AFRICAN CENTRE FOR BIODIVERSITY

Greenhouse gas emissions in the South African food system:

Integrated and transformative responses required

November 2024

years of advocating for food sovereignty in Africa

The African Centre for Biodiversity (ACB) is a research and advocacy organisation working towards food sovereignty and agroecology in Africa, with a focus on biosafety, seed systems and agricultural biodiversity. The organisation is committed to dismantling inequalities and resisting corporate industrial expansion in Africa's food and agriculture systems.

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Contents

Key messages

- Climate change impacts on food production, agricultural livelihoods, and food security in South Africa are significant national policy concerns. Agriculture, commercial forestry, biodiversity and ecosystems, transportation, and energy are among the priority adaptation-related sectors. Agriculture will also have defined targets for emissions reductions.
- However, climate change is just one of a set of intersecting challenges and imperatives facing the South African food system. Other key sustainability concerns about water, pollution, land degradation, biodiversity loss, and social and economic injustice require an integrated approach that responds simultaneously to all of these issues, rather than siloing the responses.
- South Africa is in the top 15–20 greenhouse gas emitters globally on multiple measures and is responsible for about one-third of total emissions from Africa. Nevertheless, the country still contributes only around 1% of total global emissions.
- While it remains important to make a national contribution to emissions reductions, building adaptive capacity and strengthening resilience is essential, especially for marginalised homestead and smallholder farmers.
- Energy production and use accounts for 81% of total emissions in South Africa and is the most important area for reduction, including in the agri-food system. About 7% of the energy amount is in the food system, including estimated energy use and transport.
- The agri-food system contributes an estimated 18% of total emissions in South Africa. Primary agricultural production constitutes around 49% of total agri-food systems emissions, mainly enteric fermentation from livestock. Energy, including transport, is the next biggest source of emissions in the agri-food system at around 41% of the total. Other food systems emissions include organic waste disposal, industrial processes, and refrigeration.
- Natural forests and grasslands are the major carbon sinks in the country.
- If emissions reductions indicated in South Africa's Nationally Determined Contribution are spread across categories so that each category aims to reduce emissions by the targeted percentages for the agri-food system, this requires a reduction of 8.7–21.2 Mt CO_2eq by 2030.
- Efforts to reduce emissions can include short-term technical interventions, but these should be situated within a longer-term 'just transition' in the food system towards ecological practices, deconcentration to dilute risk, and democratisation and greater agency in the food system for inhabitants.
- Agroecology is proposed as an integrative approach encompassing the whole spectrum of food producers for convergence on an integrated and diversified agroecological production

system, with different farmers adapting and receiving tailored support to move towards a secure common future.
- Emissions reductions in energy can be achieved through a shift away from fossil fuels, adopting renewable energy in production and transport, electrified mass transport, a shift from road to rail in the distribution of agricultural products and food, and localisation of production to reduce the distances food travels before consumption.
- Livestock production is a priority for emissions reductions in the South African food system, but it is a complex topic with deep cultural, social, nutritional, economic, and ecological dimensions. Wide and inclusive consultation and participation to consider the full array of issues and implications should inform adaptation and mitigation plans for livestock production.
- Ecosystem and landscape-based approaches that restore and conserve rangeland resources offer a pathway to sustainability in the livestock sector. This includes sustainable management of alien invasive plants, wetland restoration, mixed farming, and ecological production.
- Targeted reductions in meat consumption by wealthier consumers can ease the pressure on natural resources.
- Reduction of aggregated and non-CO_2 emissions on the land can focus on more efficient use of crop residues while balancing trade-offs between the use of residues for soil nutrition and animal feed; diverse agroecological practices for soil health and increasing soil organic carbon; limiting land use conversion from grasslands and forests into non-vegetative uses; a shift from synthetic to organic fertilisers; and a reduction in burning biomass.
- The sugar sector must be scrutinised as it has enormous environmental, health, and social costs. The sector is ripe for a structured and sequenced process of dismantling, with the return of the land to Africans to produce nutritious foods for local consumption to boost local food security.


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- Emissions from food loss and waste can be reduced through organised donations of edible food to relief schemes; value addition such as composting; investment in storage and refrigeration, especially for marginalised producers and communities; investment in local farm inputs; flexible food standards that accommodate basic food safety requirements but reduce or remove other inessential standards; and reformed labelling to reduce confusion on whether or not food is safe to eat.
- Emissions from refrigeration can be reduced by shifting from hydrofluorocarbons to natural refrigerants and placing doors on supermarket fridges.

Acronyms

AFOLU	Agriculture, forestry and other land uses
CAFOs	Concentrated animal feeding operations
CCAMP	Climate Change Adaptation and Mitigation Plan (agriculture sector)
CH_4	Methane
CO_2	Carbon dioxide
CO_2-eq	CO_2 equivalent
DFFE	Department of Forestry, Fisheries and the Environment
DMRE	Department of Mineral Resources and Energy
DTIC	Department of Trade, Industry and Competition
FAO	Food and Agriculture Organisation of the United Nations
FBDGs	Food-Based Dietary Guidelines
FOLU	Forestry and other land uses
GBF	Global Biodiversity Framework
Gg CO_2e	Gigagrams carbon dioxide equivalent (1 Gg = 0.001 Mt)
GHG	Greenhouse gas
GWP	Global warming potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HLPE	High Level Panel of Experts on Food and Nutrition of the Committee on World Food Security
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPPU	Industrial Processes and Product Use
LSM	Living Standard Measure
Mt	Megaton (one million metric tons)
N_2O	Nitrous oxide
NCCAS	National Climate Change Adaptation Strategy
NCCRWP	National Climate Change Response White Paper
NDC	Nationally Determined Contribution
NFNSP	National Food and Nutrition Security Plan
RMVCA	Red meat value chain actors
SDGs	Sustainable Development Goals
SETs	Sectoral emissions targets

Introduction

Climate change impacts on food production, agricultural livelihoods, and food security in South Africa are significant national policy concerns. In 2012 the National Climate Change Response White Paper (NCCRWP) established a mandate for agriculture and forestry (DAFF, 2015:7–8). It highlighted South African agriculture's vulnerability and exposure to the impacts of climate change due both to the socio-economic context of inequality and poverty and to the high-risk natural environment (high climate variability, extreme weather events, severe water stress at times). Agriculture, thus, urgently has to strengthen its resilience to climate change impacts.

This includes:
- mitigation,
- adaptation,
- monitoring emissions,
- managing sinks, and
- developing a plan, linked to the protection/rehabilitation of land and water resources.

The NCCRWP emphasises that plans must directly address the plight of those most impacted, for example, the rural poor. Resilience must address issues of key national importance, including food security and its links to water, health (of humans, plants, animals), and land reform.

The National Climate Change Adaptation Strategy (NCCAS) of 2019 (DFFE, 2019:10) identifies agriculture, commercial forestry, biodiversity and ecosystems, transportation, and energy as priority adaptation-related sectors. It provides a detailed framework of areas for action, but each sector is responsible for developing its specific plan.

Actions in the NCCAS to reduce vulnerability and build adaptive capacity specific to agriculture include:
- investment in climate-resilient rural livelihoods,
- support to small-scale fishers through early warning systems and sea safety training,
- support to farmers on climate-smart and conservation agriculture practices (see below for further discussion),
- expansion of urban food garden programmes,
- enhancing agricultural extension services to support vulnerable producers,
- investing in climate resilient rural homestead gardening, and
- integrating climate-smart and ecosystem-based approaches in forestry practices (DFFE, 2019:62–65).

At the same time, the agri-food system is a significant contributor to greenhouse gas (GHG) emissions, and the sector should contribute its share of the national effort to

1. https://www.gov.za/documents/acts/climate-change-act-22-2024-english-tshivenda-23-jul-2024

reduce emissions. Schedule 2 of the Climate Change Act 22 of 2024[1] includes agriculture, forestry, fisheries, environment, land reform, and rural development as sectors that require adaptation plans. Draft sectoral emissions targets (SETs) have been published, and policies and measures must be adopted to realise the targets. This paper focuses primarily on identifying the key sources of emissions in the South African food system and considering ways for their reduction.

However, climate change is just one of a set of intersecting challenges and imperatives facing the South African food system.

Other key sustainability concerns regarding commercial-industrial agriculture are

- water use and availability,
- chemical water pollution,
- land degradation and soil erosion,
- biodiversity loss, and
- social and economic justice and transformation.

As such, an integrated approach is required that responds simultaneously to all of these issues rather than siloing the responses. According to the Food and Agriculture Organisation of the United Nations (FAO) (2023:4), "ending hunger is inseparable from ending ecosystem degradation". According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), biodiversity and ecosystems goals will not be met unless there is a "fundamental system-wide reorganisation across technological, economic and social factors, including paradigms, goals, and values" (IPBES, 2019:14). An approach that deals with emissions reductions in isolation from the necessary restructuring and democratisation of wider food systems will fail to place food systems on a more stable footing. Given the continuing imperative in South Africa for social and economic redress and justice, there may be a need to consider increases in emissions in some areas to enable the marginalised population to increase their production and consumption while established, large-scale producers and wealthier consumers simultaneously reduce consumption, improve resource use efficiency, and contribute to the redistribution of resources as the transition unfolds.

Agroecology[2] is proposed as an integrative approach that can encompass the whole spectrum of food producers, from homestead and smallholder producers to large-scale industrial plantations. The vision is for convergence on an integrated and diversified agroecological production system, with different farmers adapting and receiving tailored support to move towards a secure common future.

A comprehensive agroecology strategy can integrate ecological, social, and economic justice dimensions, providing a framework for priority initiatives on:

- climate,
- biodiversity,
- land degradation,
- food security,
- resource redistribution, and
- economic agency and participation.

2. The 13 principles of agroecology drawn up by the FAO's Committee on World Food Security (CFS) High Level Panel of Experts (HLPE) is adopted as a frame for a shared definition of agroecology. These principles are globally recognised by leading inter-governmental and civil society entities and coalitions. They were first articulated in HLPE (2019).

South African emissions in a global context

Estimates vary on which countries have the largest cumulative territorial emissions[3] (depending on dates selected and methodologies employed), but there is general agreement that the United States, followed by China and then Russia have contributed by far the majority of emissions both in single years and cumulative historical emissions (see Figure 1) (Evans, 2021; Statista, 2023). Evans indicates that Brazil and Indonesia follow Russia, based on a methodology that incorporates both fossil fuel combustion and land use change and deforestation. Note that formerly colonised countries carry the responsibility here for historical emissions resulting from extractive industries like mining and timber under colonialism. Statista shows Germany and the United Kingdom after Russia, but based only on fossil fuel combustion. From different estimates, the top five emitters have contributed 47–57% of total emissions to date. Including emissions from imports and exports does not make a significant difference to the picture (Evans, 2021).

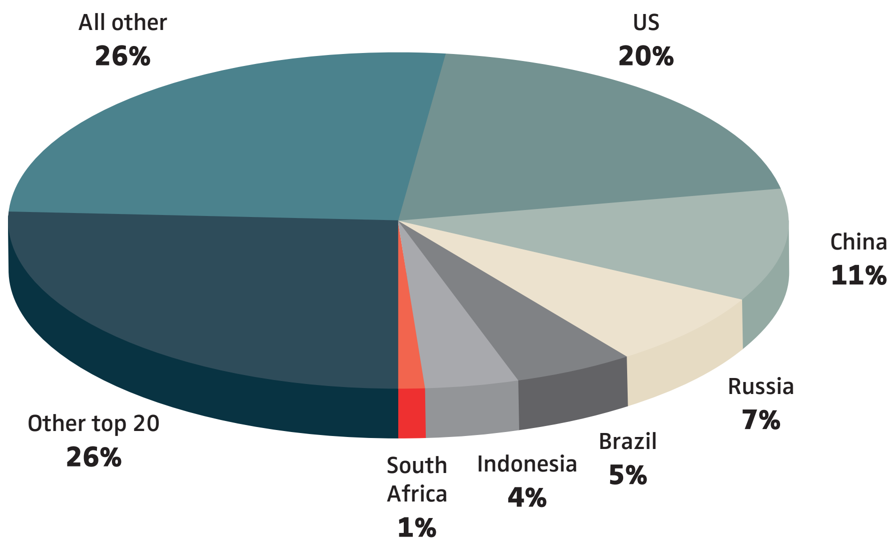

Figure 1. Cumulative global CO_2 emissions from fossil fuel combustion and land use change, 1850–2021

Source: Evans, 2021

3. Territorial emissions are restricted to emissions produced only in the national territory and exclude colonial activities or trade.

South Africa is in the top 15–20 emitters globally on multiple measures and is responsible for about one-third of total


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emissions from Africa. Nevertheless, the country still contributes only around 1% of total global emissions. When considering per capita emissions (both in single years and cumulatively), South Africa drops down the ranks of the biggest emitters to around 38th position globally, although per capita emissions remain above the global average (Statista, 2023). After this, we must also recognise differentiated internal responsibility, with corporations and wealthy households responsible through consumption for a much greater share of and benefit from historical emissions. This makes it clear that restrictions should not be imposed on the majority of the population who are least responsible and who have benefited least from activities resulting in emissions from South Africa. A differentiated response is required, which simultaneously lifts food and energy consumption for those at the bottom, reduces consumption, and increases efficiencies of the biggest users.

The global data indicates that the primary responsibility for mitigation lies with the US, China, Russia, and Europe. Looking at global developments and the power of ecocidal capitalists and political elites, it is highly unlikely that a rapid and coordinated response will materialise. All indications are that the 1.5°C threshold in global warming will be surpassed within the next decade, producing increasingly unpredictable, chaotic, and extreme climate effects in the future.

Mitigation across sectors remains critical, however, as the slower we are to react, the worse the medium- and long-term outcomes will be. Nevertheless, we need to focus on preparing for these inevitable developments by building adaptive capacity and strengthening resilience in the production and distribution of food. Efforts to reduce emissions should, therefore, be integrated with efforts to strengthen productive capability and resilience for the marginalised population and to ensure the realisation of the right to food as a guiding objective of food systems interventions. As indicated below, many overlapping practices respond to both mitigation and adaptation, with agroecology contributing strongly in this regard.

Estimated emissions from the South African food system

Overview

Emissions data is drawn from the Department of Forestry, Fisheries, and the Environment (DFFE)'s 8th National Greenhouse Gas Report, for 2022. Total South African emissions[4] were 468,812 Gg CO_2e, excluding forestry and other land use (FOLU),[5] in 2020 (DFFE, 2022:xi). It should be noted that this was the first year of the Covid pandemic, with the economic slowdown and consequent emissions reductions that entailed. So the figure is somewhat lower than 'normal' and only offers a snapshot of the relationships between the different sub-sectors. At the same time, trends show that in five-year blocks, emissions rose by 8.8% from 2000–04 to 2005–09, but after that, they began to

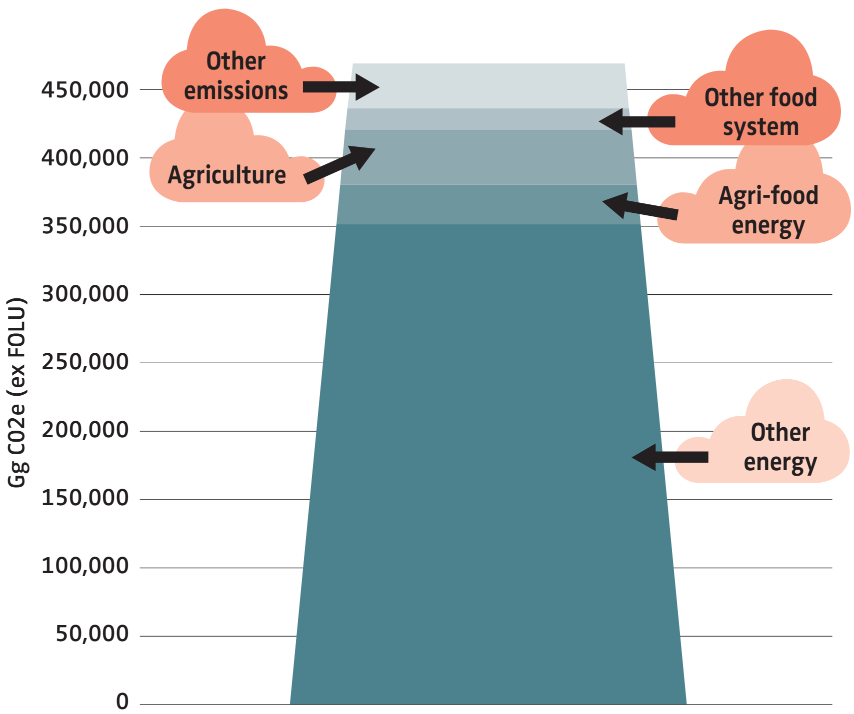

Figure 2. SA agri-food system emissions (ex FOLU) as a share of total, 2020

Source: Extrapolated from DFFE, 2022

4. One gigagram (Gg) = one thousand metric tons. One megaton (Mt) is one million metric tons. Thus one Gg = 0.001 Mt.

5. Agriculture, forestry and other land use are placed together in the official methodology, but figures excluding FOLU are also supplied. In this paper, we use the figure excluding FOLU because, as a whole, FOLU is a sink and deducting these sinks from agriculture at the outset can result in an understatement of actual emissions.

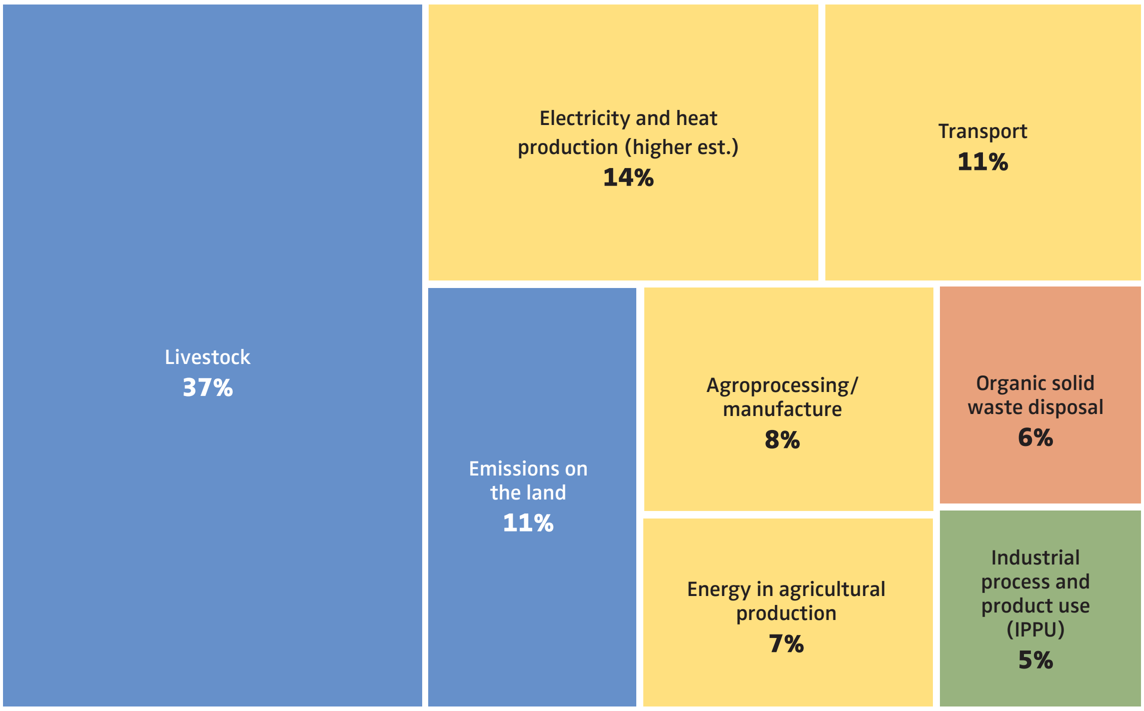

Figure 3. Sources of emissions from the SA agri-food system (ex. FOLU)

Source: Own estimates based on DFFE 2022 emissions data

decline overall: first by just -0.14% from 2009 to 2014, but then by -5.1% from 2014 to 2020. So, although Covid may have resulted in abnormally reduced emissions, specifically in 2020, there was a declining trend before this (which may also have to do with the growing energy crisis during the later period, with supply shortfalls). Ultimately, 2020 is simply being used as a baseline to compare agro-food systems and overall emissions.

Energy production and use accounts for 81% of total emissions in South Africa (DFFE, 2022:76) (Figure 3, Table 1) and is the most important area for reduction. Low energy efficiency is a key issue (Maina and Huan, 2015:8). About 7% of the energy amount is in the food system, including estimated energy use and transport in the agri-food system. Primary agricultural production is the second largest source of total country emissions after energy, at around 8.7% of the total. Other food systems emissions, aside from energy and primary production, constitute another estimated 3.4% of total country emissions. Combined, this means the agri-food system contributes an estimated 18% of total emissions in South Africa. This figure is similar to that found in other sources (Crippa et al., 2021; Bennie et al., 2023; FAO, 2023), which are based on the Emissions Database for Global Atmospheric Research (EDGAR).[6] Other national emissions, aside from energy and the agro-food system, total around 8%. To an extent, energy emissions can be disaggregated to different economic sectors as well, as we do with agriculture and the food system, see below.

As previously indicated, land use change has been excluded from the calculations because including it can distort the view on emissions from the food system. Forests and grasslands are key carbon sinks in South Africa, and

6. https://edgar.jrc.ec.europa.eu/edgar_food

Table 1. Estimated emissions from the South African agri-food sector (Gg CO_2e, ex FOLU, 2020)

	Agri-food sub-category	Agri-food	Total	Agri-food as % of total	Category as share of agri-food %
Total		83,800.8	468,812.0	17.9	100.0
Agriculture		**40,774.6**	**40,774.6**	**100.0**	**48.7**
Livestock	31,372.0				37.4
Aggregated and non-CO_2 emissions on the land	9,403.0				11.2
Energy		**33,936.0***	**379,505.0**	**8.9**	**40.5**
Electricity and heat production (higher)	11,515.0		205,621.0		13.7
Electricity and heat production (lower)	4,935.0				5.9
Transport	9,494.0		48,193.0		11.3
Manufacturing industries and construction	7,001.0		33,336.0		8.40
Agriculture/ forestry/ fishing/ fish farms	5,926.0				7.10
Waste		**4,746.0**	**23,046.0**	**20.6**	**5.70**
Organic solid waste disposal	4,746.0		18,253.0		5.70
Industrial processes and product use (IPPU)		**4,344.2**	**25,486.0**	**17.0**	**5.20**
Mineral industry	41,200.0		4,774.0		0.05
Chemical industry	425,000.0		2,264.0		0.51
Refrigeration and air conditioning	3,878.0		4,847.0		4.63

Source: Author calculations based on data indicated in text
*Using higher electricity and heat production estimate

their inclusion in agriculture emissions calculations (agriculture, forestry, and other land uses – AFOLU) reduces the amount by two-thirds (from 40,774.6 to 14,088 Gg CO_2e). This obscures rather than informs our understanding of the actual emissions from the food system since it is not food system activities but the underlying natural processes that produce these sinks. However, this does indicate that agricultural production can also contribute to short and longer-term carbon storage if properly managed, especially in biomass and in the soil.

The main sinks in South Africa are indigenous forests and woodlands (69% of sequestration from AFOLU), even though natural forests cover just 0.4% of South Africa's land surface (around half a million hectares), with a further 39 million hectares covered by savannah woodland systems (Forestry South Africa, 2020). Existing commercial timber plantations, which occupy about 1% of the land area, are shown to be a slight source of emissions overall, but this fluctuates, and net emissions average around zero for plantations (DFFE, 2022:207–208). Timber plantations are not natural forests, but they may perform some of the ecological functions of natural forests, including carbon sequestration and oxygen release. However, new commercial plantations may have significant negative ecological impacts on, for example, on-site biodiversity loss because of direct habitat loss and changes in ecosystem dynamics, and increased water use compared with natural vegetation (SANBI, 2007:24). Forest fires can convert forests from sinks to sources due


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to biomass loss, which occurred especially between 2004 and 2012 in South Africa (DFFE, 2022:209). Nevertheless, indigenous forests in South Africa rarely burn, due to high humidity.[7]

Grasslands are also a significant carbon sink. Covering about 29% of South Africa's land surface, grasslands are also high in biodiversity, second only to the fynbos biome.[8] Grassland converted to forest land (afforestation) is the largest sink component in the converted lands category (DFFE, 2022:209). Conversely, conversion out of grasslands into non-vegetated land uses (e.g. settlement or mining) is the largest cause of emissions from land use change, resulting in both biomass and soil carbon loss (DFFE, 2022:217). Most of South Africa's high-potential arable land is in the grassland biome in Mpumalanga and KwaZulu-Natal. The main crops are maize, sugar cane, groundnuts, soya beans, and sunflower (SANBI, 2007:12). Cultivation leads to direct habitat loss, fragmentation of habitats for plants and animals, and disruption of ecosystem function, with a permanent loss of geophytic plant species (those with an underground storage organ) in initial cultivation. Nevertheless, overall threats to the grassland biome are considered low to moderate (SANBI, 2007).

Primary agriculture

Figure 3 and Table 1 indicate sources of emissions (excluding FOLU) in the South African food system. Primary agricultural production (shown in blue in Figure 3) is the main source of emissions, at 48.6% of the total for the food system. Livestock constitute about 77% of emissions from primary agriculture and about 37% of total agri-food system emissions. This is mainly in the form of enteric fermentation (a form of animal digestion that releases methane gas as a by-product). Enteric fermentation is in the top 10 overall emissions every year, although with a declining contribution to GHG emissions with declining livestock population trends since 2014. Cattle (non-dairy) and sheep are the largest contributors, but with increasing emissions from dairy cattle and pigs as stock numbers increase (DFFE, 2022:xviii, xxix). Poultry do not use enteric fermentation to break down food and thus do not contribute to emissions here (DFFE, 2022:201). Manure management is a smaller emissions category within livestock, mainly cattle, with poultry to a lesser extent.

7. https://pza.sanbi.org/vegetation/forests

8. https://pza.sanbi.org/vegetation/grassland-biome

The livestock sector is the largest agricultural sub-sector in South Africa, at around 42% of the total value of production in 2022/23 (DALRRD, 2024:78). The sector consists mainly of cattle (beef and dairy), sheep, goats, pigs, and chickens. Cattle and poultry are the most significant commercial sub-sectors. About 80% of the national cattle herd is beef, with the remaining 20% dairy. Commercial cattle numbers have declined since the 1980s but stabilised since the early 2000s at just under six million head (DALRRD, 2024:68). However, overall cattle numbers have dropped below 13 million head since 2017, the lowest numbers since the 1980s (DALRRD, 2024:58). This follows the serious drought period of 2015–16. In combination, these statistics indicate that the main decline in cattle numbers is amongst non-commercial (mainly communal) farmers. Commercial poultry numbers have expanded more than four times since the 1980s. There has been a definite decline, of over 70% each, in sheep and goat numbers since the 1980s (DALRRD, 2024:68). There are also significant interlinkages with field crops, in particular maize and soya, which are the two largest field crops in the country. Animal feed uses about half of the total production of these crops, placing the 'grain-livestock complex' at the heart of commercial agriculture in South Africa.

Intensive and extensive systems characterise livestock production in South Africa, broadly along the lines of commercial and communal smallholder production but with overlaps. Intensive systems may have some initial pasture or extensive grazing, but livestock are sent to concentrated feedlot operations for fattening and finishing. In the extensive system, grazing is on rangelands with limited supplementary feed. An estimated 40% of the cattle herd is owned by smallholder/communal farmers with access to 17% of the land (Slayi, et al., 2023:2; Oduniyi et al., 2020:2; Meissner et al., 2013:306). This is the biggest share of black ownership in any of the major agricultural sub-sectors, although small-scale and communal farmers owned 67% of goats in 2013 (Meissner et al., 2013). The decline in the goat population thus also indicates livestock losses primarily for black smallholder farmers in the past decade or two. An estimated 60% of cattle went to feedlots for finishing, with the remaining 40% raised on natural pasture, which aligns with the ownership patterns (SANBI, 2007:13). Feedlots have one of the most highly concentrated corporate ownership patterns in agricultural processing. Shifts in herd numbers and ownership in the past decade may suggest even higher numbers now going to feedlots, especially given the more recent emphasis on bringing communal producers into corporate value chains (RMVCA, 2022).

It is important to note that livestock are multi-functional and should not be reduced to commercial markets. There are multiple reasons for farmers to hold livestock, including for their own food (meat, milk) and non-food (leather, bone) consumption, sales, emergencies, lobola (bridewealth), as a store of wealth, as well as for soil nutrients in the form of manure. Ceremonies, dowry payment rituals, social status, and other functions are important and there are multiple economic and socio-cultural uses of livestock outside of market sales (Mbatha, 2021:144–6). Cattle are held for cash when required rather than for sale at optimum market value. Cultural motivations for keeping and using livestock challenge market-oriented interventions (Mbatha, 2021:145). There is a difference between holding cattle as a flexible source of wealth that can be monetised as needed and that performs multiple other functions and services on the one hand, and market orientation towards commercial livestock production on the other. The majority of communal livestock owners are not producing primarily for the market. The latter requires different management and planning, emphasising animal health and weight, identifying markets, and timing of sales. Herd duality should be respected, incorporating both traditional animals for cultural/own use/resilience purposes, with breeding programmes for sales.

Key challenges facing communal farmers include climate change impacts on livestock (water shortages, heat stress, forage quality, excess mortality), the generally poor condition of rangelands, including bush encroachment, lack of supplementary feed in the winter, poor genetics and uncontrolled genetic mixing, disease management, lack of infrastructure (fencing for grazing camps, handling facilities, and water points), the disintegration of communal rangeland management systems and their replacement with uncontrolled open access, and resulting poor conditioning of the animals, which means lower sales prices (DAFF, 2015; Matela and McLeod, 2016; Zhou et al., 2022). Key challenges for commercial producers and feedlots are stagnant domestic markets, excessive water use, water pollution from effluent and excess nutrients, and excessive use of growth hormones with rising health and welfare concerns for both the animals and human consumers (Szejda et al., 2021).


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Concentrated feedlots, also known as concentrated animal feeding operations (CAFOs), are a significant source of methane emissions from enteric fermentation in cattle. In CAFOs, cattle are fed a high-energy, high-grain diet that increases their susceptibility to digestive disorders and increases methane emissions. CAFOs are not the only source of methane emissions from enteric fermentation, and emissions can also occur in other types of farming systems, such as pasture-based systems. However, the concentration of animals in CAFOs makes them a particularly significant source of methane emissions in terms of absolute volumes.

When comparing livestock production systems and emissions per kilogram, the argument is that large-scale commercial farming may have higher overall emissions (because of larger numbers) but with much higher per-unit yields than small-scale 'traditional' agricultural practices. When emissions are divided by yield, the large-scale commercial system is thus considered to perform better than smallholder open grazing, with evidence that there are fewer methane (CH_4) emissions from feedlots than from extensive grazing (Meissner et al., 2013). However, this isolates GHG emissions from integrated ecological and social impacts of the production system as the only relevant variable for consideration, a point returned to later.

A comparative study of extensive dairy farming in Mali, intensive dairy farming in Reunion Island, and semi-intensive dairy farming in France showed that extensive systems in Mali are more efficient than the intensive system and equivalent to the semi-intensive system. Less processing of animal feeds is a key difference (lower energy input), with animal feed coming from local raw resources and residues from local grain processing in extensive systems (Vigne, 2014:2).

Although beef cattle produce the most emissions in absolute terms, goats and sheep have higher emissions per kilogram of product. Commercial beef also has the highest emissions by the value of the product, followed closely behind by commercial sheep and goats, with lower emissions for game and dairy cattle (where milk is the product) (Meissner et al., 2013:302).

Poultry has a low carbon impact mainly because of limited enteric fermentation. Manure treatment is the main issue for GHG emissions. Emissions are mostly through liquid stored manure (anaerobic fermentation by methanogenesis), mainly from the intensive production system (Ncobela and Wepener, 2021:473). Nitrous oxide (N_2O) emissions are generated from high-protein diets and dry stored manure (aerobic decomposition), and poultry accounts for about a quarter of livestock N_2O emissions. Feed digestibility and composition, manure management practices, environmental conditions, and duration of waste management determine the amount of N_2O produced (Ncobela and Wepener, 2021:474)

Within primary agricultural production, emissions from the land are the other category, contributing just under a quarter of emissions from primary agriculture. From managed soils, N_2O is the biggest sub-category here, followed by the burning of biomass. Its releases from managed soils are mainly from crop residues, inorganic fertilisers, and nitrogen inputs from urine and dung. Microbial production and consumption in the soil are dynamic and complex processes and are not fully understood. There are variations in emissions depending on how soils are managed. The application of nitrogen fertiliser, higher soil moisture, and higher temperatures all contribute to higher emissions.

Fire has been associated with maintaining the grass cover in the grassland, woodland, and savanna biomes by preventing successional development beyond the grassland stage to the thicket. It has been instrumental in the evolution of climax grasslands in the humid higher-lying eastern regions of South Africa and those rangelands that would otherwise have evolved into forests or savannas. This is seen as a valuable management tool. However, planned fires are more regular than natural fires, and fires release carbon into the air both directly and indirectly through residual decaying material and exposed soils. Carbon is only partially recovered through vegetation regrowth (Meissner et al., 2013:303). Ninety per cent of sugar cane is burned before harvesting, also generating emissions (Mashoko et al., 2010).

Energy in the food system

After primary production, the second largest category of emissions in the food system is energy use. This includes an estimated food system share of overall energy production, transport, and energy use in agriculture and food manufacturing (shown in yellow in Figure 3). Electricity and heat production are the largest components of overall energy sector emissions. The agri-food system is responsible for a proportion of this. Here we use the agriculture and agro-processing share of the economy as a proxy to estimate the share of energy production allocated to the food system. According to the Abstract

9. https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=ZA

of Agricultural Statistics 2022, agriculture contributed 2.8% of the total value added to the economy (DALRRD, 2022:74). According to the Department of Mineral Resources and Energy (DMRE, 2022), agriculture and food production combined accounted for 2.4% of total energy demand in the economy in 2018. Elsewhere, the Department of Trade, Industry and Competition (DTIC) estimates food and beverages manufacturing to be around 23% of total manufacturing (see below), which in turn is about 12% of the total economy in the past few years.[9] Thus, food and beverage manufacturing is estimated at around 2.8% of the total economy. Using the share of agriculture and food manufacturing as a rough proxy for the agri-food emissions share in energy production, this gives between 2.4% (DMRE) and 5.6% (DALRRD plus DTIC) of energy emissions, thus between 4,935 Gg CO_2e and 11,515 Gg CO_2e in 2020.

The next three energy sub-categories are estimates of emissions from energy consumption in the food system, distinct from the food system's share of energy production indicated above. Transport is the second highest sub-category of overall energy emissions at 48,193 Gg CO_2e (13%), of which road transport constitutes 93%[10] (DFFE, 2022:75–76). For freight transport, agriculture and forestry primary products are weighted at 7.5%; and manufactured food, beverage, and tobacco products are weighted at 12.2% (StatsSA, 2023a) for a combined total of 19.7%. This indicates a proxy share of transport emissions of 9,494 Gg CO_2e from the food system.

Manufacturing industries and construction contributed 33,336 Gg CO_2e (9%) of total energy sector emissions in 2020 (DFFE, 2022:75). The sub-category includes chemicals, pulp and paper, and food and tobacco manufacturing. Food and beverages are weighted at 20.75% of total manufacturing in South Africa (StatsSA, 2023b). DTIC estimates that food and beverage manufacturing was the largest manufacturing sector, constituting 23% of total manufacturing in 2018 (Invest SA, 2020). Based on these figures, we use a rough proxy share of 21% of sub-category emissions (7,001 Gg CO_2e) allocated to the agro-processing and food manufacturing sectors. Dairy products, confectionaries, meat, and meat products are the largest in terms of output. These three clusters accounted for over half of the total sales value in the processed food sector (Chitonge, 2021:10). This reinforces the focus on livestock as a key sector for consideration in mitigation and adaptation efforts.

Direct emissions from fuel combustion in agriculture, forestry, fishing, and fishing industries, such as fish farms, contributed another 5,926 Gg CO_2e (1.6% of the energy sector) (DFFE, 2022:75).

Food loss and waste

Organic solid waste disposal (landfills) is the largest source of emissions in the waste category, at 18,253 Gg CO_2e (79% of total emissions from waste). This rises with increasing population. Methane is generated during anaerobic fermentation of degradable organic waste deposited in landfill sites (DFFE, 2022:353). The composition of waste going into solid waste disposal sites is assumed in the 2022 National Emissions Report to be 26% food, 17% garden, 18% paper, 2% wood, 0% textile, 0% nappies, and 37% plastic or other inert substance (DFFE, 2022:363).

10. Calculation includes emissions from off-road and other machinery, other mobile machinery (DFFE, 2022:38)

11. For reasons of consistency, page numbers for DFFE 2023 reference Government Gazette No. 49321, in which the draft strategy was published.

Proxy agri-food emissions are thus taken as 26% of solid waste disposal emissions (4,746 Gg CO_2e).

An estimated 34–45% of food produced in South Africa is lost or wasted (Fourie et al., 2023:5; DFFE, 2023:23).[11] Losses are throughout the supply chain, with about 50% at harvesting, 45% from processing to retail, and 5% at the consumer level (DFFE, 2023:10). Losses are highest for fruit and vegetables (45% of food waste, 42% of cost, and 24% of water wasted) (Oelofse, 2019). This includes food that is perfectly nutritious but which has failed to meet strict manufacturing or retail standards (DFFE, 2023:9). 'Food loss' is mainly caused by supply chain inefficiencies, such as poor infrastructure and logistics; a lack of technology; insufficient skills, knowledge and management capacity of supply chain actors; and a lack of access to markets. Natural disasters can also play a role. Food loss occurs primarily at the production, post-harvest, and processing stages of the supply chain. 'Food waste' refers to food appropriate for human consumption being discarded. It could be spoiled, or it could be the result of oversupply or individual shopping and eating habits. Food waste occurs at the later stages of the food supply chain (retail and consumer level) (Fourie et al., 2023:7).

Food waste is a wider social and environmental concern (DFFE, 2023). It costs the economy the equivalent of 2.4% of GDP (DFFE, 2023:30). It has an obvious negative impact on food availability and wastes "all the embedded energy used to produce, process, transport, store and retail it" (Garnett, 2007:7), as well as scarce arable land and water resources. DFFE (2023:28) estimates that food loss and waste result in the loss of 4% of commercial agricultural land and 20% of irrigation water, and it also contributes excess nutrients of an estimated 2.5 kg nitrogen equivalent per hectare to eutrophication (oxygen depletion) of water systems. Food waste is also implicated in biodiversity loss, to the extent that Target 16 of the recently concluded Global Biodiversity Framework (GBF), to which South Africa is a signatory, calls for the halving of global food waste in efforts to reduce biodiversity loss (CBD, 2022:11). As such, reducing food loss and waste is a very significant area for intervention even if its contribution to emissions is comparatively smaller.


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Industrial Processes and Product Use

The final emissions category is called Industrial Processes and Product Use (IPPU), which contributes an estimated 5% of total food system emissions in South Africa. The largest sub-category is refrigeration and air conditioning, including commercial and industrial refrigeration and cold storage, and transport refrigeration (DFFE, 2022:17–18; 187–188). Refrigeration creates GHGs both because of the energy used to operate the equipment and because of the inherent global warming potential (GWP) of the refrigerant gases (Garnett, 2007), mostly

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hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). HFCs are the most commonly used refrigerants in cooled transport processes in South Africa (GIZ, 2014).

"Mobile air conditioning is the largest consumer of refrigerants in the world, followed by commercial refrigeration. Mobile air conditioning consumes 31% of the world's refrigerant" (Maina and Huan, 2015:6). There are about 9,000 trucks and trailers in the refrigerated transport sector in South Africa. In terms of their direct GHG emissions, each truck contains refrigerants, mainly the hydrofluorocarbon blend R404a, which has a GWP of 3,922 and to a lesser extent, hydrofluorocarbon 134a (HFC-134a), which has a GWP of 1,430 times that of CO_2. Furthermore, the refrigeration unit and truck engine consume fuel and, therefore, create indirect emissions in the form of CO_2. These indirect emissions contribute less than 50% in smaller trucks, but up to 75% in trailers (GIZ, 2014). With the growth in online grocery sales, the number of refrigerated transport vehicles in operation is expected to grow rapidly (EIA, 2014:11).

According to Maina and Huan (2015:6), commercial refrigeration produces around 37% of total emissions from refrigeration:

"Commercial refrigeration is the equipment used by retail outlets to display, hold, or prepare food and beverages that customers purchase. This equipment includes refrigerated display counters in supermarkets, refrigerated vending machines, water coolers/heaters, and ice-generating machines. Commercial refrigeration consumes about 28% of worldwide refrigerants and thus is the second largest user of refrigerants."

12. https://www.marketsandmarkets.com/Market-Reports/commercial-refrigeration-equipment-market-32445265.html

13. https://www.marketsandmarkets.com/Market-Reports/industrial-refrigeration-system-market-245749288.html

Supermarkets and hypermarkets are the largest commercial users, trailed by hotels and restaurants, bakeries, and then convenience stores.[12] Industrial refrigeration consists mainly of refrigerated warehouses in the food sector and food processing (fruit and vegetables; beverages; dairy and ice cream; meat, poultry, and fish). Chemicals, petrochemicals, and pharmaceuticals are the only non-food categories that use industrial refrigeration.[13] Additional uncalculated emissions also arise from residential refrigeration, mainly of food and high-performance data centres.

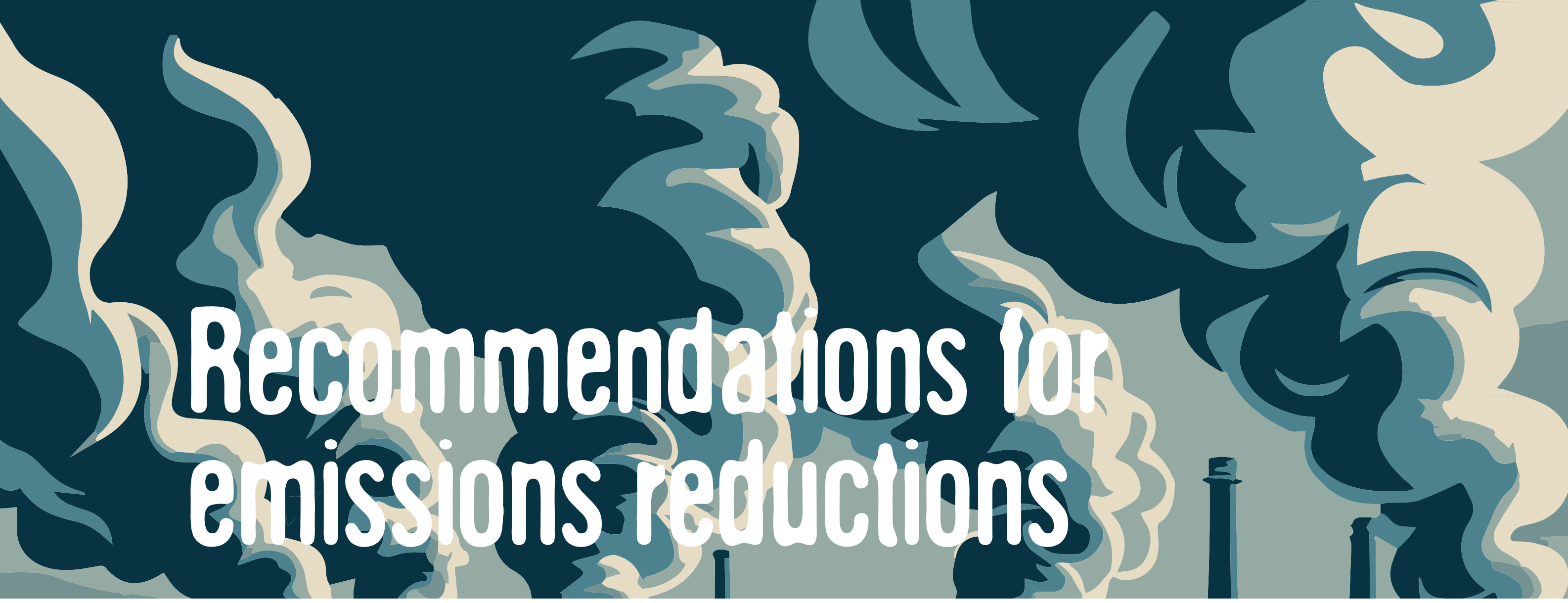
The emissions data does not provide a breakdown into sub-categories. From the above, we can assume that the food sector is the main user of refrigeration, and we have made a proxy estimate of contributions at 80% of the total for refrigeration (3,878 Gg CO_2e). It should be noted that "while refrigeration entails the use of energy it can of course also help save energy by reducing food waste", including both the direct emissions from landfills and the embedded energy used to produce the product (Garnett, 2007:7).

Smaller sub-categories within IPPU are the minerals and chemicals industries. Emissions from the minerals industry are mostly cement production, with a small amount of lime. The share of emissions from lime production for agriculture is based on an estimate of 5% of lime being used in agriculture (Motsie, 2013). The chemical industry includes the production of organic and inorganic chemicals, including ammonia (fertiliser and other uses) and nitric acid production (mainly for fertiliser) (DFFE, 2022:134–135; 159–160).

Ammonia is the most important nitrogenous material produced and is a major industrial chemical. About 70% of ammonia globally is used for fertilisers, while the remainder is used for various industrial applications, such as plastics, explosives, and synthetic fibres (IEA, 2021). Nitric acid is a raw material used mainly in producing nitrogenous-based fertilizer. Almost 80% of nitric acid is used in manufacturing fertilisers (Businesswire, 2020). A detailed breakdown of emissions data per product is not provided due to business confidentiality. Eight industry divisions are indicated. Here we have simply assumed an even distribution of emissions across the chemical industry divisions to calculate estimated emissions. Ammonia and nitrous oxide combined are thus allocated 25% of total emissions from the chemical industry. We then use a proxy of a 75% allocation of emissions in these two divisions to the agri-food system based on the shares indicated above to arrive at the estimate indicated in Table 1.

Table 2. In a nutshell: Key agri-food related categories and percentage of total agri-food emissions

Category	% total agri-food emissions
Livestock	37.4
Electricity and heat production	13.7
Transport	11.3
Aggregated and non-CO_2 emissions on the land	11.2
Total for these four	**73.6**



Recommendations for emissions reductions

Establishing and working towards a transformative vision

At the outset, we must acknowledge that South Africa should do its share to contribute to global emissions reduction targets, but recognise that if South Africa acts alone, it will have a very limited impact globally as South African emissions are comparatively irrelevant. Global coalitions of states and citizens need to pressure the US, European Union, United Kingdom, China, and Russia to reduce their emissions as an urgent priority.

We should also recognise that we may be entering a period of 'non-linear' change, where events and outcomes are unpredictable, including massive environmental disasters that we have not seen to date. While South African emissions reductions will not make much difference to that, it is important to still make the effort. The real focus for the coming decades will need to be effective adaptation and resilience to disasters and shocks, especially for marginal producers and communities with limited options. This requires a focus on shoring up and building adaptive capacity and resilience.

There are two elements to the suggestions below for potential emissions reductions in the agri-food system. There are short-term technical interventions, but these should be coupled with a longer-term reorientation of the food system towards ecological practices, deconcentration to dilute risk, and democratisation and greater agency in the food system for inhabitants. Thus, even short-term technical responses should be situated in a wider transformative vision. We must recognise that "in a world where we manage to end the climate emergency, agriculture may be the last activity in which we continue to use fossil fuels" (Cox, 2021:107), as there are deep socio-economic, behavioural, and nutritional complexities to navigate.

The mainstream approach to emissions reductions can be characterised as technological fundamentalism, "the belief that the human economy can rely purely on technical innovation to expand material abundance while easily tidying up the wreckage we inflict on the biosphere in the process" (Cox, 2021:59). This is not the case.

We cannot consider emissions in isolation from the wider system. Emissions are just one of several interconnected sustainability issues to confront. Emissions reductions should be situated in the context of the longstanding imperative for progressive socio-economic transformation ('just transition'), which includes redistribution of resources, greater agency and participation in the economy for those who were previously and remain marginalised, and the realisation of the right to food as a core objective of food system structuring. For this, we need to look decisively beyond capitalism, which has revealed its inability to balance environmental protection with profit extraction. There is a need for a deliberate, systematic, and timebound movement towards an eco-socialist future.

Eco-socialism (Klein, 2021) identifies capitalist logic and practice as the root cause of the multiple crises we face as a species and a planet. The main barriers to transition are not technical or economic but rather social and political. A radical post-capitalist alternative is needed, through consolidating and building a material base of alternative practice in the present and to resist further destruction, as this will limit the possibilities in the future. Eco-socialism recognises ecological principles and sustainability as essential to life. It is democratic, with sustainable production based on human needs rather than profit, a reduction of wasteful energy use in commodity manufacture, and the provision of free basic services (health care, education, mass transportation based on renewable energy, and others). This will require adaptation and repurposing of existing infrastructure, the democratic socialisation of large-scale industry and money supply, agreed indigenous and scientific procedures to restore biospheres, the expansion of environmental goods and services in energy, transport, housing, education, food production, environmental remediation and management, and ultimately the democratic socialisation of surplus value.

Economic-political elites are not prepared to move away from the use of fossil fuels. We should thus call for elements of a transitional programme, including nationalising the fossil fuel industry and industries dependent on fossil fuels, to phase them out, and nationalising the banks and money supply, bearing in mind that the positive effects of nationalisation are dependent on democratic and accountable governance (Rose, 2021). Limits should be placed on individual income and wealth, with democratic ownership and decision-making, mutual aid, and environmental justice underpinning relationships. Public employment programmes should be developed to retrain workers into a sustainable economy with a universal basic income grant (Klein, 2021). These may seem radical, but in the face of the ecocide of global capitalism, there does not seem to be an option.

Overall, there is a need for longer-term solutions geared towards a fundamental shift of relations in the agro-food system, supporting diversity and justice in rural society. A mix of technical responses can likely be achieved by private actors in the immediate term, but this must be combined with an explicit focus on a just transition also resolving issues of social equity. At a global level, there is a need for a sharp reduction in consumption of meat products, targeting those who are overconsuming. Many smaller-scale efforts can contribute to shifting the balance of power and promoting democratic and environmentally sustainable systems. These include worker-owned cooperatives, tighter regulation of health and safety for workers and food, growing as much fresh produce as possible close to consumption, promoting community gardens and greenhouses, eating seasonally and preserving surpluses for off-season consumption, breaking up large farms and facilitating land redistribution, diversifying production, and including migrant workers (Cox, 2021:97–102). Displacement of annual monocultures with multi-species perennial landscapes can produce enough food while at least partially restoring soil ecosystems to a state of health, coupled with social principles of sufficiency, responsibility, and co-creation (Cox, 2021:107–108). Agroecology offers an integrative approach, as discussed below.

Collective concepts should be strengthened, not just individual rights; for example, collectively managed gardens and farms and cooperative grocery stores. Promote the commons as a "wide variety of self-organized social practices that enable communities to manage resources for collective benefit in sustainable ways" (David Bollier, cited in Rose, 2021:950), with autonomy, sovereignty, and control over everyday lives. Cooperatives and communal activities may be seen as embryonic expressions of alternatives. However, on a small scale, they may be susceptible to co-optation or serve to stabilise capitalism. There is thus a need for a transformative political-economic and cultural vision and strategies based on an ethic of solidarity and mutual aid, and emphasising ownership of means of production and redistribution of assets (Rose, 2021).

Specific recommendations for reductions in agri-food system emissions

As explained above, we are using the base emissions in 2020, which came to 468,812 Gg CO_2e (ex FOLU) as indicated in the 8th emissions report (468.8 Mt). The draft Sectoral Emissions Targets 2025–30 (DFFE, 2024) do not provide specific targets but indicate priority actions.

South Africa's Nationally Determined Contribution (NDC) was set at 350–420 Mt CO_2 equivalent (CO_2-eq) by 2030 in its updated first NDC published in 2021 (RSA, 2021:15). This means a reduction of between 10.4% and 25.3% of 2020 emissions in the next five years. If emissions reductions are spread across categories so that each category aims to reduce emissions by the targeted percentages, for the agri-food system this requires a reduction of 8.7-21.2 Mt CO_2-eq by 2030.

Energy

Energy is the biggest issue regarding emissions, even in the agri-food system. We cannot replicate today's high-energy living arrangements for a few in the face of the vast imbalances in energy security. There is an urgent need to move away from the deadly reliance on fossil fuels, and to adopt renewable energy on-farm, in manufacturing and transport. This requires investment in energy conservation programmes, renewable energy, and electrified mass transport (Klein,

Table 3: Synopsis of lower and upper targets for emissions reductions by agri-food category (Mt CO_2e)

Category	2020 emissions ex FOLU	Target reductions by 2030	
		Lower	Upper
Energy	33.94	3.50	8.59
Livestock	31.37	3.26	7.94
Aggregated and non-CO_2 emissions on the land	9.40	0.98	2.38
Organic waste	4.75	0.49	1.20
Refrigeration	3.88	0.40	0.98

2021; DFFE, 2024:28), with a shift from road to rail for the distribution of agricultural and food products, and from internal combustion engines to electric vehicles powered by renewable energy sources (DFFE, 2024:27). A more radical agenda requires the nationalisation of the fossil fuel industry to systematically phase it out and replace fossil fuels with renewable energy sources within defined timeframes. It is important to note that debt and financial issues loom large in any transition to renewable energy. Without adequate resources, it will be impossible to make the required shift.

Energy efficiency in agricultural production will need to improve in any scenario (DFFE, 2024:25). Longer-term changes in energy input vs output in agricultural production pose challenges. An increase in the use of animal draft power would require a huge expansion of grain production. The use of biofuels would require a huge expansion of oilseed production, noting that fuel ethanol doesn't save energy or emissions. An alternative is on-farm biogas production, although quantities may be limited. The DFFE draft strategy on food loss and waste calls for the development of a strategic framework for the biogas industry, including subsidies or tax exemptions (DFFE, 2023:40). Other alternatives are electric tractors and combines powered by solar and wind, although there are current limits to battery storage technologies (Cox, 2021:102-105).

An agroecological approach calls for local solutions wherever possible, such as on-farm renewable energy based on solar or biogas technologies. This would also generate economic activity that could be built on small enterprises. Re-embedded local food systems based on local production for local consumption align both with the National Food and Nutrition Security Plan (NFNSP) and with the recent food systems transformation pathways (DALRRD, 2021). This structural approach can reduce transport emissions through shorter supply chains.

Livestock

Managing livestock is a priority for emissions reductions in the South African food system, but it is a complex topic with deep cultural, social, nutritional, economic, and ecological dimensions. The livestock sector offers a good example of how we cannot isolate emissions reductions from wider considerations. It is essential to consider knock-on effects and local contexts. This requires deliberation amongst key actors, and not just agribusiness and government sitting together to decide what happens.

There is ongoing talk in policy about the need for participation. This has to be operationalised in practice, including marginalised smallholder producers, communities, consumers, and other supply chain actors to articulate their vision of the role of livestock in a future system and forms of production and discuss the challenges, difficulties, and possible responses. This offers the basis for a way forward rather than leaving it to industry to develop a 'Master Plan' (RMVCA, 2022) that focuses on consolidating and building the commercial sector, with the main role for smallholders to achieve standards and requirements to participate in agribusiness value chains.

There are multiple contentious issues in the debate about feedlots vs grazing, which include emissions, but also environmental pollution, human health and nutrition, and animal health and welfare. Multi-dimensional assessments are required, as are more detailed studies on the multiple trade-offs in different contexts. Emissions reductions are one element, but other issues must be considered, such as nutrition, culture, grassland restoration and maintenance, water pollution, soil fertility, and livelihood resilience (with livestock as a buffer for resource-poor communities and producers). Any proposed solutions must be filtered through all these dimensions to better understand the multi-dimensional impacts of interventions.

The 2015 agriculture sector Climate Change Adaptation and Mitigation Plan (CCAMP) tends to adopt a market-based and technocratic approach to emissions reductions in the commercial sector and, in places, promotes consolidation of production and the phasing out of small-scale producers as unviable. For adaptation in extensive grazing systems, CCAMP suggests that producers will have to adapt stock densities to accommodate changes in grassland carrying capacity, reduce alien invasive grass species (which tend to be less palatable than indigenous species), promote fodder storage, and provide supplemental feed and water. While the CCAMP says that "several adaptation strategies can be implemented to protect intensive livestock production", it doesn't list these and indicates that infrastructure investment may reduce profitability (DAFF, 2015:46). Climate is mentioned only four times in the government-supported Red Meat Industry Strategy 2030, with no discussion on adaptation or mitigation (RMVCA, 2022). Mitigation measures include optimising grazing intensity, altering the length and timing of grazing, and grassland renovation, but all with relatively low mitigation potential (DAFF, 2015:57–58). The draft agriculture SETs emphasise emissions reduction technologies for livestock (DFFE, 2024:25). The Just Transition Framework also promotes the belief that (market-based) innovation in production and freight transport will stabilise the agricultural sector despite the climate and other pressures (PCC, 2022:14).

On the more positive side, ecosystem-based approaches have some traction in existing strategies and plans. Climate-smart agriculture is adopted as the framing. Although this can be seen as a movement in the right direction, this approach is essentially limited to 'ecological modernisation' (resource use efficiency) without the transformative elements, especially on ownership and control. The draft agriculture SETs refer to conservation agriculture, and generally water and soil conservation as indicated in the Conservation of Agricultural Resources Act (DFFE, 2024:25).

In line with the wider suggestion that emissions reductions in the agri-food system must go hand in hand with a more transformative and democratic vision, there is a need to counter the 'business as usual' approach of CCAMP. Agroecology offers an integrative approach that explicitly orients towards the redistribution of resources, including land and water, a change in production systems towards integration, mixed farming, diversity in farm sizes, multiple uses of livestock, and an emphasis on grasslands and the restoration and conservation of land and biodiversity.

On the demand side, reducing meat consumption is widely proposed as a key element of reducing emissions in the livestock sector globally (e.g. IPCC, 2019). This will confront social and cultural barriers in a country where meat consumption is a core part of diets. Animal proteins can play a positive role in human nutrition.

"Food products from animals provide a variety of macro- and micronutrients. Animal sources of food, such as fish, chicken, meat, and eggs, constitute high-quantity and high-quality protein, as they contain essential amino acids in the right proportions ... Adding a small amount of these food products to a plant-based diet can yield considerable improvements in human health." (Schonfeldt et al., 2013:S66)

The South African Food-Based Dietary Guidelines (FBDGs) recommend that "fish, chicken, lean meat and eggs can be eaten daily" (Schonfeldt et al., 2013:S75), with the emphasis on "can". While animal protein contains key nutrients including protein and diverse micronutrients not readily available in other foods, it also introduces unhealthy saturated fats into the diet. The FBDGs recommend that fish be eaten two to three times a week (160–270 grams/week), about four eggs be eaten per person per week, and a serving of lean meat of no more than 90 grams a day (Schonfeldt et al., 2013:S75). These figures convert to 8.3–14 kg of fish, 208 eggs (9.4 kg at an average of 45 grams/egg), and 32.8 kg of lean meat per year.

Meat consumption in South Africa has increased across all income categories, especially driven by the growth in the middle classes. Ninety per cent of the South African population eats meat (NielsenIQ, 2021:6), and meat represents 26% of the typical adult plate, against a recommended 12% (26% for children) (NielsenIQ, 2021:7–8). Forty-six per cent of the population eats meat daily, with another 46% eating meat two to three times a week (NielsenIQ, 2021:12). Poultry and beef are the main types of meat consumed. South Africa's per capita consumption of poultry meat and beef was 34.8 kg and 16.5 kg respectively in 2023/4 (DALRRD, 2024:60). Pork and sheep consumption added another 5.7 kg and 2.7 kg respectively in 2023/24 (DALRRD, 2024:62,64), making a total of 59.7 kg/capita /year of meat consumed.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Per capita consumption of fish was 6.45 kg in 2021, with a general downward trend from the mid-1970s to the mid-1990s, after which the trend flattened (Our World in Data, 2024). Unsurprisingly, coastal communities have traditionally consumed more fish in their diets than inland communities (FAO, 2018:12). Per capita egg consumption was 7.35 kg in 2022/23 (DALRRD, 2024:69). This indicates that both fish and eggs could be increased in the dietary mix as meat alternatives, especially for low-income consumers.

Meat consumption is, therefore, well above the FBDG recommendations. However, consumption is unevenly distributed across income categories. "Low LSM [Living Standard Measure] groups spend proportionally more of their income on grain-based foods compared to meat and also more on chicken than on beef, while the opposite applies to high LSM groups" (Strydom et al., 2019:122). There is surprisingly little data on food consumption by income categories. A 2012 report by Statistics South Africa shows that consumption of animal protein was high across income quintiles, but rising with income (StatsSA, 2012:34). There is little difference across urban and rural areas in the percentage of households consuming meat.

However, although households in lower quintiles do consume meat, there is no data on the quantities consumed by different income categories. Another study based on the same data (Vermeulen et al., 2015) showed that low-income households (most households in South Africa) accounted for less than 20% of total expenditure on any type of meat, including poultry, dropping below 5% for mutton and pork. This signifies a very sharp difference in consumption between wealthier and poorer households. The implications of this for emissions reductions is that dietary changes are required to reduce consumption by wealthier consumers, but this will be somewhat offset by an increase in consumption for those below recommended daily levels as part of a commitment to realise the right to food and healthy nutrition.

We should also recognise that livestock, especially in feedlots, depend on grains and oilseeds, with animal feed utilising up to 50% of these crops annually. Emissions from the production and distribution of these crops should thus be added to the livestock contribution. Ecological production methods that reduce emissions from grain and oilseed production should be adopted, including reduced use of synthetic fertilisers and replacement with compost, manure, and legume intercrops or rotations for nitrogen. Agrochemicals in the form of synthetic fertilisers and pesticides pollute water and soil, reduce biodiversity, and increase GHG emissions from degraded soils. As such, biodiversity loss, climate change, land degradation, and water and soil pollution are all interconnected, with an integrated response to all required, not to one or the other in isolation. This is recognised in global climate and biodiversity agreements, which have explicitly called for the adoption of agroecological practices, the reduction of 'excess nutrients' (mainly nitrogen and phosphorous from synthetic fertilisers), and the phasing out of toxic chemicals (CBD, 2022).

Aggregated and non-CO_2 emissions on the land

The main sources of emissions in this category are crop residues, inorganic (and organic) fertiliser, and burning biomass.

Above-ground crop residues (primarily cereals, e.g. stalks and stover) are a valuable resource, representing more biomass than is harvested as grain. Unlike biofuels, crop residues do not require additional land to generate the resource. Crop residues embody energy equal to about 15% of global human primary energy usage, and approximately 19% of livestock feed by weight (globally). Crop residues are used as a domestic fuel source, but residues are also left in the field as an important source of carbon and nitrogen for agricultural soils and to maintain or enhance soil organic carbon stocks. However, there is a general lack of knowledge about how current residues are being used (Smerald, et al., 2023).

The main emissions issues with crop residues are decomposition if they are left in place or combustion (burning of residues in the field), which releases GHG emissions (Lussich et al., 2024). Using residues for animal feed can reduce the number of grains and oilseeds planted, representing avoided emissions. Residues can also be used to produce biochar to reduce emissions and improve soil fertility. Biochar is stable and can sequester carbon in the soil for relatively long periods and can also reduce fertiliser requirements and transport. The sequestration potential of biochar is estimated at 3–7% of total emissions. Two constraints in using residues are the fraction that can be harvested without increasing soil degradation and the fraction already used for fodder (Karan et al., 2023). It appears that in South Africa, most residues are used for animal feed (Smerald, et al., 2023), and there are thus trade-offs between residues for livestock feed and for biochar production.

The CCAMP recommends conservation agriculture practices (minimum soil disturbance, intercropping/crop rotation, permanent ground cover), water harvesting and recycling, water use efficiency, wetlands conservation, integrated crop and livestock production, and indigenous crops suited to local conditions as key adaptation measures. These are very much in line with agroecological principles and practices. From a mitigation angle, the CCAMP notes that non-CO_2 emissions are more difficult to mitigate than CO_2 emissions. Increasing soil organic carbon stocks could compensate, although the plan notes that carbon sequestration is only temporary, whereas reductions in N_2O emissions are permanent and non-saturating (DAFF, 2015:55). The management practices with the greatest potential for mitigation of non-CO_2 emissions are extensification, permanent crops, grass in orchards and vineyards (N_2O), and organic soil restoration (CH_4). The high-potential practices for N_2O mitigation, however, have a low likelihood of implementation as they may reduce production and flexibility (DAFF, 2015:57-58).

The South African National Biodiversity Institute and the DFFE call for limitations on further non-vegetative land use conversion of grasslands and forests as a key pillar of mitigation and biodiversity conservation. Future cropping can be planned to take place on previously utilised but now fallow lands, and to accommodate biodiversity


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priorities (SANBI, 2007:24). The draft SETs on environment and forestry call for enhancing carbon sequestration in disturbed ecosystems such as grasslands and indigenous forests (DFFE, 2024:28). The CCAMP notes that "measures with high mitigation potential (zero tillage, adding legumes, reduced tillage, residue management – no removal of residues, rotation species, catch crops, fertiliser application/type) are all associated with no or low implementation costs", and that these measures have multiple environmental benefits and should therefore be considered as part of improving the general environmental performance of agriculture (DAFF, 2015:55).

For soil fertility, alternatives are needed to replace the industrial production of nitrogen fertiliser. Reduction of the use of synthetic fertilisers also finds support in GBF Target 7, which calls for reducing pollution risks and negative impacts of pollution. This includes reducing by at least half excess nutrients (phosphorous and nitrogen) lost to the environment, through more efficient nutrient cycling and use. Examples of alternatives are using legumes (intercropping to save space), manure, and biochar (which also provides carbon sequestration). The million tons of animal manure produced annually in South Africa is enough to meet soil nutrient needs of around 13.3% of nitrogen, 27.6% of phosphorus, and 9.9% of potassium. However, only 25% is currently used on the soil, while the remainder is unexploited due to management constraints (Raimi et al., 2017). These constraints include variability in the nutrient composition of manure, appropriate application to avoid nutrient loss, and the regulatory environment for manure use. These are knowledge-intensive practices, and there is a need for comprehensive manure nutrient management plans that address feed management, manure handling and storage, land application of manure, land management, and record-keeping (Fulhage, 2018).

We must recognise that not only synthetic fertiliser but also manure, to some extent, produce emissions. Harvesting results in nutrient extraction from the soil, and production constantly needs nutrient addition to recover this loss. This, therefore, poses a limit to emissions reductions from using less synthetic fertiliser. On the other hand, it does reduce emissions from the production and transport of these fertilisers. All of these aspects require thorough consideration to assess possible impacts on overall production and the ongoing imperative to rebalance consumption inequities.

There has been a gradual decline in emissions from burning biomass since 2005 (DFFE, 2022:208). There are differing scientific views on the value of burning grasslands, with general agreement that prescribed burning can play a useful role in land management to remove moribund and unpalatable grass material and to prevent bush encroachment. But this needs to be done with caution as it is an "extreme defoliation treatment". In general, there is excessive burning in South Africa, which can result in exposed soil and soil erosion, reduced water absorption, lower canopy cover, diminished species diversity and veld condition, and desertification. Emissions reduction plans can target reduced prescribed burning through better management and a deeper understanding of ecosystem dynamics. The least damage is done when grass is dormant, temperatures are below 20°C, and relative humidity is above 40%. Controlled burning requires firebreaks and well-trained staff. Patch burning (mosaic of burned and unburned areas) could be used to reduce fire hazards and provide biodiversity islands (Dugmore, 2012).

Sugar is a special case for consideration. For various reasons, 90% of sugar cane is burnt before harvesting. Cutting without burning is very difficult and time-consuming for workers. Burning frightens off cane rats and snakes (beneficial for worker safety). The weight of the harvested crop is reduced, hence lowering transport costs (and reduction of emissions from transport), and improving sucrose quality (Appleton, 2013). Burning of cane is one of multiple reasons to reconsider the sugar industry, which currently occupies the best agricultural land in South Africa, has an excessive water footprint, and generates an unhealthy product implicated in the growth of dietary-related diseases, including diabetes and obesity. The sugar sector is a locus of financial and corporate power which has led us down an unsustainable agri-food system path. Although there are several smallholder producers in the industry, there has been a sharp decline in numbers in recent times and the industry is under pressure. Land use is being converted out of agriculture into higher value development, including top-end residential settlement. Climate change is likely to see an inland shift in cane production, potentially leading to the displacement of populations currently living in those areas. There are multiple negative impacts of sugar production and consumption with few upsides. Proponents point to employment and exports as key positives. However, this land could be used in other ways that can also generate livelihoods for large numbers of people. Breaking up sugar estates and redistributing the land for local food production should be considered.

Overall, the response to non-CO_2 emissions from the land calls for more efficient management in the short term, altering production systems to incorporate lower synthetic fertiliser use, using more manure, legumes, and crop residues as synthetic fertiliser replacements, and reducing biomass burning. A key requirement is strengthened knowledge and capacity to adopt these practices.

Food loss and waste

As indicated earlier, although food loss and waste constitute a relatively small contribution to emissions, action to reduce loss and waste is highly relevant for biodiversity, water use and quality, climate (emissions reductions, less pressure to increase production), food security (nutrients and scarce resources being lost) and the economy as a whole. Sustainable Development Goal (SDG) 12.3 and GBF Target 16 both call for halving food waste (by 2030 for the SDG). Emissions reductions from halving food loss and waste are estimated at around 2.37 Mt, which is approximately the targeted reduction for this category as indicated in Table 3 above. If this target is achieved, it could ease the pressure for reductions in more difficult categories.

DFFE's draft Strategy on Food Loss and Waste indicates best practices for reducing food loss and waste, based on a 'food recovery hierarchy' (from most to least preferred practices): reduce the volume of surplus food produced at source; donate extra food to food banks, soup kitchens, and shelters;


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divert food scraps to animal feed, industrial uses (waste oil for rendering and fuel conversion, food scraps to biodigesters for energy production), or composting for soil improvement; and the least preferred option – send waste to landfills or incineration (DFFE, 2023:22). Specific suggestions include improving access to market, transport and storage infrastructure to reduce losses (DFFE, 2023:26–27), and promoting a circular economy (DFFE, 2023:75). The draft strategy also calls for an agroecology strategy to ease the certification burden and encourage smallholder farming (DFFE, 2023:36), to increase investments in local farm inputs and climate resilience (DFFE, 2023:48), and to expand local grower associations to facilitate group price negotiation and to receive services (DFFE, 2023:49).

Food standards can be adapted to allow nutritious and safe food that may not meet stringent commercial standards (including superficial cosmetic issues), but which is still safe to eat, to reach consumers (DFFE, 2023:39). Labelling can be clarified and standardised to reduce inconsistency and confusion resulting in food waste (DFFE, 2023:45). Food with quality labels such as 'sell by' or 'best before' dates may


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have reduced quality but can still be safe for consumption after those dates (DFFE, 2023:81–82). There is a relation between food loss and waste and refrigeration, with the latter potentially reducing food losses but also contributing to GHG emissions as discussed above. The DFFE calls for investment in refrigeration for smallholder farmers to reduce their losses (DFFE, 2023:84). This is an example of the type of trade-off needed for a just transition, where human needs (and especially those of marginalised people) are at the core, and then environmental actions are structured around this core.

The DFFE strategy aligns with an agroecological approach, in particular around directing edible and safe food to those in need, recycling (composting, biodigesters), circular economy, promotion of organic fertiliser, contribution to soil health, and promotion of agroecological production amongst homestead and smallholder farmers. Currently, there is only cursory mention of reducing food waste in the CCAMP or in the NFNSP, without inclusion as a priority in indicators or planned actions. It is relevant to both and should be included explicitly, as a cross-cutting objective.

Refrigeration

Refrigeration contributes a relatively small share of emissions, but there is room for reductions, coupled with an increase in refrigeration for those without access as part of just transition. There is a need to shift away from HCFCs and HFCs to natural refrigerants, in line with the Montreal Protocol on Substances that Deplete the Ozone Layer and amendments, to which South Africa is a signatory. The draft SETs on environment and forestry call for reducing HFC emissions into the atmosphere (DFFE, 2024:28). Resource use efficiency could be bolstered by a statutory requirement for doors to be placed on fridges in supermarkets. Cutting emissions from refrigeration by 25% could meet the upper-level reduction target by 2030. Agroecological approaches such as collective consumption, shorter supply chains, and increasing local production for local consumption, as well as increasing access to refrigeration for households and smallholder producers, as part of a just transition, can contribute to reducing emissions from refrigeration and simultaneously address unequal access to refrigeration for the population.

Conclusion

The agri-food sector needs to make its contribution to global and national reduction targets, while acknowledging that South Africa cannot make much of a dent in global emissions on its own. Given the vulnerability of the South African agri-food system to climate change impacts, especially smallholder producers, there should be a strong focus on adaptation in the context of a just transition. Without this, smallholder farmers are liable to be forced out of production and into migration into urban areas, which are poorly equipped to provide services and alternative livelihoods for millions of additional people.

As this backgrounder indicates, some adjustments can be made across the different emissions categories in the agri-food system. However, it is important to integrate climate response with wider environmental issues, as well as a just transition approach, to ensure that the marginalised and disadvantaged don't carry the costs of transition. A key element of any approach must be the participation of those directly affected in defining the problem, analysing the context, setting priorities, proposing solutions, implementing, and reviewing. It is widely accepted that impacts happen at the local level and solutions must be driven by local actors in their context with support from wider actors.

It is apparent from the literature that agroecology encapsulates many of the adaptation and mitigation options being suggested, including landscape and ecosystem-based approaches. This calls for an integrated and systemic response across environment, social justice, economic diversity, and democracy. We call for the promotion of agroecology as a key framing and guiding approach for the South African agri-food sector as it adapts to the imperatives of climate change.

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