuming a 75% penetration rate**	See penetration rates above

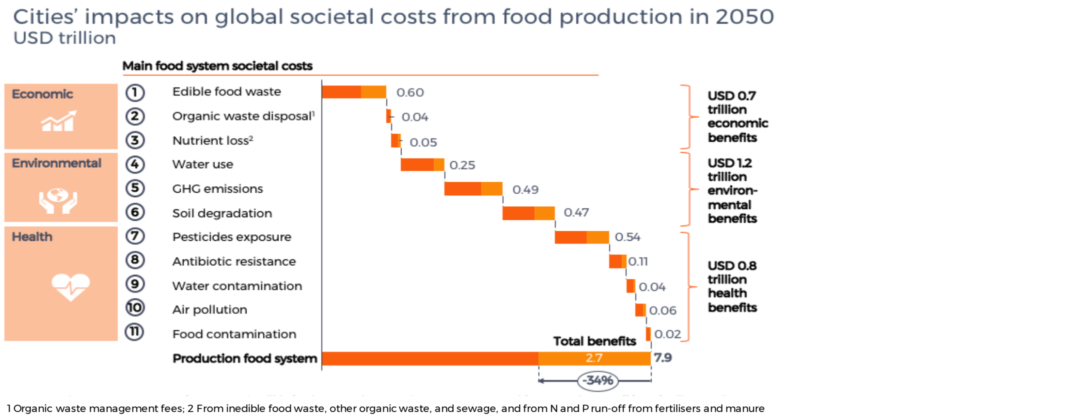
		METRIC	VALUE	UNIT	COMMENT	
SUMMARY	100% PENETRATION RATE (THEORETICAL)	SUM OF THEORETICAL BENEFITS	7.53	USD trillion p.a.		
		-				
		DOUBLE-COUNTING	-1.07	USD trillion p.a.	Reducing the double-counting of different levers	
		=				
		TOTAL POTENTIAL BENEFITS	**6.45**	**USD trillion p.a.**		
		NEW TOTAL COSTS OF FOOD SYSTEM	**9.32**	**USD trillion p.a.**	**= 2050 BAU costs - potential benefits**	
		NEW ECONOMICAL COSTS PER USD SPENT ON FOOD	0.02	USD / USD		
		NEW HEALTH COSTS PER USD SPENT ON FOOD	0.89	USD / USD		
		NEW ENVIRONMENTAL COSTS PER USD SPENT ON FOOD	0.07	USD / USD		
		NEW TOTAL COSTS PER USD SPENT ON FOOD	**0.98**	**USD / USD**		
	TECHNICALLY FEASIBLE PENETRATION RATES (POTENTIAL)	SUM OF POTENTIAL BENEFITS	3.55	USD trillion p.a.	Taking into account the penetration rates	
		-				
		DOUBLE-COUNTING	-0.19	USD trillion p.a.	Reducing the double-counting of different levers	
		=				
		TOTAL POTENTIAL BENEFITS	**3.36**	**USD trillion p.a.**		
		NEW ECONOMICAL COSTS PER USD SPENT ON FOOD	**12.40**	**USD trillion p.a.**	**= 2050 BAU costs - potential benefits**	
		NEW ECONOMICAL COSTS PER USD SPENT ON FOOD	0.11	USD / USD		
		NEW HEALTH COSTS PER USD SPENT ON FOOD	0.96	USD / USD		
		NEW ENVIRONMENTAL COSTS PER USD SPENT ON FOOD	0.28	USD / USD		
		NEW TOTAL COSTS PER USD SPENT ON FOOD	**1.36**	**USD / USD**		

		METRIC	VALUE	UNIT	COMMENT	SOURCE
ANNUAL DEATHS RELATED TO THE FOOD SYSTEM		2050 Deaths from air pollution	1,136,064		Deaths attributable to ammonia from agriculture annually (800,000), increased by 42% proportionate to food production	Max Planck Society, Cities and Circular Economy for Food team calculations
		+				
		2050 Deaths from AMR	3,102,000		Projected deaths from AMR by 2050 x Estimated share of AMR due to food system	RAND corporation, iPES Food, Cities and Circular Economy for Food team calculations
		+				
		2050 Deaths from waterborne diseases	669,516		Deaths due to contaminated drinking water, inadequate handwashing facilities and sanitation services * Share of water-related disease burden attributed to drinking water and sanitation * Share of waterborne disease spread by poorly handled human waste and manure, increased by 35% proportionate to world population growth.	WHO, expert interview, Cities and Circular Economy for Food team calculations
		+				
		2050 Deaths from pesticides	736,137		Deaths from pesticides were not available from the source used. Instead they were calculated based on their share in the total health costs applied proportionately total deaths.	Cities and Circular Economy for Food team calculations
		=				
		2050 Total annual deaths related to the food system	5,643,717			

ROLE OF CITIES: the following share (per lever) is influenced by cities

		METRIC	VALUE	UNIT	COMMENT	SOURCE
SHARES OF LEVERS THAT ARE INFLUENCED BY CITIES 2013		Food waste prevention	66%		Equals the share of today's population living in cities (54%), adjusted for higher GDP (leading to higher amounts of food produced and increased consumption per capita in cities). The city share of impacts are calculated based on their share of food consumed by their inhabitants and its corresponding impacts, and waste arising from urbanites. Note that only a share of all impacts emerge in or affect cities; rather this is intended to emulate a full system perspective.	FAOSTAT, Cities and Circular Economy for Food team calculations
		Regenerative agriculture on cropland	68%		Equals the share of food production for consumption in cities: assuming cities contribute to the shift for the food they consume, both when it's produced in peri-urban areas and when it's not.	FAOSTAT, Cities and Circular Economy for Food team calculations
		Managed grazing (animal product production)	68%			
		Composting from inedible food waste	66%		Equals the share of food waste generated by city consumption, irrespective of urban location (a share happens early in the value chain).	FAOSTAT, Cities and Circular Economy for Food team calculations
		Composting from other organic waste (green waste)	68%		Equals the share of food production for consumption in cities: assuming MSW generation is two times higher in cities than in rural regions (according to World Bank) and thus urban waste generation approximately equals that of food generation.	FAOSTAT, World Bank, Cities and Circular Economy for Food team calculations
		Wastewater treatment	54%		Equals the urbanisation share: assuming that excretion in cities and rural areas is the same.	UN

		METRIC	VALUE	UNIT	COMMENT	SOURCE
SHARES OF LEVERS THAT ARE INFLUENCED BY CITIES 2050		Food waste prevention	79%	Urban share	Equals the share of 2050's population living in cities (68%), adjusted for higher GDP (leading to increased food production per capita)	FAOSTAT, Cities and Circular Economy for Food team calculations
		Regenerative agriculture on cropland	80%	Urban share	Equals the share of food production for consumption in cities: assuming cities contribute to the shift for the food they consume, both when it's produced in peri-urban areas and when it's not	FAOSTAT, Cities and Circular Economy for Food team calculations
		Managed grazing (animal product production)	80%			
		Composting from inedible food waste	79%	Urban share	Equals the share of food waste generated by cities consumption, irrespective of urban location (a share happens early in the value chain)	FAOSTAT, Cities and Circular Economy for Food team calculations
		Composting from other organic waste (green waste)	80%	Urban share	Equals the share of food production for consumption in cities: assuming MSW generation is two times higher in cities than in rural regions (according to World Bank) and thus urban waste generation approximately equals that of food generation	FAOSTAT, World Bank, Cities and Circular Economy for Food team calculations
		Wastewater treatment	68%	Urban share	Equals the urbanisation share: assuming that excretion in cities and rural areas is the same	UN



CITIES' IMPACTS ON GLOBAL SOCIETAL COSTS FROM FOOD PRODUCTION IN 2050

	METRIC	VALUE	UNIT	COMMENT	SOURCE
Economic	Cities' share of impact on edible food waste prevention	79%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Economic	=				
Economic	Cities' contributions to benefits from edible food waste prevention	0.60	USD trillion		
Economic	Economic impact of global edible food waste prevention	0.77	USD trillion	Economic value that would not be lost if edible food waste was prevented according to feasible penetration rates	Cities and Circular Economy for Food team calculations
Economic	Cities' share of impact on organic waste disposal	79%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Economic	=				
Economic	Cities' contributions to benefits from organic waste disposal	0.04	USD trillion		
Economic	Cities' share of nutrients loss and waste management impact	75%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Economic	=				
Economic	Cities' contributions to benefits from avoiding nutrients loss and improving waste management	0.05	USD trillion		
Economic	**TOTAL economic impact generated by cities**	**0.7**	**USD trillion**		
Health	Pesticides exposure	80%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Health	=				
Health	Cities' potential impact on pesticides	0.54	USD trillion		
Health	Antibiotic resistance	70%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Health	=				
Health	Cities' potential impact on antibiotic resistance	0.11	USD trillion		
Health	Water contamination	68%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Health	=				
Health	Cities' potential impact on water contamination	0.04	USD trillion		
Health	Air pollution	79%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Health	=				
Health	Cities' potential impact on air pollution	0.06	USD trillion		
Health	Foodborne diseases	72%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Health	=				
Health	Cities' potential impact on foodborne diseases	0.02	USD trillion		
Health	**TOTAL health benefits generated by cities'**	**0.8**	**USD trillion**		
Environmental	GHG emissions	78%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Environmental	=				
Environmental	Cities' potential impact on GHG emissions	0.49	USD trillion		
Environmental	Water use	80%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Environmental	=				
Environmental	Cities' potential impact on water use	0.25	USD trillion		
Environmental	Soil degradation	80%			Weighted average of levers; Cities and Circular Economy for Food team calculations
Environmental	=				
Environmental	Cities' potential impact on soil degradation	0.47	USD trillion		
Environmental	**TOTAL environmental benefits generated by cities**	**1.2**	**USD trillion**		
	TOTAL potential impacts generated by cities	**2.7**	**USD trillion**		

5 BENEFITS FACTORS TABLE

Note: The general approach for the following chart is total costs or total externalities divided by the respective tonnes or ha.
The derived values constitute simplified theoretical global averages and can therefore differ substantially from specific conditions in local areas.

		METRIC	VALUE	UNIT	COMMENT	SOURCE
BENEFITS PER HA / TONNE (2013)	FOOD WASTE PREVENTION	Direct economic benefits of edible food waste prevention per tonne	742	USD / tonne	= Cost per tonne edible food waste and losses	FAO, Cities and Circular Economy for Food team calculations
		Waste management costs benefits through food waste prevention per tonne	127	USD / tonne	= Waste collection and disposal costs	World Bank
		Water use benefits through food waste prevention per tonne*	193	m^3 / tonne	= Water intensity of food production (in km^3 / t)	FAO, Cities and Circular Economy for Food team calculations
		Water use benefits through food waste prevention per tonne*	111	USD / tonne	= Water intensity of food production (in km^3 / t) x Societal costs of water use in agriculture	FAO, Cities and Circular Economy for Food team calculations
		GHG emission benefits through food waste prevention per tonne*	1.5	tCO_2e / tonne	= Theoretical GHG emission benefits through food waste prevention / Edible food waste and losses	Cities and Circular Economy for Food team calculations, see charts above
		GHG emission benefits through food waste prevention per tonne*	171	USD / tonne	= GHG emission benefits [tCO_2e] through food waste prevention per tonne x Societal costs of carbon	FAO, Cities and Circular Economy for Food team calculations
		Soil degradation benefits through food waste prevention per tonne*	32	ha / tonne	= Avoided soil degradation from food production. Note that double counting of effects with regenerative agriculture on cropland is accounted for.	GLASOD, Pimentel, Cities and Circular Economy for Food team calculations, see charts above
		Soil degradation benefits through food waste prevention per tonne*	178	USD / tonne	= Weighed average USD / ha / t shifting for avoided land degradation from shifting cropland and pasture land to regenerative practices	GLASOD, Pimentel, Cities and Circular Economy for Food team calculations, see charts above
		Pesticide exposure benefits through food waste prevention per tonne	160	USD / tonne	= Theoretical pesticide exposure benefits through food waste prevention / Edible food waste and losses (animal share)	Cities and Circular Economy for Food team calculations, see charts above
		AMR benefits through food waste prevention per tonne*	21	USD / tonne	= Theoretical AMR benefits through food waste prevention / Edible food waste and losses	Cities and Circular Economy for Food team calculations, see charts above
		Air pollution benefits through food waste prevention per tonne	25	USD / tonne	= Theoretical air pollution benefits through food waste prevention / Edible food waste and losses	Cities and Circular Economy for Food team calculations, see charts above
	REGENERATIVE AGRICULTURE ON CROPLAND	Fertiliser leakage benefits through regenerative agriculture on cropland per tonne avoided	1,086	USD / tonne	= Weighted average of prices for N (739 USD / t) and P (2,225 USD / t)	Cities and Circular Economy for Food team calculations, see charts above
		Waster use benefit through regenerative agriculture on cropland per tonne	115.6	m^3 / tonne	= Water intensity of food production (in km^3 / t) x Reduction potential of water efficiency through regenerative agriculture on cropland	FAO, Cities and Circular Economy for Food team calculations, see charts above
		Water use benefits through regenerative agriculture on cropland per tonne	66	USD / tonne	= Water use benefits [m^3] through regenerative agriculture on cropland per tonne x Social costs of water use in agriculture	FAO, Cities and Circular Economy for Food team calculations
		GHG emission benefits through regenerative agriculture on cropland per ha	0.8	tCO_2e / ha	GHG emissions mitigation potential of regenerative agriculture on cropland compared to conventional methods	Drawdown
		GHG emission benefits through regenerative agriculture on cropland per ha	95	USD / ha	= GHG emission benefits [tCO_2e] through regenerative agriculture on cropland per tonne x Societal costs of carbon	FAO, Cities and Circular Economy for Food team calculations
		Soil degradation benefits through regenerative agriculture on cropland per ha	1	ha / ha	Assumption: 100% reduction of soil degradation through regenerative agriculture on cropland	GLASOD, World Bank, Cities and Circular Economy for Food team calculations
		Soil degradation benefits through regenerative agriculture on cropland per ha	229	USD / ha	= Weighted average USD / ha / t shifting for avoided land degradation from shifting cropland and pasture land to regenerative practices	GLASOD, World Bank, Cities and Circular Economy for Food team calculations
		Pesticide exposure benefits through regenerative agriculture on cropland per tonne	160	USD / tonne	= Theoretical pesticide exposure benefits through regenerative agriculture on cropland / tonnes of animal food produced	Cities and Circular Economy for Food team calculations, see charts above
		Air pollution benefits through regenerative agriculture on cropland per tonne	11	USD / tonne	= Theoretical air pollution benefits through regenerative agriculture on cropland / tonnes of non-animal food produced	Cities and Circular Economy for Food team calculations, see charts above
		Food contamination benefits (excluding pesticides) through regenerative agriculture on cropland per tonne	2	USD / tonne	= Theoretical food contamination benefits (excluding pesticides) through regenerative agriculture on cropland / tonnes of non-animal food produced	Cities and Circular Economy for Food team calculations, see charts above

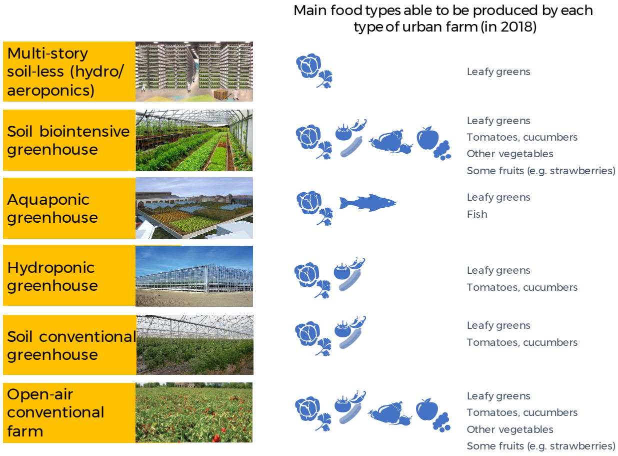
MANAGED GRAZING	GHG emission benefits through managed grazing per ha	2.3	tCO_2e / ha	GHG emissions mitigation potential of managed grazing compared to conventional methods	Drawdown
	GHG emission benefits through managed grazing per ha	261	USD / ha	= GHG emission benefits [tCO_2e] through managed grazing per tonne x Societal costs of carbon	FAO, Cities and Circular Economy for Food team calculations
	Soil degradation benefits through managed grazing per ha	1	ha / ha	Assumption: 100% reduction of soil degradation through managed grazing	GLASOD, World Bank, Cities and Circular Economy for Food team calculations
	Soil degradation benefits through managed grazing per ha	153	USD / ha	= Weighted average USD / ha / t shifting for avoided land degradation from shifting cropland and pasture land to regenerative practices	GLASOD, World Bank, Cities and Circular Economy for Food team calculations
	Air pollution benefits through managed grazing per tonne	80	USD / tonne	= Theoretical air pollution benefits through managed grazing / tonnes of grazing animal food produced	Cities and Circular Economy for Food team calculations, see charts above
	Food contamination benefits (excluding pesticides) through managed grazing per tonne	28	USD / tonne	=Theoretical food contamination benefits (excl. pesticides) through managed grazing / tonnes of grazing animal food produced	Cities and Circular Economy for Food team calculations, see charts above
COMPOSTING FROM INEDIBLE FOOD WASTE	Benefits of prevented nutrient loss from composting inedible food waste and losses per tonne	7	USD / tonne	= Theoretical Benefit of prevented nutrient loss from composting inedible food waste and losses / Inedible food waste and losses	Cities and Circular Economy for Food team calculations, see charts above
	Benefits from composting inedible food waste and losses	35	USD / tonne	= Value per tonne compost x Mass reduction during composting	Expert input
	GHG emission benefits from composting inedible food waste and losses per tonne	0.36	tCO_2e / tonne	= CO_2 emission for food waste x CO_2e mitigation potential through composting in comparison to dumping x Share of food waste that is not currently composted	Cities and Circular Economy for Food team calculations, see charts above
	GHG emission benefits from composting inedible food waste and losses per tonne	41	USD / tonne	= GHG emission benefits [tCO_2e] from composting inedible food waste and losses per tonne x Societal costs of carbon	FAO, Cities and Circular Economy for Food team calculations
COMPOSTING FROM OTHER ORGANIC WASTE	Benefits of prevented nutrient loss from composting other organic waste per tonne	7	USD / tonne	= Theoretical benefit of prevented nutrient loss from composting of other organic waste / Total other municipal organic waste	Cities and Circular Economy for Food team calculations, see charts above
	Benefits from composting other organic waste per tonne	35	USD / tonne	= Value per tonne compost x Mass reduction during composting	Expert input
	GHG emission benefits from composting other organic waste per tonne	0.36	tCO_2e / tonne	= CO_2 emission for food waste per tonnene x CO_2e mitigation potential through composting in comparison to dumping x Share of organic waste that is not currently composted	Cities and Circular Economy for Food team calculations, see charts above
	GHG emission benefits from composting other organic waste per tonne	41	USD / tonne	= GHG emission benefits [tCO_2e] from composting other organic waste and losses per tonne x Societal costs of carbon	FAO, Cities and Circular Economy for Food team calculations
WASTEWATER TREATMENT	Benefits of prevented nutrient loss through wastewater treatment per tonne	8	USD / tonne	= Theoretical benefits of prevented nutrient loss through wastewater treatment / tonnes of human waste	Cities and Circular Economy for Food team calculations, see charts above
	GHG emission benefits through wastewater treatment per tonne	0.14	tCO_2e / tonne	= CO_2e from CH_4 and N_2O from wastewater x CO_2e mitigation potential from tertiary wastewater treatment / tonnes of human waste not undergoing tertiary treatment (95%)	Cities and Circular Economy for Food team calculations, see charts above
	GHG emission benefits through wastewater treatment per tonne	15	USD / ha	= GHG emission benefits [tCO_2e] through wastewater treatment and losses per tonne x Social costs of carbon	FAO, Cities and Circular Economy for Food team calculations
	AMR benefits through wastewater treatment per tonne	40	USD / tonne	= Theoretical AMR benefits through wastewater treatment / Untreated share (80%) of tonnes of human waste	Cities and Circular Economy for Food team calculations, see charts above
	Water contamination benefits through wastewater treatment per tonne	14	USD / tonne	= Theoretical water contamination benefits through wastewater treatment / Untreated share (80%) of tonnes of human waste	Cities and Circular Economy for Food team calculations, see charts above
	Food contamination benefits (excluding pesticides) through wastewater treatment per tonne*	4	USD / tonne	= Theoretical food contamination benefits through wastewater treatment / Untreated share (80%) of tonnes of human waste	Cities and Circular Economy for Food team calculations, see charts above

* different values for 2013 and 2015

6 BEYOND CIRCULAR ECONOMY LEVERS

		METRIC	VALUE	UNIT	COMMENT	SOURCE
POTENTIAL BENEFITS BEYOND CIRCULAR ECONOMY LEVERS		Reduction potential of GHG emissions through diet shifts 2050 compared to BAU 2050 assuming no further change in waste reduction and technological improvement	-52%		Flexitarian (FLX): 'Dietary shift towards more plant-based, flexitarian dietary patterns based on recent evidence on healthy eating that include more stringent limits for red meat (one serving per week), limits for white meat (half a portion a day) and dairy (one portion a day), and greater minimum amounts of legumes, nuts, and vegetables.'	Springmann *et al.*
		Reduction potential of blue water use by agriculture through diet shifts 2050 compared to BAU 2050 assuming no further change in waste reduction and technological improvement	-11%			
		Reduction potential of GHG emissions through technological development 2050 compared to BAU 2050 assuming no further change in waste reduction and diet shifts	-11%		Tech+: 'Additional increases in agricultural yields that close yield gaps to 90%; a 30% increase in nitrogen use efficiency (...), and 50% recycling rates of phosphorus; phase-out of first-generation biofuels; and implementation of all available bottom-up options for mitigating food-related GHG emissions.'	Springmann *et al.*
		Reduction potential of blue water use by agriculture through technological development 2050 compared to BAU 2050 assuming no further change in waste reduction and diet shifts	-28%			
		Reduction potential of GHG emissions in 'Towards Sustainability Scenario' (TSS) compared to BAU scenario; % includes further levers apart from diet shift	-31%		Towards Sustainability Scenario (TSS): 'Balanced, healthy and environmentally sustainable diets are mostly universally adopted. (...) Global meat production increases by just under 30 percent by 2050 compared with 2012, due to lower demand and the adoption of less-intense production practices. (...) sustainable agricultural intensification leads to higher land-use intensity.' Further interventions: low-input precision agriculture applied robotics, strong internal redistribution, suitable crop technologies, reforestation, afforestation, conservation practices, investments in technology, renewable energy sources, low-input water processes, no substantial expansion of agricultural land, organic agriculture.	FAO
		Reduction potential of N application in 'Towards Sustainability Scenario' (TSS) assuming a 100% decrease of N application as fertiliser; % includes further levers apart from diet shift	-100%			
		Reduction potential of the number of undernourished people in 'Towards Sustainability Scenario' (TSS) compared to BAU scenario; % includes further levers apart from diet shifts	-51%			
		Reduction potential of obesity (affected people) by introducing a systemic program of multiple interventions set by MGI	-20%		Diet shift triggered by 44 of MGI's identified interventions to reduce obesity (incl. portion control, reformulation, and healthy meals).	McKinsey

7 URBAN FARMING



Note 1: In 2018, food types that are typically produced in indoor urban farms are highly perishable leafy greens, herbs, other vegetables, selected fruit such as strawberries, and fish. Our estimates show the share of cities' food needs could be produced by high-yield urban farms, assuming they achieved maximum potential yields for these food types. Considering estimated yields for five farm types, this food volume potential is then translated into the urban space that would be required.

Note 2: The following 'per city' refers to a statistical average city based on global data from cities with a population of over 100,000 people, adjusted for higher per capita consumption in cities than rural areas.

		DESCRIPTION	VALUE	UNIT	COMMENT	SOURCE
URBAN FARMING CALCULATIONS	FOOD SUPPLY	Total supply of food, per city	1,042,958	tonnes p.a.	= 0.02% of global food supply for direct human consumption in cities	FAOSTAT, IIED, UN, United States Census Bureau
		Supply of vegetables and selected fruit, per city	212,133	tonnes p.a.	0.02% of global volume for vegetables and fruit types that are already produced in indoor farms in 2018 (on a large or limited scale). Vegetables are defined here as leafy greens, herbs and other vegetables, including fruiting crops (such as tomatoes), that are produced in indoor farms today (on a large or limited scale). Selected fruit types are those that are grown in indoor urban farms today (at limited scale), such as strawberries.	FAOSTAT, IIED, UN, United States Census Bureau
		+				
		Supply of fish, per city	28,413	tonnes p.a.	= 0.02% of total fish supply based on share of statistical average city's consumption	FAOSTAT, IIED, UN, United States Census Bureau
		=				
		Maximum potential food supply from indoor urban farming, per city	**240,546**	**tonnes p.a.**	Defined here as the supply of 100% of volumes for the food types that are already produced in indoor farms today (on a large or limited scale).	
		Share of food supply assumed to be suitable for indoor urban farming in global food volume	**23%**		**= 240,546 tonnes p.a. / 1,042,958 tonnes p.a.. The share of the amount by mass (tonnes) is not equal to the shares of other applicable metrics such as kcal, protein, and fats. Since the majority of produce covered in this analysis is vegetables, the share of such criteria possible through urban farming is likely significantly lower.**	Cities and Circular Economy for Food team calculations
	YIELDS	Estimated indoor urban farming yields for vegetables and selected fruit	496	tonnes / ha p.a.	Average yields based on estimated yields for five types of foods in five indoor UF types: leafy greens, other vegetables, selected fruits, herbs, and fish produced in an aquaponic greenhouse, soil-less multi storey, soil biointensive greenhouse, hydroponic greenhouse, soil conventional biogreenhouse.	Alberta Agriculture and Rural Development, Agrilyst, Willis, Quarz, expert input
		+				
		Estimated indoor urban farming yields for fish	258	tonnes / ha p.a.	Similar to yields of conventional intense aquafarming operations	Expert input
		=				
		Estimated average indoor urban farming yields	**468**	**tonnes / ha p.a.**		
	SHARE OF URBAN AREA SUITABLE / REQUIRED FOR URBAN FARMING	Total urban area, per city	39,327	ha	Total urban area per city at ground level	Lincoln Institute of Land Policy
		Urban unbuilt land, per city	6,568	ha	Assumed to be ~17% of total urban land based on empirical research for the USA	Lincoln Institute of Land Policy, Newman *et al*.
		+				
		Potentially suitable urban rooftop space per city	276	ha	Assumed to be similar to the rooftop space suitable for solar PV, assessed based on OECD/IEA global formula (172.3 x pop. density^-0,352 x cap.) and taking into account additional limitations like roof angle, roof access, minimal size requirements, etc.	OECD/IEA
		=				
		Urban area potentially suitable for UF, per city	**6,844**	**ha**		Cities and Circular Economy for Food team calculations
		Estimated area required to produce 100% of vegetables and selected fruit for a city in indoor urban farming, per city	428	ha	= 212,133 tonnes p.a. / 496 tonnes / ha p.a. Vegetables are defined here as leafy greens, herbs and other vegetables, including fruiting crops (such as tomatoes). Fruit includes selected fruit types that are grown in nascent indoor urban farms today, such as strawberries.	Cities and Circular Economy for Food team calculations
		+				
		Estimated area required to produce 100% of fish for a city in indoor urban farming, per city	11	ha	= 28,413 tonnes p.a. / 258 tonnes / ha p.a.	Cities and Circular Economy for Food team calculations
		=				
		Estimated area required to produce 100% of food categories above for a city in indoor urban farming, per city	**538**	**ha**		Cities and Circular Economy for Food team calculations
		Share of urban area potentially suitable for UF that would be required to produce 100% of food types that are already produced in indoor farms today (on a large or limited scale)	**8%**		**= 538 ha / 6,844 ha Note that a number of barriers exist to access urban space potentially suitable for urban farming, such as zoning/legal rules, detailed technical feasibility constraints, or competition with other uses for land**	Cities and Circular Economy for Food team calculations
		Share of total urban area that would be required to produce 100% of the food types above	**1.4%**		**= 538 ha / 39,327 ha**	Cities and Circular Economy for Food team calculations