TECHNICAL APPENDIX

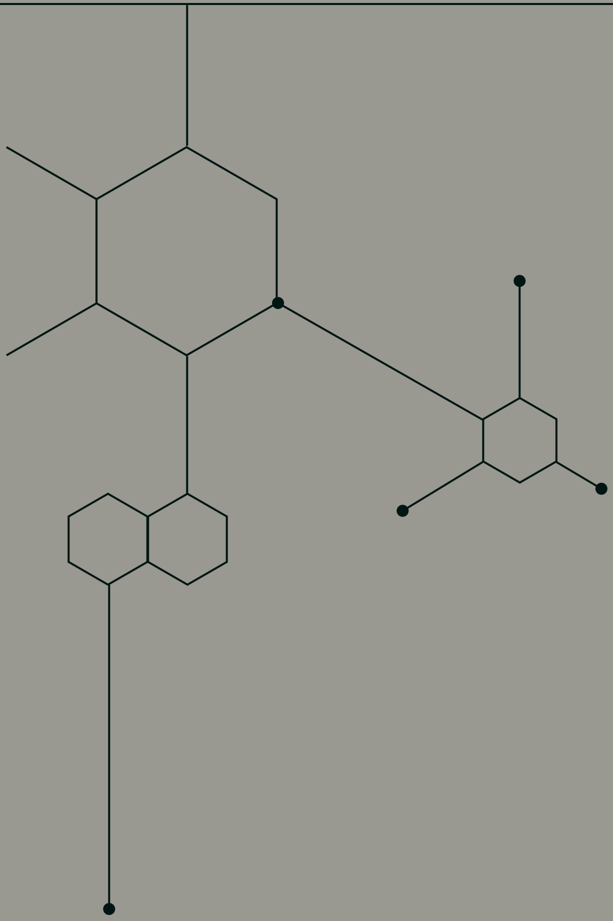
The True Cost of Food in the United States

The ROCKEFELLER FOUNDATION

JULY 2021

Contents

1 Principles



The US food system creates enormous benefits. Many benefits are reflected in food prices paid by consumers (e.g., profits for large producers, wages for workers), however some benefits are not accounted for (e.g., widespread food safety and availability, job creation, local economic multipliers). The full report details many of these benefits, while this technical appendix summarizes the methodology to determine the true cost of food in the U.S.

Scientific consensus on measuring the true cost of food is still evolving. Acknowledging that the method proposed in this collaboration represents a first actionable framework towards a refined, (inter-) nationally agreed-on framework as the basis for food system related decisions, the methodology and quantification is based on the following principles.

1. **Quantification accounts for primary impact only:** For each impact area, only primary impacts are captured. Secondary/downstream impacts may be significant even if not currently captured.

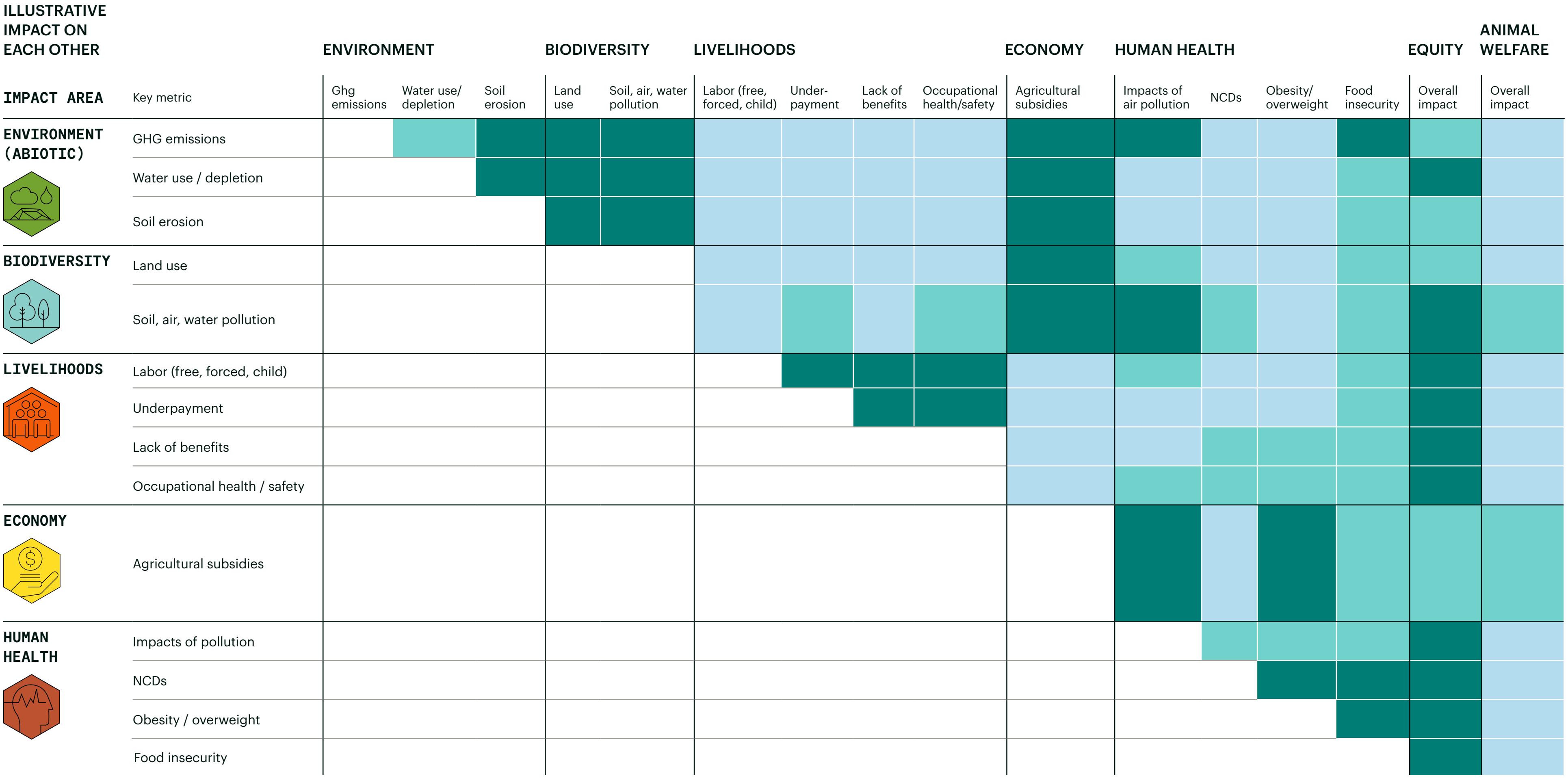
TABLE 1

	Included in approach (examples)	Future / secondary impacts (examples)
ENVIRONMENT (ABIOTIC)	Greenhouse gas (GHG) emissions, water use, and soil erosion	• Future food insecurity due to increased climate variability • Increased migration (climate refugees) Soil health • Food waste
BIODIVERSITY	Land uses, air, and water pollution, and impacts of soil pollution and run-offs	• Contribution to likelihood of biodiversity collapse • Increased exposure to novel viruses due to deforestation • Acidification
LIVELIHOODS	Labor, underpayment of wages, lack of benefits, occupational health, and safety issues	• Reduced access to and time spent for education • Increased rates of suicide amongst farmers
ECONOMY	Agriculture Subsidies	• Operating costs of food-related government bodies • Research and development cost
HUMAN HEALTH	Share of direct medical costs attributable to diet and/or food Productivity loss associated with diet and/or food	• Reduced national security (due to overweight/obesity)[2] • Dietary contribution to mental health illnesses • Dietary contribution to educational achievement
ANIMAL WELFARE	Qualitative effect of how animal welfare has intrinsic (on animal lives / wellbeing) and extrinsic impacts (antibiotic resistance)	• Ethical considerations of livestock farming practices (caged animals, inhumane slaughter) and its effect on societal well-being
EQUITY	Selected examples of how food system impacts (costs) disproportionately affect people of color	• Worsening social cohesion, civil unrest etc. from racial inequity • Impacts on spending on housing, education, medication etc. from food insecurity among specific populations

Interdependencies between the key costs identified in this collaboration are not quantified but should be acknowledged in future work, with Table 2 highlighting some particularly notable interdependencies between metrics. While adjustments were made to estimate each key metric independently and remove instances of double-counting costs, the extent of interdependencies across metrics means that there is likley minor double-counting between highly interconnected metrics.

TABLE 2 **Immediate interdependency**

○ Low ◐ Medium ● High



ILLUSTRATIVE IMPACT ON EACH OTHER		ENVIRONMENT			BIODIVERSITY		LIVELIHOODS				ECONOMY	HUMAN HEALTH				EQUITY	ANIMAL WELFARE
IMPACT AREA	Key metric	Ghg emissions	Water use/ depletion	Soil erosion	Land use	Soil, air, water pollution	Labor (free, forced, child)	Under-payment	Lack of benefits	Occupational health/safety	Agricultural subsidies	Impacts of air pollution	NCDs	Obesity/ overweight	Food insecurity	Overall impact	Overall impact
ENVIRONMENT (ABIOTIC)	GHG emissions		◐	●	●	●	○	○	○	○	●	●	○	○	●	◐	○
	Water use / depletion			●	●	●	○	○	○	○	●	○	○	○	◐	●	○
	Soil erosion				●	●	○	○	○	○	●	○	○	○	◐	◐	○
BIODIVERSITY	Land use						○	○	○	○	●	◐	○	○	◐	◐	○
	Soil, air, water pollution						○	◐	○	◐	●	●	◐	○	◐	●	◐
LIVELIHOODS	Labor (free, forced, child)							●	●	●	○	◐	○	○	◐	●	○
	Underpayment								●	●	○	○	○	○	◐	●	○
	Lack of benefits										○	○	◐	◐	◐	●	○
	Occupational health / safety										○	◐	◐	◐	◐	●	○
ECONOMY	Agricultural subsidies											●	○	●	◐	◐	◐
HUMAN HEALTH	Impacts of pollution												◐	◐	◐	●	○
	NCDs													●	●	●	○
	Obesity / overweight														●	●	○
	Food insecurity															●	○

2. **The work is based on existing literature:** Costs are measured using existing scientific literature; therefore, areas of impact that have not been well studied may be underestimated compared to other areas (e.g., biodiversity loss costs are less studied than health costs). The specific literature used to quantify each metric is included in the 'Metrics' section.

3. **Metrics included were expansive, not exhaustive:** Metrics are prioritized based on potential impact and availability of scientifically acknowledged monetization factors; however, some metrics lack quality data and/or cannot be monetized. Several of these are discussed in the 'qualitative spotlights' section.

   In Table 3, some metrics are labeled as having a 'lack of data'. Such a classification means that data estimates for either the unit, impact, or monetization factor are incomplete or unavailable. In many cases, significant data sources exist for aspects of the metric (e.g., impact and unit), while other aspects are not widely available (e.g., monetization factors).

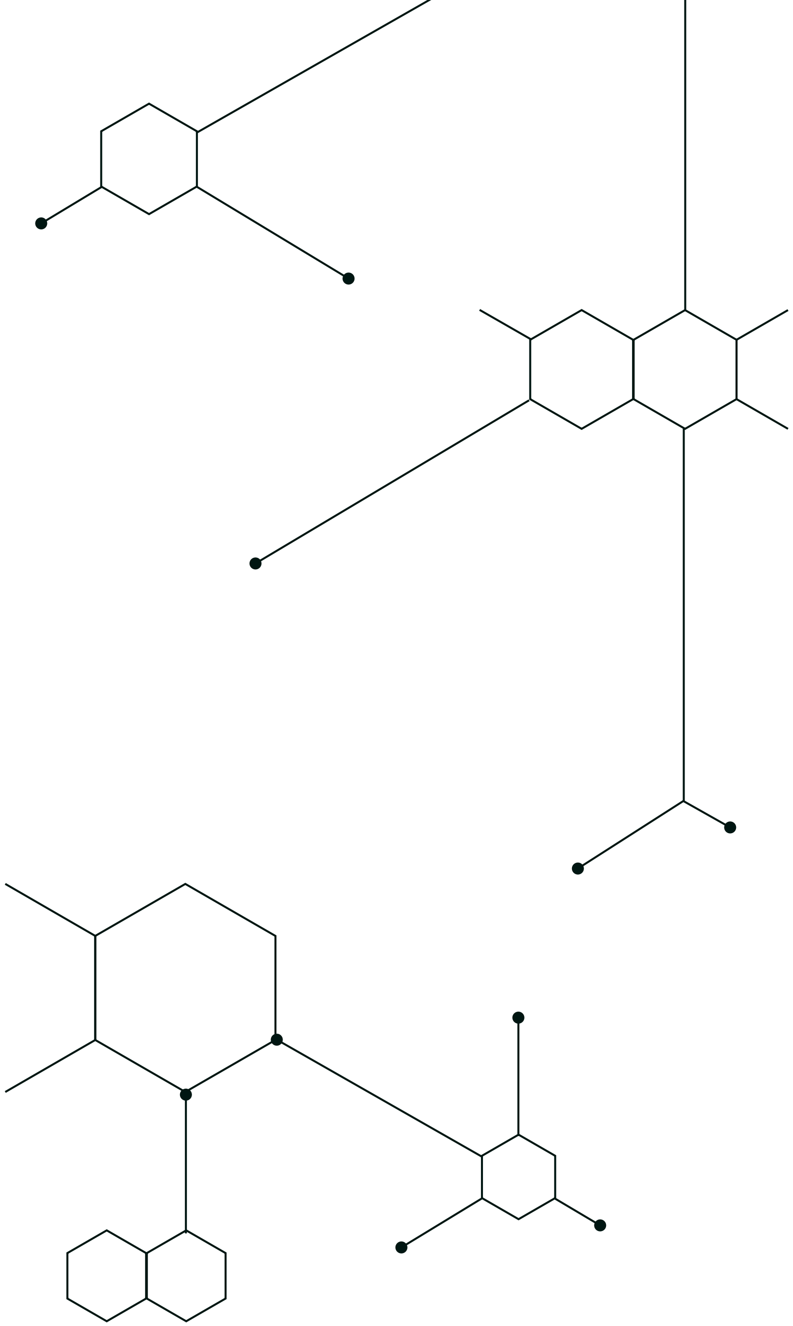


TABLE 3

○ Not assessed ◔ Low ◑ Medium ◕ High ● Very high

				Data Quality			Completeness
Impact area	Cost/benefit	Metric	Unit	Impact	Monetization		
ENVIRONMENT (ABIOTIC)	Cost	GHG emissions	kg CO_2-eq	Governmental statistics	Leading organization in monetization, factors based on scientific literature	◕	◑
	Cost	Scarce water use	km^3	Governmental statistics	Leading organization in monetization, factors based on scientific literature	◑	
	Cost	Soil erosion	t/ha	Governmental statistics	Leading organization in monetization, factors based on scientific literature	◑	
	Cost	Soil health	n/a	Lack of data[1]		○	
BIODIVERSITY	Cost	Soil pollution	$	Scientific literature	Impact provided in monetary terms	◑	◔
	Cost	Air pollution	$	Scientific literature	Impact provided in monetary terms	◑	
	Cost	Water pollution	$	Scientific literature	Impact provided in monetary terms	◑	
	Cost	Eutrophication	$	Scientific literature	Impact provided in monetary terms	◑	
	Cost	Acidification	Kg SO2-eq	Lack of data1	—	○	
	Cost	Land use	MSA ha*yr	Renowned publications	Leading organization in monetization, factors based on scientific literature	◕	
	Cost	Land transformation	ha/km^2	Lack of data1	—	○	
	Cost	Biodiversity loss	$/ha	Lack of data1	—	○	
LIVELIHOODS[1]	Cost	Labor (free, forced, child)	FTE	Combination of governmental statistics and NGO publications	Leading organization in monetization, factors based on scientific literature	◔	◔
	Cost	Underpayment	$/$	Governmental statistics	Leading organization in monetization, factors based on scientific literature	◑	
	Cost	Lack of benefits (e.g., healthcare)	$	Combination of governmental statistics and NGO publications	Impact provided in monetary terms	◑	
	Cost	Occupational health and safety issues	$	Renown publication	Impact provided in monetary terms	◑	
	Cost	Land access/farm ownership	n/a		—	○	
	Benefit	Rural employment	$		—	○	

TABLE 3

○ Not assessed ◔ Low ◑ Medium ◕ High ● Very high

				Data Quality		Completeness	
Impact area	**Cost/benefit**	**Metric**	**Unit**	**Impact**	**Monetization**		
ENVIRONMENT (ABIOTIC)	Cost	GHG emissions	kg CO_2-eq	Governmental statistics	Leading organization in monetization, factors based on scientific literature	◕	◑
	Cost	Scarce water use	km^3	Governmental statistics	Leading organization in monetization, factors based on scientific literature	◑	
	Cost	Soil erosion	t/ha	Governmental statistics	Leading organization in monetization, factors based on scientific literature	◑	
	Cost	Soil health	n/a	Lack of data[1]		○	
BIODIVERSITY	Cost	Soil pollution	$	Scientific literature	Impact provided in monetary terms	◑	◔
	Cost	Air pollution	$	Scientific literature	Impact provided in monetary terms	◑	
	Cost	Water pollution	$	Scientific literature	Impact provided in monetary terms	◑	
	Cost	Eutrophication	$	Scientific literature	Impact provided in monetary terms	◑	
	Cost	Acidification	Kg SO2-eq	Lack of data1	—	○	
	Cost	Land use	MSA ha*yr	Renowned publications	Leading organization in monetization, factors based on scientific literature	◕	
	Cost	Land transformation	ha/km^2	Lack of data1	—	○	
	Cost	Biodiversity loss	$/ha	Lack of data1	—	○	
LIVELIHOODS[1]	Cost	Labor (free, forced, child)	FTE	Combination of governmental statistics and NGO publications	Leading organization in monetization, factors based on scientific literature	◔	◔
	Cost	Underpayment	$/$	Governmental statistics	Leading organization in monetization, factors based on scientific literature	◑	
	Cost	Lack of benefits (e.g., healthcare)	$	Combination of governmental statistics and NGO publications	Impact provided in monetary terms	◑	
	Cost	Occupational health and safety issues	$	Renown publication	Impact provided in monetary terms	◑	
	Cost	Land access/farm ownership	n/a		—	○	
	Benefit	Rural employment	$		—	○	

TABLE 3

○ Not assessed ◔ Low ◑ Medium ◕ High ● Very high

				Data Quality		Completeness	
Impact area	Cost/benefit	Metric	Unit	Impact	Monetization	Metric	Impact area
ECONOMY	Cost	Welfare and social service taxes	$	Lack of data[1]	—	○	◑
	Cost	Agricultural subsidies	$	Governmental statistics	Impact provided in monetary terms	●	
	Benefit	Contribution to cross-industry innovation	n/a	Lack of data[1]	—	○	
ANIMAL WELFARE	Cost	Animal well-being	n/a	Lack of data[1]	—	○	○
HUMAN HEALTH	Cost	Health impacts of pollution (e.g., air, water)	DALY, $	Combination of highly renowned statistics and publications	Widely used approach	●	◕
	Cost	Non-communicable diseases (e.g. CVD, hypertension, cancer, diabetes)	DALY	Internationally highly renowned statistics	Widely used approach	●	
	Cost	Overweight and obesity	DALY	Internationally highly renowned statistics	Widely used approach	●	
	Cost	Food insecurity	$	Renown publication	Impact provided in monetary terms	●	
	Cost	Food poisoning	DALY	Lack of data[1]	—	○	
	Cost	Anti-microbial resistance	DALY	Lack of data[1]	—	○	
	Cost	Nutrition impact on mental health	DALY	Lack of data[1]	—	○	

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[1] Data estimates for the unit, impact, or scientifically agreed-upon monetization factor are incomplete or unavailable

4. **The quantification is conservative:** Metrics were included only if impact size and monetization factors were widely cited; any metrics understudied or underreported were not included in cost estimated. For those with widely cited impact and monetization, the most conservative estimate of a well-cited options was used.[2]

- Estimates are conservative because of the limited numbers of metrics included (e.g., metrics not included add $0 to TCOF). Metrics excluded for data quality reasons almost certainly would increase cost estimates had they been included.
- Estimates are conservative within included metrics (i.e. when different papers have varying estimates, the highest quality data that was conservative was used). As such, the quantification represents a conservative estimate to the TCOF in the US.

5. **The estimations captured parts of the value chain (Table 4):** Costs are captured for production, processing, consumption and retail (food services are not included in the cost estimates).

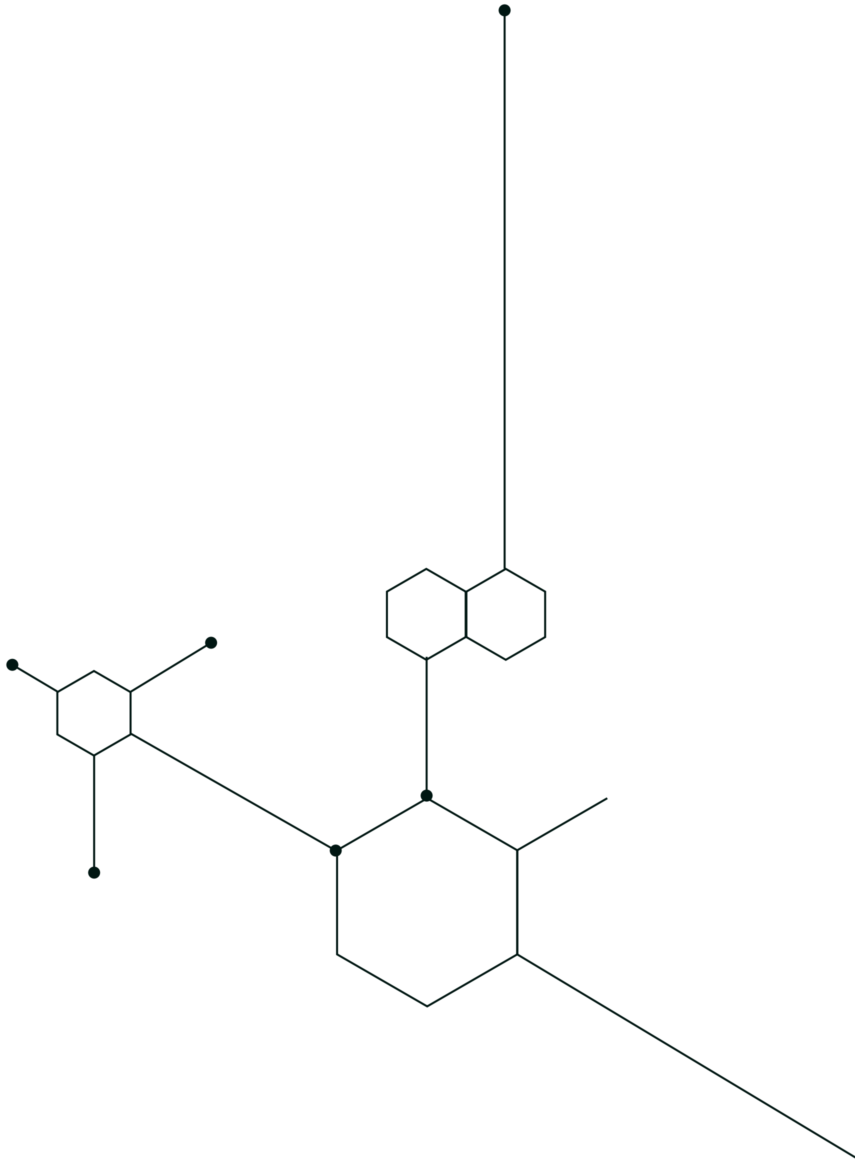


TABLE 4

	Production →	Processing →	Retail →	Food service →	Consumption →	Waste
FOOD VALUE CHAIN	Clear impact attribution possible *High data availability*	Impact attribution partially possible *Limited data availability*	Impact attribution partially possible *Limited data availability*	Impact attribution increasingly challenging *Limited data availability*	Impact attribution partially possible *Relatively high data availability*	Impact attribution partially possible *Limited data availability*
IMPACTS COVERED	**Environment** GHG emissions, water use, soil erosion	**Environment** GHG emissions	**Environment** GHG emissions		**Human health** Overweight and obesity, NCDs, food insecurity	**Environment** GHG emissions from landfills
	Biodiversity Land Use	**Livelihoods** Underpayment, child labor, occupational hazards, lack of benefits	**Livelihoods** Underpayment, child labor, occupational hazards, lack of benefits			
	Livelihoods Underpayment, child labor, occupational hazards, uninsured costs					
	Economy Subsidies					
	Human health Chronic respiratory disease	Focus on early value chain steps due to clear impact attribution and high data availability Resulting true cost of US food system therefore represent an underestimation of actual true costs				

6. **The type of costs captured varied (Tables 5 and 6):** Impact areas capture costs differentially based on characteristic of the metric itself and the way monetization is measured (e.g., retribution costs, compensation cost, etc.).

TABLE 5

Component	Description	
RESTORATION COST	Cost of bringing people's health, wealth etc. or environmental stocks to the state they would have been in the absence of the damage)	
COMPENSATION COST	Cost of compensating affected people for economic and/or non-economic damage caused by the impacts of producing or consuming a product)	Case by case combination of 4 component types (1-4) as basis for definition of **remediation costs for each impact**
PREVENTION OF RE-OCCURRENCE COST	Cost that would be incurred in the future to avoid, avert or prevent the identified impact of producing or consuming a product)	
RETRIBUTION COST	Cost associated with fines, sanctions or penalties imposed by governments for certain violations of legal or widely accepted obligations)	
TRUE PRICING PRINCIPLES	"Where business enterprises identify that they have caused or contributed to adverse impacts, they should provide for or cooperate in their remediation through legitimate processes. Remedy may include apologies, restitution, rehabilitation, financial or non-financial compensation and punitive sanctions (whether criminal or administrative, such as fines), as well as the prevention of harm through, for example, injunctions or guarantees of non-repetition." (UN Guiding Principles on Business and Human Rights, Article 22 and commentary to Article 25)	

TABLE 6

		Components				
Impact area	Metric	Restoration	Compensation	Prevention of re-occurrence	Retribution	Description
ENVIRONMENT (ABIOTIC)	GHG emissions	X				Abatement cost for achieving 2-degree policy targets
	Water use / water depletion	X				Annualized cost of desalination
	Soil erosion		X			Combination of on- and of-site costs of soil erosion
BIO-DIVERSITY	Land use		X			Opportunity cost of land occupation
	Soil, air, water pollution	No monetization necessary (provided in monetary terms)				
LIVELIHOODS	Labor (free, forced, child)	X	X	X	X	Combination of all four cost types
	Underpayment		X	X	X	Combination of three major cost types
	Lack of benefits	X	X			Cost to avert underpayment of food system workers
	Occupational health/ safety	No monetization necessary (provided in monetary terms)				
ECONOMY	Agricultural subsidies	No monetization necessary (provided in monetary terms)				
HUMAN HEALTH	Health impacts from pollution (e.g., air, water)	X	X			Direct medical cost and value of a DALY
	NCDs	X	X			Direct medical cost and value of a DALY
	Obesity / overweight	X	X			Direct medical cost and value of a DALY
	Food insecurity	No monetization necessary (provided in monetary terms)				

Decision makers and cost bearers were identified for key metrics in the framework

Decision makers generally do not bear the costs related to their decisions. The following table represents a high-level summary, with individual metrics having varied decision-makers and cost bearers. Combining these marginal costs accrued to different stakeholders (e.g., some to individuals, some to society) represents a limitation of this report.

TABLE 7

Impact area	Metric	Externality type[1]	Cost type[2]	Currently paid?	Main cost bearer
ENVIRONMENT (ABIOTIC)	GHG emissions	Real	Future cost	No	Future generations, tax payers
	Water use / water depletion	Pecuniary	Future cost	No	Future generations, tax payers
	Soil erosion	Real	Direct cost	Yes (partially)	Producers, tax payers
BIO-DIVERSITY	Land use	Real	X		
	Soil, air, water pollution	No monetization necessary (provided in monetary terms)			
LIVELIHOODS	Labor (free, forced, child)	Real	Indirect cost	No	Affected workers, tax payers
	Underpayment	Real	Indirect cost	No	Affected workers, tax payers
	Lack of benefits	Real	Indirect cost	No	Affected workers, tax payers
	Occupational health and safety issues	Real	Indirect cost	Yes (partially)	Affected workers, tax payers

TABLE 8

		Externality type		Cost type	
EXTERNALITY	What type of externality does the metric represent	**REAL**	Direct externality effect on a third party (e.g. pollution harming the environment)	**DIRECT COST**	Current monetary expenditure
COST TYPE	What type of cost does the metric cause?	**PECUNIARY**	Indirect externality effect on a third party (e.g. influence of market price)	**INDIRECT COST**	Cost not connected to concrete monetary expenditure (social cost/foregone benefit)
PAYMENT COST BEARER	Is the cost currently paid for?[1] Wo bears the cost caused by the metric?			**FUTURE COST**	Future monetary expenditure

[1] Some metrics (e.g., health costs monetized through DALYs) incorporate future impacts into current estimates, with costs standardized to a single year's benchmark

TABLE 9

⚙ Decision-maker $ Cost bearer

Impact Area	Key Metric	Unit	Producers	Workers	Consumers	Government (Regulators)	Tax Payers	Business Owners	Insurance	Health Systems	Underserved Populations	Future Genera-Tions
ENVIRONMENT	GHG emissions	kg CO2-eq	⚙			⚙	$	⚙	$		$	$
	Water use/water depletion	km3	⚙ $			⚙	$	⚙	$		$	$
	Soil erosion	t/ha/yr	⚙ $			⚙	$	⚙	$		$	$
BIODIVERSITY	Land use	MSA ha*yr	⚙			⚙	$	⚙			$	$
	Soil, air, water pollution	$	⚙	$		⚙	$	⚙			$	$
LIVELIHOODS	Labor (free, forced, child)	FTE	⚙	$		⚙	$	⚙			$	
	Underpayment	$/$	⚙	$		⚙	$	⚙			$	
	Lack of benefits	$	⚙	$		⚙	$	⚙			$	
	Occupational health / safety	$	⚙ $			⚙	$	⚙ $		$	$	
ECONOMY	Agricultural subsidies	$	⚙			⚙	$	⚙			$	$
HUMAN HEALTH	Health impacts of pollution (e.g., air, water)	DALY, $	⚙		⚙ $	⚙	$	⚙		$	$	
	Other non-communicable diseases (e.g. CVD, hyper-tension, cancer, diabetes)	DALY	⚙		⚙ $	⚙	$	⚙		$	$	
	Overweight and obesity	DALY	⚙		⚙ $	⚙	$	⚙		$	$	
	Food insecurity	DALY	⚙			⚙	$	⚙			$	

7. **The estimations were restricted to the US:** Impact areas capture costs for food produced (includes food exports at production level) and consumed in the United States (includes food imports at consumption level).

In adhering to these 7 principles, the work in this report also highlights multiple areas where deeper study is required to understand and quantify costs. Accordingly, the true cost of food is expected to increase with increasing development and completeness of the methodology.

TABLE 10

Agricultural trade in the US (bn USD, 2018) → True cost difference

For the true cost quantification within this work, true costs of imported food **are assumed to be comparable to exports** Actual true costs of imported products are likely **significantly different from exports**

Main products: coffee, cocoa, fresh and processed vegetables, grains and feed	Main products: soybeans, beef, veal, pork, poultry and fresh and processed fruits and vegetables

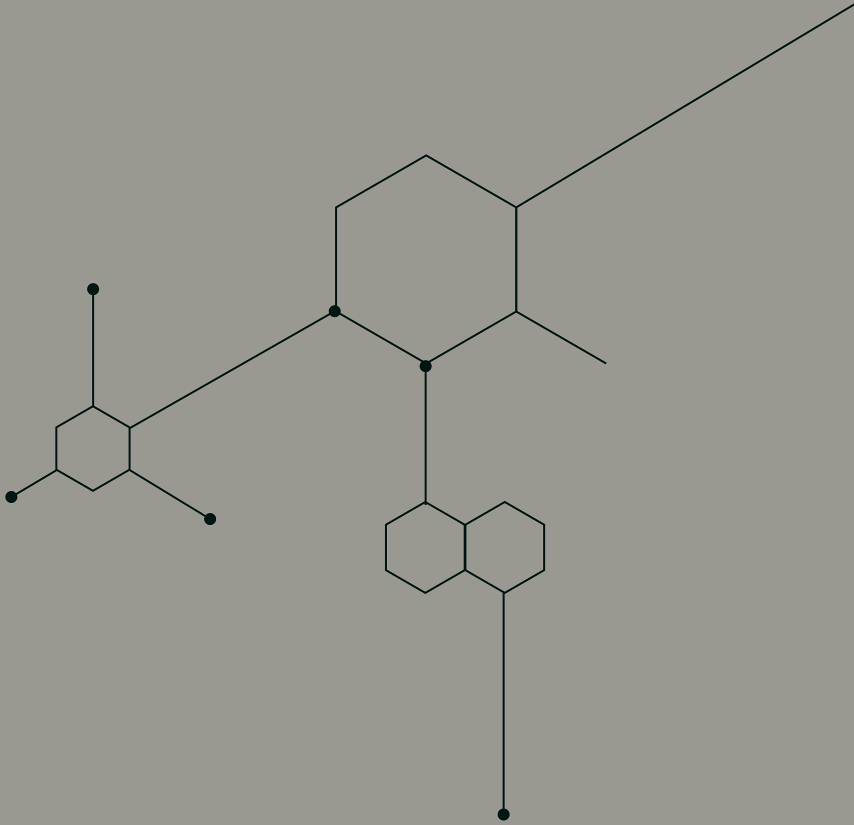
Impact area	Imported products likely change[1]	Example	Exported products likely change[1]	Example
ENVIRONMENT (ABIOTIC)	Likely higher true cost	Avocado from Mexico (water use)	Costs captured	n/a
BIODIVERSITY	Likely higher true cost	Soy from Brazil (land transformation)	Costs captured	n/a
LIVELIHOODS	Likely higher true cost	Cocoa from the Ivory Coast (underpayment)	Costs captured	n/a
ECONOMY	Dependent on local economic structure	Mexican economy highly depends on food exports to US	Costs captured	n/a
ANIMAL WELFARE	Dependent on local regulations	Lack of governmental accountability for animal welfare in Australia[2]	Costs captured	n/a
HUMAN HEALTH	Likely higher production-related health costs (dependent on local regulations)	Agricultural emissions in Europe, Russia and East Asia contribute significantly to premature mortality	Likely higher consumption-related health costs (dependent on local diets)	Corn from Iowa contributes to food security in developing countries
EQUITY	Dependent on local context / inequities	Indigenous communities in Brazil disproportionality affected by land transformation	Dependent on local context / inequities	Displacing local farming practices / markets through subsidized US crops

[1] Current hypothesis based on expert interviews and literature review

[2] Beef import to USA primarily sourced from Australia

[3] Consumption-related human health costs of imported food and production-related human health costs of exported food covered in quantification approach

2 Methodology



The five following steps explain how the priority metrics in the TCOF framework proposed in this report were derived. To apply the proposed framework to a different context, these steps do not need to be repeated. It is, however, important to mention that the framework is expected to further develop with increasing scientific knowledge and data availability / accessibility on food system impacts.

1. Framing of different types of capital crucial to food systems (according to TEEBAgriFood, 2018): natural, human, social, and produced capital.
2. Definition of food system impact areas that are affected by changes in these types of capital (based on Perotti, 2020, addition of equity as a 7th impact area): environment, biodiversity, livelihoods, economy, human health, animal welfare and equity.
3. Collection of >100 metrics from existing approaches to assessing the true cost of food and system level quantifications (TEEBAgriFood, 2018; Food and Land Use Coalition, 2019; World Business Council for Sustainable Development, 2018; Food Tank, 2015; True Price, 2020; Sustainable Food Trust, 2019; Prince's Charities, 2011; Capitals Coalition, 2020; World Wide Fund for Nature, 2020; Perotti, 2020).
4. Grouping of identified food system costs and benefits into ~30 key impacts according to frequency mentioned across existing approaches to assessing the true cost of food and system level quantifications into a long list tested with multiple experts.
5. Identification of priority metrics based on size of primary impact (independent of other areas), ease of quantification, feasibility of intervention to modify impact, likely future impact and expert feedback.
6. Identify impact units for the priority metrics.

TABLE 11

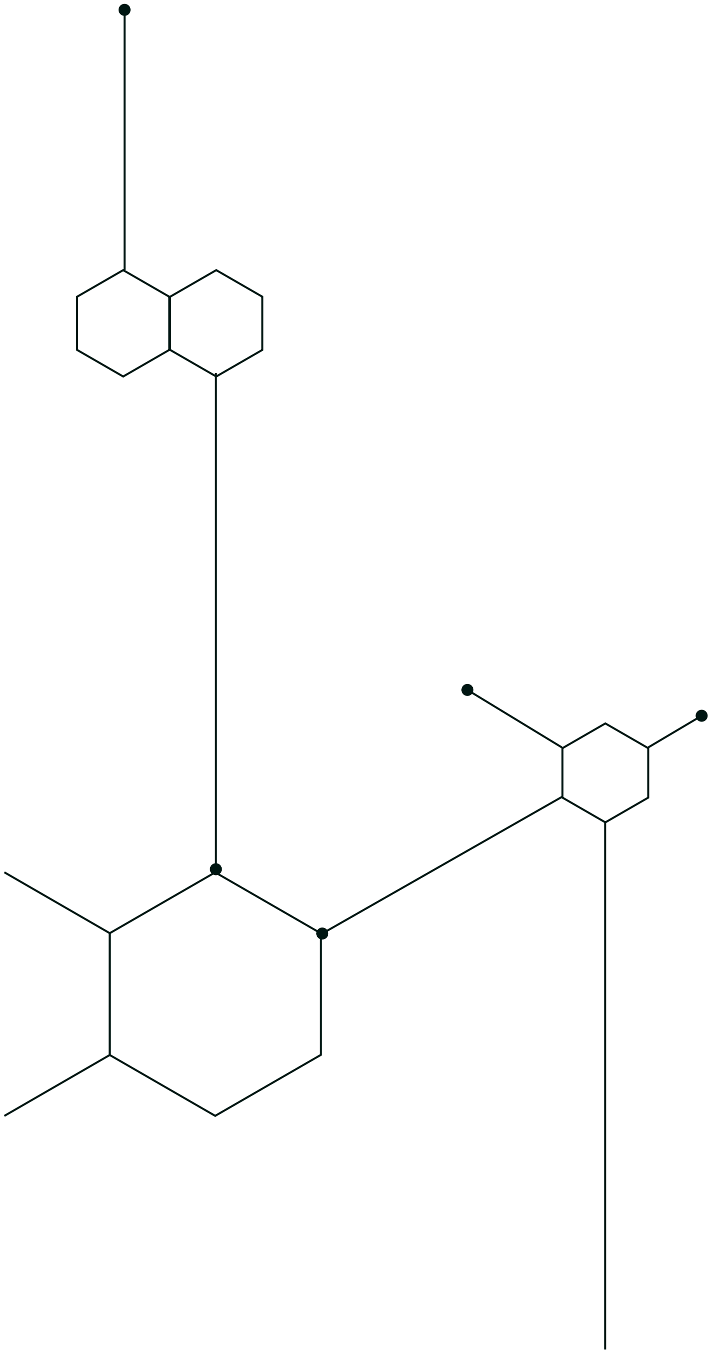
Impact area	Type	Metric
ENVIRONMENT	Cost	GHG emissions
	Cost	Scarce water use
	Cost	Soil erosion
	Cost	Soil health
BIODIVERSITY	Cost	Soil pollution
	Cost	Air pollution
	Cost	Water pollution
	Cost	Eutrophication
	Cost	Acidification
	Cost	Land use
	Cost	Land transformation
LIVELIHOODS	Cost	Labor (free, forced, child)
	Cost	Underpayment
	Cost	Lack of benefits (e.g. healthcare)
	Cost	Occupational health and safety issues
	Cost	Land access/farm ownership
	Benefit1	Rural employment
ECONOMY	Cost	Welfare and social service taxes
	Cost	Agricultural subsidies
	Benefit1	Contribution to cross-sectoral innovation
ANIMAL WELFARE	Cost	Animal well-being
HUMAN HEALTH	Cost	Health impacts of pollution (e.g., air, water)
	Cost	Non-communicable diseases (e.g. CVD, hypertension, cancer, diabetes)
	Cost	Overweight and obesity
	Cost	Food insecurity
	Cost	Food poisoning
	Cost	Anti-microbial resistance
	Cost	Nutrition impact on mental health

TABLE 12

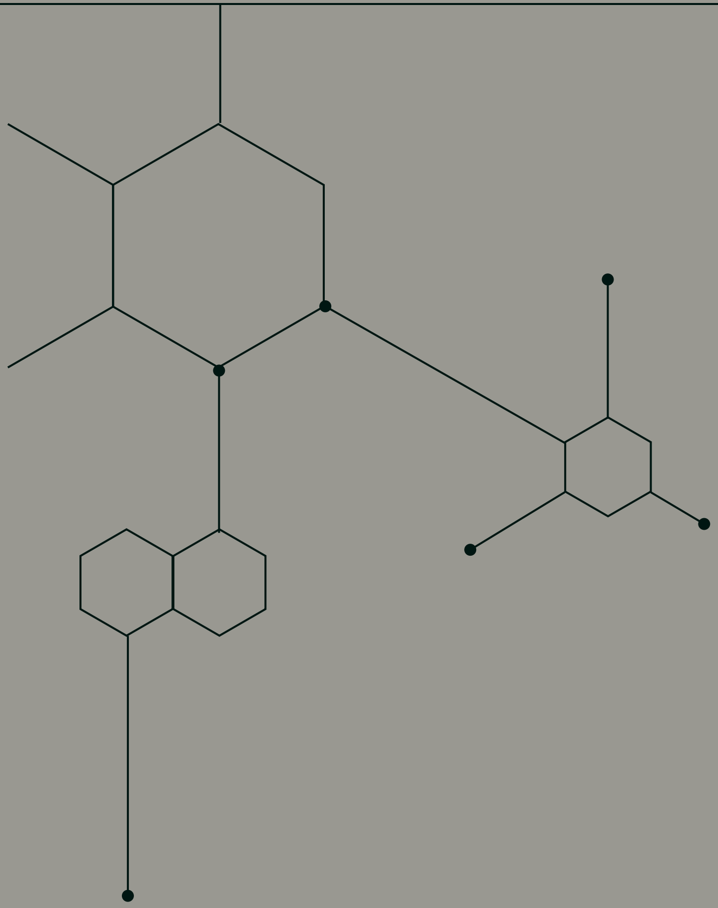
Impact area	Type	Metric	Ease of quantification[1]	Feasibility of intervention to modify impact	Size of impact (by food system – hypothesis)	Likely future impact
ENVIRONMENT	Cost	GHG emissions	🟦	🟦	🟦	🟦
	Cost	Scarce water use	🟦	🟦	🟦	🟦
	Cost	Soil erosion	🟥	🟥	🟥	🟦
	Cost	Soil health	🟥	🟥	🟥	🟦
BIODIVERSITY	Cost	Soil pollution	🟥	🟥	🟥	🟥
	Cost	Air pollution3	🟥	🟥	🟥	🟥
	Cost	Water pollution	🟥	🟥	🟥	🟥
	Cost	Eutrophication	🟥	🟩	🟥	🟥
	Cost	Acidification	🟥	🟩	🟥	🟦
	Cost	Land use	🟥	🟩	🟦	🟦
	Cost	Land transformation	🟥	🟩	🟦	🟦
LIVELIHOODS	Cost	Labor (free, forced, child)	🟧	🟦	🟥	🟥
	Cost	Underpayment	🟥	🟦	🟦	🟦
	Cost	Lack of benefits (e.g., healthcare)	🟥	🟥	🟥	🟦
	Cost	Occupational health and safety issues	🟥	🟥	🟥	🟥
	Cost	Land access/farm ownership	🟩	🟥	🟥	🟥
	Benefit	Rural employment	🟩	🟩	🟩	🟩
ECONOMY	Cost	Welfare and social service taxes	🟥	🟥	🟥	🟥
	Cost	Agricultural subsidies[5]	🟦	🟦	🟦	🟦
	Benefit	Contribution to cross-industry innovation	🟩	🟩	🟩	🟩
ANIMAL WELFARE	Cost	Animal well-being	🟥	🟧	🟩	🟩
HUMAN HEALTH	Cost	Health impacts of pollution (e.g., air, water)	🟥	🟥	🟦	🟦
	Cost	Non-communicable diseases	🟦	🟦	🟦	🟦
	Cost	(e.g., CVD, hypertension, cancer, diabetes)	🟦	🟦	🟦	🟦
	Cost	Overweight and obesity	🟦	🟦	🟦	🟦
	Cost	Food insecurity	🟥	🟥	🟥	🟦
	Cost	Food poisoning	🟥	🟩	🟧	🟧
	Cost	Anti-microbial resistance	🟥	🟥	🟩	🟦
	Cost	Nutrition impact on mental health	🟧	🟧	🟩	🟥

TABLE 13

Impact area	Metric	Unit
ENVIRONMENT	GHG emissions	kg CO_2-eq
	Water use/water depletion	km^3
	Soil erosion	t/ha/yr
BIODIVERSITY	Land use	MSA ha*yr
	Soil, air, water pollution	$
LIVELIHOODS	Labor (free, forced, child)	FTE
	Underpayment	$/$
	Lack of social security/healthcare benefits	$
	Occupational health and safety issues	$
ECONOMY	Agricultural subsidies	$
HUMAN HEALTH	Health impacts from pollution (e.g., air, water)	DALY
	NCDs	DALY
	Obesity/overweight	DALY
	Food insecurity	DALY



3 Quantification



Having defined the key metrics and underlying principles to assess the true cost of food, the following steps were taken for each of the metrics individually. These are suggested to be followed in applying the framework to a different context.

A three-step approach was used to assess the costs associated with quantifiable metrics

● Highly dependent of data availability

ILLUSTRATED BY USING A METRIC THAT MEASURES THE ENVIRONMENTAL COST

	STEP 0 Select metric within impact area	**STEP 1** Identify share of metric attributable to the assessed system	**STEP 2** Identify monetization factor corresponding to the metric	**STEP 3** Multiply share of metric attributable to the assessed system by the monetization factor
EXAMPLE	Impact area environment Greenhouse gas emissions ($t\ CO_2$-eq)	GHG emissions along food supply chain provided directly from multiplesources[1]: ~ 1300 mn t CO_2-eq	True Price: ~ 170 USD/t CO_2-eq	~220+ bn USD
GUIDING PRINCIPLES	Use metrics that have been used / defined in reputed scientifuc studies Utilize metrics that capture key system cost or benefits	Utilize conservative estimate, if multiple sources avaliable. Set clear boundaries for assessed system, e.g., pre-consumption and landfill emissions for GHG emissions (does not include food serices) If required, use attribution factors from literacture review or government source	Use existing, well-established monetization factors Use U.S.-specific monetization factors (where possible)	Showcase range of overall cost or benefit Highlight data gaps ("the known unknonw")

1. **Identify share of metric attributable to the assessed system (in the case of this study: US food system)**

   Potential metric conversion depending on source metric.

2. **Identify monetization factor corresponding to the metric**

   In this quantification, US-specific monetization factors were provided by True Price (as below). For average global monetization factors, see (insert link). Note that a wide range of monetization factors exist, and those provided through the sources above represent one option for monetization estimates.

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[1] Details available in methodology. numbers shown based on 100-year warming potentials

TABLE 14

Metric	Year	Currency	Factor	Unit (Eur)	Conversion	Unit (Usd)
GHG EMISSIONS	2020	EUR	0.15	EUR/kg CO2-eq	0.17	USD/kg CO2-eq
WATER DEPLETION	2020	EUR	1.27	EUR/m3	1.45	USD/m3
SOIL EROSION (WATER)	2020	EUR	0.03	EUR/kg soil loss	0.03	USD/kg soil loss
SOIL EROSION (WIND)	2020	EUR	0.04	EUR/kg soil loss	0.04	USD/kg soil loss
LAND OCCUPATION: TROPICAL FOREST	2020	EUR	2,089.66	EUR/(ha*yr)	2,386.39	USD/(ha*yr)
LAND OCCUPATION: OTHER FOREST	2020	EUR	1,000.02	EUR/(ha*yr)	1,142.02	USD/(ha*yr)
LAND OCCUPATION: WOODLAND/SHRUBLAND	2020	EUR	1,350.52	EUR/(ha*yr)	1,542.29	USD/(ha*yr)
LAND OCCUPATION: GRASSLAND/SAVANNAH	2020	EUR	2,394.01	EUR/(ha*yr)	2,733.96	USD/(ha*yr)
CHILD LABOR 1	2020	EUR	35,572.03	EUR/child FTE	40,623.26	USD/child FTE
CHILD LABOR 2	2020	EUR	17,895.62	EUR/FTE	20,436.80	USD/FTE
UNDERPAYMENT	2020	EUR	1.02	EUR/EUR	1.17	USD/USD

3. Multiply share of metric attributable to the assessed system by the monetization factor

In some cases, sources used to identify the share of metric attributable to the assessed system may provide the monetary cost of the impact. In that case, steps 2-3 are redundant.

For other metrics, the final step of estimating the share of costs preventable for each metric concludes the quantification (see Section 4 for each metric and steps involved in quantification).

Potential reduction with intermediate steps:

In addition to the 3 quantification steps above, each of the 14 key metrics has an example of the potential cost reduction achievable with intermediate steps (e.g., short-to-medium time horizon).

The potential reduction estimates included are based on other scenarios (e.g., GHG emissions averted to comply with the 1.5°C pathway) or countries (e.g., diet-related DALYs averted if the US mirrored the diet-related DALY rates in Canada) selected from literature. Each potential reduction estimate is illustrative using one selected counterfactual example to the current system, as there are likely multiple counterfactual examples for each metric (e.g., GHG emissions also has a 2°C pathway).

4 Metrics

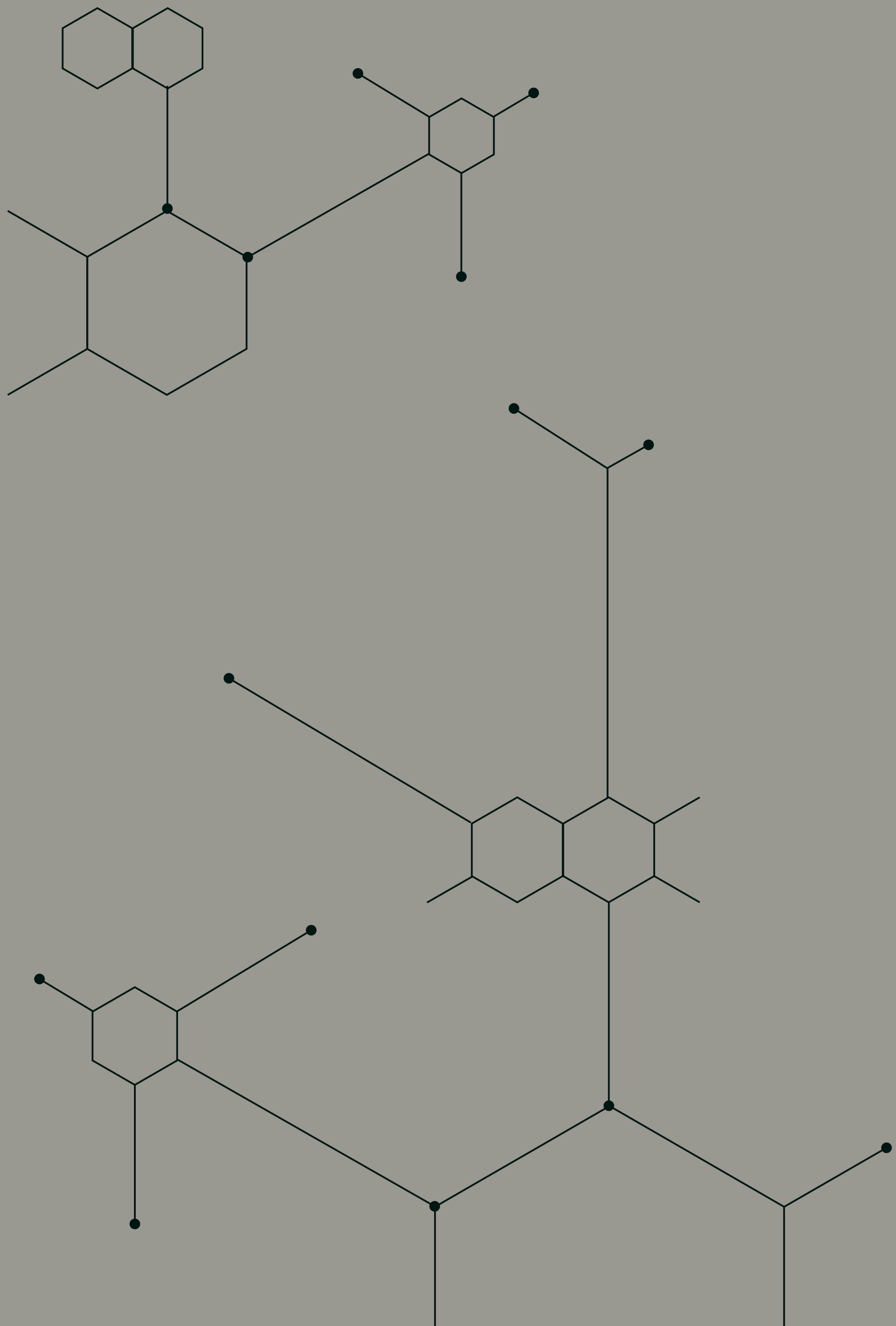


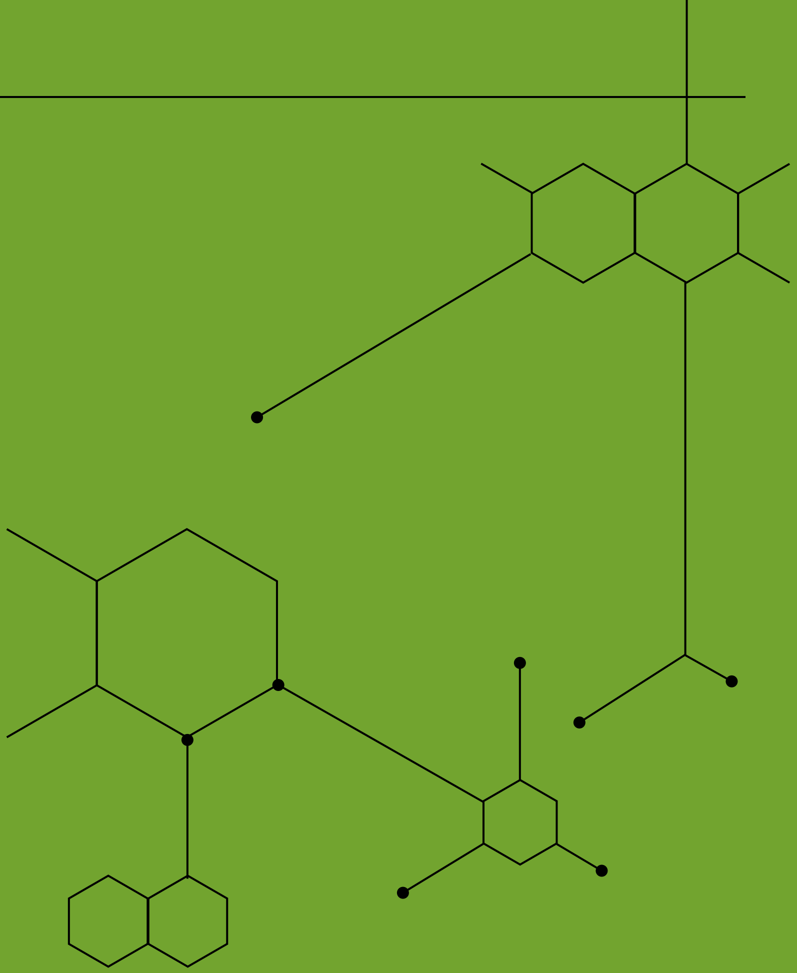
Table 15 gives a high-level overview of the data used to quantify each of the key metrics.

TABLE 15

Impact area	Key metric	Methodology overview	Metric type
ENVIRONMENT (ABIOTIC)	GHG emissions	Multiply GHG emissions related to food production by marginal abatement cost of reducing GHG emissions	System output
	Water use/depletion	Multiply agricultural scarce water use by annualized water desalination cost	System input
	Soil erosion	Multiply total soil erosion with on- and off-site costs of soil erosion (wind and water erosion)	System output
BIODIVERSITY	Land use	Multiply land use related to food production by opportunity cost of land occupation (e.g., counterfactual of land's natural biome)	System input
	Soil, air, water pollution	Directly sourced from Sobota et al. (2015): annual freshwater ecosystem, land system and coastal zone costs of nitrogen pollution	System output
LIVELIHOODS	Labor (free, forced, child)	Number of FTE-equivalents <18 years old multiplied by restoration, compensation, prevention and retribution cost combination for underage workers involved in hazardous work	System input
	Underpayment	List all agricultural, food processing, and food retail workers, compare hourly wage to living wage, and multiply the gap by compensation, prevention and retribution cost combination for underpayment	System input
	Lack of benefits	The cost to extend health insurance, term life insurance, and social security benefits to all food system workers	System input
	Occupational health/ safety	Acute workplace injuries based on national worker estimates adjusted for increased risk of injury among food workers and the cost of medical, productivity, and death loss from chronic pesticide exposure (e.g., from cancer)	System output
ECONOMY	Agricultural subsidies	Directedly sourced from USDA: federal government direct farm program payments	System input
HUMAN HEALTH	Impacts from pollution		System output
	NCDs	Disability-Adjusted Life Years (DALYs) are a standardized way to compare the burden of different diseases. DALYs attributable to the food system (e.g., diet, air pollution from food system) were isolated and monetized using GDP per capita excluding healthcare costs to estimate the loss of productivity. Direct medical costs for these conditions attributable to the food system were then added for the total	System output
	Obesity/overweight		System output
	Food insecurity	Directly sourced from 'The Cost of Hunger' Report, who synthesized peer-reviewed research on the impact that food insecurity has on human health and the higher healthcare costs associated	System output

The following sections describe each of the steps taken to quantify the impact areas and key metrics categorized in them.

5 Environment impact area summary



The environment impact area quantifies the impact of food production in the US on the environment, captured by metrics as such greenhouse gas emission (GHG emissions), water use / depletion, and soil erosion attributable to food system, summarized below.

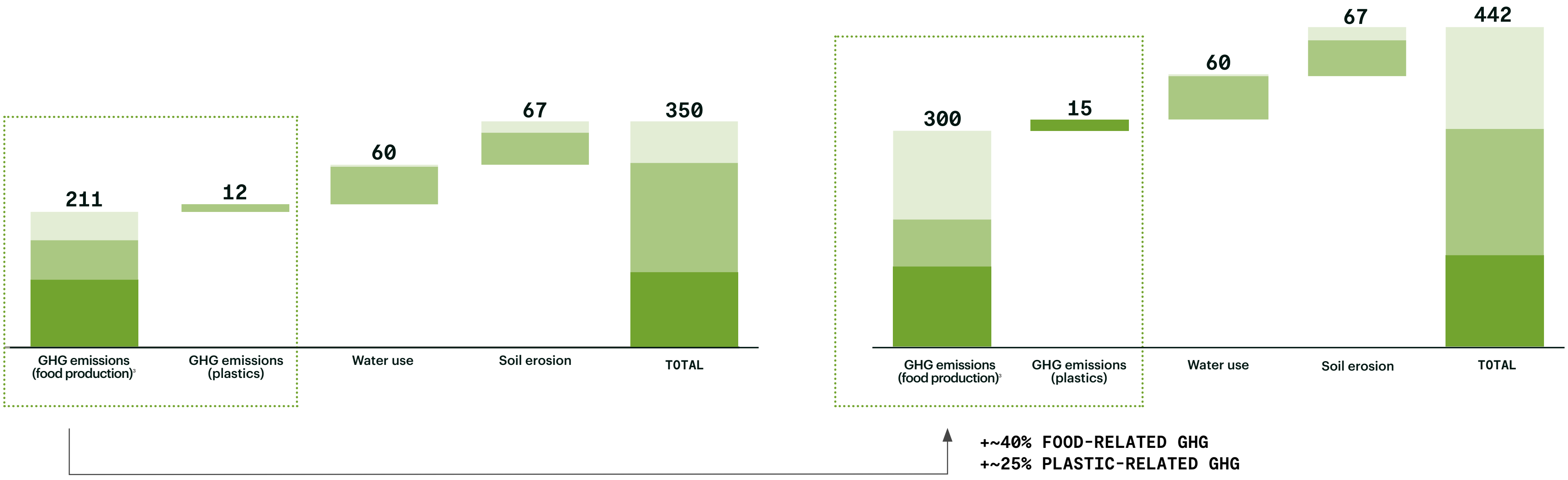
Environmental costs
impact area deep dive

not exhaustive

● Livestock ● Crop cultivation ● Other

ESTIMATED ENVIRONMENTAL FOOD SYSTEM COST (bn USD)
Minimum estimate with GHG based on IPCC AR4 GWP100[1]

Maximum estimated with GHG based on IPCC AR4 GWP202
Maximum estimated with GHG based on IPCC AR4 GWP202



+~40% FOOD-RELATED GHG
+~25% PLASTIC-RELATED GHG

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1 100-year global warming potential according to the 4th IPCC report 1 (CO2) 25 (CH4) 298 (N20)
2 20-year global warming potential according to the 4th IPCC report 1 (CO2) 74 (CH4) 289 (N20)
3 Livestock: enteric fermentation, manure management. Crop cultivation: urea fertilization, liming, rice cultivation, field burning of agriculture residues, agriculture soil managing. Other: production of nitrogen fertilizer, production of phosphoric acid, land use and land-use change, fuel combustion, electricity use, food processing, food transport, food packaging, retail and food-attributable landfill emissions
4 Production, conversion and landfill emissions associated with U.S. plastics use (limited data avaliability on plastics pollution)
Source: U.S. Greenhouse Gas Inventory, Poorse & Nemecek (2018), McKinsey, Zheng & Suh (2019), EPA, USGS, FAOSTAT, FOLU, True Price, National Resources Inventory, WWF

5.1 GHG emissions

1. **Identify share of metric attributable to the US food system:** Greenhouse gas emissions along the food value chain were sourced according to Table 16 below.

TABLE 16

Category	100y gwp, mn t CO_2-eq	20y gwp, mn t CO_2-eq	Source
PRODUCTION OF NITROGEN FERTILIZER	69.8	69.8	FAOSTAT, 2021, FOLU, 2019
PRODUCTION OF PHOSPHORIC ACID	0.9	0.9	US GHG Inventory, 2020
CROP CULTIVATION	360.0	375.6	US GHG Inventory, 2020
LIVESTOCK	258.6	707.8	US GHG Inventory, 2020
LAND USE AND LAND-USE CHANGE	25.3	25.3	US GHG Inventory, 2020
FUEL COMBUSTION	40.1	40.1	US GHG Inventory, 2020
ELECTRICITY USE	39.7	39.7	US GHG Inventory, 2020
FOOD PROCESSING	88.5	88.5	Crippa et al., 2021
PACKAGING	58.3	58.3	Crippa et al., 2021
TRANSPORT	211.5	211.5	Crippa et al., 2021
RETAIL	96.4	96.4	Crippa et al., 2021
LANDFILL (FOOD)	26.5	76.4	US GHG Inventory, 2020, EPA
LANDFILL (PACKAGING)	8.8	25.5	US GHG Inventory, 2020, EPA, McKinsey
TOTAL	**1284.5**	**1815.8**	

Wherever detailed emissions of individual greenhouse methane (CH4) and nitrous oxide (N20) were available, the gases were converted to CO2e according to both the 100- and 20-year Global Warming Potential of the 4th IPCC Assessment Report (AR4) (Table 17). This is reflected in the range given for GHG impacts. The 5th IPCC Assessment Report (AR5) represents an updated version, however because the US GHG inventory report cited above uses AR4 estimates, AR4 was used for consistency. Should AR5 estimates be used instead, the GHG emissions metric estimate would increase by ~ 6%.

TABLE 17

Gas	100-Year gwp	20-Year gwp
CO_2	1	1
CH_4	25	72
N_2O	298	289

Production of nitrogen fertilizer

In 2018, 11,264,596 tonnes of nitrogen fertilizer were produced in the USA (FAOSTAT, 2021). According to the Food and Land Use Coalition (2019), the production of one ton of nitrogen fertilizer emits 6.2 tons of CO_2-eq.

Production of phosphoric acid

Emissions connected to the production of phosphoric acid were directly sourced from the Environmental Protection Agency (EPA) US Greenhouse Gas Inventory (2020). It is assumed that all phosphoric acid produced in the US is used as fertilizer. Although this is likely an overestimation, it is defined as acceptable due to the small size of the number.

Crop cultivation

Emissions connected to crop cultivation were directly sourced from the Environmental Protection Agency (EPA) US Greenhouse Gas Inventory (2020). Table 18 below details the specific sources assessed by the Agency.

TABLE 18

Gas	Source	100y gwp, mn t CO_2-eq	20y gwp, mn t CO_2-eq
CO_2	Urea fertilization	4.6	4.6
CO_2	Liming	3.1	3.1
CH_4	Rice cultivation	13.3	38.4
CH_4	Field burning of agricultural residues	0.4	1.2
N_2O	Agricultural soil management	338.2	328.0
N_2O	Field burning of agricultural residues	0.3	0.3

Livestock

Emissions connected to livestock were directly sourced from the Environmental Protection Agency (EPA) US Greenhouse Gas Inventory (2020). Table 19 below details the specific sources assessed by the Agency.

TABLE 19

Gas	Source	100y gwp, mn t CO_2-eq	20y gwp, mn t CO_2-eq
CH_4	Enteric fermentation	177.6	511.4
CH_4	Manure management	61.7	177.6
N_2O	Manure management	19.4	18.8

Land use and land-use change

Emissions connected to land use and land-use change were directly sourced from the Environmental Protection Agency (EPA) US Greenhouse Gas Inventory (2020). The specific changes in land use listed by the EPA were cropland remaining cropland, land converted to cropland, grassland remaining grassland, and land converted to grassland. These land use and land-use changes only account for the US, and this is therefore an underestimation of costs.

Fuel combustion

Emissions connected to agricultural fuel combustion were directly sourced from the Environmental Protection Agency (EPA) US Greenhouse Gas Inventory (2020).

Electricity use

Emissions connected to agricultural electricity use were directly sourced from the Environmental Protection Agency (EPA) US Greenhouse Gas Inventory (2020).

Post-agricultural emissions

The US Greenhouse Gas Inventory does not provide any information on post-agricultural emissions. Emissions for food packaging, processing, transport, and retail are thus derived separately. The latter three are derived from Crippa et al. (2021), which assesses GHG emissions along the US food supply chain.

TABLE 20

Category	Kt CO_2e	Use	Mn t CO_2e
PRODUCTION	512,125	Not included	Not included
LULUC (PRODUCTION)	158,609	Not included	Not included
CONSUMPTION	48,878	Not included	Not included
END_OF_LIFE	81,190	Not included	Not included
PROCESSING	88,462	100%	88.46
PACKAGING	58,320	100%	58.32
TRANSPORT	211,475	100%	211.48
RETAIL	311,093	31%	96.44

Crippa et al. emissions for food processing, packaging and transport are directly used. Retail emissions in the paper also include emissions related to food service, which are not assessed in this quantification. As such, the estimate was adjusted according to a McKinsey report which estimated that 31% of the retail footprint is related to wholesale/supermarkets.

Landfill

Emissions connected to landfills use were directly sourced from the Environmental Protection Agency (EPA) US Greenhouse Gas Inventory (2020). In 2018, 4,422 kt of CH4 was emitted from landfills. According to EPA (2021), landfills are composed of 24% of food products. Accordingly, 24% of landfill emissions are used for the quantification of food related landfill emissions in this report.

This quantification also includes the landfill GHG footprint of plastics. 18.5% of landfills are filled with plastics (EPA, 2021), of which 43% are estimated to be food related. Accordingly, out the methane emitted from landfills (Table 21), a further 8% are estimated to be food related.

TABLE 21

Landfill emissions	100-Year gwp, mn t co_2-eq	20-Year gwp, mn t co_2-eq
FOOD	26.5	76.4
PACKAGING	8.8	25.5

2. **Identify monetization factor corresponding to metric:** 173$/t CO_2e (True Price, 2020)
3. **Multiply share of metric attributable to US food system by the monetization factors**

Potential reduction with intermediate steps:

Multiple reduction estimates exist for GHG emissions (e.g., based on different counterfactual scenarios). For instance, the FOLU 'Growing Better Report' offers two scenarios based on current trajectory and a 'better' counterfactual, with the potential reduction with intermediate steps estimated through the difference between these two scenarios.

In this report, the potential reduction with intermediate steps is based on the 31% reduction of US agriculture-specific emissions necessary by 2050 to comply with 1.5 °C pathway. The estimate used comes from an upcoming McKinsey report on the US pathway to net zero.

5.2 Water use/depletion

2. **Identify share of metric attributable to the US food system**

TABLE 22

Category	Value	Source
LIVESTOCK	2 Bgal/d = 2.8 km3/year	U.S. Geological Survey, 2015
CROP CULTIVATION	118 Bgal/d = 163.0 km3/year	U.S. Geological Survey, 2015
AQUACULTURE	7.55 Bgal/d = 10.4 km3/year	U.S. Geological Survey, 2015

As a part of water used for aquaculture is saline, water use for aquaculture is not considered for the quantification. According to the Food and Land Use Coalition (2020), 25% of global freshwater withdrawals are either unsustainable or at risk of becoming unsustainable. The US is assumed to mirror global withdrawal patterns, which represents a limitation of this study's methodology. Under this assumption, of water used in US livestock and crop cultivation are thus assumed to deplete water resources.

3. **Identify monetization factor corresponding to metric:** 1.45$/m3 (True Price, 2020)

4. **Multiply share of metric attributable to US food system by the monetization factors:** 60.2 USD bn

Potential reduction with intermediate steps:

Similar to GHG emissions, multiple counterfactual examples exist to estimate the potential reduction in true cost with intermediate steps. One such example is a 25% reduction estimate for the share of water consumption considered unsustainable or at risk of becoming so.

5.3 Soil erosion

1. **Identify share of metric attributable to the US food system**
The annual amount of soil erosion due to wind and water is derived by multiplying the total area of US land used as cropland and pasture with annual soil erosion rates.

TABLE 23

Category	Value, Ha	Source
CROPLAND	124,645,000	WWF, 2020
GRAZING LAND	250,900,000	WWF, 2020

TABLE 24

Categ`ory	Value, t/acre	Source
2017 WIND EROSION (CROPLAND)	1.96	(to add)
2017 WIND EROSION (PASTURE)	0.2	(to add)
2017 WATER EROSION (CROPLAND)	2.67	(to add)
2017 WATER EROSION (PASTURE)	0.61	(to add)

Annual soil erosion rates are first converted to t/ha.

2. **Identify monetization factor corresponding to metric (True Price, 2020)**
   a. From wind erosion: 0.040 USD/kg soil loss
   b. From water erosion: 0.031 USD/kg soil loss

3. **Multiply share of metric attributable to US food system by the monetization factors**

Potential reduction with intermediate steps:

The potential reduction with intermediate steps listed in the report

is assumed to approximate the land use potential reduction estimate subsequently detailed.

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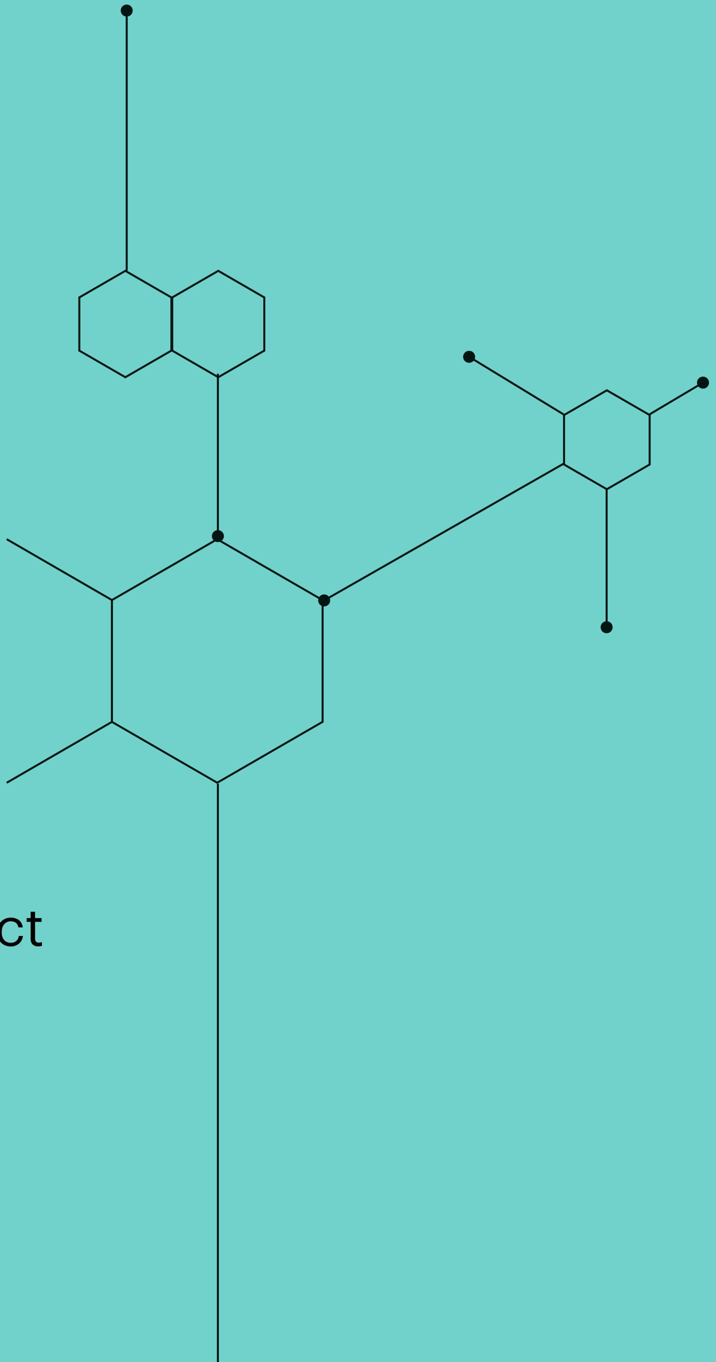
4 Grazing land, grassland pasture and range as well as pasture...

6 Biodiversity impact area summary



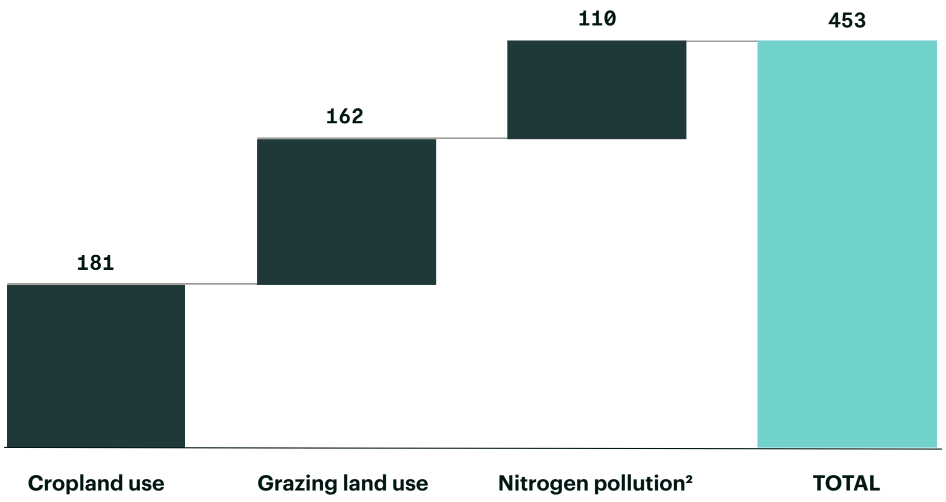
The biodiversity impact area quantifies the impact of food production in the US on biodiversity loss, captured by metrics such as land use and pollution (e.g., soil, air, and water) attributable to food system summarized below.

6.1 Land use

Biodiversity costs
Impact area deep dive

Not exhaustive

TOTAL COST OF BIODIVERSITY FROM THE FOOD SYSTEM, (BN USD)[1]



[1] Cover land occupation and nitrogen pollution only, true costs likely to be hight
[2] Cost of impact on freshwater ecosystems, land systems and coastal zone
Source: WWF, University of Cambridge/Natural Capital Impact Group, True Price, Sobota et al. (2015)

1. Identify share of metric attributable to the US food system

TABLE 25

Category	Value	Source
CROPLAND	124,645,000 ha	WWF, 2020
GRAZING LAND[5]	250,900,000 ha	WWF, 2020

2. Identify monetization factor corresponding to metric

True Price provides monetization factors for land occupation of different types of biomes:

TABLE 26

Biome	Monetization factor	Unit
TROPICAL FOREST	2,386.39	USD/MSA ha yr
OTHER FOREST	1,142.02	USD/MSA ha yr
WOODLAND/SHRUBLAND	1,542.29	USD/MSA ha yr
GRASSLAND/SAVANNAH	2,733.96	USD/MSA ha yr

These monetization factors were combined to a monetization factor specific to the US context, e.g., representing the biome composition of US land. To define this average factor, USDA ERS data on major land uses per state was used to identify the amount of cropland and grassland pasture and range per state. Each US state was then attributed its main biome type, enabling the understanding of the amount of agricultural land occupying the different types of naturally occurring biomes in the US.

TABLE 27

Biome	Cropland (,000 acres)	Grassland pasture and range (,000 acres)	Total agricultural land (,000 acres)	% Of total agricultural land across all biomes
TROPICAL FOREST	2,834	5,100	7,934	1%
OTHER FOREST	202,278	134,901	337,179	32%
WOODLAND/SHRUBLAND	173,622	358,663	532,285	51%
GRASSLAND/SAVANNAH	12,764	155,349	168,113	16%
		SUM	**1,045,511**	

Having defined the share of naturally occurring biomes in the US, each of the four True Price monetization factors in Table 27 were multiplied with the respective shares and added to each other, resulting in a US-specific land use monetization factor of 1611 USD/MSA ha yr.

To apply the monetization factor to total US cropland and pasture use, a final step of identifying the intensity of agricultural land use through cropland and pasture must is undertaken. Intensity of land use is accounted for with the MSA coefficient (MSA: mean species abundance), which reflects the share if species lost with increasing levels of land use intensity). MSA coefficients were based on coefficients by the Natural Capital Impact Group.

MSA coefficients per land use type and use intensity

TABLE 28 **Selected MSA coefficients**

Land use	Intensity	Description	Coefficient
CROPLAND	Minimal	Low-intensity farms, with small fields, mixed crops, crop rotation, little or no inorganic fertilizer use, little or no pesticide use, little or no ploughing, little or no irrigation, little or no mechanization	0.6
	Light	Medium-intensity farming, typically showing some but not many of the following: large fields, annual ploughing, inorganic fertilizer application, pesticide application, irrigation, no crop rotation, mechanization, monoculture crop. Organic farms in developed countries often fall within this category, as may high-intensity farming in developing countries	0.7
	Intense	High-intensity monoculture farming, typically showing many of the following features: large fields, annual ploughing, inorganic fertilizer application, pesticide application, irrigation, mechanization, no crop rotation	0.9
PASTURE	Minimal	Pasture with minimal input of fertilizer and pesticide, and with low stock density (not high enough to cause significant disturbance or to stop regeneration of vegetation)	0.2
	Light	Pasture either with significant input of fertilizer or pesticide, or with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation)	0.4
	Intense	Pasture with significant input of fertilizer or pesticide, and with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation)	0.7

3. Multiply share of metric attributable to US food system by the monetization factors

a. Cost of cropland use: 181 USD bn
b. Cost of pasture use: 162 USD bn

This results in a total cost of land use in the US of 343 USD bn.

Potential reduction with intermediate steps:

One example for reducing the impact of land use is a 35% reduction though reducing agricultural intensity with no change in land use.
The estimate is based on the MSA coefficient change from 0.9 (high intensity) to 0.7 (light intensity) for cropland and from 0.4 (light intensity) to 0.2 (minimal intensity) for pasture. Further details can be found in the biodiversity impact area methodology.

6.2 Soil, air, water pollution

Directly sourced from Sobota et al. (2015): Cost of reactive nitrogen release from human activities to the environment in the United States.

TABLE 29

		Range			
Cost From...	Value	Min	Max	Unit	Included
FRESHWATER ECOSYSTEM IMPACT	78	33	126	USD bn	Yes
AIR/CLIMATE IMPACT	44	2	145	USD bn	No
LAND SYSTEM IMPACT	39	15	65	USD bn	Yes
COASTAL ZONE IMPACT	30	12	53	USD bn	Yes
DRINKING WATER IMPACTS[1]	19	19	52	USD bn	No
TOTAL (ALL IMPACTS)	210	81	441	USD bn	
TOTAL (INCLUDED IMPACTS)	147	60	244	USD bn	

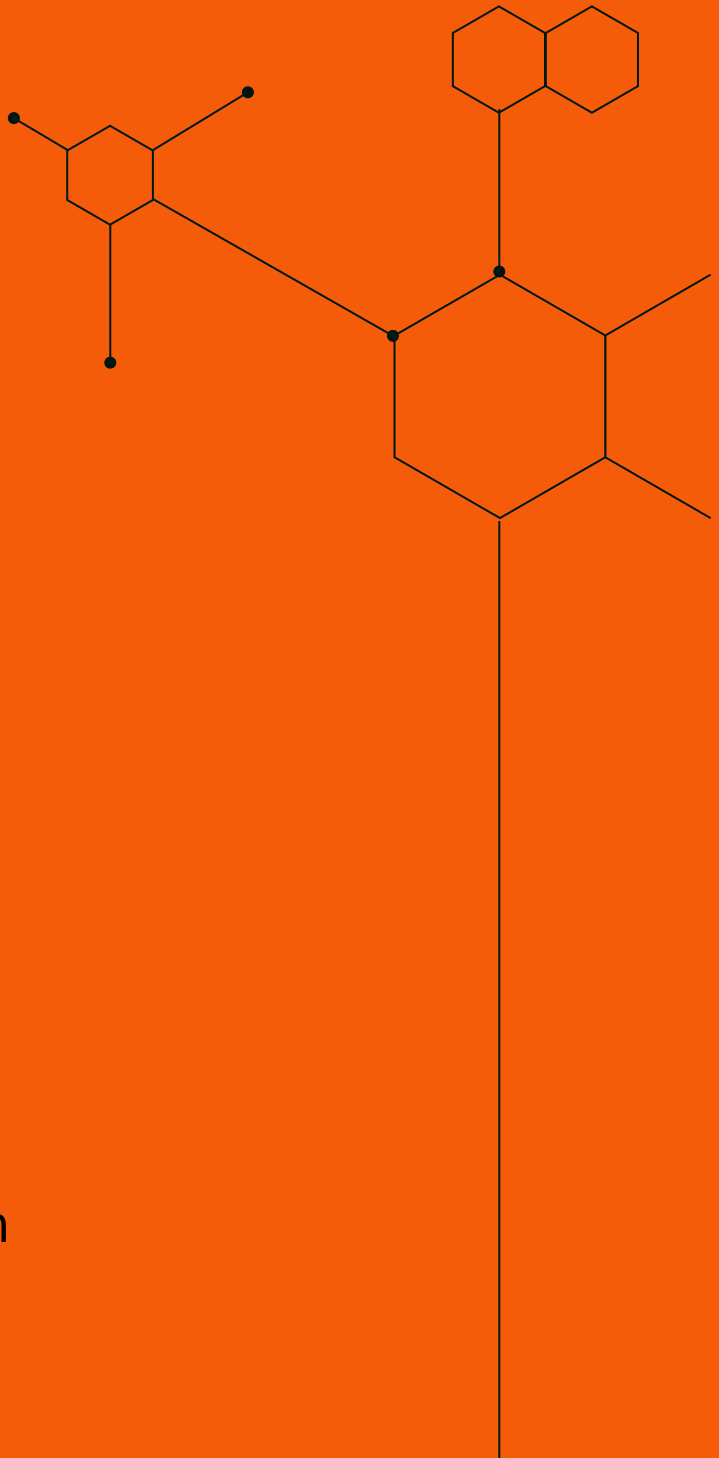
[1] Drinking water impacts from Sobota et al categorized under 'health impacts of pollution' metric

According to Sobota el al, 75% of emissions assessed are attributable to agriculture This results in $147 USD bn of costs related to soil, air and water pollution.

Potential reduction with intermediate steps:

The estimate listed in the report is consistent with the example counterfactual used in GHG emissions.

7 Livelihoods impact area summary



The livelihoods impact area quantifies the impact of no payment or underpayment of labor across the food value chain the US, captured the free, forced, and child labor, underpayment (below living wage of $16.08 per hour detailed in the 'underpayments' section), lack of benefits, and occupational health / safety costs for food system workers summarized below.

It is important to note that when quantifying underpayment, lack of benefits, and occupational health / safety of US food system workers, food service employees (e.g., fast-food workers) were not included. Food service employees represent the largest group of food system employees and their inclusion would substantially increase the 'livelihoods' impact area estimate given their low median hourly wage, lack of benefits, and occupational health / safety hazards.

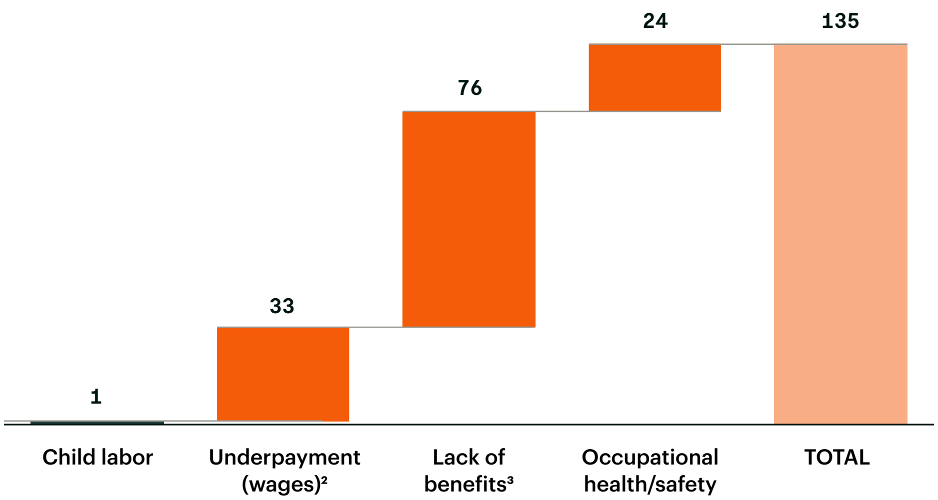
All estimates related to the number of food system workers likely represent underestimations of the actual number. Some types of workers excluded from official estimates (e.g., undocumented, incarcerated) are addressed in some way, though likely still undercounted. Other classes of workers (e.g., gig workers) are not addressed, though costs associated with a lack of benefits, underpayment, and occupational health / safety certainly apply.

Livelihood costs

Impact area deep dive

not exhaustive

TOTAL COST OF LIVELIHOODS FROM THE FOOD SYSTEM, (BN USD)[1]



[1] Estimates noted to be particularly low due to underreporting of exploited labor along the value chain (e.g., incarcerated, undocumented individuals)

[2] Calculated based on living wage in the ALICE Household Survival Budget of $16.08/hour for one adult working in a family of 4, alternatives include MIT living wage calculator ($16.14) and the ALICE Household Stability Budget ($31.53)

[3] Based on the cost to extend health insurance, life insurance, and social security benefits to all food system workers

[4] Based on acute workplace injuries and chronic exposure to pesticides

7.1 Labor (free, forced, child)

1. **Identify share of metric attributable to the US food system**
   Labor exploitation is calculated by estimated impact of child labor in the US. Other forms of labor underpayment and exploitation (e.g., incarcerated labor) are included in section 4.7: Underpayments.

   The metric used to estimate child labor is the number of hired FTE-equivalents under the age of 17 years old who work in US agriculture. Estimates are noted to be particularly low due to underreporting of exploited labor along the value chain.

   First, the Government Accountability Office (GAO) estimates the number of children by age group working in different segments of the agricultural sector. Note that these estimates are limited to hired children.

TABLE 30

Working children	Value
# OF CHILDREN AGED 15-17 WORKING (CROP)	67195
# OF CHILDREN AGED 15-17 WORKING (LIVESTOCK)	58389
# OF CHILDREN AGED 14 AND UNDER WORKING (CROP)	12131
# OF CHILDREN AGED 14 AND UNDER WORKING (LIVESTOCK)	10130
TOTAL 14 AND BELOW	22261
TOTAL 15-17	**125584**

Next, the GAO lists the mean number of working days for hired workers in each of these segments which is then used to calculate the number of FTE equivalents

TABLE 31

Mean working days	Value	Unit	Year
14-YEARS-OLD	65	days	2013-16
15-YEARS-OLD	101	days	2013-16
16-YEARS-OLD	57	days	2013-16
17-YEARS-OLD	74	days	2013-16
AVERAGE 15-17	77	days	2013-16

2. **Identify monetization factor corresponding to metric**
   True Price lists monetization factors for underage workers below different age thresholds summarized below. Their estimates refer to work done by children beyond what is allowed by law, and monetization estimates account for the costs of missed education and lower future earnings if unable to attend school, and in some cases physical and psychological damage from hazardous labor.

TABLE 32

Indicator	Value	Unit
UNDERAGE WORKERS BELOW MINIMUM AGE (12 OR 13) INVOLVED IN HAZARDOUS WORK	$40,623.26	USD/child FTE
WORKERS ABOVE MINIMUM AGE (14 OR 15) AND BELOW 18 INVOLVED IN HAZARDOUS WORK	$20,436.80	USD/child FTE

3. **Multiply share of metric attributable to US food system by the monetization factors**
   The cost of child labor in US agriculture is estimated to be $0.98 bn annually. Again, this represents a very low estimate of true cost given likely underreporting.

TABLE 33

Cost of child labor in us agriculture

14 YEARS AND BELOW	$224,352,811.07	USD
15-17 YEARS	$757,552,402.96	USD
TOTAL	$981,905,214.03	USD
	0.98	**USD bn**

Potential reduction with intermediate steps:

All livelihood metrics related to the exploitation of labor (e.g., free, forced, child) are assumed to be potentially reduced with intermediate steps. In this case, all forms of child labor occurring in the US outside of the law are assumed to be reducible given the important moral and ethical implications.

7.2 Underpayment

1. **Identify share of metric attributable to the US food system**
   Underpayments in this case is defined as the difference between the value of labor from food system employees, defined through a selected definition of living wage, and wages currently being paid for that labor. Underpaid food system workers are those receiving wages below a living wage of $16.08 per hour per adult in a family of 4, according to the ALICE Household Survival Budget. Alternate living wage definitions not used here include the MIT living wage calculator at $16.14 per hour and the ALICE Household Stability Budget at $31.53 per hour. The hourly living wage chosen represents a national average applied to all US workers, despite significant differences in purchasing power across the country.

   To identify which food system workers, excluding food service, are underpaid, Bureau of Labor Statistics (BLS) data was used to list all agricultural, food processing, and food retail position categories with percentiles of wage, with wage in each percentile compared to the $16.08 per hour living wage to determine positional underpayment.

   Undocumented and incarcerated agricultural worker estimates were taken from other sources detailed following Table 36.

TABLE 34 **Documented Agricultural workers:**

Occupation	Group	Employees	10th percentile	25th percentile	50th percentile (median)	75th percentile	Mean	Living wage low-end	Under-payment? (10th)	$/H (10)	$/H (25)	$/H (50)	$/H (75)	Total ($/year)
FARMING, FISHING, AND FORESTRY OCCUPATIONS	major	484,750	11.00	11.62	13.07	16.72	15.07							
SUPERVISORS OF FARMING, FISHING, AND FORESTRY WORKERS	minor	22,560	14.49	17.76	23.21	30.77	25.25	16.08	Yes	1.59	0.00	0.00	0.00	7640819
AGRICULTURAL WORKERS	minor	415,390	10.82	11.52	12.52	14.97	14.00							
AGRICULTURAL INSPECTORS	broad	13,760	13.51	16.33	21.87	27.09	22.67	16.08	Yes	2.57	0.00	0.00	0.00	7532779
ANIMAL BREEDERS	broad	1,610	12.51	15.25	20.64	27.28	22.32	16.08	Yes	3.57	0.83	0.00	0.00	1651299
GRADERS AND SORTERS, AGRICULTURAL PRODUCTS	broad	34,340	9.39	11.25	12.34	14.12	13.25	16.08	Yes	6.69	4.83	3.74	1.96	206168353
MISCELLANEOUS AGRICULTURAL WORKERS	broad	365,680	10.98	11.50	12.41	14.78	13.71							
AGRICULTURAL EQUIPMENT OPERATORS	detailed	26,990	10.44	12.70	15.36	18.62	16.01	16.08	Yes	5.64	3.38	0.72	0.00	71922349
FARMWORKERS AND LABORERS, CROP, NURSERY, AND GREENHOUSE	detailed	295,520	11.06	11.50	12.23	14.32	13.36	16.08	Yes	5.02	4.58	3.85	1.76	1631329772
FARMWORKERS, FARM, RANCH, AND AQUACULTURAL ANIMALS	detailed	36,630	9.10	10.86	13.38	17.03	14.37	16.08	Yes	6.98	5.22	2.70	0.00	168224539
AGRICULTURAL WORKERS, ALL OTHER	detailed	6,540	9.23	11.50	14.23	19.14	16.31	16.08	Yes	6.85	4.58	1.85	0.00	25556368

TOTAL	**2120026279**
DOCUMENTED TOTAL	**2.12 bn**

TABLE 35 **Documented industry workers:**

Occupation	Group	Employees	10th percentile	25th percentile	50th percentile (median)	75th percentile	Mean	Living wage low-end	Under-payment? (10th)	$/H (10)	$/H (25)	$/H (50)	$/H (75)	Total ($/year)
FOOD PROCESSING WORKERS	minor	802,290	10.15	11.79	14.09	17.48	14.94							
BAKERS	broad	184,990	9.77	11.29	13.32	16.41	14.25	16.08	Yes	6.31	4.79	2.76	0.00	803666070
BUTCHERS AND OTHER MEAT, POULTRY, AND FISH PROCESSING WORKERS	broad	364,150	10.22	11.92	14.19	17.37	14.87							
BUTCHERS AND MEAT CUTTERS	detailed	136,770	10.47	12.35	15.62	19.55	16.35	16.08	Yes	5.61	3.73	0.46	0.00	359945930
MEAT, POULTRY, AND FISH CUTTERS AND TRIMMERS	detailed	153,990	10.05	11.55	13.51	15.82	13.85	16.08	Yes	6.03	4.53	2.57	0.26	652753586
SLAUGHTERERS AND MEAT PACKERS	detailed	73,390	10.32	12.07	14.05	16.39	14.23	16.08	Yes	5.76	4.01	2.03	0.00	263414977
MISCELLANEOUS FOOD PROCESSING WORKERS	broad	253,140	10.41	12.05	14.52	18.32	15.56							
FOOD AND TOBACCO ROASTING, BAKING, AND DRYING MACHINE OPERATORS AND TENDERS	detailed	20,830	10.24	12.25	15.19	19.23	16.29	16.08	Yes	5.84	3.83	0.89	0.00	61275466
FOOD BATCH MAKERS	detailed	159,390	10.44	12.18	14.80	18.93	15.92	16.08	Yes	5.64	3.90	1.28	0.00	498754167
FOOD COOKING MACHINE OPERATORS AND TENDERS	detailed	30,030	10.67	12.46	14.96	18.15	15.54	16.08	Yes	5.41	3.62	1.12	0.00	87251595
FOOD PROCESSING WORKERS, ALL OTHER	detailed	42,890	10.29	11.45	13.24	15.50	13.85	16.08	Yes	5.79	4.63	2.84	0.58	194461384
	CHECK	802,280									TOTAL			**2921523175**
	(SEE RAW DATA)										TOTAL			**2.92 bn**

TABLE 36 **Documented food transportation and food retail:**

Other	Occupation	Group	Employees	10th percentile	25th percentile	50th percentile (median)	75th percentile	Mean	Living wage low-end	Under-payment	$/H	
41-0000	Sales and related occupations (Retail, F&B only)	major	1,168,020	n/a	n/a	n/a	n/a	13.54	16.08	Yes	2.54	6319572011
53-0000	Transportation employees (Logistics, F&B only)	major	725,960	n/a	n/a	n/a	n/a	13.26	16.08	Yes	2.82	4360792995

10680365005

TOTAL **10.68 bn**

Undocumented agriculture workers:

Undocumented worker estimates took the estimated number of undocumented agricultural workers from Farm Worker Justice and used the average annual wage for an agricultural worker published by the National Center for Farmworker Health to estimate hourly wage of a 40 hour work-week. The annual income is likely to be an overestimate due to increased probability of wage exploitation for undocumented workers, and this is therefore an underestimate of underpayment impact.

TABLE 37

	Number	Unit	Living wage low-end	Underpayment?	$/H	Total ($/year)
NUMBER OF UNDOCUMENTED WORKERS	1.2	million	16.08			
ANNUAL WAGE (2/3 RECEIVE LESS, SO THIS IS OVERESTIMATION)	20000	USD				
HOURLY WAGE	9.62	USD	16.08	Yes	6.46	16524 mn

UNDOCUMENTED TOTAL **16.52 bn**

Incarcerated workers:

Incarcerated individuals are included in the underpayments calculation because the value of their labor remains consistent with a living wage of $16.08 per hour. If incarcerated individuals were unavailable to be food system workers, the difference between their current wages and the value of labor (e.g., living wage estimate) represents an unaccounted food system cost.

Data on underpayment of incarcerated individuals is particularly sparse. Food First estimates that 30,000 incarcerated individuals work in agricultural labor and that the daily wage is ~$2 per day. Following the same logic as other populations, the following table is likely a significant underestimate of underpayment.

TABLE 38

Agricultural labor	Number	Unit	Living wage low-end	Underpayment?	$/H	Total ($/year)
ESTIMATED INCARCERATED INDIVIDUALS WORKING IN AGRICULTURAL LABOR	0.03	million	16.08			
DAILY WAGE ESTIMATE	2	USD				
HOURLY WAGE	0.25	USD	16.08	Yes	15.83	1012 mn
				INCARCERATED	**TOTAL**	1.01 bn

2. **Identify monetization factor corresponding to metric**
   Beyond the difference between current wages and a living wage, True Price has an additional monetization factor to quantify the impact of being underpaid. The True Price monetization factor of $1.02 Euros for every $1 Euro underpaid was assumed to be the same for USD.

3. **Multiply share of metric attributable to US food system by the monetization factors**
   Underpayment estimates for all included food system employees are summarized below, with food service employees (e.g., fast-food workers) excluded from this analysis.

TABLE 39

	Underpayment estimate (bn usd)
TOTAL UNDERPAYMENT	$33.26
AGRICULTURE (DOCUMENTED)	$2.12
AGRICULTURE (UNDOCUMENTED)	$16.52
INDUSTRY	$2.92
RETAIL	$6.32
TRANSPORTATION	$4.36
INCARCERATED INDIVIDUALS	$1.01

Potential reduction with intermediate steps:

All livelihood metrics related to the exploitation of labor (e.g., underpayment) are assumed to be potentially reduced with intermediate steps given the implications for equity.

7.3 Lack of benefits

1. **Identify share of metric attributable to the US food system**
   The lack of benefits calculation for food system employees is based on 3 employee benefits

- Health insurance
- Term life insurance
- Social security payments

These metrics are considered externalities because the cost of underpaying labor (e.g., through inadequate benefits) is shifted from employers onto tax payers (e.g., through government interventions) and not currently fully accounted for in the food system.

Health insurance

Lack of health insurance is quantified as the cost to extend health insurance to food production, processing, distribution, retail, and preparation workers who are uninsured or underinsured based on the average cost of employer health insurance.

The number of employees along the food production value chain were sourced from a report by the Food Chain Workers Alliance and the Solidarity Research Cooperative. The percent of uninsured employees for each segment used estimates from the Kaiser Family Foundation, Center on Budget and Policy Priorities, and the Urban Institute. The average cost of employer health insurance was taken as $7,188 per policyholder.

Insuring the uninsured

TABLE 40

Employment	Number of workers (m)	% Uninsured	Number of uninsured workers (m)	Average cost of employer health insurance	Cost to insure the uninsured (bn)
TOTAL	11.59		3.24		$23.32
FOOD PRODUCTION (FARM WORKERS)	2.5	65%	1.63	$7,188	$11.68
FOOD PROCESSING	1.8	17%	0.31	$7,188	$2.20
FOOD DISTRIBUTION	3.3	17%	0.56	$7,188	$4.03
FOOD RETAIL	3.1	17%	0.53	$7,188	$3.79
FOOD PREPARATION	0.89	25.30%	0.23	$7,188	$1.62

Underinsured individuals are individuals with health insurance, but with high out-of-pocket costs or deductibles relative to their incomes. The Commonwealth Fund estimates that 23% of all working adults are underinsured. This estimate is assumed to also apply to food system workers. The cost to insure the underinsured are assumed to be 50% of the cost of employer health insurance.

Insuring the underinsured

TABLE 41

Employment	Number of workers(m)	% Underinsured	Number of underinsured workers (m)	Average cost of employer health insurance	Cost to insure the underinsured (bn)
TOTAL	11.59		2.67		$9.58
FOOD PRODUCTION (FARM WORKERS)	2.5	23%	0.58	$3,594	$2.07
FOOD PROCESSING	1.8	23%	0.41	$3,594	$1.49
FOOD DISTRIBUTION	3.3	23%	0.76	$3,594	$2.73
FOOD RETAIL	3.1	23%	0.71	$3,594	$2.56
FOOD PREPARATION	0.89	23%	0.20	$3,594	$0.74

Life insurance

The cost to extend life insurance to food production, processing, distribution, retail, and preparation workers was based on the average premium on a term life insurance policy. The number of workers for each segment along the food system value chain is similarly sourced from the Food Chain Workers Alliance. Though life insurance premiums vary significantly, the specific assumption used is the average premium per policy of a $500,000 policy size per the Life Insurance Marketing and Research Association. The percentage of food system employees without life insurance is assumed to mirror the lack of life insurance coverage rates of the general population, sourced from the Insurance Information Institute.

TABLE 42

Sector	Number of workers (m)	Percentage with life insurance	Number without life insurance (m)	Annual cost of life insurance	Cost to insure (bn)
TOTAL	11.59		4.64		$4.68
FOOD PRODUCTION (FARM WORKERS)	2.5	60%	1.00	$1,010	$1.01
FOOD PROCESSING	1.8	60%	0.72	$1,010	$0.73
FOOD DISTRIBUTION	3.3	60%	1.32	$1,010	$1.33
FOOD RETAIL	3.1	60%	1.24	$1,010	$1.25
FOOD PREPARATION	0.89	60%	0.36	$1,010	$0.36

Social security

The cost to extend annual social security payments to undocumented workers in the food system is based on the number of undocumented workers in the US food system, excluding restaurants, sourced from the Migration Policy Institute. Undocumented social security payment amounts are assumed to mirror the national average from AARP.

TABLE 43

Undocumented workers in food system (m)	Avg monthly social security payment	Avg annual social security payment	Cost to extend social security (bn)
2.1	$1,543	$18,516	$38.88

2. **Identify monetization factor corresponding to metric**
Metrics were already provided in monetary terms, so no further monetization necessary.

3. **Multiply share of metric attributable to US food system by the monetization factors**

TABLE 44

Benefit	Cost	Unit
TOTAL	$76.47	bn USD
HEALTH INSURANCE	$32.90	bn USD
LIFE INSURANCE	$4.68	bn USD
SOCIAL SECURITY	$38.88	bn USD

Potential reduction with intermediate steps:

All livelihood metrics related to the exploitation of labor (e.g., lack of benefits) are assumed to be potentially reduced with intermediate steps given the implications for equity.

7.4 Occupational health/safety

1. **Identify share of metric attributable to the US food system**
   Occupational health and safety costs were estimated from the cost of acute injuries and chronic exposure to pesticides for food system workers along the value chain.

Acute workplace injuries

The annual cost of acute workplace injuries for food system employees is based on the following inputs:

TABLE 45

Metric	Estimate	Unit
ANNUAL COST OF WORK INJURY IN THE US	171	USD bn
NUMBER OF TOTAL WORKERS IN THE US	152	million people
FOOD PRODUCTION (FARM WORKERS) EMPLOYEES	2.5	million people
FOOD PROCESSING EMPLOYEES	1.8	million people
FOOD DISTRIBUTION EMPLOYEES	3.3	million people
FOOD RETAIL EMPLOYEES	3.1	million people
FOOD PREPARATION EMPLOYEES	0.89	million people
RATE OF INJURY IN PRIVATE INDUSTRY	3.2	injuries per 100 workers
RATE OF INJURY IN AGRICULTURE	5.5	injuries per 100 workers
RATE OF INJURY IN FOOD MANUFACTURING	5.1	injuries per 100 workers

The annual cost of injuries is taken from Injury Facts, the number of total workers in the US is based on BLS estimates, and the remaining inputs (e.g., number of workers along the food value chain, injury rates per 100 workers) are sourced from the Food Chain Workers Alliance.

To estimate the impact, the overall annual cost of workplace injury in the US is multiplied by the percentage of food production, processing, distribution, retail, and preparation workers within that estimate. The resulting initial estimate is then adjusted for the increased rate of injury among food system workers at different segments along the value chain.

Summary

TABLE 46

Employment	Number of workers	Occupational hazard cost (bn)
TOTAL	**11.6**	**$16.26**
FOOD PRODUCTION	2.5	$4.83
FOOD PROCESSING	1.8	$3.23
OTHER FOOD WORKERS (DISTRIBUTION, RETAIL, AND PREP)	7.3	$8.20

Calculation

TABLE 47

FOOD PRODUCTION

Metric	Estimate	Unit
ANNUAL COST OF WORK INJURY IN THE US	171	USD bn
PERCENTAGE OF FOOD PRODUCTION	1.64%	percent
EXPECTED OCCUPATIONAL HAZARD COST FOR FOOD PRODUCTION	2.81	USD bn
% DIFFERENCE IN INJURY RATES FOR FOOD PRODUCTION VS OVERALL WORKER	72%	percent
ESTIMATED OCCUPATIONAL HAZARD COST	**4.83**	**USD bn**

FOOD PROCESSING

Metric	Estimate	Unit
ANNUAL COST OF WORK INJURY IN THE US	171	USD bn
PERCENTAGE OF FOOD PROCESSING	1.18%	percent
EXPECTED OCCUPATIONAL HAZARD COST FOR FOOD PROCESSING	2.03	USD bn
% DIFFERENCE IN INJURY RATES FOR FOOD PROCESSING VS OVERALL WORKER	59%	percent
ESTIMATED OCCUPATIONAL HAZARD COST	**3.23**	**USD bn**

OTHER FOOD WORKERS (FOOD DISTRIBUTION, RETAIL, AND PREP)

Metric	Estimate	Unit
ANNUAL COST OF WORK INJURY IN THE US	171	USD bn
PERCENTAGE OF OTHER F OOD WORKERS	4.80%	percent
ESTIMATED OCCUPATIONAL HAZARD COST	8.20	USD bn

Chronic exposure

The impact of food system employees (e.g., agricultural workers) chronically exposed to pesticides is directly sourced from Bourguet & Guillemaud (2016), who calculated the direct and indirect costs of acute / chronic exposure to pesticides from cancer. The share attributable to the food system assumes that 75% of pesticide usage in the US occurs in agriculture, sourced form Calvert et al (2008).

TABLE 48

Number	Metric
75%	Percent of total pesticide usage from agriculture
$0.20	Total direct medical costs of acute pesticide exposure (bn)
$10.20	Total direct and indirect medical costs of cancer caused by chronic pesticide exposure (bn)
$7.80	**TOTAL COST OF PESTICIDE EXPOSURE IN THE FOOD SYSTEM (BN)**

The estimate for chronic exposure is limited to pesticide exposure due to lack of available data. There are a host of other chronic occupational hazards (e.g., musculoskeletal conditions) that are not included in the cost estimate. The chronic exposure of pesticides is also limited to the impact of cancer quantified in the studies above. Other long-term impacts of pesticide exposure (e.g., reproductive issues) are not included.

2. **Identify monetization factor corresponding to metric**
   Both acute workplace injuries and the impact of chronic exposure to pesticide were already provided in monetary terms.

3. **Multiply share of metric attributable to US food system by the monetization factors**
   The cost of occupational hazards is taken from the sum of acute injuries and chronic exposure to pesticides.

TABLE 49

Category	Total cost (bn)
TOTAL	**$24.06**
ACUTE INJURIES	$16.26
CHRONIC EXPOSURE	$7.80

Additional workplace exposures (e.g., COVID-19) are important to consider yet not quantified here.

Potential reduction with intermediate steps:

Potential reduction through intermediate steps was not assessed for acute workplace injuries and chronic pesticide exposure. This is likely to significantly underestimate the share of costs in the livelihoods impact area that can potentially be reduced through intermediate steps.

8 Economy impact area summary

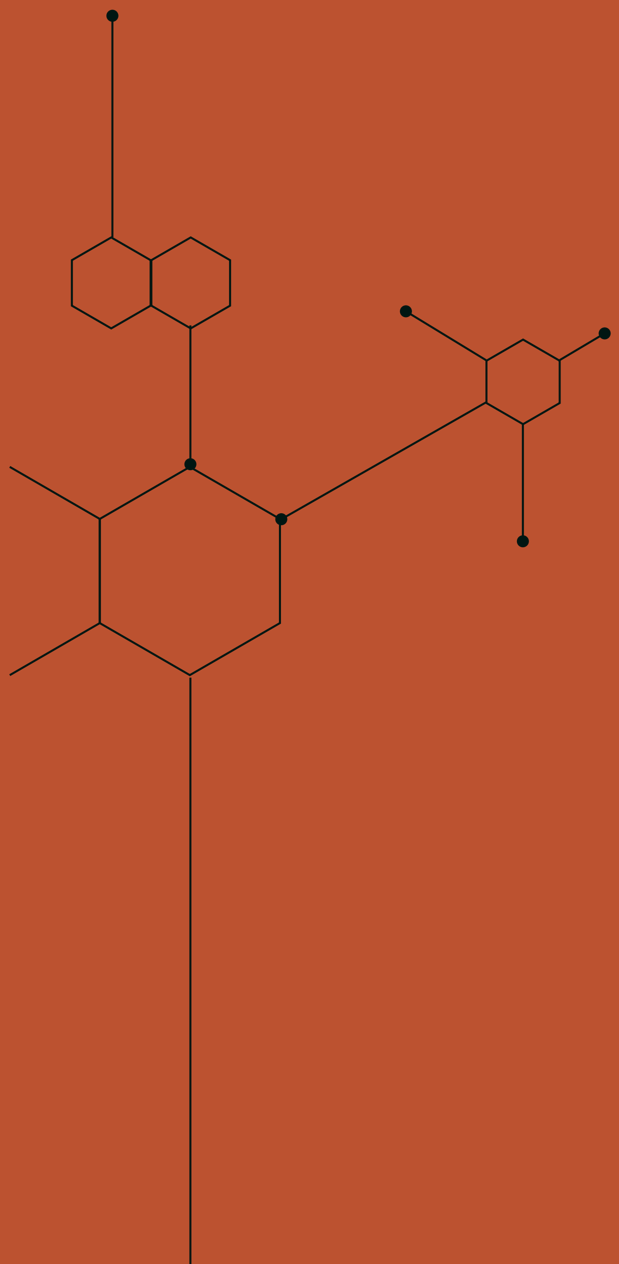
Some economic benefits of the food system (such as employment) are assumed to be captured in food prices currently, while others (such as local GDP multipliers) are excluded from this analysis. As such, the economy impact area quantifies the cost of agricultural subsidies in the US food system currently not captured in food prices.

8.1 Agricultural subsidies

Directly sourced from USDA. Average value of federal agricultural subsidies over past 5 years taken to account for year-by-year variability in payments, averaging to approximately $20 billion per year. While this amount may not appear significant compared to other impact areas, the downstream effects of this unaccounted food system cost remain significant (e.g., subsidies for certain types of crops / products) and affect other impact areas (e.g., human health).

9

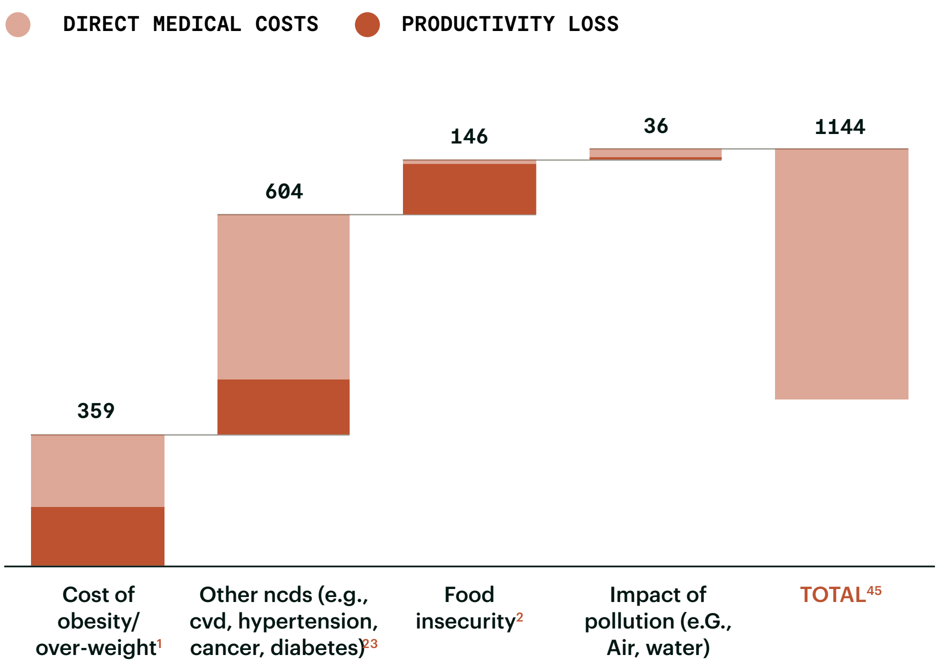
Human health impact area summary



The human health impact area quantifies the impact of food consumption on the health of those in the US, captured through direct and indirect costs of obesity / overweight, non-communicable disease (NCDs), food insecurity, and health impacts from pollution attributable to the food system summarized below.

not exhaustive

TOTAL COST OF HUMAN HEALTH FROM THE FOOD SYSTEM, (BN USD)



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[1] The Milken institute estimates that the total cost of obesity/overweight in the U.S. is $1.72 trn annually. With an estimated 33% of this impact attributable to diet, the Milken institute estimate for obesity/overweight is $0.57 trn

[2] Given that 10-20% of the U.S. population is food insecure and these individuals disproportionately shoulder the burden of obesity, diabetes, and NCDs, this impact may be felt in other health cost categories as well. Not ranged because directly sourced from The Cost of Hunger Report

[3] Quantified through the cost of CVD, hypertension, neoplasms, diabetes, chronic kidney disease, and nutritional deficencies attributable to diet

[4] Cost of lack of health insurance counted under the "Livelihoods" impact area

[5] Weighted 10-year average of GDP per capita used as monetized factor. Alternate method (e.g., from True Price) use the perceived value of a year of healthy life, a monetization more than double GDP per capita

9.1 Obesity/overweight

1. **Identify share of metric attributable to the US food system**
   Disability-Adjusted Life Years (DALYs) represent the total number of years uniquely lost to illness, disability, or premature death for a given year. DALYs provide a proven, standardized way to compare the burden of different diseases. The 2019 DALYs attributable to high BMI as a risk factor in the US were directly sourced from the IHME Global Burden of Disease, with the specific conditions for high BMI DALYs outlined below.

TABLE 50

Condition	2019 Dalys lost attributable to high bmi	Upper estimate	Lower estimate
TOTAL	**12,536,102.16**	**16,165,298.23**	**8,694,734.50**
CHRONIC RESPIRATORY DISEASES	433,065.20	656,141.30	267,375.38
NEOPLASMS	1,239,333.13	1,701,827.56	786,808.34
SENSE ORGAN DISEASES	11,363.70	19,645.35	5,427.80
NEUROLOGICAL DISORDERS	407,810.14	965,583.31	120,053.03
CARDIOVASCULAR DISEASES	5,280,703.89	6,792,621.81	3,582,343.48
MUSCULOSKELETAL DISORDERS	1,092,359.95	1,704,487.71	617,869.64
DIABETES AND KIDNEY DISEASES	3,913,847.99	5,085,204.61	2,906,161.99
DIGESTIVE DISEASES	157,618.16	231,241.19	100,106.28

Given that factors outside of the food system impact DALYs lost from obesity (e.g., physical activity, genetics), Scarborough et al (2011) estimated that 33% of high BMI is attributable to diet. The DALYs from high BMI are therefore multiplied by this 33% estimate to calculate the DALYs from high BMI attributable to the food system through diet as listed in Table 51 below.

TABLE 51

Condition	Dalys from high bmi attributable to food system	Upper estimate	Lower estimate
TOTAL	**4,136,913.71**	**5,334,548.42**	**2,869,262.39**
CHRONIC RESPIRATORY DISEASES	142,911.52	216,526.63	88,233.88
NEOPLASMS	408,979.93	561,603.09	259,646.75
SENSE ORGAN DISEASES	3,750.02	6,482.96	1,791.18
NEUROLOGICAL DISORDERS	134,577.34	318,642.49	39,617.50
CARDIOVASCULAR DISEASES	1,742,632.28	2,241,565.20	1,182,173.35
MUSCULOSKELETAL DISORDERS	360,478.79	562,480.94	203,896.98
DIABETES AND KIDNEY DISEASES	1,291,569.84	1,678,117.52	959,033.46
DIGESTIVE DISEASES	52,013.99	76,309.59	33,035.07

2. **Identify monetization factor corresponding to metric**
The monetary impact of obesity / overweight was measured using 2 methods and summing the results:

- Monetizing DALYs using GDP per capita estimates, excluding direct health costs, to estimate productivity loss
- Estimating the direct medical costs from obesity / overweight attributable to the food system through diet

GDP per capita estimates include the 17.7% of US GDP spend within the healthcare system. However, monetizing DALYs with just GDP per capita (e.g., not separating direct medical costs) assumes that the direct medical costs from obesity are proportional to the medical costs of other conditions (e.g., infectious diseases). Given the chronic nature of obesity and the significant health costs associated, this methodology could lead to undercounting the impact of obesity / overweight. As such, productivity loss was estimated by monetizing DALYs through US GDP per capita without GDP spent in the healthcare system and then adding in the estimated direct medical costs of obesity attributable to the food system through diet.

Alternate methods for monetization exist outside of GDP per capita. For instance, True Price uses a monetization estimate based on the perceived value of a year of healthy life, an estimate that is more than double the GDP per capita estimated used here.

Productivity Loss:

Productivity loss was calculated by multiplying the DALYs from high BMI attributable to the food system outlined above in Table 51 to GDP per capita estimates excluding health costs. Given that GDP per capita estimates differ over time, a weighted 10-year average of US GDP per capita from World Bank data is summarized below, concluding in a weighted 10-year average of $58,872.84.

TABLE 52

Year	Gdp per capita estimate	Weight applied
2010	$48,467.52	1
2011	$49,886.82	2
2012	$51,610.61	3
2013	$53,117.67	4
2014	$55,064.74	5
2015	$56,839.38	6
2016	$57,951.58	7
2017	$60,062.22	8
2018	$62,996.47	9
2019	$65,297.52	10

CMS then estimates that 17.70% of US GDP is spent within the healthcare system. Excluding these health costs from GDP per capita signifies that the monetization factor for DALYs to estimate productivity loss from high BMI is $48,452.34.

Multiplying this monetization factor by the DALY ranges from high BMI listed in Table 52, the productivity loss estimates are summarized below in Table 53.

TABLE 53

TOTAL COST (BN)	**$200.44**
UPPER ESTIMATE (BN)	$258.47
LOWER ESTIMATE (BN)	$139.02

Direct medical costs:

Direct medical costs associated with high BMI were directly sourced from a 2018 Milken Institute Report. The same 33% estimate of high BMI attributable to diet used for DALYs was also used to estimate direct medical costs attributable to the food system. Below is a table summarizing the direct medical cost inputs.

TABLE 54

Input	Estimate
COST FROM FOOD SYSTEM (BN)	$158.63
DIRECT MEDICAL COST FROM OBESITY / OVERWEIGHT (BN)	$480.70
PERCENTAGE ATTRIBUTABLE TO DIET	33%

3. **Multiply share of metric attributable to US food system by the monetization factors**
   The results of each segment (e.g., productivity loss, direct medical costs) are summarized below:

TABLE 55

TOTAL COST ESTIMATE (BN)	$359.07
PRODUCTIVITY COST ESTIMATE (BN)	$200.44
DIRECT MEDICAL COST ESTIMATE (BN)	$158.63

As an alternative method, the Milken institute estimates that the total cost of obesity / overweight in the US is $1.72 trn annually. With an estimated 33% of this impact attributable to diet, the Milken institute estimate for obesity / overweight is $570 bn, higher than the $369 bn estimated here.

Potential reduction with intermediate steps:

The potential reduction with intermediate steps was estimated by comparing the rate of DALYs lost to high BMI per 100,000 people in the US to Canada. Other potential countries for comparison, including Canada are outlined below.

TABLE 56

DALYS ATTRIBUTABLE TO OBESITY / OVERWEIGHT PER IHME

Country	US	Israel	Australia	France	Canada	Japan
DALYS PER 100,000 PEOPLE	3,822.23	1,480.54	2,137.47	1,656.86	2,283.36	1,065.68
TOTAL EXPECTED DALYS IN THE US	12,544,558.86	4,859,132.28	7,015,176.54	5,437,814.52	7,493,987.52	3,497,561.76
EXPECTED DALYS ATTRIBUTABLE TO FOOD SYSTEM	4,139,704.42	1,603,513.65	2,315,008.26	1,794,478.79	2,473,015.88	1,154,195.38
EXPECTED PRODUCTIVITY LOSS (BN)	**$200.58**	**$77.69**	**$112.17**	**$86.95**	**$119.82**	**$55.92**
DIFFERENCE FROM US ESTIMATE (BN)	**$-**	**$122.88**	**$88.41**	**$113.63**	**$80.75**	**$144.65**
% DIFFERENCE FROM US ESTIMATE	**0%**	**61%**	**44%**	**57%**	**40%**	**72%**

9.2 Non-Communicable Diseases (NCDs)

1. **Identify share of metric attributable to the US food system**
   Similar to obesity, DALYs from IHME were used to estimate the economic burden of NCDs attributable to the food system. The dataset provides all DALYs attributable to diet, and therefore 100% attributable to the food system, broken down into the following categories of NCDs:

- Cardiovascular disease (CVD), including hypertension
- Neoplasms / cancers
- Diabetes and Chronic Kidney Disease (CKD)
- Nutritional deficiencies

CVD, including hypertension:

DALYs attributable to diet and associated with CVD are listed below, with the overall number of CVD being an aggregate of each individual condition evaluated.

TABLE 57

Condition	2019 Dalys lost attributable to diet	Upper estimate	Lower estimate
CARDIOVASCULAR DISEASES	6,288,500.12	7,645,373.50	5,099,407.55
ISCHEMIC HEART DISEASE	5,069,195.44	5,878,322.22	4,106,839.59
STROKE	1,007,295.13	1,327,876.10	759,803.75
HYPERTENSIVE HEART DISEASE	110,257.87	342,019.31	6,121.95
ATRIAL FIBRILLATION AND FLUTTER	34,634.14	103,749.77	2,739.97
CARDIOMYOPATHY AND MYOCARDITIS	20,011.65	56,822.60	1,754.56
OTHER CARDIOVASCULAR AND CIRCULATORY DISEASES	15,955.48	45,533.12	1,287.75
AORTIC ANEURYSM	9,492.56	27,454.37	813.53
NON-RHEUMATIC VALVULAR HEART DISEASE	8,003.61	24,670.98	774.91
PERIPHERAL ARTERY DISEASE	5,555.71	18,986.73	485.26
ENDOCARDITIS	5,193.43	15,663.34	428.19
RHEUMATIC HEART DISEASE	2,905.10	8,718.78	324.07

Neoplasms / cancer:

DALYs attributable to diet and neoplasms are listed by condition below in Table 58. The following neoplasm types did not have DALYs attributable to diet per IHME: pancreatic cancer, prostate, leukemia, Non-Hodgkin lymphoma, brain and central nervous system cancer, other malignant neoplasm, liver cancer, kidney cancer, ovarian cancer, bladder cancer, multiple myeloma, malignant skin melanoma, uterine cancer, cervical cancer, lip and oral cavity cancer, other neoplasm, non-melanoma skin cancer, larynx cancer, gallbladder and biliary tract cancer, other pharynx cancer, thyroid cancer, mesothelioma, Hodgkin lymphoma, nasopharynx cancer, and testicular cancer.

TABLE 58

Condition	2019 Dalys lost attributable to diet	Upper estimate	Lower estimate
NEOPLASMS	**877,928.64**	**1,045,913.17**	**685,801.43**
COLON AND RECTUM CANCER	565,375.90	696,827.79	407,667.17
TRACHEAL, BRONCHUS, AND LUNG CANCER	155,398.76	231,948.02	41,519.61
BREAST CANCER	70,396.60	95,962.64	35,499.07
ESOPHAGEAL CANCER	60,194.75	123,467.59	15,744.70
STOMACH CANCER	26,562.63	114,906.50	821.81

Diabetes and CKD:

DALYs attributable to diet associated with Type 2 diabetes and chronic kidney disease are listed below. Note that Type 1 diabetes and acute glomerulonephritis do not have DALYs attributable to diet per IHME.

TABLE 59

Condition	2019 Dalys lost attributable to diet	Upper estimate	Lower estimate
DIABETES AND KIDNEY DISEASES	**1,730,644.11**	**2,233,326.59**	**1,333,246.47**
DIABETES MELLITUS TYPE 2	1,631,916.93	2,106,610.88	1,261,918.53
CHRONIC KIDNEY DISEASE	98,727.19	292,583.23	7,229.03

Nutritional deficiencies:

The specific conditions and DALYs associated with nutritional deficiencies are listed below. 100% of nutritional deficiencies are assumed to be from diet.

TABLE 60

Condition	2019 Dalys lost attributable to diet	Upper estimate	Lower estimate
NUTRITIONAL DEFICIENCIES	**411,913.49**	**558,450.76**	**300,188.49**
DIETARY IRON DEFICIENCY	215,326.31	333,521.78	133,955.67
PROTEIN-ENERGY MALNUTRITION	151,178.11	190,406.49	120,340.99
OTHER NUTRITIONAL DEFICIENCIES	36,461.46	52,367.38	24,382.60
IODINE DEFICIENCY	8,649.41	16,304.44	4,025.96
VITAMIN A DEFICIENCY	298.20	542.26	144.14

2. **Identify monetization factor corresponding to metric**
   Monetization factors for each category of NCD followed a similar methodology as obesity / overweight, with costs broken down into:

- Productivity loss estimated by multiplying GDP per capita estimates excluding healthcare costs due to disproportionally high costs of NCDs.
- Direct medical costs directly sourced from leading organizations, with the percent attributable to diet taken from IHME estimates of attribution.

CVD, including hypertension:

Productivity loss:

Using the same GDP per capita estimates excluding healthcare costs as high BMI, the cost ranges for productivity loss in CVD are listed in Table 61.

TABLE 61

TOTAL COST (BN)	**$304.69**
UPPER ESTIMATE (BN)	$370.44
LOWER ESTIMATE (BN)	$247.08

Direct medical costs:

The overall direct medical cost of CVD was directly sourced from the American Heart Association, with the ranged percent attributable to diet taken from IHME.

TABLE 62

	Cost (bn)	High estimate	Low estimate
TOTAL COST	**$77.94**	**$93.71**	**$63.34**
OVERALL COST OF CVD	$214.00	$214.00	$214.00
% OF DALYS ATTRIBUTED TO DIET	36.42%	43.79%	29.60%

Neoplasms / cancer:

Productivity loss:

Using the same GDP per capita estimates excluding healthcare costs as high BMI, the cost ranges for productivity loss in neoplasms / cancer are listed in Table 63.

TABLE 63

TOTAL COST (BN)	**$42.54**
UPPER ESTIMATE (BN)	$50.68
LOWER ESTIMATE (BN)	$33.23

Direct medical costs:

The overall direct medical cost of neoplasms / cancer was directly sourced from the American Association for Cancer Research, with the ranged percent attributable to diet taken from IHME.

TABLE 64

	Cost (bn)	High estimate	Low estimate
TOTAL COST	**$9.64**	**$11.57**	**$7.50**
OVERALL COST OF NEOPLASMS	$183.00	$183.00	$183.00
% OF DALYS ATTRIBUTED TO DIET	5.27%	6.32%	4.10%

Diabetes and CKD

Productivity loss:

Using the same GDP per capita estimates excluding healthcare costs as high BMI, the cost ranges for productivity loss in diabetes and CKD are listed in Table 65.

TABLE 65

TOTAL COST (BN)	**$83.85**
UPPER ESTIMATE (BN)	$108.21
LOWER ESTIMATE (BN)	$64.60

Direct medical costs:

The overall direct medical cost of diabetes and CKD were directly sourced from the American Diabetes Association, with the ranged percent attributable to diet taken from IHME.

TABLE 66

	Cost (bn)	High estimate	Low estimate
TOTAL COST	**$60.62**	**$71.62**	**$49.96**
OVERALL COST OF DIABETES	$237.00	$237.00	$237.00
% OF DALYS ATTRIBUTED TO DIET	25.58%	30.22%	21.08%

Nutritional deficiencies

Productivity loss:

Using the same GDP per capita estimates excluding healthcare costs as high BMI, the cost ranges for productivity loss in nutritional deficiencies are listed in Table 67.

TABLE 67

TOTAL COST (BN)	**$19.96**
UPPER ESTIMATE (BN)	$27.06
LOWER ESTIMATE (BN)	$14.54

Direct medical costs:

Direct medical costs from nutritional deficiencies were assumed to be proportional to the overall healthcare system (e.g., 17.70% of GDP per capita). The direct medical costs attributed to nutritional deficiencies are therefore estimated to be $4.29 bn.

3. Multiply share of metric attributable to US food system by the monetization factors

The overall cost for the overall NCD metrics and each individual condition is summarized below.

TABLE 68

Category	Productivity cost estimate (bn)	Direct medical cost estimate (bn)	Total cost estimate (bn)
TOTAL	**$451.04**	**$152.50**	**$603.54**
CVD AND HYPERTENSION	$304.69	$77.94	$382.63
NEOPLASMS / CANCER	$42.54	$9.64	$52.18
DIABETES AND CKD	$83.85	$60.62	$144.48
NUTRITIONAL DEFICIENCIES	$19.96	$4.29	$24.25

Potential reduction with intermediate steps:

The potential reduction with intermediate steps was estimated by comparing the rate of DALYs attributable to diet per 100,000 people in the US to Canada. Other potential countries for comparison, including Canada are outlined below.

TABLE 69

Dalys attributable to diet per ihme

Country	US	Israel	Australia	France	Canada	Japan
DALYS PER 100,000 PEOPLE	2,712.70	953.43	1,598.48	1,638.91	1,848.12	1,895.88
EXPECTED DALYS IN THE US	8,903,081.40	3,129,157.26	5,246,211.36	5,378,902.62	6,065,529.84	6,222,278.16
EXPECTED PRODUCTIVITY COST (BN)	**$431.38**	**$151.62**	**$254.19**	**$260.62**	**$293.89**	**$301.48**
DIFFERENCE FROM US ESTIMATE (BN)	**$-**	**$279.76**	**$177.18**	**$170.75**	**$137.49**	**$129.89**
% DIFFERENCE FROM US ESTIMATE	0%	65%	41%	40%	32%	30%

9.3 Food insecurity

Food insecurity estimates were directly sourced from The Cost of Hunger report, which compiled monetary estimates of the impact of food insecurity from literature. Though the overall report estimates an annual food insecurity cost of $160 bn, some categories have already been identified and quantified in other sections, namely NCDs and nutrition / digestion problems. A summary of the food insecurity costs sourced included and excluded from the report are below in Table 70 for a total of $145.86 bn in included costs. Please note that the bolded categories are aggregations of the subsequent, not bolded costs.

Given that 10-20% of the US population is food insecure and these individuals disproportionately shoulder the burden of obesity, diabetes, and other NCDs, this metric significantly impacts other health categories as well.

Similarly, improvements in other key metrics (e.g., underpayments) will likely improve food insecurity costs. As such, there may be double-counting between the two metrics.

Potential reduction with intermediate steps:

All food insecurity costs are assumed to be potentially reduced with intermediate steps.

TABLE 70

Inclusion	Category	Cost (bn)
INCLUDED IN TOTAL COST	**Mental health**	**57.08**
	Depression	32.03
	Anxiety	19.08
	Adult Mental Health Treatment	4.75
	Child Mental Health Treatment	1.22
	Poorer general health	**45.95**
	Poor overall health status	42.66
	Migraines	2.41
	Colds	0.88
	Suicide	**21.61**
	Hospitalizations	**11.51**
	Hospital stays, adults	8.18
	Non-neonatal hospital stays, children <18	1.82
	Ambulatory visits	1.51
	Lost productivity	5.48
	Other	4.23
	Osteoarthritis and inflammation	3.37
	Additional dental care visits	0.8
	congenital defects	0.06
EXCLUDED FROM TOTAL COST TO AVOID REDUNDANCY	**NCDs**	**7.12**
	treatment of DM	4.9
	treatment of hyperlipidemia	1.41
	treatment of endocrine system problems related to DM	0.81
	Nutrition and digestion problems	**7.1**
	Treatment of upper gastrointestinal disorders	6.25
	Treatment of anemias and other deficiencies	0.85

9.4 Impacts of pollution

1. **Identify share of metric attributable to the US food system**
   The health impacts of pollution were separated into 2 categories:

- Health impacts of air pollution estimated using the percent of DALYs attributable to the food system.
- Health impacts of drinking water pollution from Nitrogen directly sourced from literature.

Health impacts from air pollution:

Table 71 below summarizes the total DALYs lost from air pollution by condition (e.g., not just those attributable to the food system).

TABLE 71

Condition	2019 Dalys lost attributable to air pollution	Upper estimate	Lower estimate
TOTAL	**1,421,461.42**	**2,252,230.50**	**739,347.35**
CARDIOVASCULAR DISEASES	563,666.34	848,240.35	302,190.29
CHRONIC RESPIRATORY DISEASES	371,031.18	565,559.58	203,819.61
DIABETES AND KIDNEY DISEASES	240,477.48	433,313.51	105,085.46
NEOPLASMS	167,774.22	281,157.71	80,878.66
MATERNAL AND NEONATAL DISORDERS	45,332.47	61,167.68	32,038.86
RESPIRATORY INFECTIONS AND TUBERCULOSIS	32,232.24	61,226.82	14,809.70
OTHER NON-COMMUNICABLE DISEASES	458.50	638.47	310.16
SENSE ORGAN DISEASES	319.60	702.73	92.17
OTHER INFECTIOUS DISEASES	104.33	138.82	75.05
ENTERIC INFECTIONS	65.06	84.84	47.40

Our World in Data, a collaboration between Oxford University and the Global Change Data Lab, estimates that the food system accounts for 26% of global GHG emissions. Using this attribution percentage, the DALYs from air pollution attributable to the food system are below.

TABLE 72

Condition	2019 Dalys lost attributable to air pollution	Dalys from air pollution attributable to food system
TOTAL	**1,421,461.42**	**369,579.97**
CARDIOVASCULAR DISEASES	563,666.34	146,553.25
CHRONIC RESPIRATORY DISEASES	371,031.18	96,468.11
DIABETES AND KIDNEY DISEASES	240,477.48	62,524.15
NEOPLASMS	167,774.22	43,621.30
MATERNAL AND NEONATAL DISORDERS	45,332.47	11,786.44
RESPIRATORY INFECTIONS AND TUBERCULOSIS	32,232.24	8,380.38
OTHER NON-COMMUNICABLE DISEASES	458.50	119.21
SENSE ORGAN DISEASES	319.60	83.10
OTHER INFECTIOUS DISEASES	104.33	27.13
ENTERIC INFECTIONS	65.06	16.92

Water pollution:

Sabota et al (2015) estimates the total cost of Nitrogen pollution attributable to the food system, including drinking water pollution. The total annual cost estimated and the percent attributable to the food system are listed below.

TABLE 73

	Low cost (bn)	Median cost (bn)	High cost (bn)
TOTAL ANNUAL COST OVERVIEW (BN)	$19	$19	$52
COST ATTRIBUTABLE TO FOOD SYSTEM	75%	75%	75%
ANNUAL COST TO FOOD SYSTEM (BN)	**$14.25**	**$14.25**	**$39.00**

A further breakdown of the cost per kg of N in the US as pertaining to drinking water is also listed.

TABLE 74

Category	Subfactor	Low cost	Median cost	High cost
FRESHWATER N LOADING	Undesirable odor and taste	$0.14	$0.14	$0.14
	Nitrate contamination	$0.54	$0.54	$0.54
	Increased colon cancer risk	$1.76	$1.76	$5.15
GROUNDWATER N LOADING	Undesirable odor and taste	$0.14	$0.14	$0.14
	Increased colon cancer risk	$0.54	$0.54	$0.54
	Increased colon cancer risk	$1.76	$1.76	$5.15
TOTAL HEALTH COST PER KG OF N		**$4.88**	**$4.88**	**$11.66**

2. **Identify monetization factor corresponding to metric**

   Air pollution:
   Air pollution estimates were monetized using the same GDP per capita estimates as other health costs (e.g., obesity / overweight, NCDs). Direct medical costs from air pollution were assumed to be proportional to the overall 17.70% of US GDP.

   Water pollution:
   Water pollution estimates were already provided in monetary terms.

3. **Multiply share of metric attributable to US food system by the monetization factors**
   Health impacts from pollution are estimated to be $36.01 bn, with the breakdown between air pollution and water pollution below.

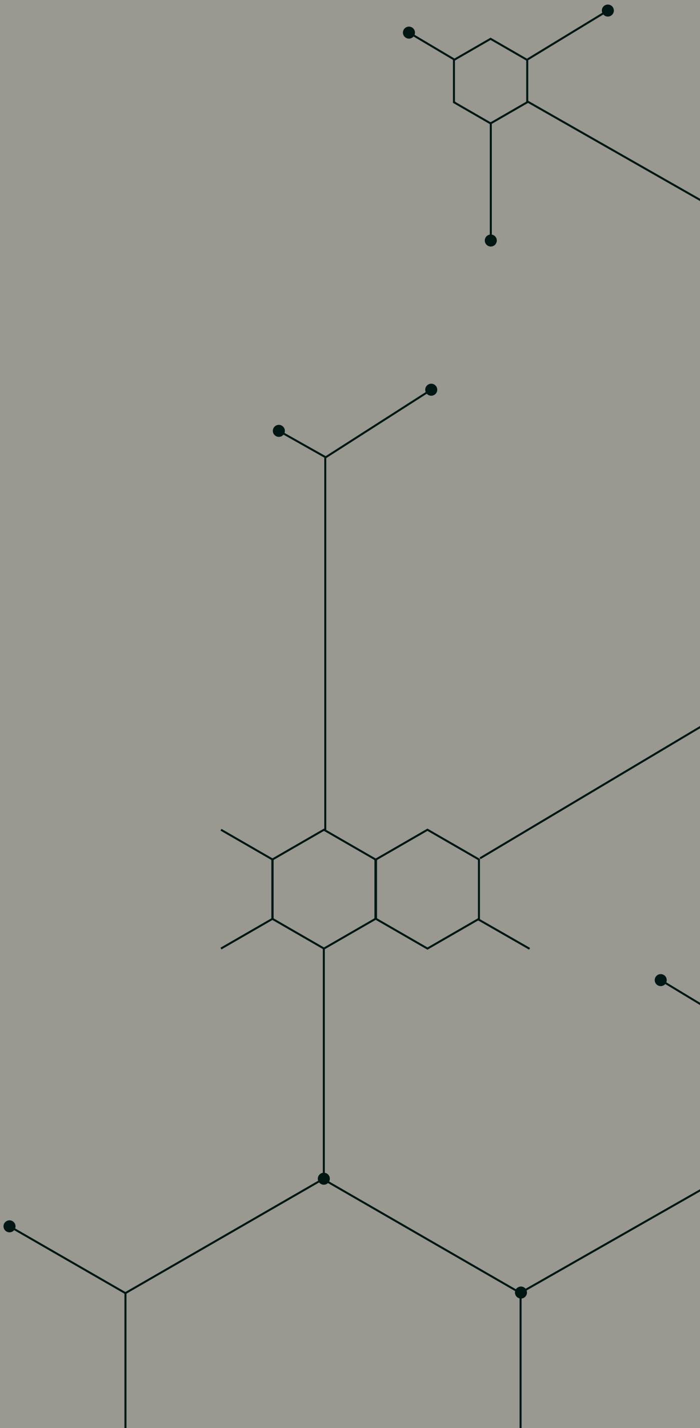
TABLE 75

Category	Productivity cost estimate	Direct medical cost estimate	Total cost Estimate
IMPACTS OF AIR POLLUTION	$17.91	$3.85	$21.76
IMPACTS OF DRINKING WATER POLLUTION	Presented in combined view	$14.25	

Potential reduction with intermediate steps:

The potential reduction with intermediate steps reported is consistent with the estimate for the air and water pollution in the biodiversity impact area.

10 Qualitative spotlights



Each of the following areas are important to consider when evaluating future interventions but the data available to measure their current monetary impacts was incomplete and/or inconsistent

10.1 Animal suffering and its impact

- More than 10 billion farm animals are killed each year in the U.S. for meat consumption.
- In global rankings, the U.S. ranks low for farm animal welfare (E, on a scale of A-G), with countries such as Mexico and Canada ranking higher than the U.S.
- These rankings are based on mistreatment of animals across rearing, transport, and slaughter – all of which can be improved using aggressive options (e.g., decreasing animal protein consumption) or conservative options (e.g., mandating larger space for rearing, banning extremely long-distance transport, expanding painless slaughter etc.).
- The conservative option is already practiced worldwide, and in some U.S. states (for example California), which may improve animal welfare at relatively low costs (less than 20 billion dollars per year across the US).

10.2 Antimicrobial resistance continues to be a threat

- Driven by the heightened use of antibiotics in medicine and livestock production, antimicrobial resistance (AMR) is increasingly recognized as global health threat.
- In the U.S., AMR leads to 35,000 human deaths per year, with 2.8 million infections per year.
- Food systems are estimated to contribute 22% to the burden of AMR.
- The future risk is not linear and can quickly become catastrophic – this is highly dependent on rate of resistance and year of resistance emerging.
- In recent years, the U.S. has introduced several regulations to combat AMR. For example, the FDA no longer permits use of medically-important antibiotics for growth promotion, and veterinary oversight is required for 95% of medically important antibiotics used etc.

10.3 Importance of resilience in the food systems

- Food system resilience (capacity over time of a food system and its units to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances) is under-prioritized compared to its true importance and cost.
- There are four drivers of reduced resilience – dependency on a small number of crops, high geographic concentration of production, long and global supply chains, and supply chain bottlenecks due to high dependency on certain steps.
- The COVID-19 pandemic exposed some of the drivers – e.g., consolidation of meat processing – 12 plants product over 50% of beef and another 12 over 50% of pork. This consolidation meant pausing operations even during outbreaks was challenging. This has detrimental effects on the heath of workers, who tend to be from vulnerable communities – e.g., undocumented workers, POCs etc. The effect of this was approximately 300,000 excess cases of COVID-19 due to proximity to livestock and approximately 5,000 deaths.

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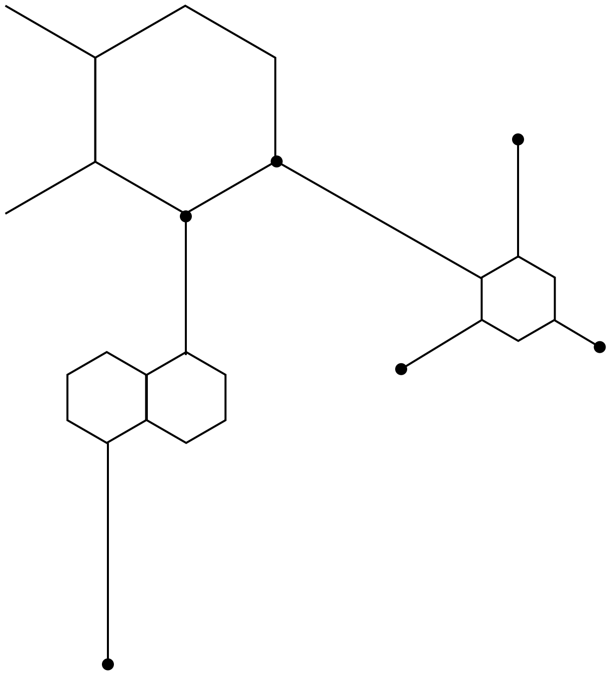

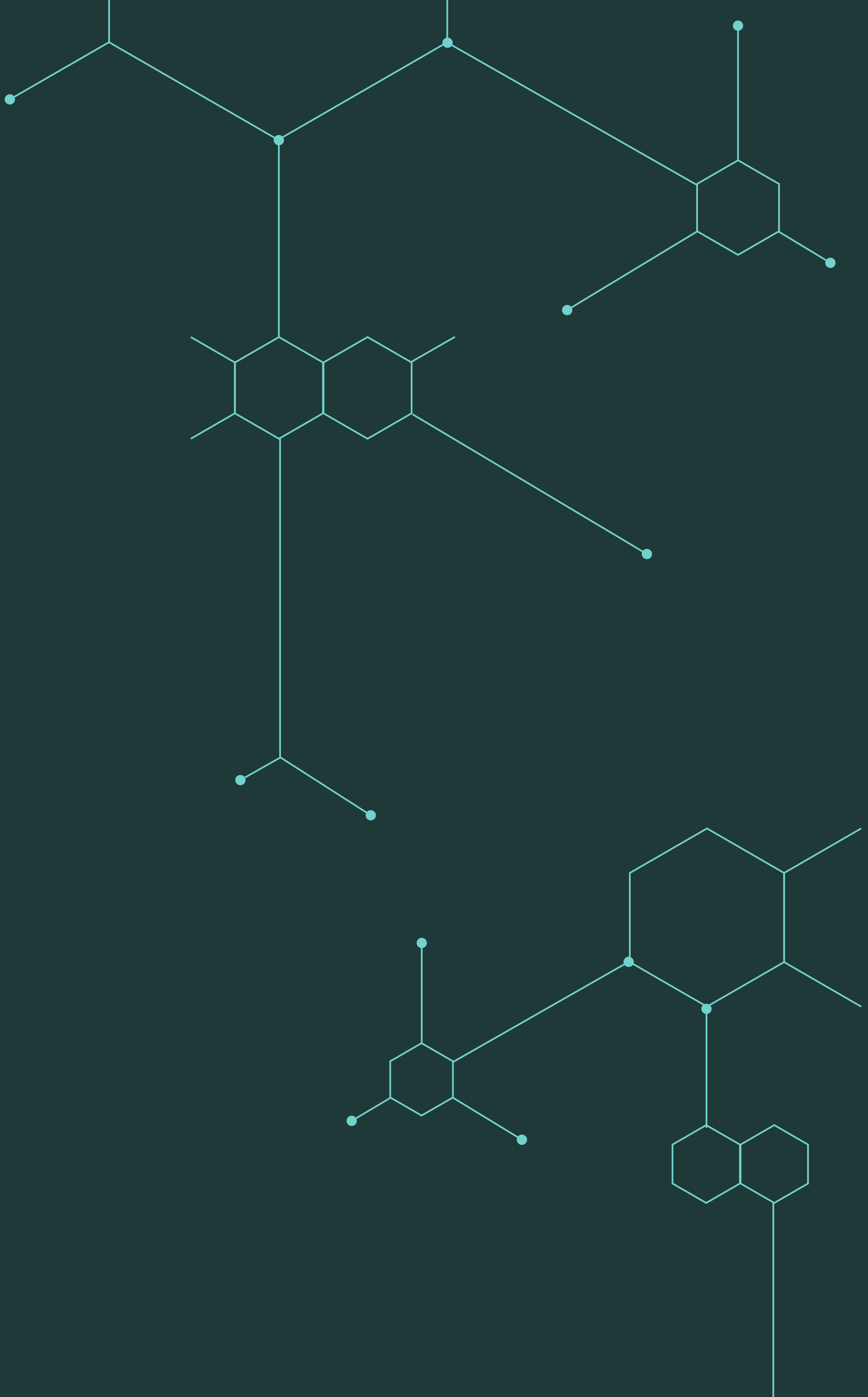

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