Assessing the role of livestock production systems and changing diets in meeting the Global Methane Pledge

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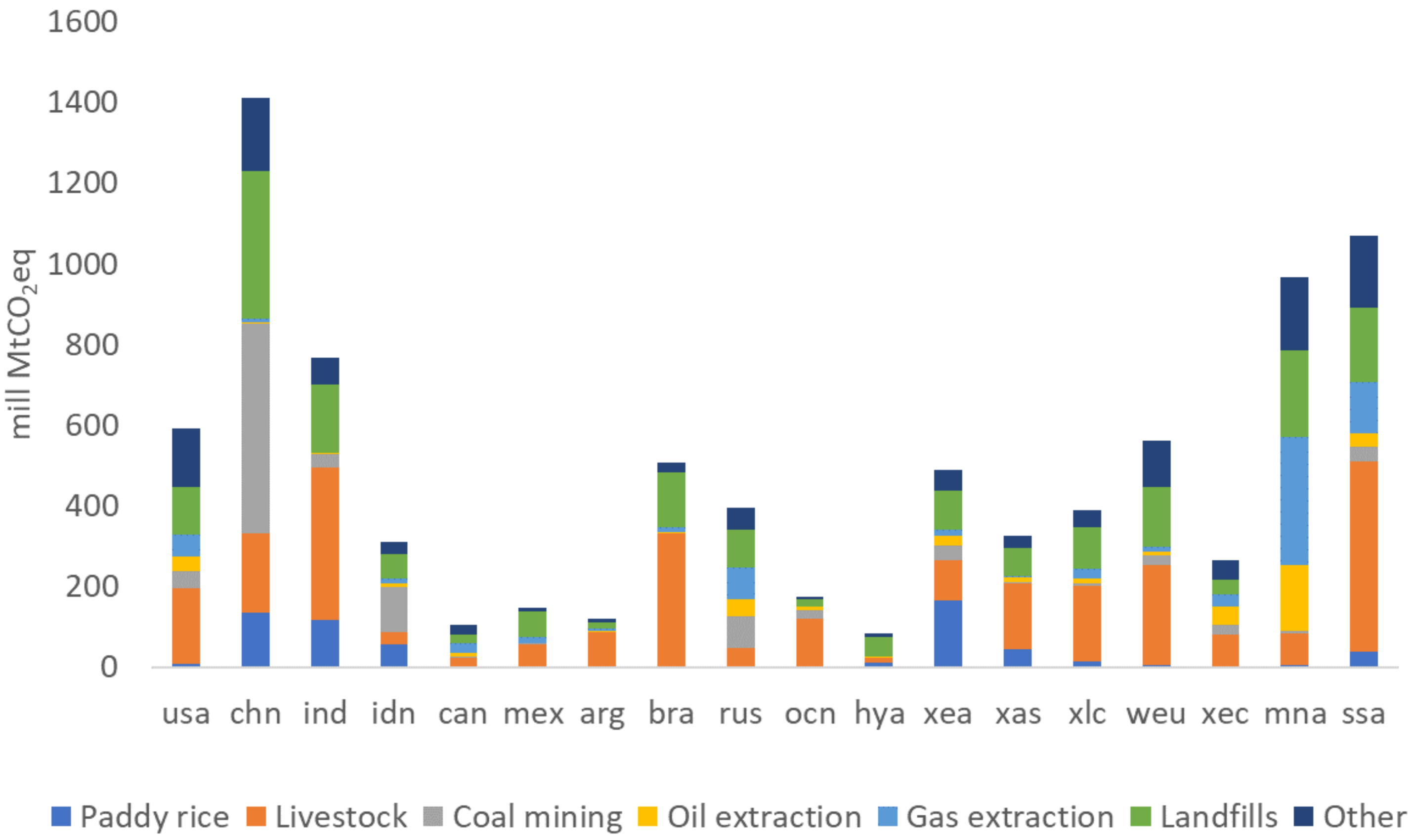
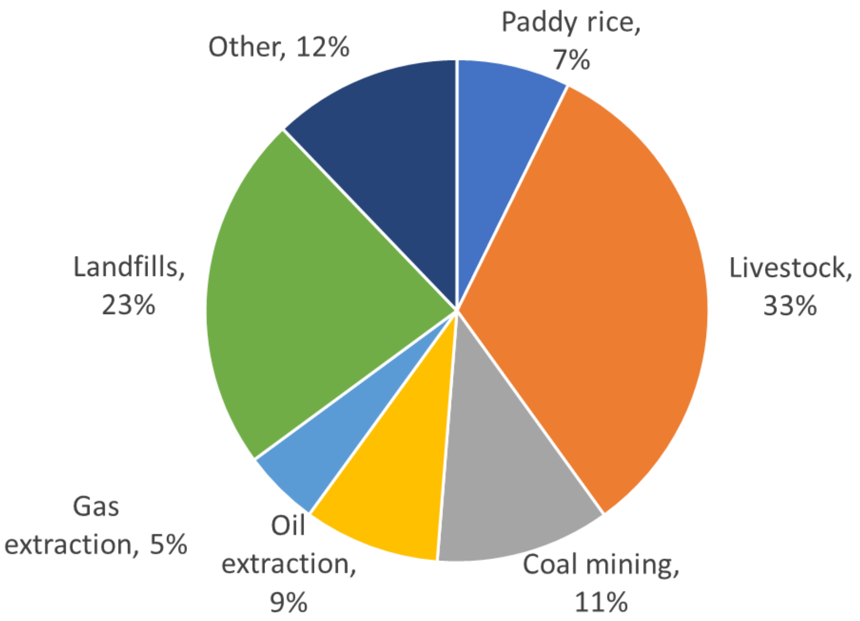
Introduction

- Methane belongs to a class of “super pollutants”
  - In comparison to carbon dioxide, methane has a much shorter atmospheric lifetime but absorbs much more energy
  - Major precursor to ground-level ozone, which harms human health, agriculture, and ecosystems
- Global Methane Pledge (GMP) initiative
  - Launched in 2021
  - 159 countries plus the European Union committed to cut global methane emissions 30% below 2020 levels by 2030
- Growth of anthropogenic methane emissions decelerated, but global level continues to increase
  - GMP non-participants (China, India, Russia, Iran) increased methane
  - 95 of 160 GMP participants exhibited either stable or rising methane emissions between 2020 and 2023 (Guo et al. 2025)
  - In 2030, methane emissions are projected to increase 5% above the 2020 level (UN Environmental Programme 2025)

Methane emissions: sources and countries

- Major sources
  - Agriculture (livestock, paddy rice)
  - Fossil fuel extraction
  - Waste





- Major emitters
  - China
  - India
  - The United States
  - Brazil
  - Russia

Source: GTAP database v. 11

Measures to reduce methane

- Substantial expansion of methane abatement efforts is required to achieve the GMP target
  - Technically still possible in the case of full implementation of proven technical methane abatement measures (UN Environmental Programme 2025)
- However, currently even developed countries are reluctant to impose stringent climate policies on the agricultural sectors (Leahy et al. 2020)
  - Only 4% of the second round of NDCs have time-bound agricultural methane emission reduction targets (Crumpler et al. 2024)
- Policy measures
  - Supply-side instruments
    - Performance and equipment standards, price on methane, reward for reduction
  - Demand-side instruments that affect methane indirectly
    - Meat consumption taxes, subsidies for plant-based foods, and dietary guidelines promoting low-meat diets

A shift to low-meat human diets

- Flexitarianism is a primarily plant-based diet that allows for the occasional consumption of meat or animal products
- A flexitarian version of the Planetary Health Diet (PHD) (Rockström et al. 2025; Willett et al. 2019) serves as the EAT-Lancet Commission's main solution to achieving two goals simultaneously:
  - Improving human health
    - Increasing intake of fruits, vegetables, legumes, nuts, and whole grains
    - Reducing diseases associated with excessive consumption of red meat and sugar, and unhealthy diets
  - Reducing environmental impacts
    - Lowering methane and other GHG emissions from food production
    - Reducing land use, fresh water use, and biodiversity loss

The flexitarian version of the Planetary Health Diet

	Per capita recommended intake (g/day [range])	Per capita recommended intake (kcal/day)
Plant foods*		
Whole grains†	210 (20–50% of daily energy intake)	735
Tubers and starchy roots‡	50 (0–100)	50
Vegetables§	300 (200–600)	95
Fruits¶	200 (100–300)	145
Tree nuts and peanuts	50 (0–75)	275
Legumes‖	75 (0–150)	275
Animal-sourced foods**		
Milk or equivalents (eg, cheese)	250 (0–500)	145
Chicken and other poultry	30 (0–60)	60
Fish and shellfish††	30 (0–100)	25
Eggs	15 (0–25)	20
Beef, pork, or lamb	15 (0–30)	45
Fats, sugar, and salt		
Unsaturated plant oils‡‡	40 (20–80)	355
Palm and coconut oil	6 (0–8)	55
Lard, tallow, and butter§§	5 (0–10)	..
Sugar (added or free)	30 (0–30)	115
Sodium	<2	..

Dietary targets for a healthy reference diet for adults, with possible ranges, for a population-level energy intake of approximately 2400 kcal/day. Source: Rockström et al. (2025)

Selected studies of GHG emissions in livestock sectors

- Patterns and drivers of methane emissions in global livestock sectors (Zhang et al. 2022)
- Potential and costs of reducing methane and other GHG emissions from agricultural activities (Golub et al. 2013; Henderson et al. 2018; Winchester and White 2022; Jensbye et al. 2023)
- Environmental impacts of changes in human diets (Springmann et al. 2023; Kuiper et al. 2025)

- Many existing studies modeling GHG emissions reduction in livestock sectors have relied on a highly aggregated representation of livestock sectors

Objectives

- Evaluate demand-side and supply-side methane reduction policies using a detailed representation of livestock production systems
  - Complementarity of demand-side and supply-side measures
  - Trade-offs and co-benefits of methane mitigation

Outline

- GTAP-LVS data base
- Results from the dietary shift scenario
- Next steps

Key inputs to construct GTAP-LVS data base

- Disaggregated GTAP-Power data base (Chepeliev 2023, Peters 2016b)
  - 76 sectors and 160 regions
- Quantity of livestock outputs and feed inputs, and emissions (Herrero et al. 2017)
  - Animal species and breeds
    - Beef cattle, dairy cows, dairy sheep and goats, meat sheep and goats, pigs, chicken
  - Production systems
    - Ruminant: grazing, landless and mixed crop-livestock
    - Monogastric: backyard and industrial
  - Variables
    - Animal numbers
    - Output of meat, milk, eggs
    - Feed: grazing, barley, maize, rice, pulses, sorghum and millet, soybean, wheat, other cereals, other oilseeds, other crops, animal products
    - Livestock emissions are estimated using a process-based model that considers different animal diets and production systems
- FAOSTAT bilateral trade data and prices
  - Prices are used to convert quantity flows to monetary terms and construct shares for the splitting procedure

Sectoral splits (1)

- Split GTAP gro, osd, ctl sectors

No.	New sector/ commodity	Description	Original GTAP sector	Description of original GTAP sector
1	cor	Corn	gro	Other grains
2	sor	Sorghum		
3	bar	Barley		
4	xgr	Other cereal grains		
5	soy	Soy	osd	Oil seeds
6	xsd	Other oil seeds		
7	bcg	Beef cattle, Grazing	ctl	Cattle
8	bcm	Beef cattle, Mixed		
9	bci	Beef cattle, Industrial		
10	org	Other ruminants, Grazing		
11	orm	Other ruminants, Mixed		
12	ori	Other ruminants, Industrial		
13	dcg	Dairy cows producing meat, Grazing		
14	dcm	Dairy cows producing meat, Mixed		
15	dci	Dairy cows producing meat, Industrial		
16	dmg	Other dairy producing meat, Grazing		
17	dmm	Other dairy producing meat, Mixed		
18	dmi	Other dairy producing meat, Industrial		

Sectoral splits (2)

- Split GTAP rmk and oap sectors

No.	New sector/ commodity	Description	Original GTAP sector	Description of original GTAP sector
19	cdg	Raw milk from cows, Grazing	rmk	Raw milk
20	cdm	Raw milk from cows, Mixed		
21	cdi	Raw milk from cows, Industrial		
22	odg	Other raw milk, Grazing		
23	odm	Other raw milk, Mixed		
24	odi	Other raw milk, Industrial		
25	pgi	Pigs, Industrial	oap	Other animal products
26	pgb	Pigs, Backyard		
27	pei	Poultry (eggs), Industrial		
28	peb	Poultry (eggs), Backyard		
29	pmi	Poultry (meat), Industrial		
30	pmb	Poultry (meat), Backyard		
31	xap	Rest of animal products		

- After sectoral splits (1) and (2), 102 activities (each producing single commodity) and 160 regions in the disaggregated GTAP-LVS data base

Aggregation for analysis

- 54 production activities, 44 commodities, and 18 countries/regions in this analysis
- Structure of the “make” matrix

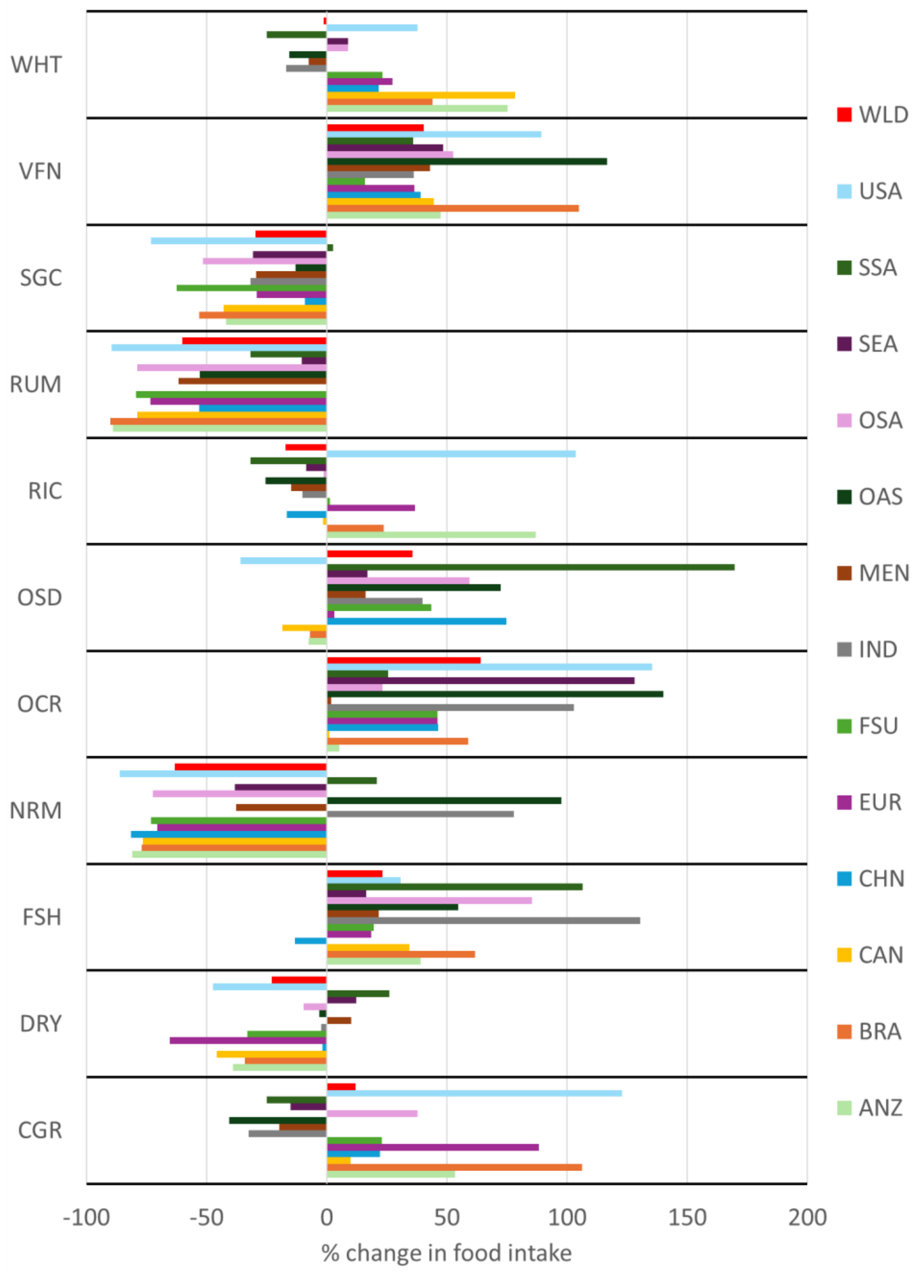
		Activities																		
		bcg	bcm	bci	org	orm	ori	mcg	mcm	mci	mog	mom	moi	pgi	pgb	pei	pmi	mpb	xap	wol
commodities	cattle	x	x	x				x	x	x										
	sheep and goat				x	x	x				x	x	x							
	pigs													x	x					
	eggs															x		x		
	poultry																x	x		
	other animal products																		x	
	cattle milk							x	x	x										
	sheep and goat milk										x	x	x							
	wool																			x

Dietary shift scenario

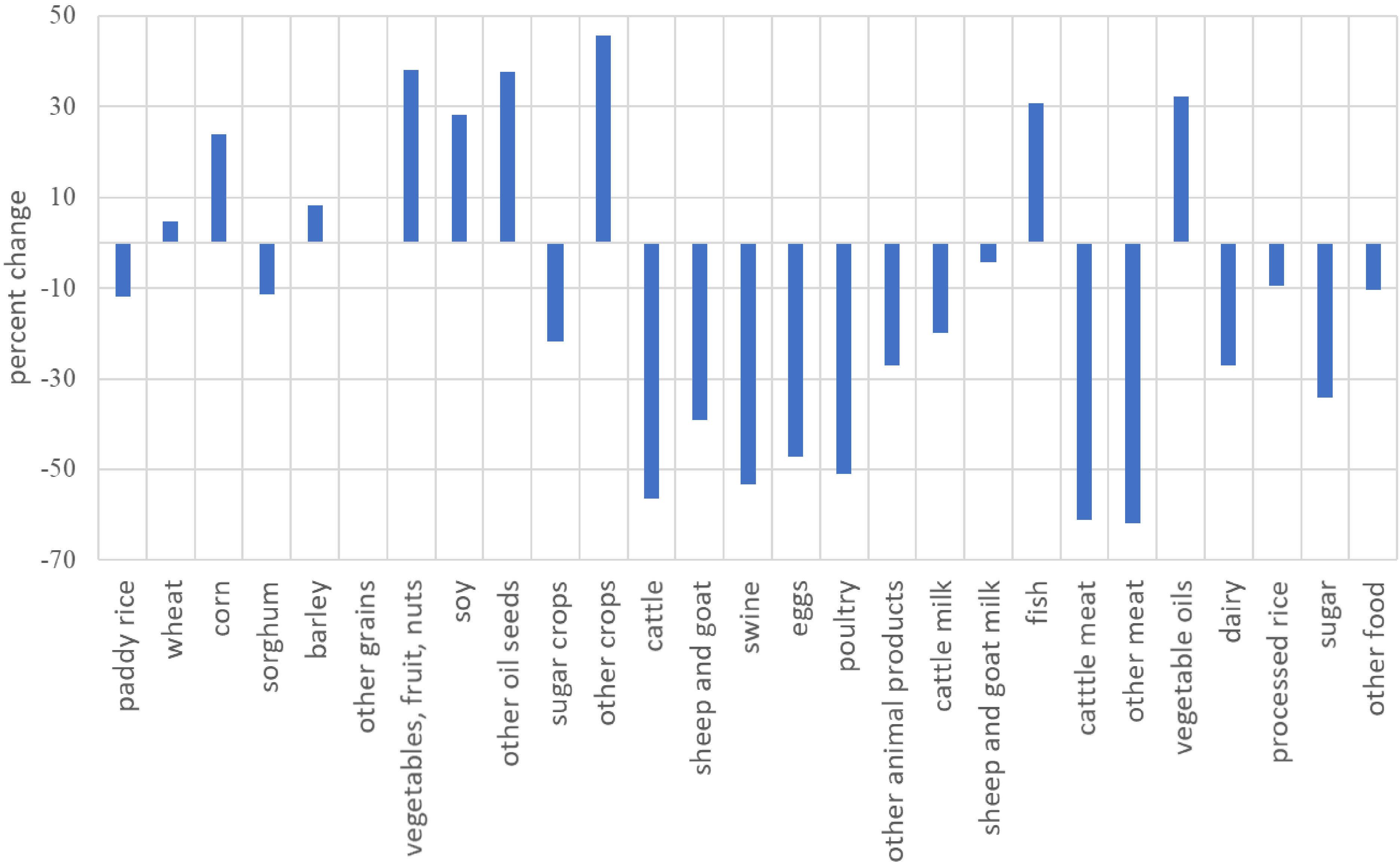
- Based on the EAT-Lancet Commission's report (Rockström et al. 2025)
  - BAU diet scenario
  - Flexitarian version of the PHD scenario

- For each food category, the shift to a flexitarian diet is calculated as the difference between projected 2050 intake under a flexitarian diet and current BAU intake, relative to current BAU intake

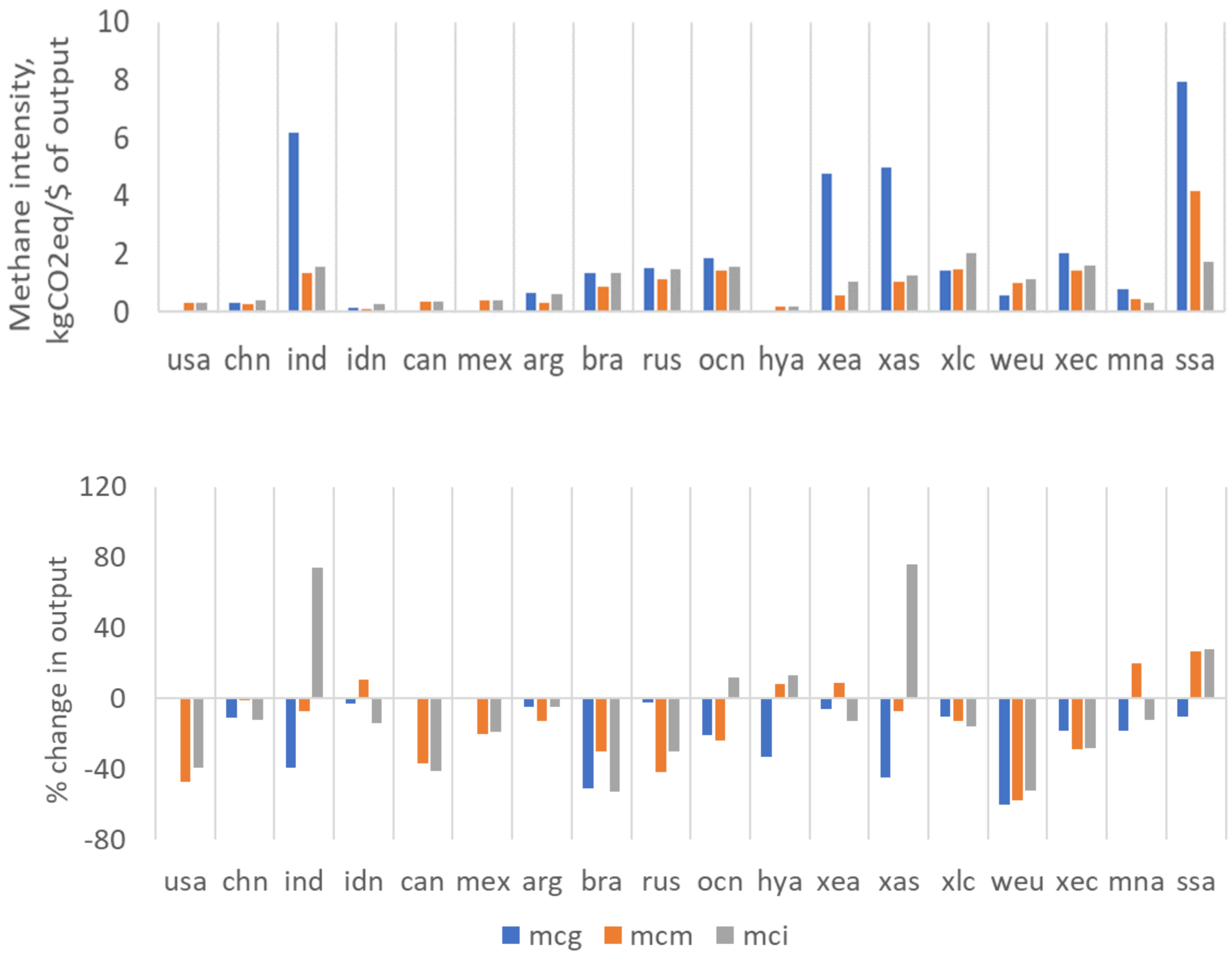
- The shifts are implemented as exogenous shocks to consumed food commodities and the intermediate demand in the processed food and food-supplying service sectors
  - with endogenous taste shifters and tech. change



Results: changes in global output of food commodities



Results: impacts on dairy cattle sectors

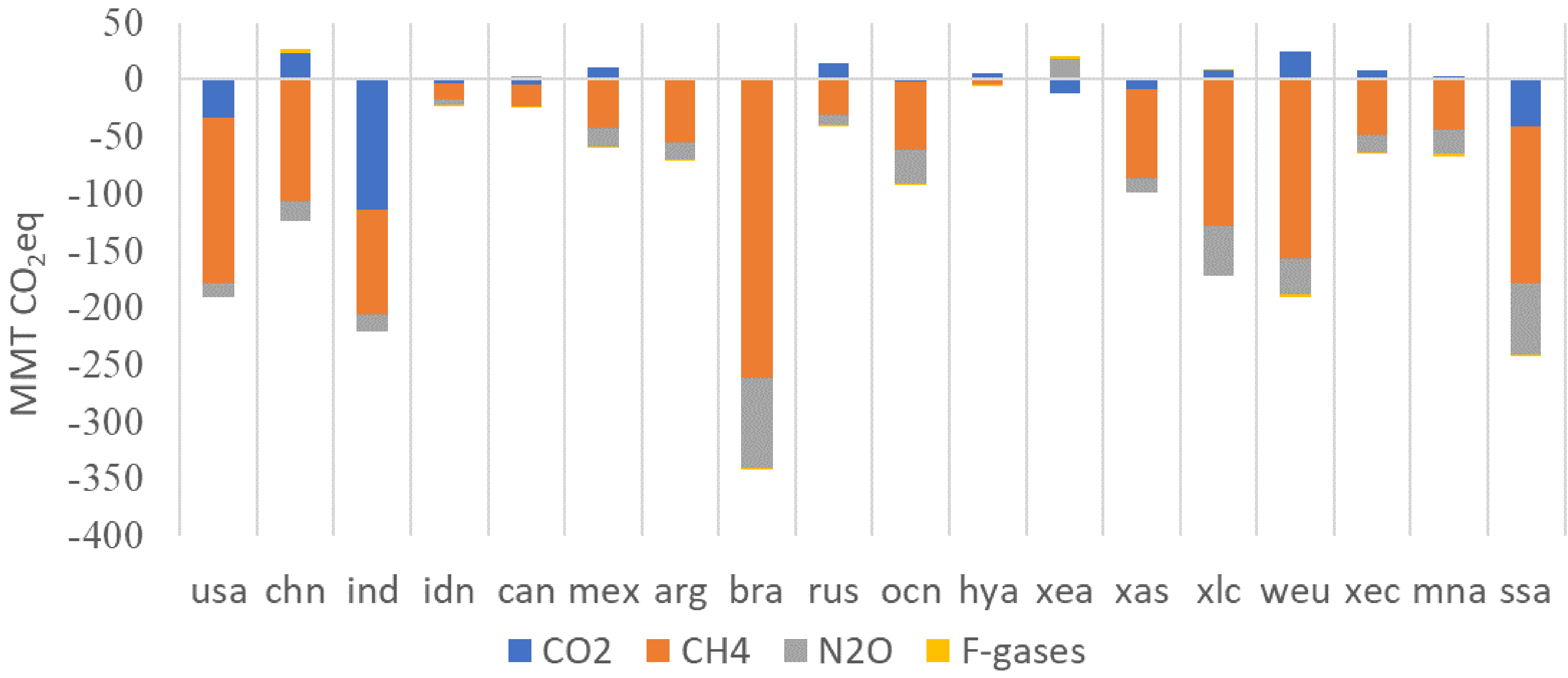


- Grazing systems are more land-intensive and usually more emission-intensive than mixed and industrial systems

- Driven by increased demand for plant-based foods, grazing systems lose more land to crop production and experience larger reductions in output than mixed and industrial systems

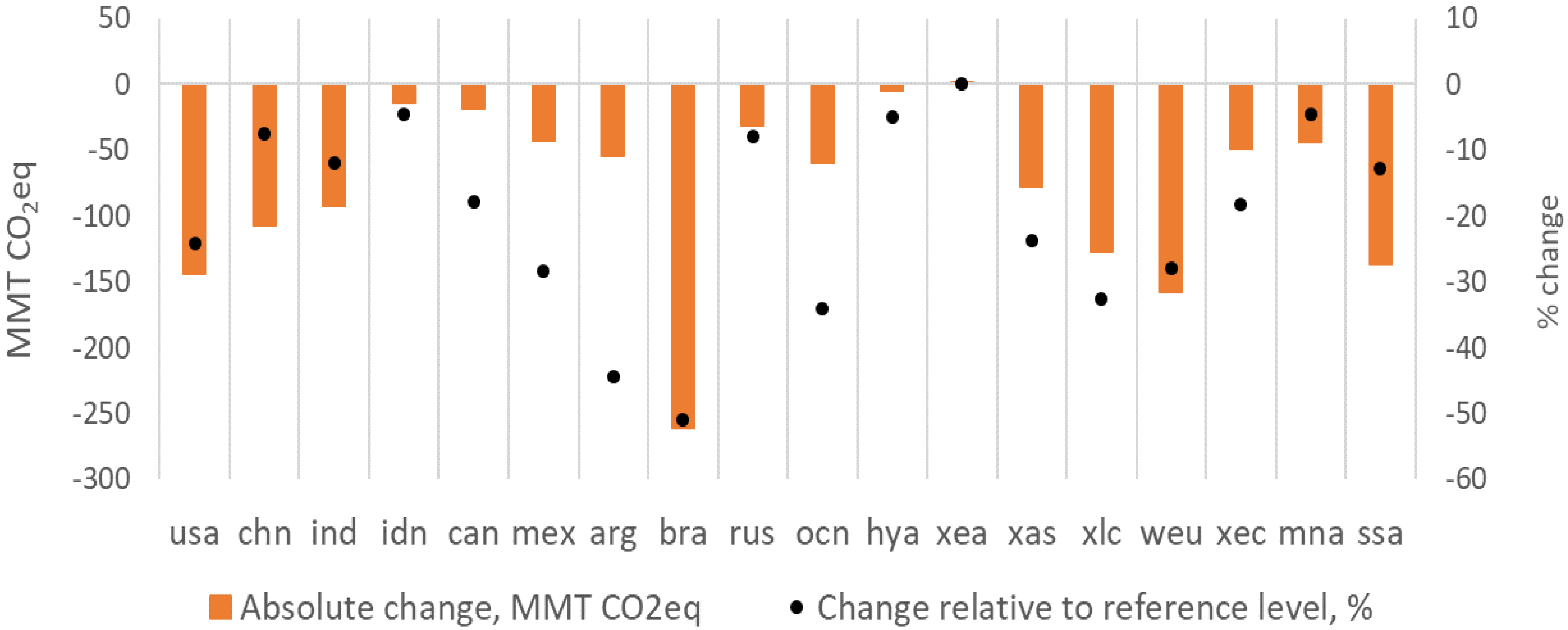
- Less land-intensive, and also less emission-intensive, dairy production in industrial systems expands in India and the Rest of South Asia, and in both mixed and industrial systems in Sub-Saharan Africa

Results: change in GHG emissions



- Global GHG emissions are reduced by 1.9 BMT CO_2eq (3.8%), including:
    - Methane by 1.4 BMT CO_2eq (16%)
    - Nitrous oxide by 366 MMT CO_2eq (13%)
    - Carbon dioxide by 118 MMT CO_2 (0.3%)

Results: change in methane



- Global methane emissions are reduced by 1.4 BMT CO_2eq (16%)
- Dietary shifts can play a significant role in methane mitigation and may complement supply-side climate policies

Work in progress

- Update GTAP-LVS data base using a new version of the FSGC data representing livestock sectors in 2020 (Bilotto et al.)
- Evaluate supply-side measures stand-alone and then combined with the shift in diets

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Thank you!

Questions/Comments?