



# Towards sustainable transitions for the global food system

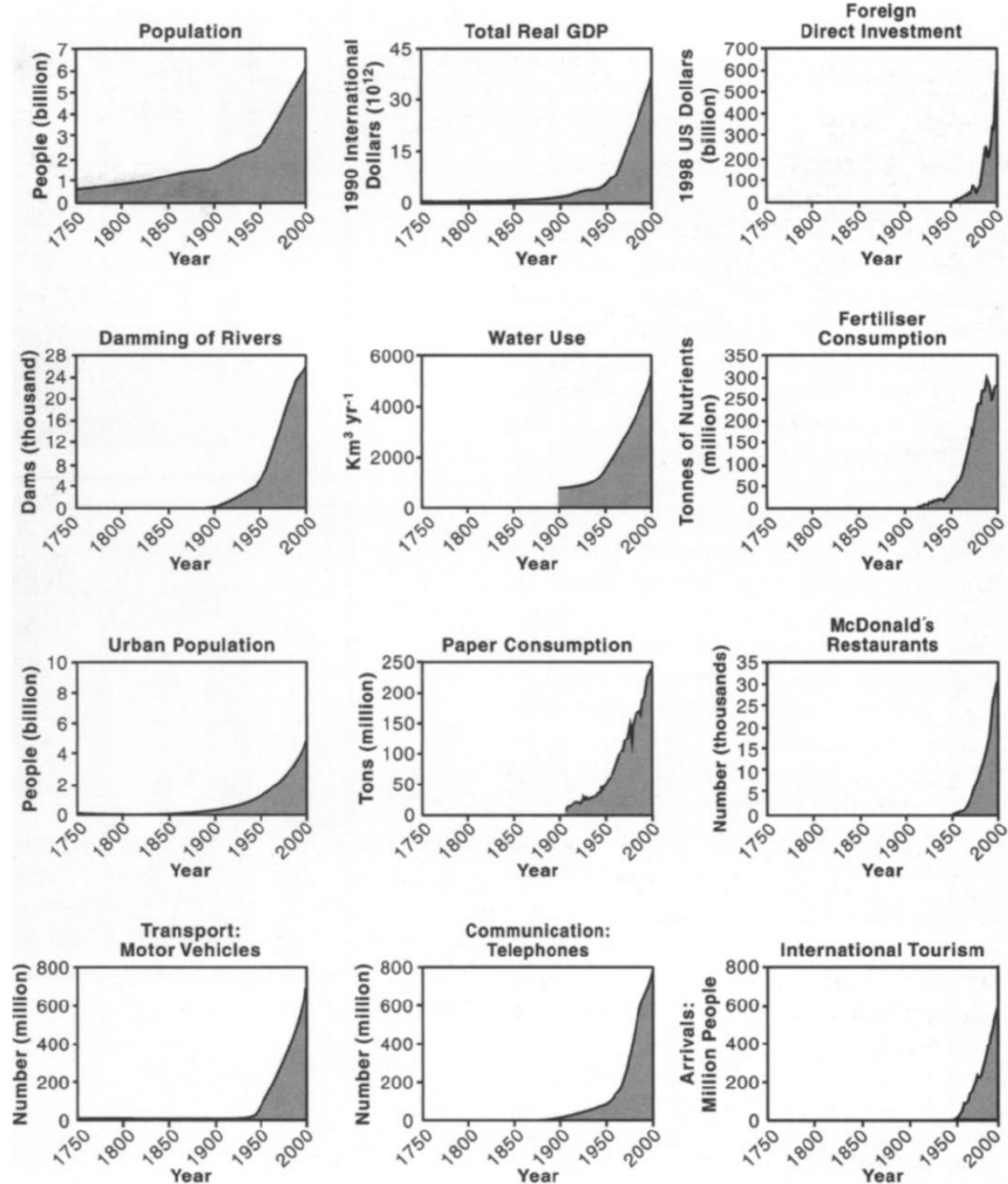
Mario Herrero



# The Anthropocene...

...the age of human - induced global change

Steffen et al. 2011





# The key issues

## Malnutrition



More than **200 million** children under five still face a life adversely affected by early years of undernutrition.<sup>3</sup>

## Climate change



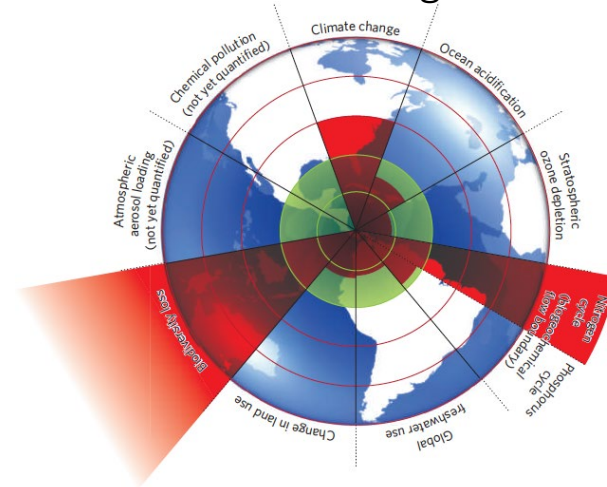
A low-income country with an annual average temperature today of **25°C** could see a fall in national economic growth (Gross Domestic Product or GDP) of **1.2%** for each **1°C** increase in temperature.<sup>8</sup>

## NCDs and their costs



The burden of diet-related disease is highest in LMICs; for diabetes alone, by 2030 (assuming present trends) the annual economic impact for East Asia and the Pacific region is expected to reach almost **US\$800 billion**, and **US\$52 billion** in sub-Saharan Africa.<sup>4</sup>

## Environmental degradation

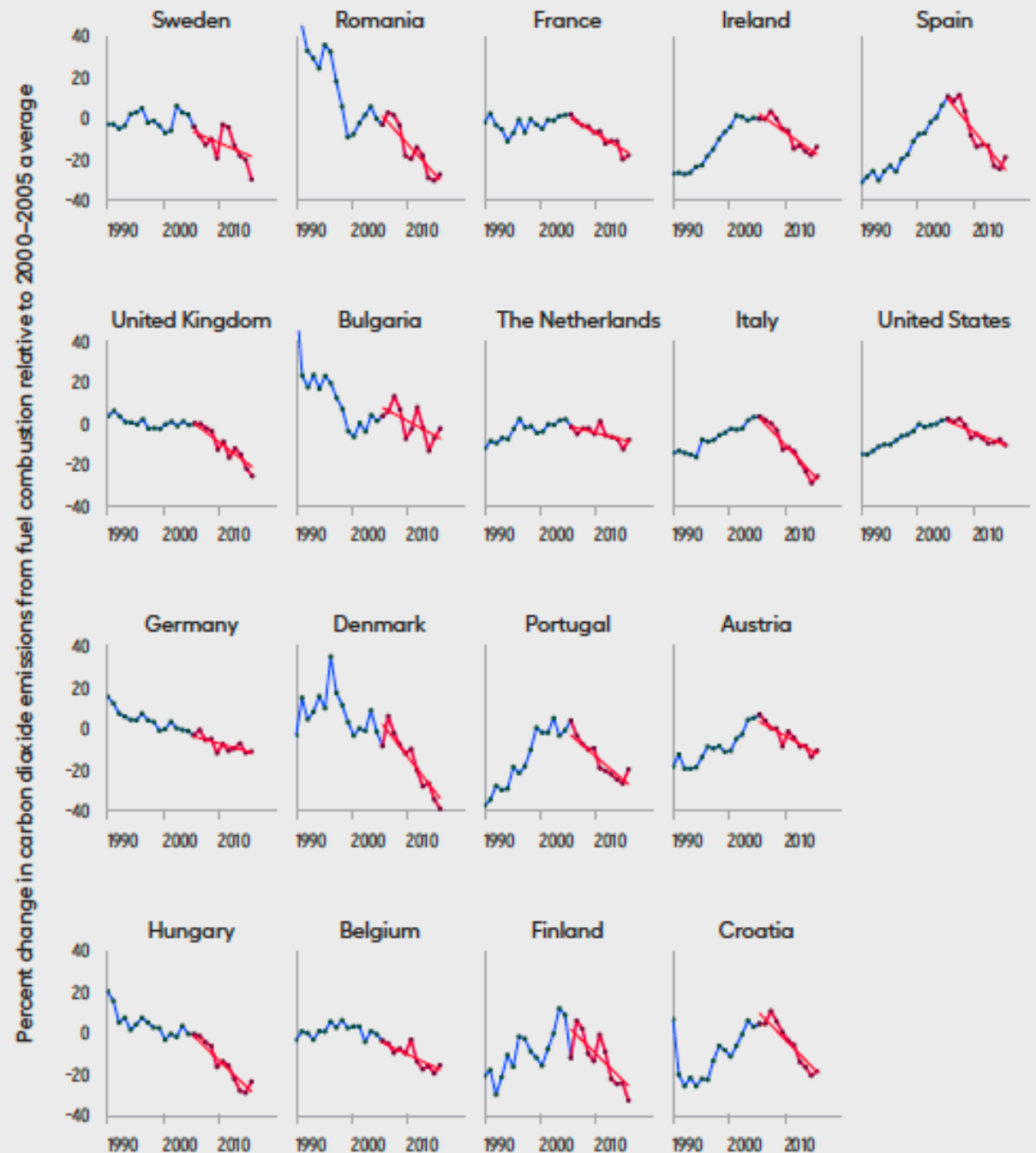


+ power asymmetries and policy distortions!

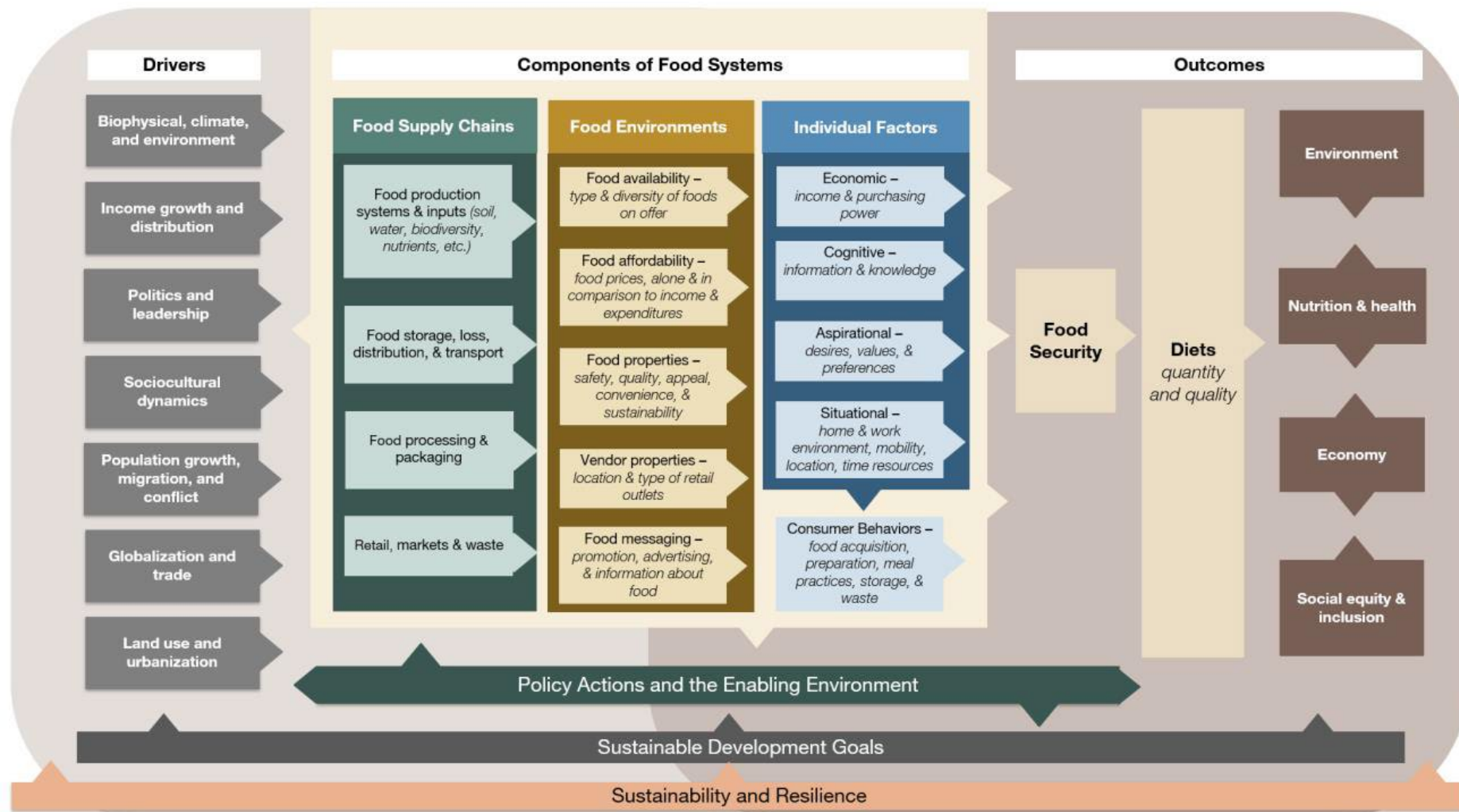
Energy  
transitions  
occurring in  
some  
countries

Investment  
Legislation  
Regulation  
Targets  
Subsidies

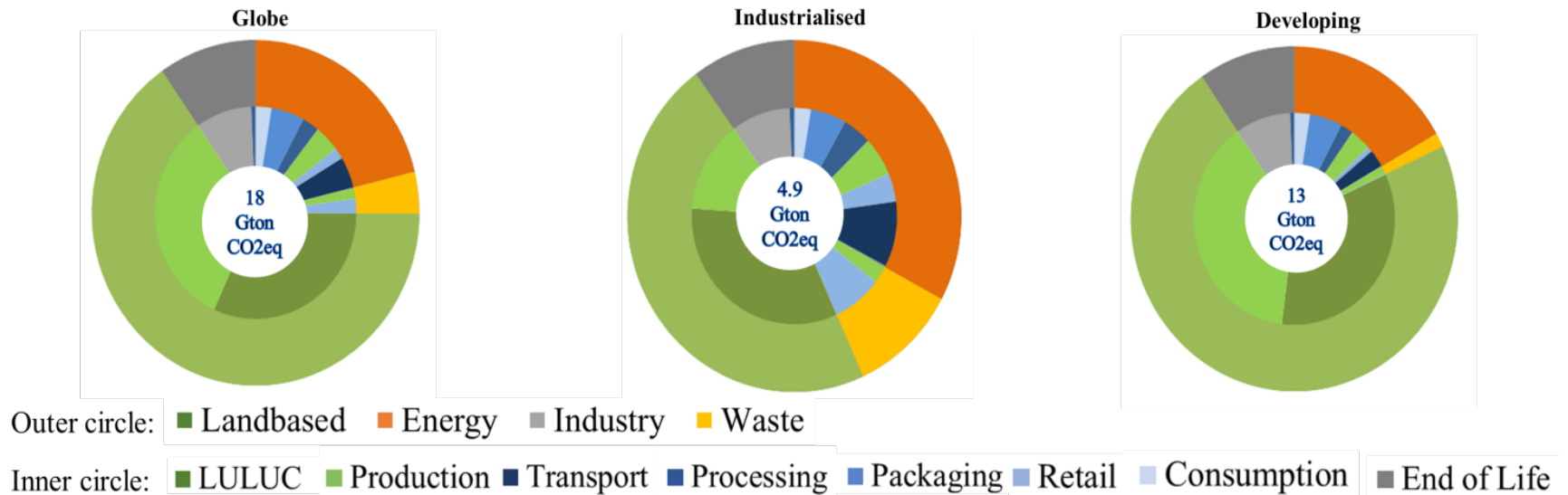
HDR 2020



# The food system



# Emissions from global food systems



Crippa et al. Nature Food 2021

21-37% of anthropogenic emissions – Rosenzweig et al 2020

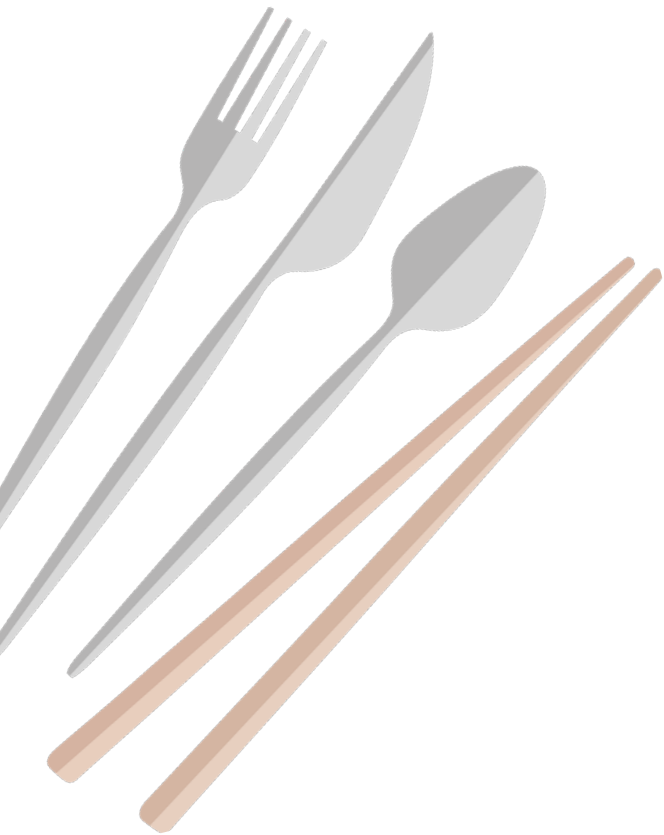
30-40% of food is wasted – SOFA 2019

70% of consumptive water use – Heinke et al 2020

Land use change major cause of biodiversity decline – Leclere et al. 2020







## Target 1 – Healthy Diets

2500 kcal/day



EAT-Lancet: Not only about diets, increases in productivity and waste reduction essential for achieving targets

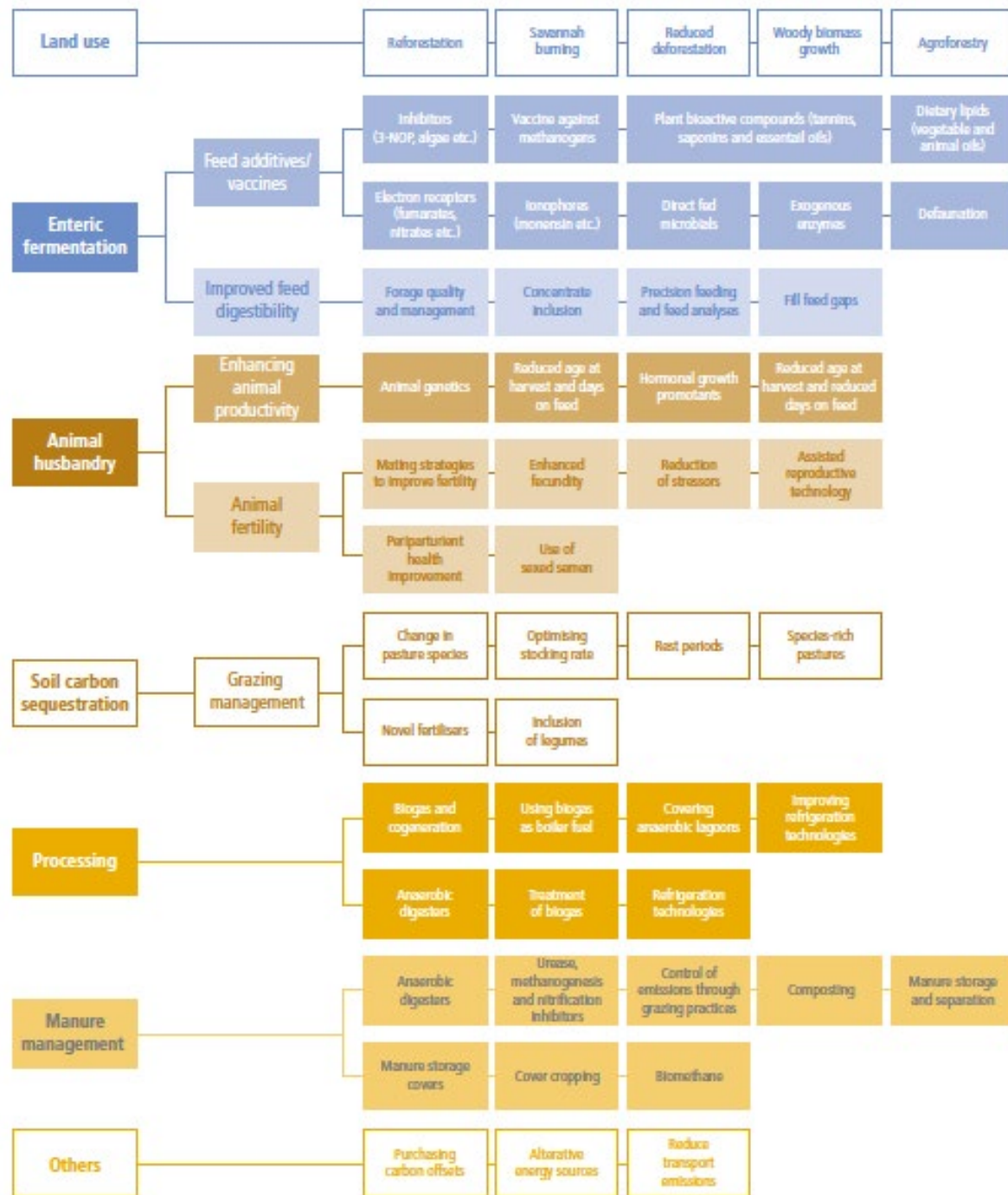
## Scenarios

								
Food production boundary			GHG emissions	Cropland use	Water use	Nitrogen application	Phosphorus application	Biodiversity loss
Baseline in 2010			5.0 (4.7–5.4)	13 (11.0–15.0)	2.5 (1.0–4.0)	90 (65.0–140.0)	8 (6.0–16.0)	10 (1–80)
Production (2050)	Waste (2050)	Diet (2050)						
BAU	Full waste	BAU	9.8	21.1	3.0	199.5	27.5	1,043
BAU	Full waste	Dietary shift	5.0	21.1	3.0	191.4	25.5	1,270
BAU	Halve waste	BAU	9.2	18.2	2.6	171.0	23.2	684
BAU	Halve waste	Dietary shift	4.5	18.1	2.6	162.6	21.2	885
PROD	Full waste	BAU	8.9	14.8	2.2	187.3	25.5	206
PROD	Full waste	Dietary shift	4.5	14.8	2.2	179.5	24.1	351
PROD	Halve waste	BAU	8.3	12.7	1.9	160.1	21.5	50
PROD	Halve waste	Dietary shift	4.1	12.7	1.9	151.7	20.0	102
PROD+	Full waste	BAU	8.7	13.1	2.2	147.6	16.5	37
PROD+	Full waste	Dietary shift	4.4	12.8	2.1	140.8	15.4	34
PROD+	Halve waste	BAU	8.1	11.3	1.9	128.2	14.2	21
PROD+	Halve waste	Dietary shift	4.0	11.0	1.9	121.3	13.1	19

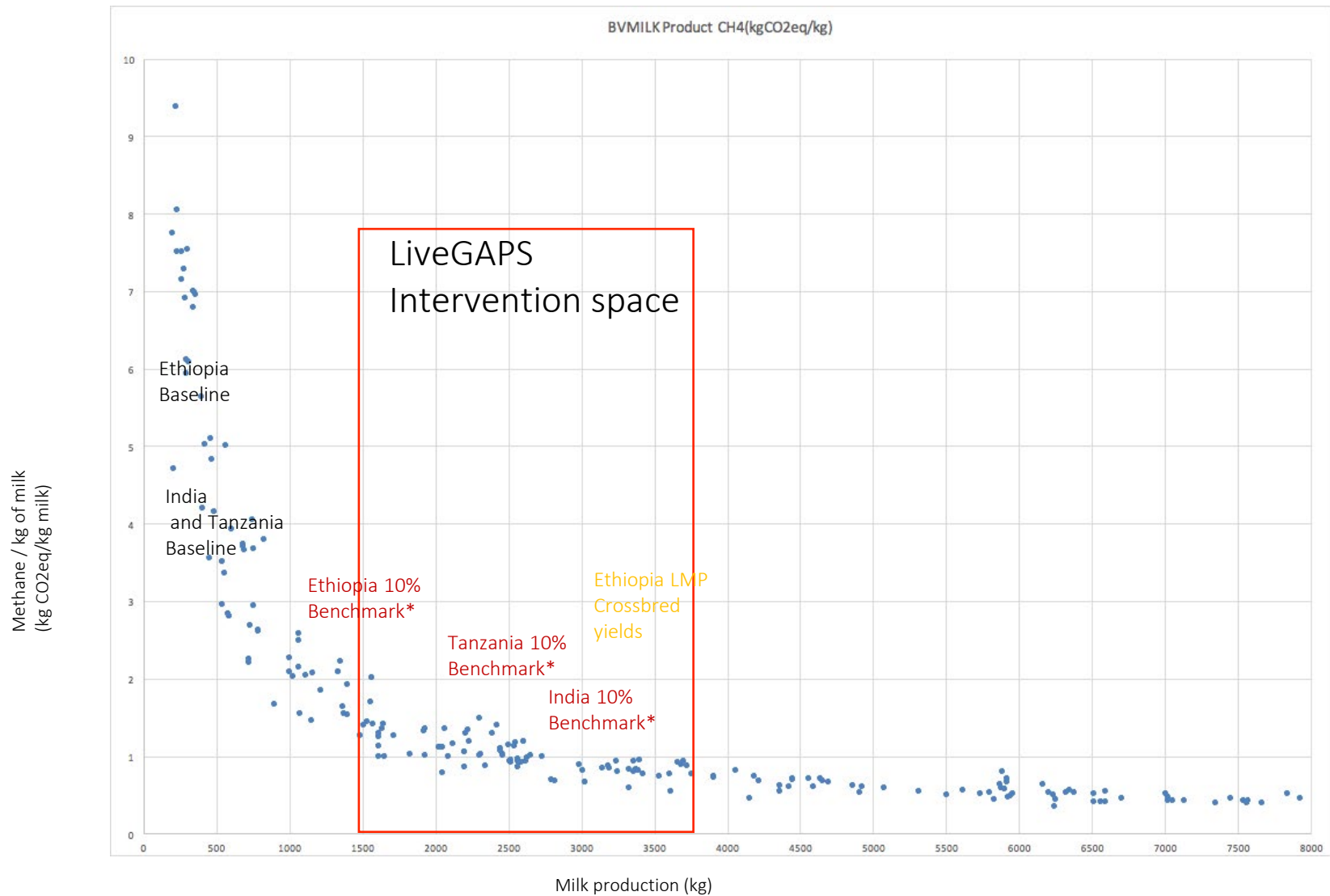


# Mitigation practices in livestock systems

IPCC SRCCL 2020



## Putting it in the BMGF context - The LiveGAPS data



\*10% benchmark – emissions intensities of the top 10% of smallholder producers

# Mitigation, adaptation and co-benefits of food systems responses

## How fast, how soon?

comment

Check for updates

### Climate change responses benefit from a global food system approach

A food system framework breaks down entrenched sectoral categories and existing adaptation and mitigation silos, presenting novel ways of assessing and enabling integrated climate change solutions from production to consumption.

Cynthia Rosenzweig, Cheikh Mbow, Luis G. Barioni, Tim G. Benton, Mario Herrero, Murugesan Krishnaswami, Emma T. Liwenga, Prajal Pradhan, Marta G. Rivera-Ferre, Tek Sapkota, Francesco N. Tubiello, Yinlong Xu, Erik Mencos Contreras and Joana Portugal-Pereira

Food systems have not been cast effectively in either the Intergovernmental Panel on Climate Change (IPCC) or the United Nations Framework Convention on Climate Change (UNFCCC) greenhouse gas (GHG) emissions inventory guidelines<sup>1,2</sup>. Food-related emissions from agriculture, transport, industry and household consumption have traditionally been reported separately, irrespective of fundamental connections between food demand and farm-level production. Unless these are conceptualised as a unified whole, climate change mitigation and adaptation strategies associated with the food system are likely to be inefficient and possibly counterproductive.

IPCC measurement protocols form the basis of national reporting under the UNFCCC and the Paris Agreement<sup>3</sup>, and the planned global stocktake due in 2023. Yet, a food system approach could be much more useful for countries designing the next stage of their nationally determined contributions as well as for the international community by improving how climate change and agriculture are addressed in three fundamental ways.

First, it would liberate agriculture from the 'agriculture, forestry, and other land use' (AFOLU) category of national greenhouse gas emissions inventories, so that the contribution of the global food system to total anthropogenic GHG emissions can be comprehensively calculated. This provides a much clearer picture of emission sources, thereby allowing for the design of more effective response options and the engagement of an expanded set of actors.

Second, a systemic approach facilitates the design of integrated adaptation and mitigation policies, which bring together supply-side (that is, crop and livestock production, processing, storage and

**Table 1** Comparison of 2007–2016 mean values and standard deviations of emissions from AFOLU and global food system emissions by component, including food loss and waste

Components	Emissions (GtCO <sub>2</sub> e yr <sup>-1</sup> ) <sup>a</sup>	Percentage of anthropogenic GHG emissions (%) <sup>a</sup>	Emissions (GtCO <sub>2</sub> e yr <sup>-1</sup> ) <sup>b</sup>	Percentage of anthropogenic GHG emissions (%) <sup>b</sup>
Agriculture	6.2 ± 1.4	9.34	6.2 ± 1.4	9.34
FOUL	5.8 ± 2.6	6.36	4.9 ± 2.5	5.34
Pre- to post-production	-	-	2.6–5.2	5–10 <sup>c</sup>
Total	12.0 ± 2.9	18–20	10.8–10.1	25–37

<sup>a</sup>Mean and 50% confidence interval, using global warming potential (GWP) values of the IPCC AR5 with no climate feedback (GWP-CG), at 2007–2016 (2010–2012). <sup>b</sup>Computed using a total emissions value for the period 2007–2016 of 62 GtCO<sub>2</sub>e per year. <sup>c</sup>Food-related FOUL for two separate categories. <sup>d</sup>Reported to represent 60% uncertainty due to assumed conversion factors.

**Table 2** Food system supply-side and demand-side technical and economic mitigation potential<sup>a</sup>

	Mitigation potential (GtCO <sub>2</sub> e yr <sup>-1</sup> )	Supply side (GtCO <sub>2</sub> e yr <sup>-1</sup> )	Demand side (GtCO <sub>2</sub> e yr <sup>-1</sup> )
Technical	2.3–9.6	0.7–8.0	
Economic	1.5–4.0 <sup>b</sup>	1.8–3.4 <sup>b</sup>	

<sup>a</sup>By 2050 at prices ranging from 20–400 USD per tCO<sub>2</sub>e. <sup>b</sup>By 2050 at prices ranging from 20–400 USD per tCO<sub>2</sub>e.

transport) and demand-side (that is, dietary change) measures. Reducing food loss and waste as a response strategy is also best addressed across the entire food system.

Third, it provides the relevant framework to identify, analyse and address synergies and trade-offs among different climate change responses, primarily in relation to the potential competition for land to satisfy projected demand for food versus land to contribute to mitigation of climate change (through bioenergy and carbon sequestration). Relevant assessments involve the combined potential of dietary change, reduction of food loss and waste, and 'land-sparing' strategies that enable

simultaneous food production, adaptation and mitigation activities.

**Food system GHG emissions**

The addition of GHG emissions from energy use, supply chains and consumption activities to those emitted within the farm gate provides a much more comprehensive depiction of how food is contributing to climate change (Table 1). The result is an overall contribution of a considerable 21–37% of total anthropogenic emissions, compared to 18–20% from agriculture combined with land-use change for food production (deforestation and peatland degradation) and ~10% from agriculture

Improved crop management

Improved livestock management

Climate services

Improved supply chain

Demand management

Food system responses	Mitigation	Adaptation	Co-benefits
Increased soil organic matter content	Very high	High	Livelihoods, biodiversity
Change in crop variety	Limited	High	Livelihoods, biodiversity
Improved water management	Limited	High	Livelihoods, water
Adjustment of planting dates	None	High	Livelihoods
Precision fertilizer management	High	High	Livelihoods, pollution
Integrated pest management	None	High	Livelihoods, biodiversity
Counter-season crop production	None	High	Livelihoods, biodiversity
Biochar application	High	High	Livelihoods
Agroforestry	High	High	Livelihoods, biodiversity
Changing monoculture to crop diversification	Limited	High	Livelihoods, biodiversity
Changes in cropping area, land rehabilitation (enclosures, afforestation), perennial farming	High	High	Livelihoods, biodiversity
Tillage and crop establishment	High	High	Livelihoods, biodiversity
Residue management	High	High	Biodiversity
Crop–livestock systems	High	High	Livelihoods, biodiversity
Silvopastoral systems	High	High	Livelihoods, biodiversity
New livestock breeds	Limited	High	Livelihoods
Livestock fattening	Limited	High	Livelihoods
Shifting to small ruminants or drought-resistant livestock or fish farming	Limited	High	Livelihoods
Feed and fodder banks	High	High	Livelihoods, biodiversity
Methane inhibitors	High	None	
Thermal stress control	Limited	High	Livelihoods, energy
Seasonal feed supplementation	High	High	Livelihoods, biodiversity
Improved animal health and parasite control	High	High	Livelihoods
Early warning systems	None	High	Livelihoods
Planning and prediction for seasonal-to-intraseasonal climate risk	None	High	Livelihoods
Crop and livestock insurance	High	High	Livelihoods
Food storage infrastructure	Limited	High	Livelihoods
Shortening supply chains	Limited	High	Livelihoods, energy
Improved food transport and distribution	High	High	Livelihoods
Improved efficiency and sustainability of food processing, retail and agrifood industries	High	High	Livelihoods
Improved energy efficiencies of agriculture	High	High	Energy
Reduced food loss	High	High	Livelihoods
Urban and peri-urban agriculture	Limited	High	Livelihoods, biodiversity
Bioenergy (for example, energy from waste)	None	Limited	Livelihoods, energy
Dietary changes	High	High	Health
Reduced food waste	High	High	Water, energy
Packaging reductions	Limited	High	Pollution
New ways of marketing (for example, direct sales)	Limited	Limited	Livelihoods, energy
Transparency of food chains and external costs	High	High	Health, energy, water

Mitigation and adaptation potential

None

Limited

High

Very high

Rosenzweig et al. 2020 Nature Food

Policy measures  
for supporting  
adaptation and  
mitigation

Plenty of great lists  
but ZERO  
accountability!

Mbow et al. 2020 SRCCL

**Table 5.6 | Potential policy ‘families’ for food-related adaptation and mitigation of climate change. The column ‘scale’ refers to scale of implementation: International (I), national (N), sub-national-regional (R), and local (L).**

Family	Sub-family	Scale	Interventions	Examples
Supply-side efficiency	Increasing agri-cultural efficiency and yields	I, N	Agricultural R&D	Investment in research, innovation, knowledge exchange, e.g., on genetics, yield gaps, resilience
		I, N	Supporting precision agriculture	Agricultural engineering, robotics, big data, remote sensing, inputs
		I, N	Sustainable intensification projects	Soils, nutrients, capital, labour (Cross-Chapter Box 6)
		N, R	Improving farmer training and knowledge sharing	Extension services, online access, farmer field schools, farmer-to-farmer networks (CABI 2019)
	Land-use planning	N, R, L	Land-use planning for ecosystem services (remote sensing, ILK)	Zoning, protected area networks, multifunctional landscapes, ‘land sparing’ (Cross-Chapter Box 6; Benton et al. 2018; Jones et al. 2013)
		N, R, L	Conservation agriculture programmes	Soil and water erosion control, soil quality improvement (Conservation Evidence 2019)
		N	Payment for ecosystem services	Incentives for farmers/landowners to choose lower-profit but environmentally benign resource use, e.g., Los Negros Valley in Bolivia (Ezzine-de-Blas et al. 2016)
	Market approaches	I, N	Mandated carbon cost reporting in supply chains; public/private incentivised insurance products	Carbon and natural capital accounts (CDP 2019), crop insurance (Müller et al. 2017a)
	Trade	I	Liberalising trade flows; green trade	Reduction in GHG emissions from supply chains (Neumayer 2001)
Raising profitability and quality	Stimulating markets for premium goods	N, R	Sustainable farming standards, agroecology projects, local food movements	Regional policy development, public procurement of sustainable food (Mairie de Paris 2015)
Modifying demand	Reducing food waste	I, N, L	Regulations, taxes	‘Pay-As-You-Throw (PAYT)’ schemes; EU Landfill Directives; Japan Food Waste Recycling Law 2008; South Africa Draft Waste Classification and Management Regulations 2010 (Chalak et al. 2016)
		I, N, L	Awareness campaigns, education	FAO Global Initiative on Food Loss and Waste Reduction (FAO 2019b)
		I, N	Funding for reducing food waste	Research and investment for shelf life, processing, packaging, cold storage (MOFPI 2019)
		I, N, L	Circular economy using waste as inputs	Biofuels, distribution of excess food to charities (Baglioni et al. 2017)
	Reducing consumption of carbon-intensive food	I, N, L	Carbon pricing for selected food commodities	Food prices reflective of GHG gas emissions throughout production and supply chain (Springmann et al. 2017; Hasegawa et al. 2018)
		I, N, L	Changing food choice through education	Nutritional and portion-size labelling, ‘nudge’ strategies (positive reinforcement, indirect suggestion) (Arno and Thomas 2016)
		I, N, L	Changing food choices through money transfers	Unconditional cash transfers; e-vouchers exchanged for set quantity or value of specific, pre-selected goods (Fenn 2018)
		N, L	Changing food environments through planning	Farmers markets, community food production, addressing ‘food deserts’ (Ross et al. 2014)
	Combining carbon and health objectives	I, N, L	Changing subsidies, standards, regulations to healthier and more sustainably produced foods	USDA’s ‘Smart Snacks for School’ regulation mandating nutritional guidelines (USDA 2016) Incentivising production via subsidies (direct to producer based on output or indirect via subsidising inputs)
		N	Preventative versus curative public healthcare incentives	Health insurance cost reductions for healthy and sustainable diets
		I, N, L	Food system labelling	Organic certification, nutrition labels, blockchain ledgers (Chadwick 2017)
		N, L	Education and awareness campaigns	School curricula; public awareness campaigns
		N, L	Investment in disruptive technologies (e.g., cultured meat)	Tax breaks for R&D, industrial strategies (European Union 2018)
		N, L	Public procurement	For health: Public Procurement of Food for Health (Caldeira et al. 2017) For environment: Paris Sustainable Food Plan 2015–2020 Public Procurement Code (Mairie de Paris 2015)





# Innovation can accelerate the transition towards a sustainable food system

Mario Herrero<sup>1</sup>✉, Philip K. Thornton<sup>2</sup>, Daniel Mason-D'Croz<sup>3</sup>, Jeda Palmer<sup>1</sup>, Tim G. Benton<sup>3</sup>, Benjamin L. Bodirsky<sup>4</sup>, Jessica R. Bogard<sup>1</sup>, Andrew Hall<sup>1</sup>, Bernice Lee<sup>3</sup>, Karine Nyborg<sup>5</sup>, Prajal Pradhan<sup>4</sup>, Graham D. Bonnett<sup>1</sup>, Brett A. Bryan<sup>6</sup>, Bruce M. Campbell<sup>7,8</sup>, Svend Christensen<sup>7</sup>, Michael Clark<sup>9</sup>, Mathew T. Cook<sup>1</sup>, Imke J. M. de Boer<sup>10</sup>, Chris Downs<sup>1</sup>, Kanar Dizyee<sup>1</sup>, Christian Folberth<sup>11</sup>, Cecile M. Godde<sup>1</sup>, James S. Gerber<sup>12</sup>, Michael Grundy<sup>1</sup>, Petr Havlik<sup>11</sup>, Andrew Jarvis<sup>8</sup>, Richard King<sup>13</sup>, Ana Maria Loboguerrero<sup>8</sup>, Mauricio A. Lopes<sup>11</sup>, C. Lynne McIntyre<sup>1</sup>, Rosamond Naylor<sup>13</sup>, Javier Navarro<sup>1</sup>, Michael Obersteiner<sup>11</sup>, Alejandro Parodi<sup>10</sup>, Mark B. Peoples<sup>1</sup>, Ilje Pikaar<sup>14,15</sup>, Alexander Popp<sup>4</sup>, Johan Rockström<sup>4,16</sup>, Michael J. Robertson<sup>1</sup>, Pete Smith<sup>17</sup>, Elke Stehfest<sup>18</sup>, Steve M. Swain<sup>1</sup>, Hugo Valin<sup>11</sup>, Mark van Wijk<sup>19</sup>, Hannah H. E. van Zanten<sup>10</sup>, Sonja Vermeulen<sup>3,20</sup>, Joost Vervoort<sup>21</sup> and Paul C. West<sup>12</sup>

Future technologies and systemic innovation are critical for the profound transformation the food system needs. These innovations range from food production, land use and emissions, all the way to improved diets and waste management. Here, we identify these technologies, assess their readiness and propose eight action points that could accelerate the transition towards a more sustainable food system. We argue that the speed of innovation could be significantly increased with the appropriate incentives, regulations and social licence. These, in turn, require constructive stakeholder dialogue and clear transition pathways.



Herrero et al. 2020 Nat Food.

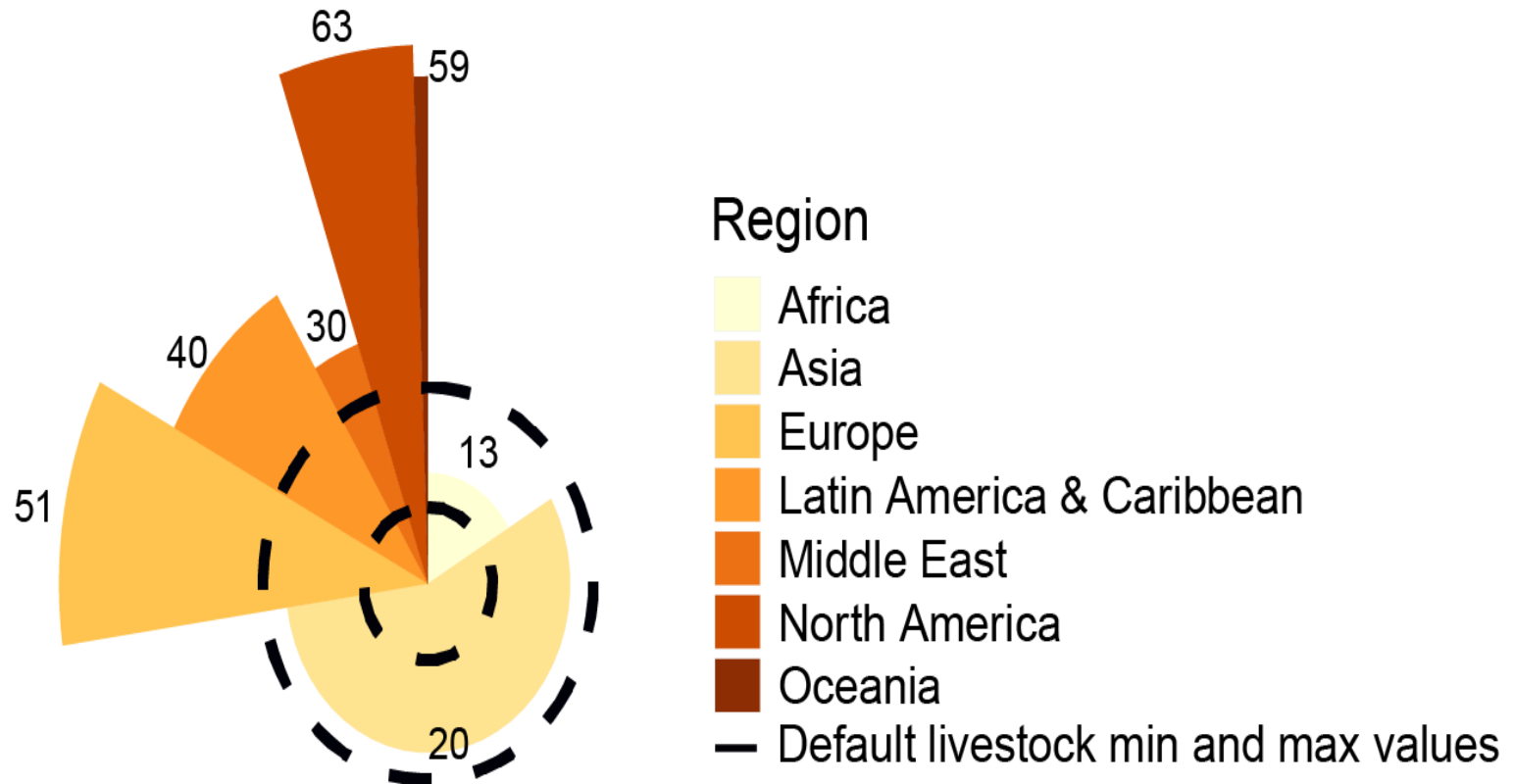
# Accelerators of food systems innovation



Herrero et al. Nature Food 2020

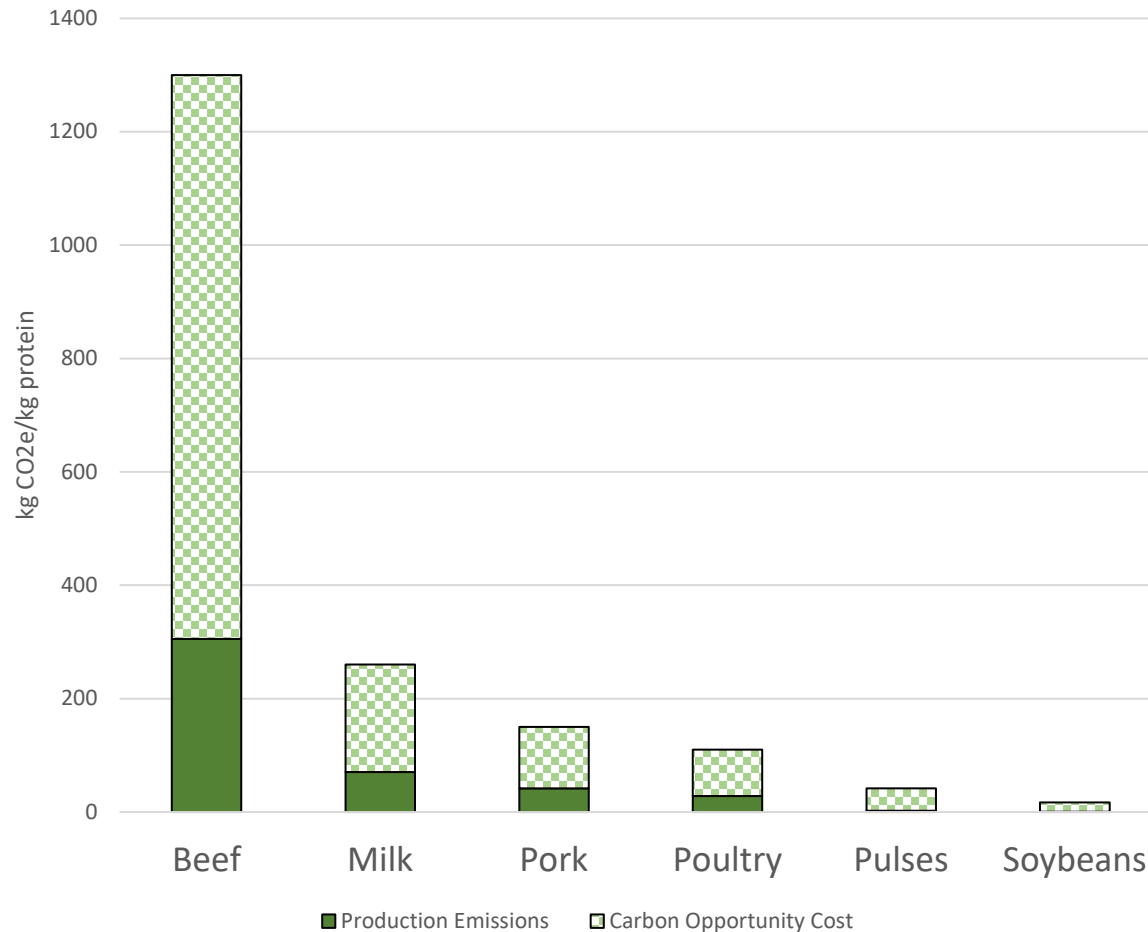
# The Circular Economy

## Decoupling livestock from land through a circular economy



# Back to better land use planning

## Account for the opportunity cost of land and carbon



Source: Searchinger et al., *Nature* (2018)



# The true cost of food is \$29 trillion dollars



United Nations Food Systems Summit 2021  
Scientific Group  
<https://sc-fss2021.org/>

A paper from the Scientific Group of the UN Food Systems Summit

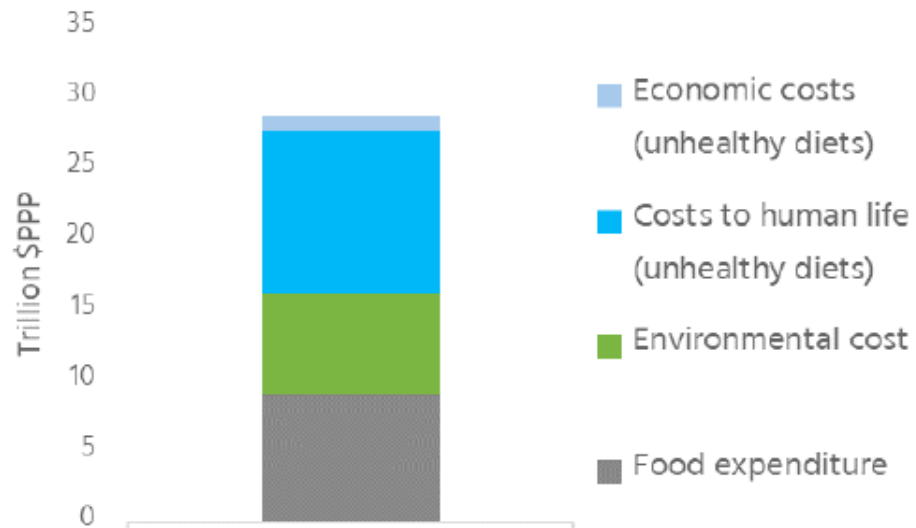
Draft

1 June 2021

## The True Cost and True Price of Food

By

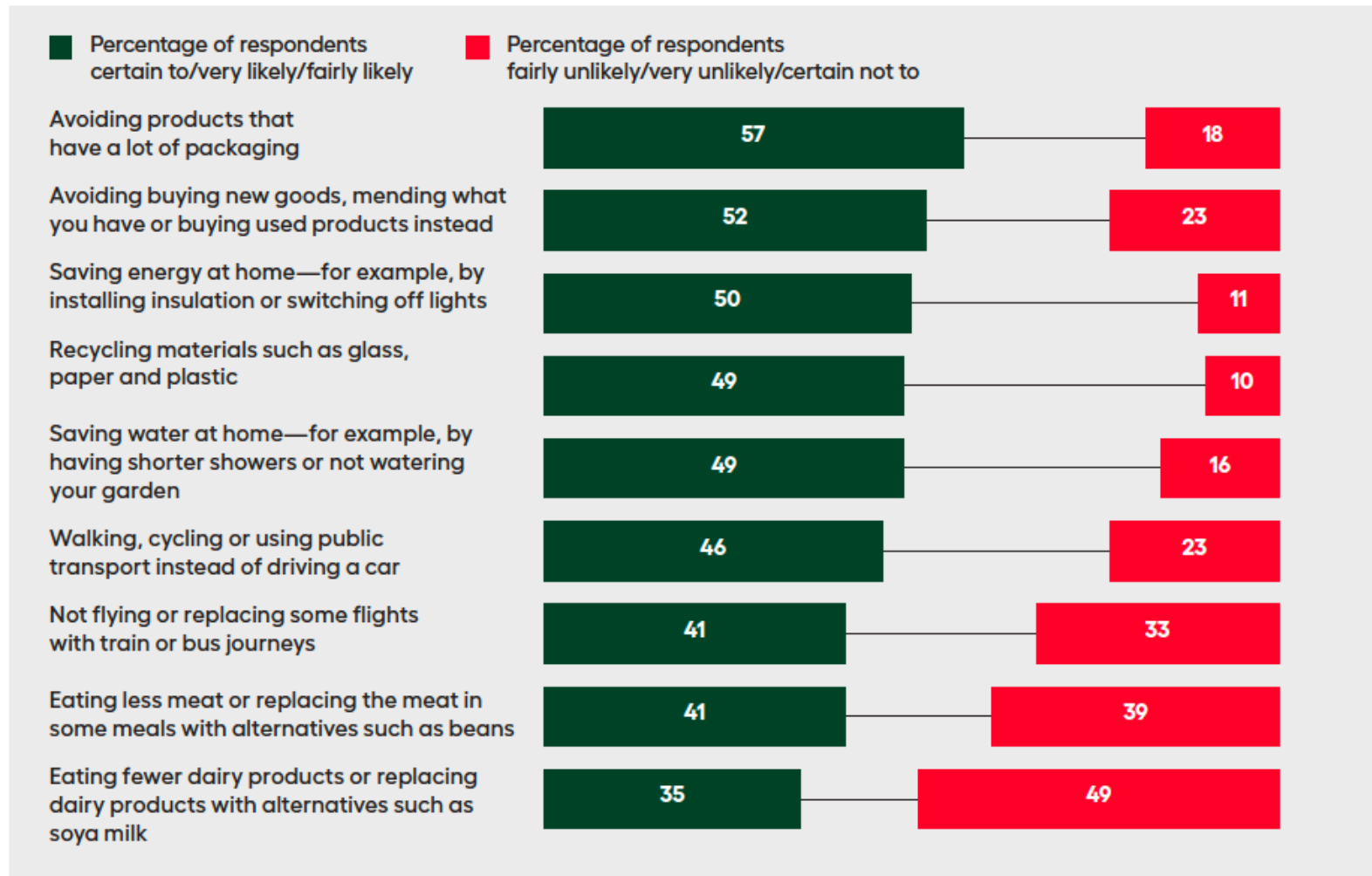
by Sheryl Hendriks, Adrian de Groot Ruiz, Mario Herrero Acosta, Hans Baumers,  
Pietro Galgani, Daniel Mason-D'Croz, Cecile Godde, Katharina Waha, Dimitra Kanidou,  
Joachim von Braun, Mauricio Benitez, Jennifer Blanke, Patrick Caron, Jessica Fanzo,  
Friederike Greb, Lawrence Haddad, Anna Herforth, Danie Jordaan, William Masters,  
Claudia Sadoff, Jean-François Soussana, Maria Cristina Tirado,  
Maximo Torero, Matthew Watkins



2/3 of the costs are currently not accounted for!!

Hendriks et al. 2021

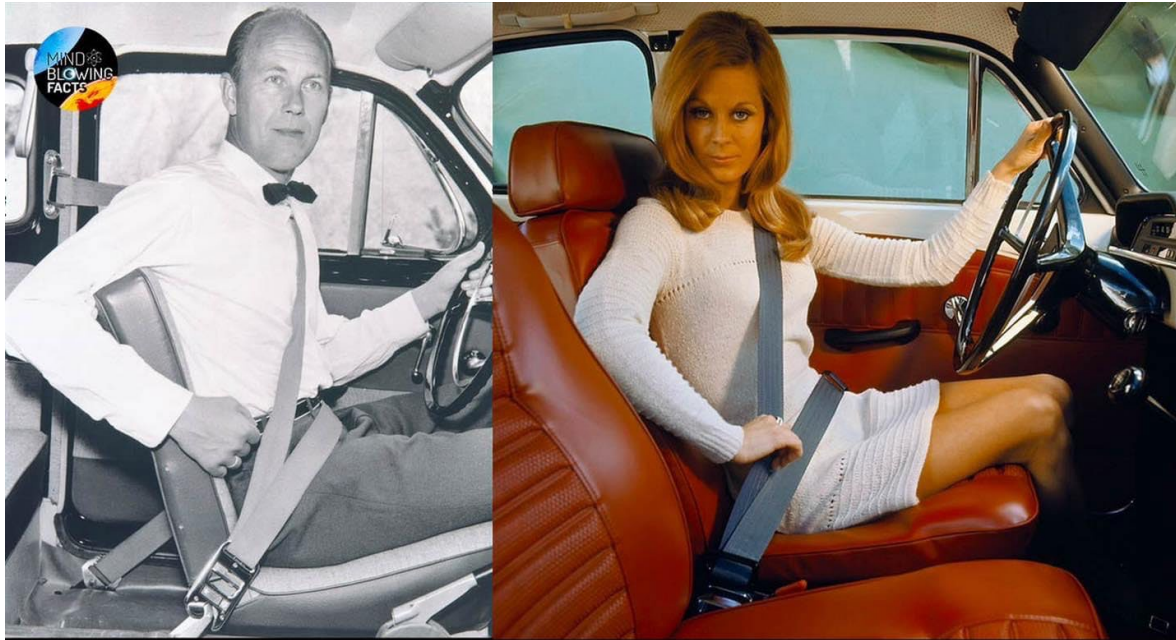
# A behavioural change revolution occurring



**Note:** Reflects online responses by 20,590 adults ages 16–74 to the question “Thinking about things you might do in order to limit your own contribution to climate change, how likely or unlikely would you be to make the following changes within the next year?”

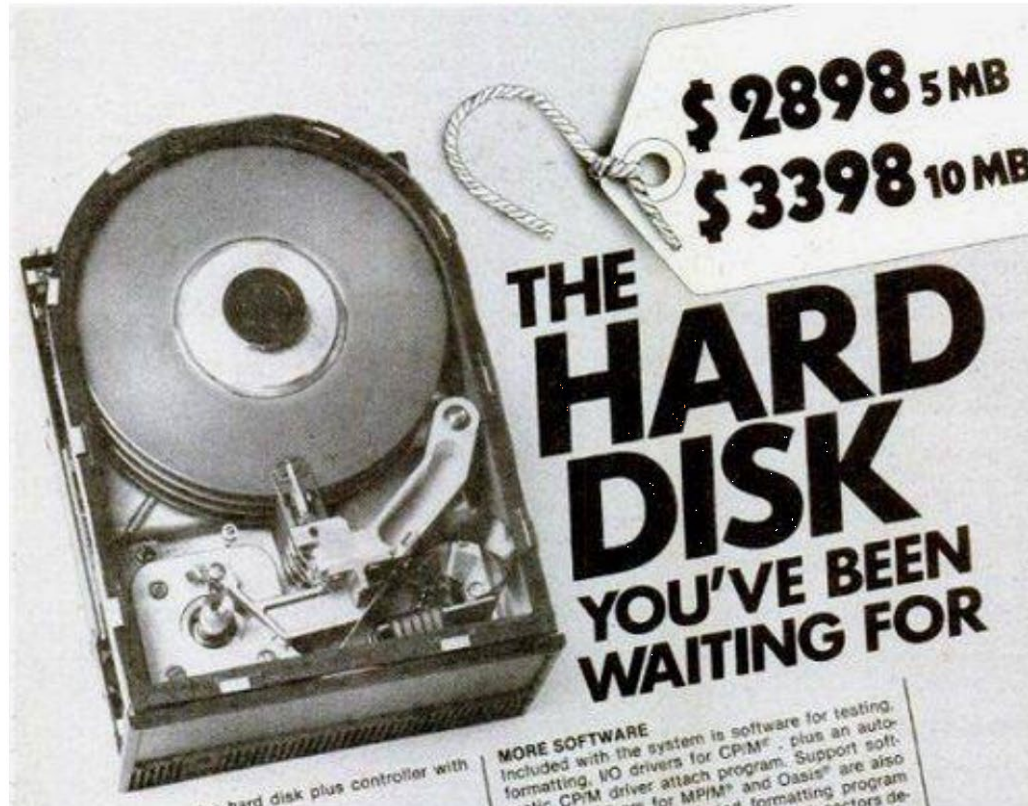
**Source:** IPSOS Global Advisor 2020.

# Responsible behaviour will help drive change



**When Volvo invented the three-point seat belt in 1959, they made the patent free for all competitors to use in order to save lives because it had more value as a free life-saving tool than something to profit from.**

It will be expensive at the beginning, but the costs of inaction will be even higher!





# Thank you

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