The Inevitable Policy Response Forecast Policy Scenario 2023 (IPR FPS 2023)

IPR Bioenergy: Land competition, sustainable guardrails & cheaper, cleaner alternatives lead to a modest growth opportunity in bioenergy

October 2023

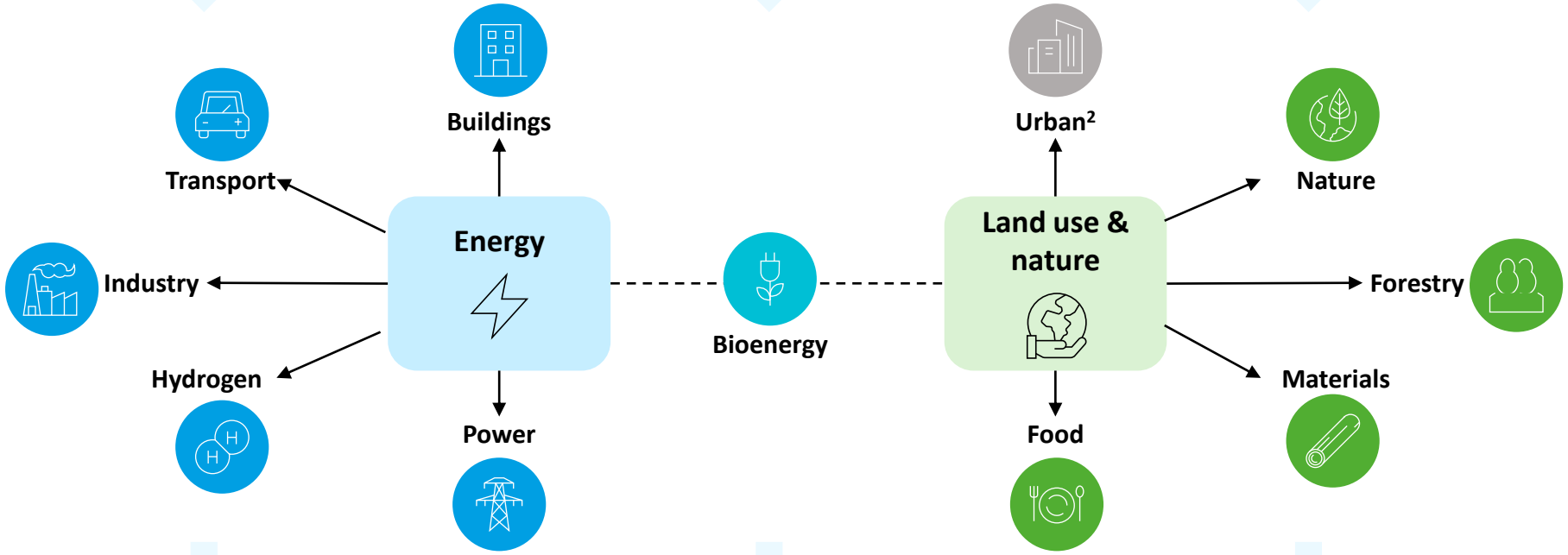
IPR offers a range of applications to help financial institutions navigate the climate transition across sectors and geographies

Policy forecast

IPR produces **>300 high-conviction policy forecasts** covering 21 countries and 10 policy areas across energy and land use

Policy forecasts feed into a fully **integrated climate and nature scenario model** that elicits the impact of the forecasted policies on the energy, land use, and nature systems up to 2050, tracing detailed effects on all emitting sectors[1]

Modeling



Value drivers

IPR's integrated scenario model outputs detail value drivers across energy and land use. See Value Driver Visualizer

Applications

Fitch Ratings, Morning Star, Paris Agreement Capital Transition Assessment (PACTA), Planetrics, *tilt (*Climate data for SMEs)

1. IPR also develops a '1.5˚C Required Policy Scenario'(1.5˚C RPS) building on the IEA NZE by deepening analysis on policy, land use, emerging economies, NETs and value drivers. The RPS scenario is also run through the model and can be used by those looking to align to 1.5˚C. 2. Urban areas are not modelled in detail in IPR

IPR FPS maps the key implications of the projected decarbonization pathway and the tremendous investment opportunities for nature and technology-based solutions for capturing emissions

Supply chain risk increases

Policy that encourages **deforestation-free supply chains** has **significant risk** implications for downstream companies in tropical commodities

Diets and waste transform

Diet shifts transform the food mix, creating opportunities in alternative proteins while innovation and increased consumption of ‘surplus food’ reduce global food waste globally

NBS takes off

Climate policy and incentives increase the uptake of NBS while increasing demand for housing drives opportunities in timber for construction

Bioenergy is constrained

Land competition, sustainable guardrails and cheaper, cleaner alternatives lead to a **modest growth opportunity in bioenergy**

The Policy Forecast remains largely consistent with 2021, though it shows some deceleration in ambition in the agricultural sector and includes three new forecast areas

Nature Action Climate Action Acceleration Deceleration No change

Policy Area	Policy Type	Policy Lever		Change in Forecast Relative to FPS 2021
Agriculture		**Emissions from agricultural production**	Policies that encourage farmers to significantly reduce emissions from agricultural production	
Land Use		**Afforestation and Reforestation**	Policies which encourage farmers to carry out significant afforestation and reforestation	
		Deforestation- free supply chains	Implementation of policies that require agricultural commodity inputs to be deforestation-free	New Forecast Area
Nature		**Land protection**	Achievement of Dec 2022 COP15 Biodiversity target of protecting 30% of land and marine area	New Forecast Area
		Nature incentives	Implementation of policies to deliver market incentives to improve biodiversity	New Forecast Area

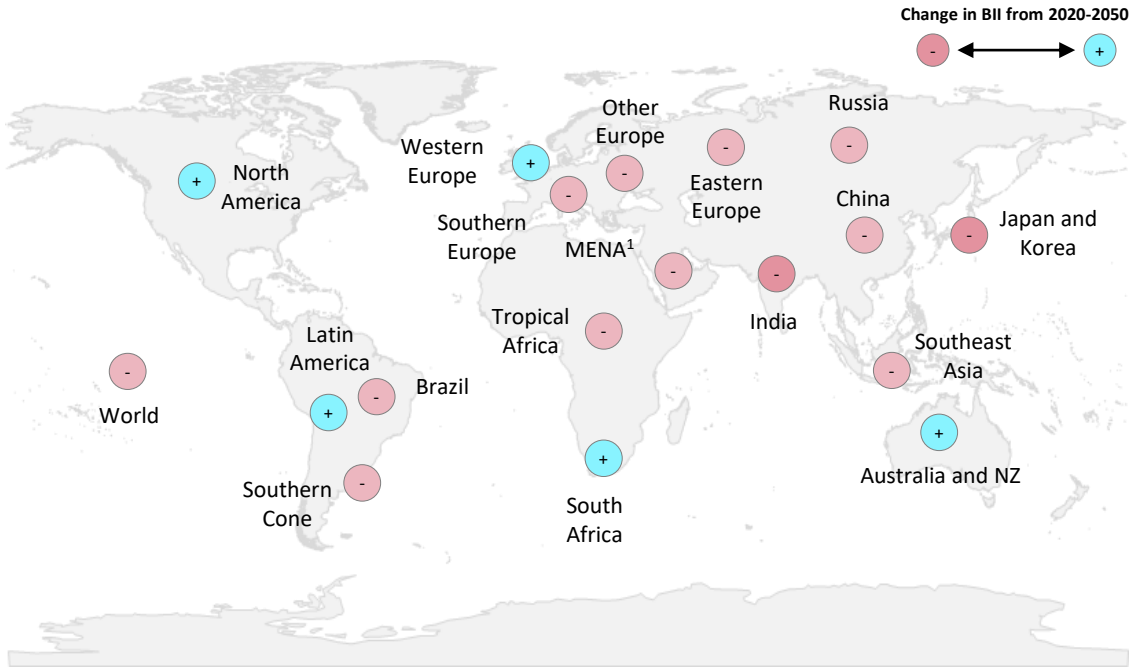
Policy Implications

1. Deceleration in some countries is often due to a delay in announcement of the policy expected in FPS 2021. However, these are mostly technical and have a small impact on overall land use projections
2. In the case that a country's policy ambition decelerates, this occurs before 2030, resulting in a low impact on the sustainable transition of agriculture in the short term
3. Area protection policies limits agricultural land expansion which interact with other agriculture policies as land competition increases

Conservation and restoration policies reverse biodiversity loss to 2020 levels by 2050

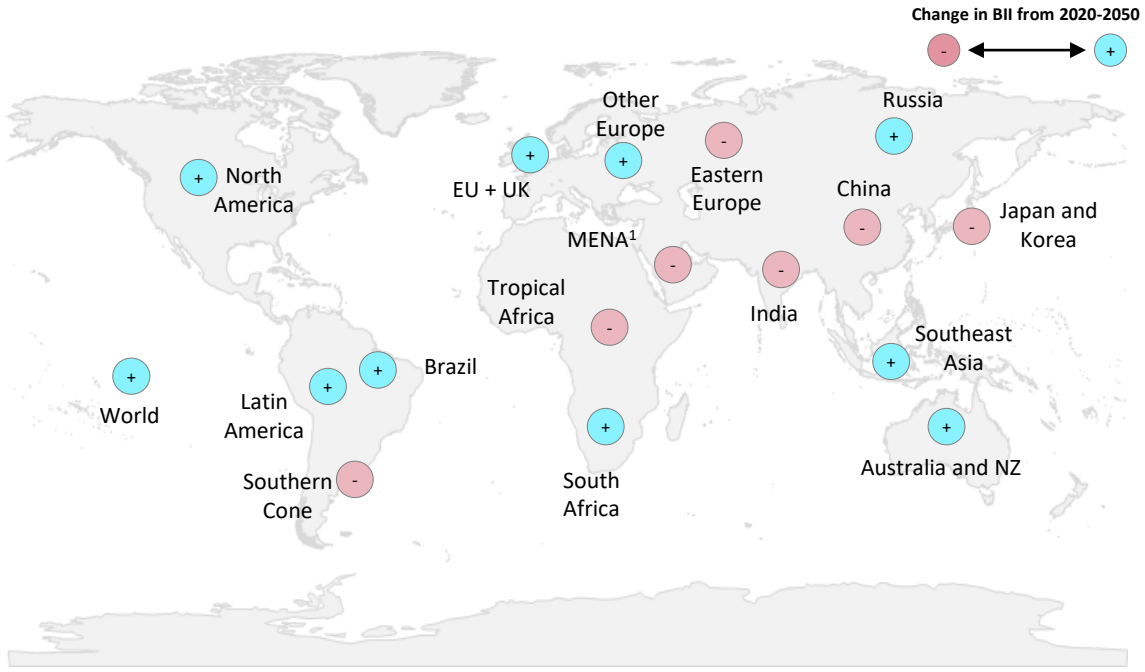
FPS 2021: Change in biodiversity 2020-2050

Pursuit of climate-only policies results in continued biodiversity decline globally and in critical regions such as Tropical Africa, Southeast Asia and Brazil



FPS 2023: Change in biodiversity 2020-2050

Nature policies related to protected areas, restoration and biodiversity valuation drives biodiversity recovery globally and in critical biodiversity-rich regions

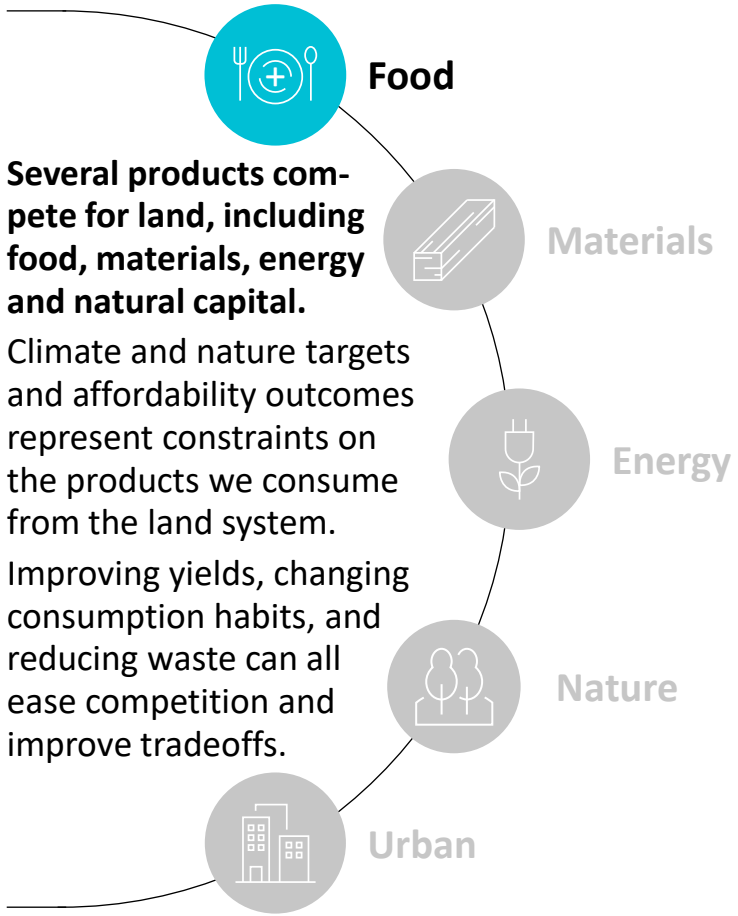


1. Middle East and Northern Africa

1. FOOD – Implications of FPS23 for food production

Deep-dive

Land system



Several products compete for land, including food, materials, energy and natural capital.

Climate and nature targets and affordability outcomes represent constraints on the products we consume from the land system.

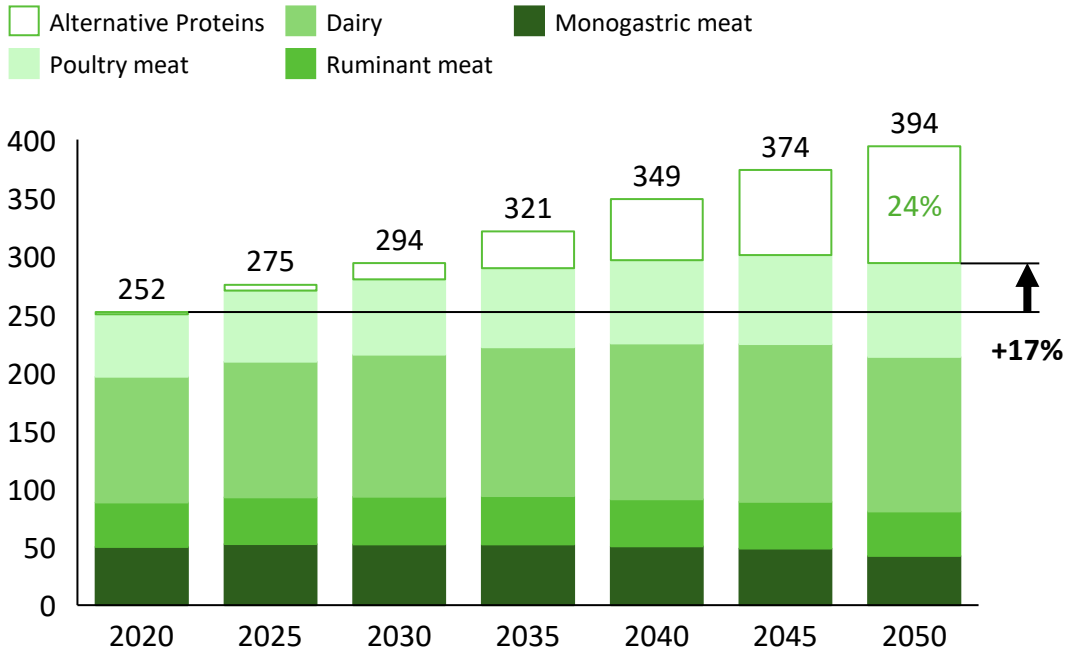
Improving yields, changing consumption habits, and reducing waste can all ease competition and improve tradeoffs.

Drivers	Description	Key Implications for the land use Sector
1. GDP and population growth	Population growth increases food demand, particularly in regions such as Tropical Africa and India	Per capita food demand grows by 26% globally as countries become wealthier and increase their consumption
2. Food waste	Food waste is particularly high in high-income countries, leading to inefficiencies in the food system	Waste reductions reduce the effect of GDP growth on food demand
3. Diet shifts and alternative proteins	Diets shift away from animal products, particularly ruminant meat (beef, sheep and goat meat) which peaks in 2035	A slowdown in per-capita consumption of animal products eases land use competition and reshapes the food mix by increasing the reliance on alternative proteins
Productivity	Increasing food demand in Emerging Markets and Developing Economies(EMDEs) is partially met by catch-up yield growth	Crop yields in EMDEs grow to accommodate some of the additional food production

Diet shifts transform the food mix, creating opportunities in alternative proteins…

Though global livestock production increases **by ~17%** by 2050, a diet shift to alternative proteins reduces overall reliance on animal products. In 2050, alternative proteins represent close to a quarter of global proteins production

Global Protein Production, Mt DM[1] per year



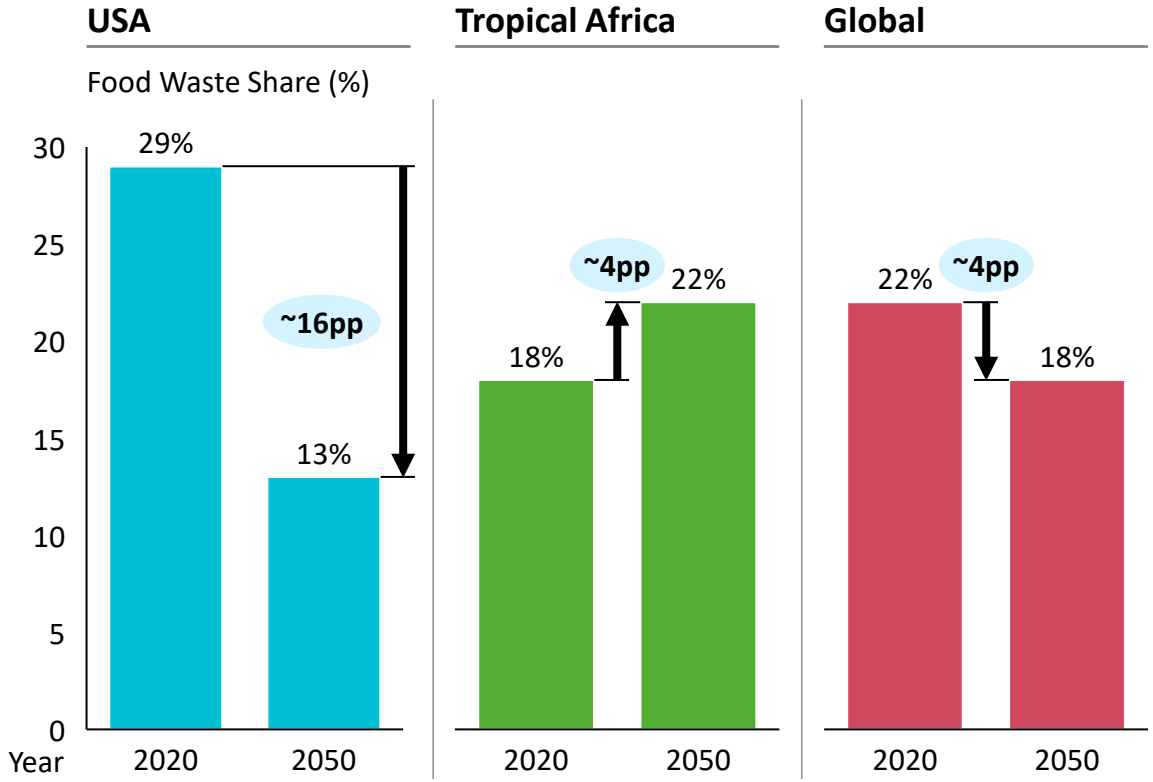
Note: 2020 baseline per capita food demand is calculated by Bodirsky et al (n.d.), using dietary data such as incomes, age distributions and BMI, calibrated against historical food demand data from FAO

1. Mega Tonnes of Dry Matter
2. Ruminants are herbivores with three- or four-chambered stomachs, such as cattle and sheep

…Innovation and increased consumption of 'surplus food' reduce global food waste globally

FPS expects the **share of waste in global food demand to decline by 4pp until 2050.** This is primarily driven by food waste reductions in **Advanced Economies**

Share of food waste in terms of food demand, 2020 vs. 2050 %



Deforestation, international trade reliance and pressure for disclosure increase financial risk

Key regions and products are at higher risk as policy tackling deforestation increases

Policy that encourages deforestation-free supply chains has significant risk implications for downstream companies in tropical commodities

Tropical soft commodity deforestation creates financial risk

Tropical soft commodities (beef, soybean, palm oil, timber, coffee, rubber, cocoa) **drive a disproportionate share of deforestation** creating financial risks for downstream companies

Reliance on international trade increases investor risk

Supply chains of tropical soft commodities are reliant on international trade, meaning that upstream deforestation in a few jurisdictions can drive direct and indirect risks to investors in downstream companies globally

Financiers and regulation are applying pressure for disclosure

There is **increased financier and regulatory pressure for companies to disclose the environmental impacts** of their supply chains and stress test their strategies for transition risk using scenario analysis

Revenues at risk in key regions and products

Revenues at risk are highest in Tropical Africa and Southeast Asia regions. Revenues at risk are also highest in beef and coffee supply chains as downstream companies sourcing from unregulated markets face additional reputational risks

Regions with integrated policies also at risk

Europe's integrated deforestation-free supply chain policies experience more risk when procuring from areas without such policies (such as Tropical Africa). This decreases over time as more regions integrate such policies

Global policy action required

An **'inevitable policy response' scenario includes significant policy action to tackle deforestation** in most jurisdictions – both exporting and importing – exacerbating risks for companies and investors

Despite challenges, climate policy and incentives increase the uptake of NBS…

Agricultural improvement

1.6 $GtCO_2$

removed a year by 2050 through agricultural improvement equivalent to ~938 Mha

Ecosystem restoration

2.2 $GtCO_2$

removed a year by 2050 through ecosystem restoration equivalent to ~302 Mha

Avoided forest loss

1.8 $GtCO_2$

In reduced emissions through avoided forest loss relative to a reference scenario by 2050

Nature action

980 MHA

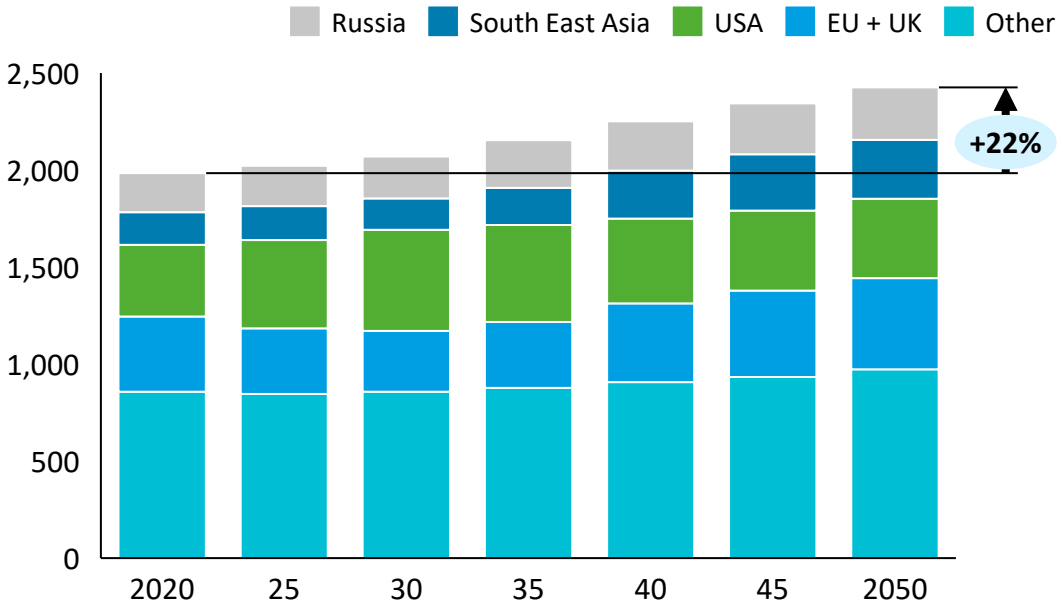
additional natural vegetation protection through increased nation action

…While increasing demand for housing drives opportunities in timber for construction

Increased use of lumber for sustainable construction materials accounts for ~1/3rd of the growth in timber demand, leading to **an overall increase 22% increase in industrial roundwood production**

Under FPS, 10% of all new buildings use wood as a construction material

Industrial roundwood, Mm^3/year



1. According to the Shared Socioeconomic Pathway 2 scenario, the global share of population living in urban areas could rise to 80% by 2100
2. IPR team modelling based on Churkina et al. (2020)

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INEVITABLE
POLICY
RESPONSE

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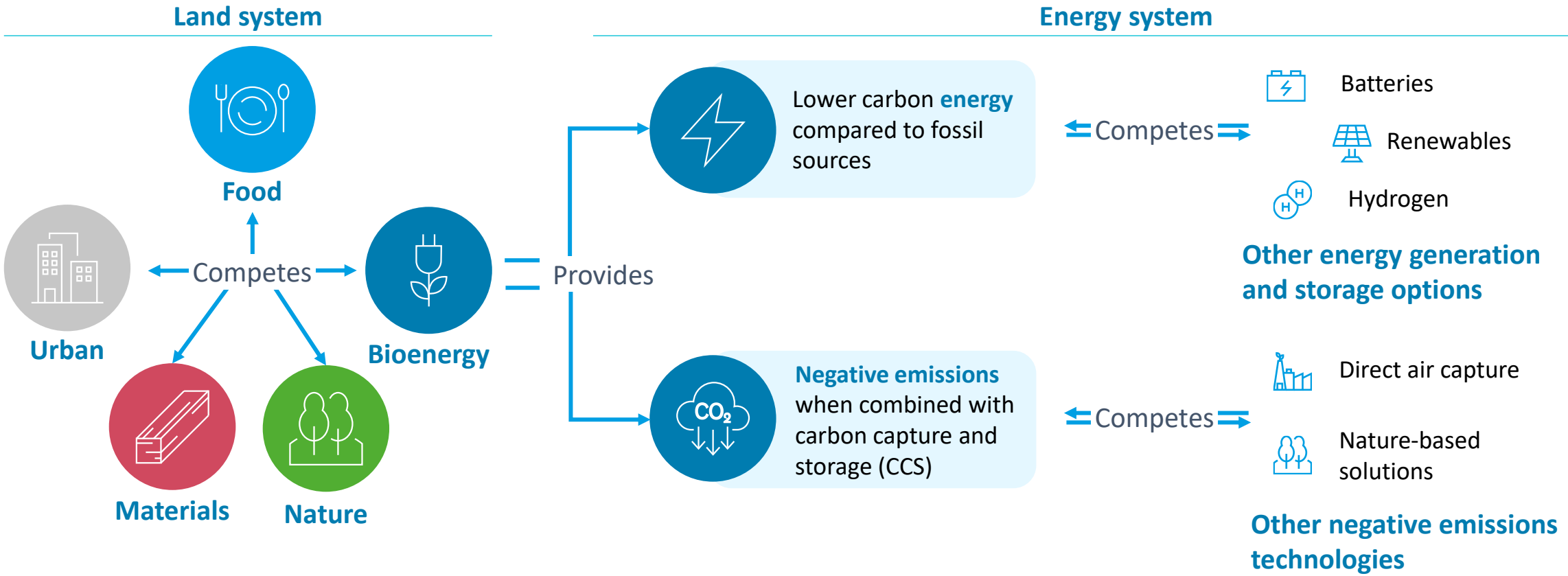
IPR Bioenergy: Land competition, sustainable guardrails & cheaper, cleaner alternatives lead to a modest growth opportunity in bioenergy

October 2023

Bioenergy bridges land and energy: Competition forces difficult trade offs between competing uses

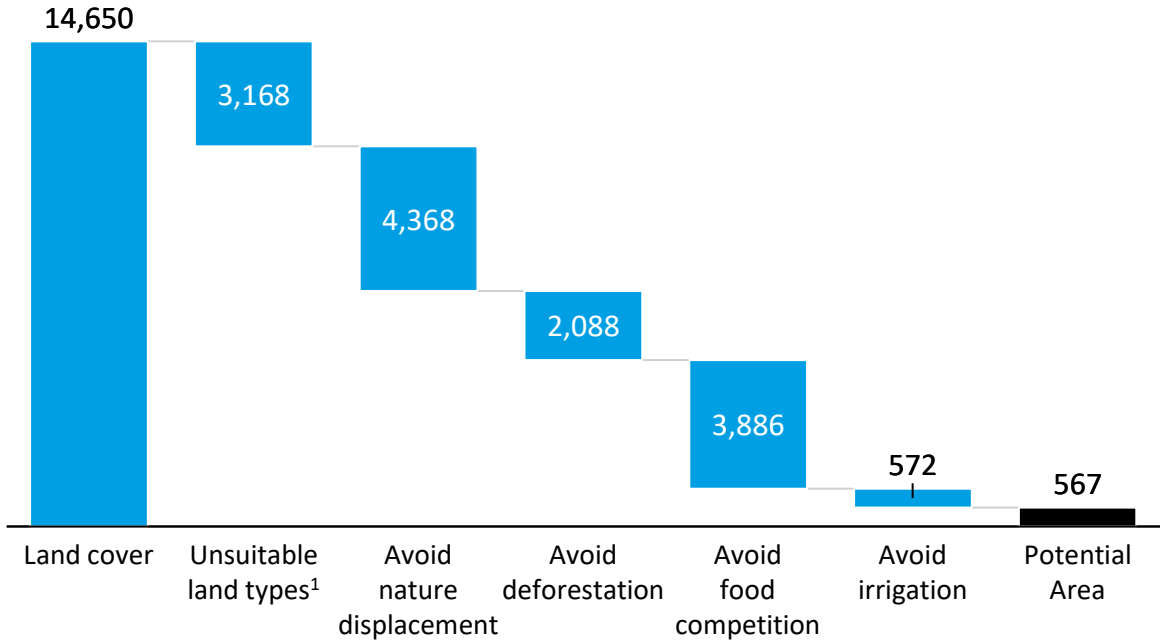
Climate, nature, and **affordability** outcomes represent **constraints on the outputs** we consume from the land system. Maintaining and restoring forested area, for example, is necessary for emissions and biodiversity targets to be realized



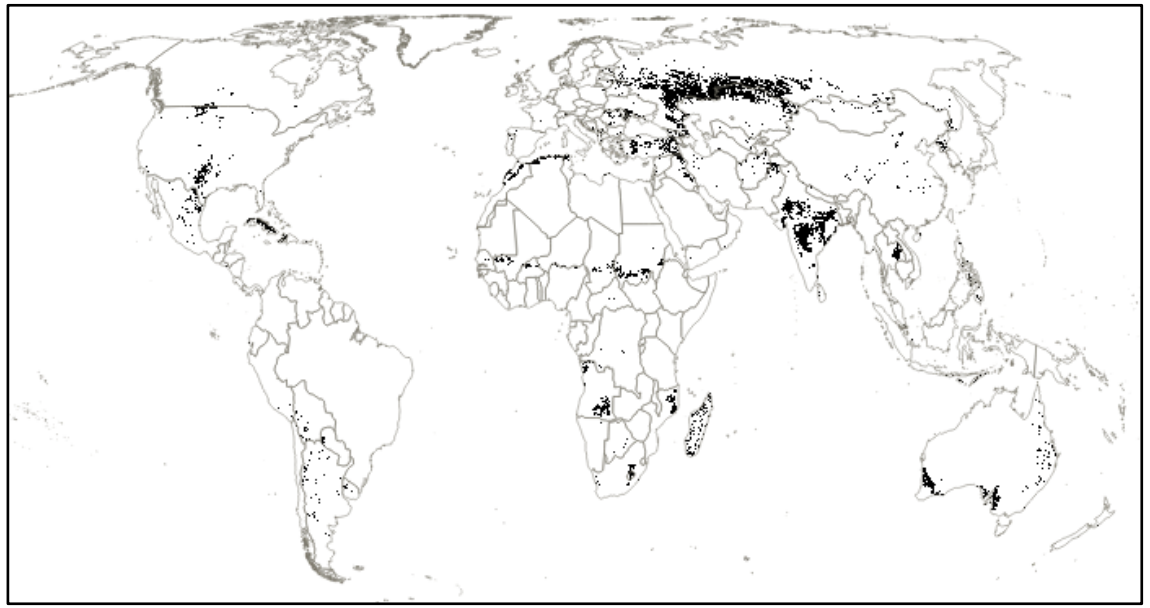
Improving yields, changing consumption habits, and **reducing waste** can all **ease competition** and improve tradeoffs

567 Mha in five different biomes satisfy the sustainability criteria, but only 15% of that will ultimately be used

Potential area for dedicated biomass crops after applying sustainability guardrails, Mha



Spatial distribution of dedicated biomass potential

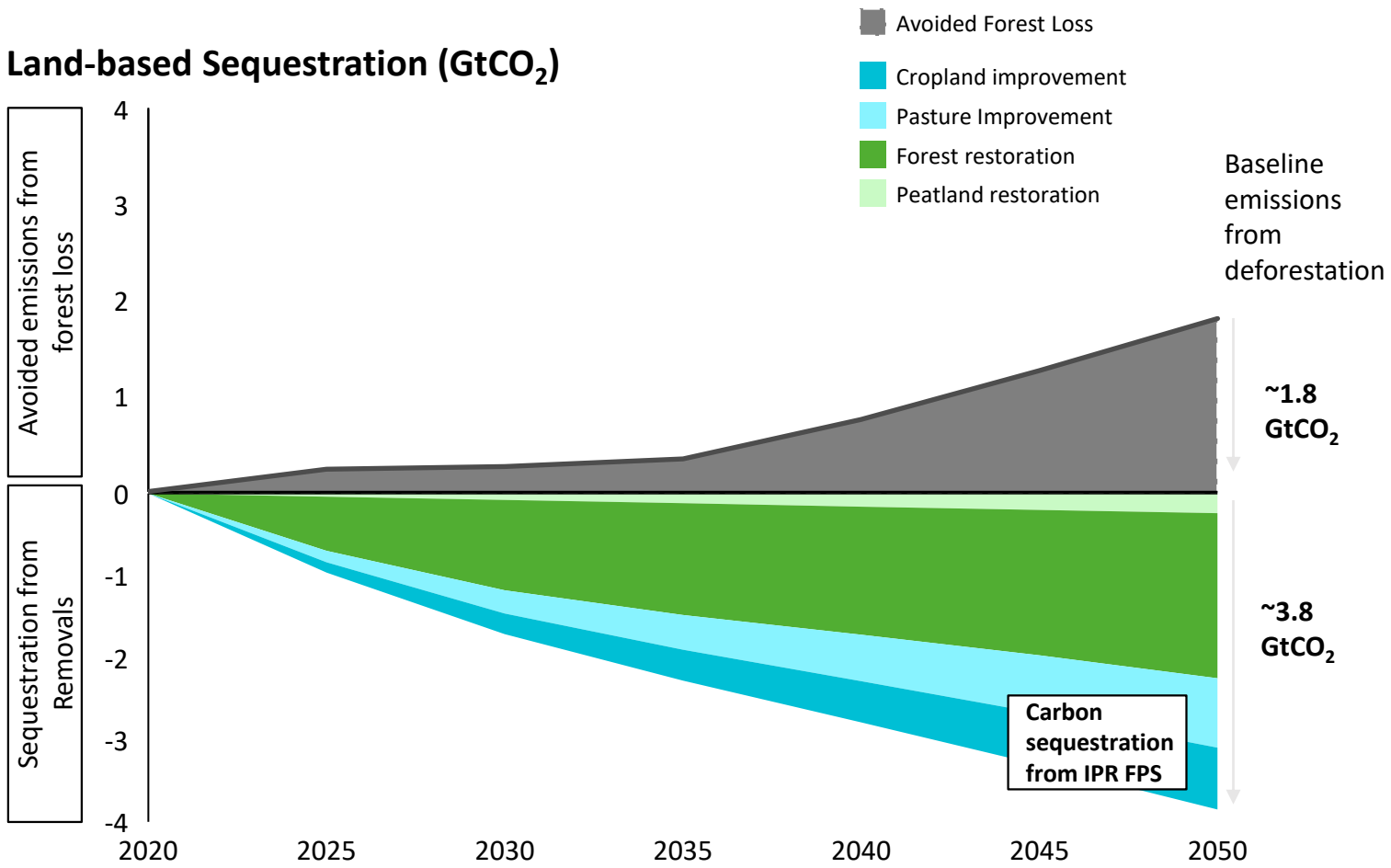


After applying the sustainability guardrails, a carbon payback period is calculated for the remaining available land to determine the most effective method of storing carbon

1. Exclusion of bare lands (e.g., deserts), urban areas, inland water bodies (lakes, rivers), and areas of permanent snow and ice.

Source: ESA CCI medium-resolution land cover; UNEP/IUCN (WDPA); IUCN; Spawn et al. Sci Data 2020; Xu et al. 2017 PEATMAP; Heiderer & Kochy 2012; Monfreda et al. GBC 2008; Biradar et al. 2009

By 2050, action to halt deforestation reduces emissions by 1.8 $GtCO_2$/yr, while other policy and market incentives helps capture an additional ~3.8 $GtCO_2$/yr



Land protection reaches 30% of national land area by 2035 in North America and China, and by 2030 in Europe. Globally, an additional 980Mha of natural vegetation is protected by 2050, stabilising biodiversity intactness to 2020 levels.

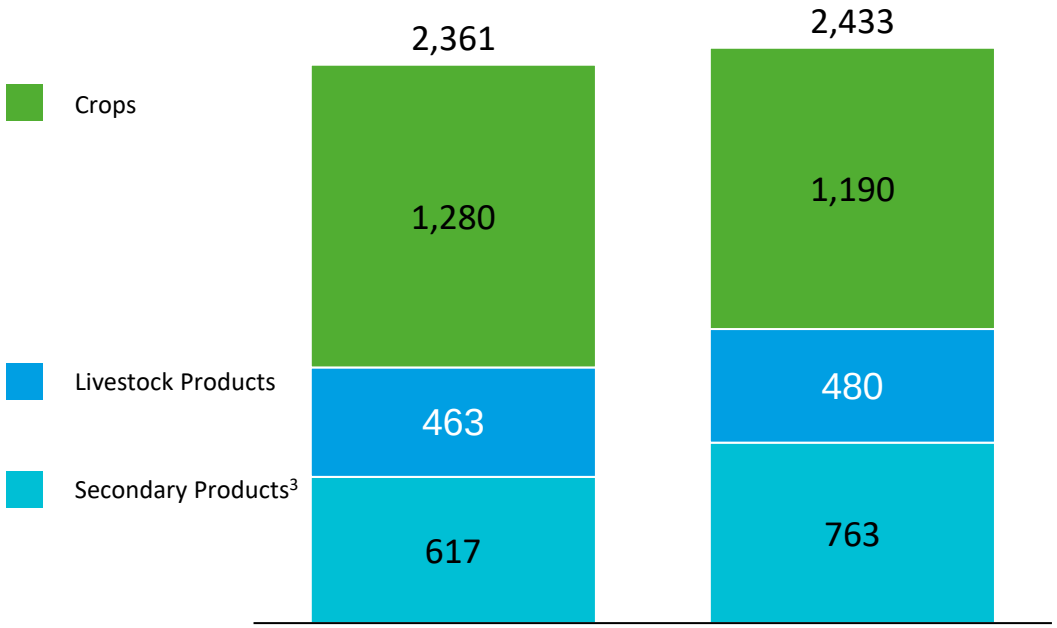
Brazil and Indonesia end effective deforestation by 2030 (each country contributes 25% of C02 emissions from land use change), with global deforestation ending by 2035.

1. The reference scenario projects the land use change we would expect to see without NBS policies that conserve forest land, improve practices to optimize sequestration, and create new ecosystems. These values represent the difference in removals and reduction between the FPS 2023 scenario and this reference scenario, as a baseline.
2. Ecosystems described here refer to major land-based and carbon-rich ecosystems (e.g. forests, peatland, mangroves, pastureland)

Cattle and sheep represents a small percentage of global average per capita caloric intake, but they could be responsible for ~20% of global emissions by 2050

Global Caloric Intake[4]

Kcal/capita/day

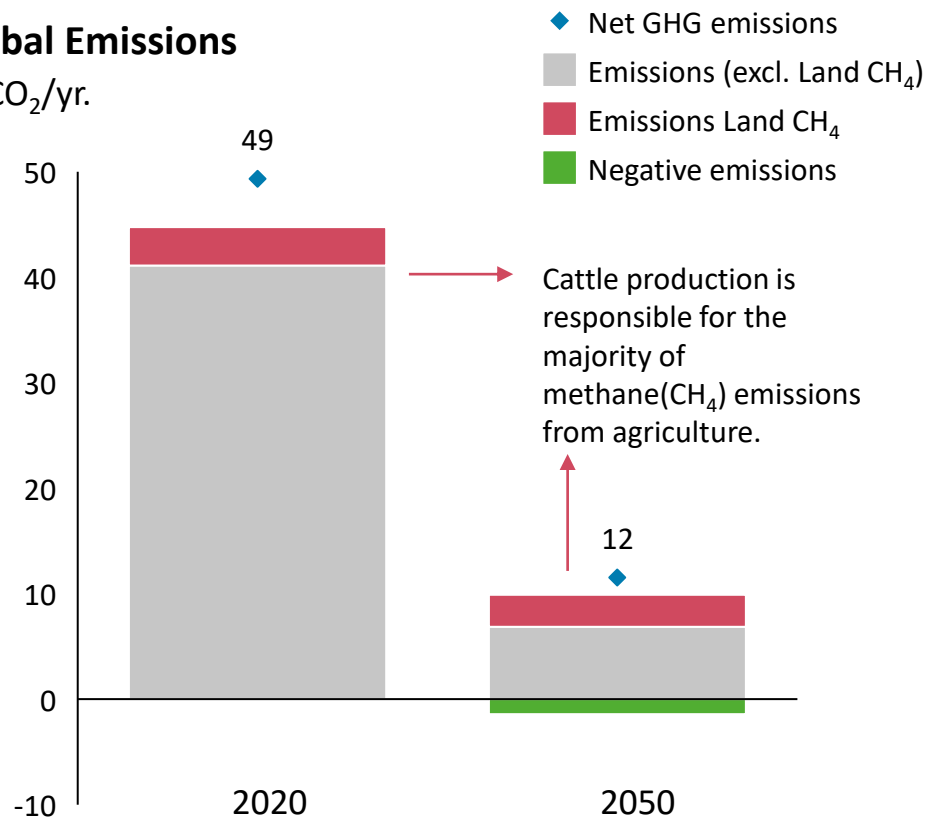


Dairy and beef consumption, %

~12% **~10%**

Global Emissions

Gt CO_2/yr.



Dairy and beef as share of total global emissions[2], %

~5% **~20%**

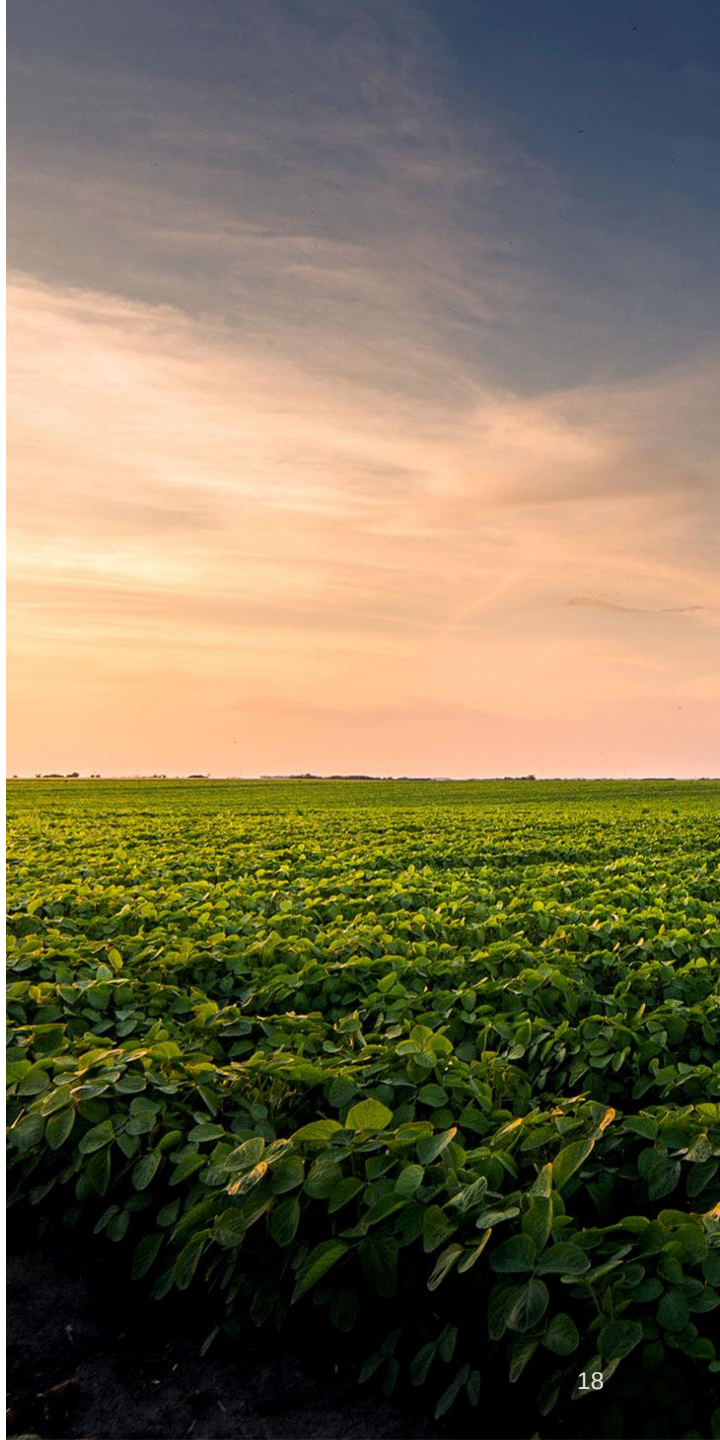
1. Using GWP 100 emissions values
2. We use enteric fermentation as a proxy for methane emissions form ruminants, which account for 70%-80% of total methane emissions from agriculture. This excludes a portion of emissions from animal waste management. Total emissions from animal waste management (covering all livestock products, not just ruminants) account for only 5-15% of overall methane emissions from land.
3. Including sugars, alcohol, brans and other secondary products
4. Caloric intake is caloric demand net of food waste

Source: Springmann M, Wiebe K, Mason-D'Croz D, Sulser T, Rayner M, Scarborough P. Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail

Land competition, sustainable guardrails, and cheaper, cleaner alternatives lead to a modest growth opportunity in bioenergy

Key takeaways from IPR FPS 2023

1. **Competition for land restrains modern biomass** for energy growth to occupy less than 1% additional cropland producing 41 EJ of energy after conversion losses by 2050
2. **Unabated biomass plays a long-term role in the aviation, shipping and pulp & paper sectors**, but is otherwise outcompeted by cleaner, cheaper alternatives
3. **Waste and residues are expected to make up a growing share of feedstock** as a more sustainable alternative to the 1G crops currently common. Some 2G dedicated biomass crops will likely be required to meet demand, but is limited to ~91Mha
4. **BECCS scales up significantly to ~1GT of removals in power and cement industries**, but further growth is constrained by high land opportunity costs combined with increased competition from DACCS
5. **Policymakers are expected to increasingly move toward sustainable biomass sourcing requirements**. Applying four guardrails can limit the high environmental costs of dedicated biomass: no nature displacement, no deforestation, no food competition and no irrigation
6. **There is a mismatch between current bioenergy infrastructure and what is needed in the long term.** Location and feedstock mismatches create both investment opportunities and stranding risks



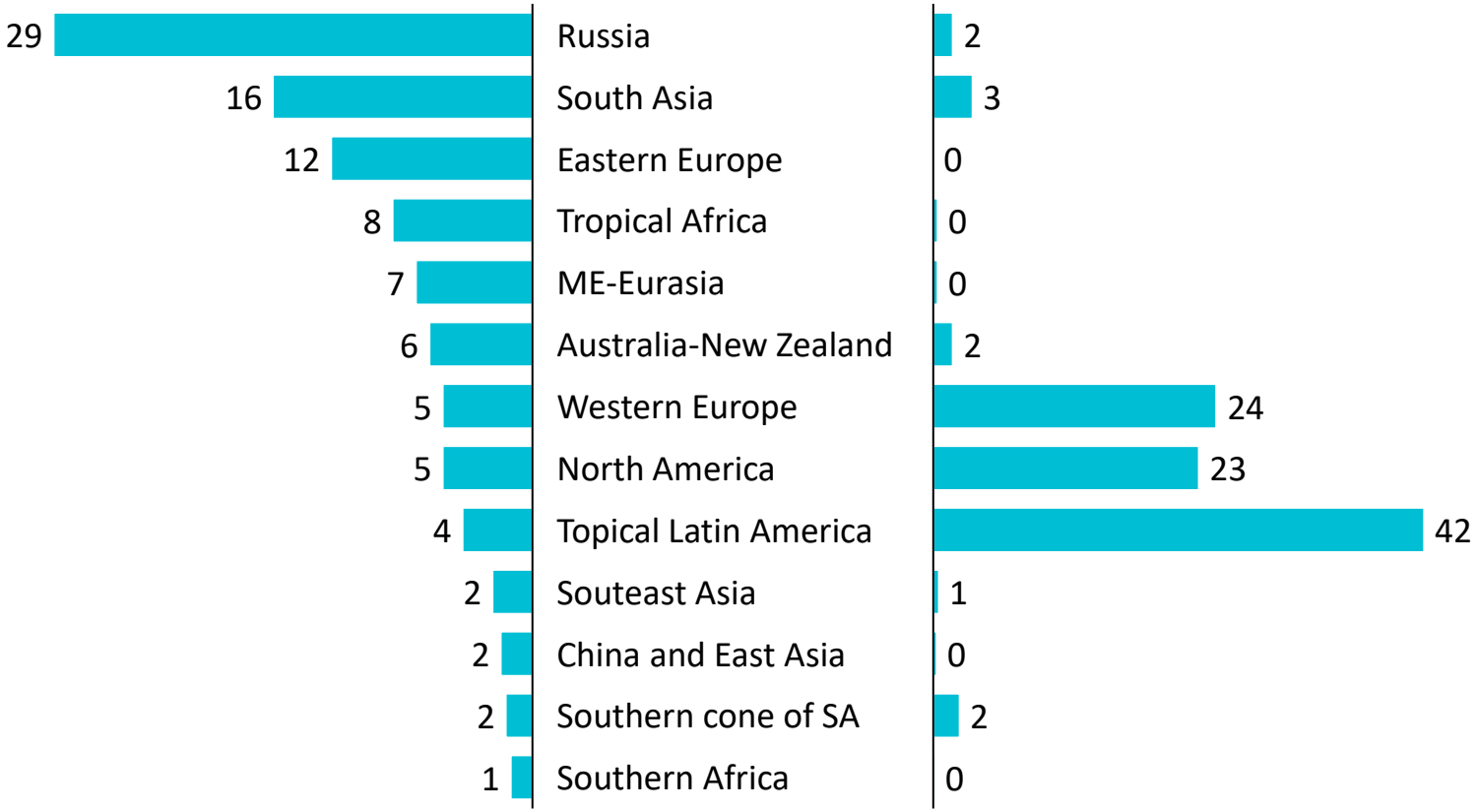
Land suited to bioenergy is typically far from current demand

Potential dedicated crop area[1]

% of global area after four guardrails (100%=567 Mha)

Biomass power plants[2]

% of global capacity



Land for dedicated bioenergy is available, though not where there is existing demand

That implies that **relatively little of the bioenergy capital stock currently deployed is well positioned for sustainable long-term supply.**

Feedstock sourcing is an important challenge for these plants if they are to continue operating long term.

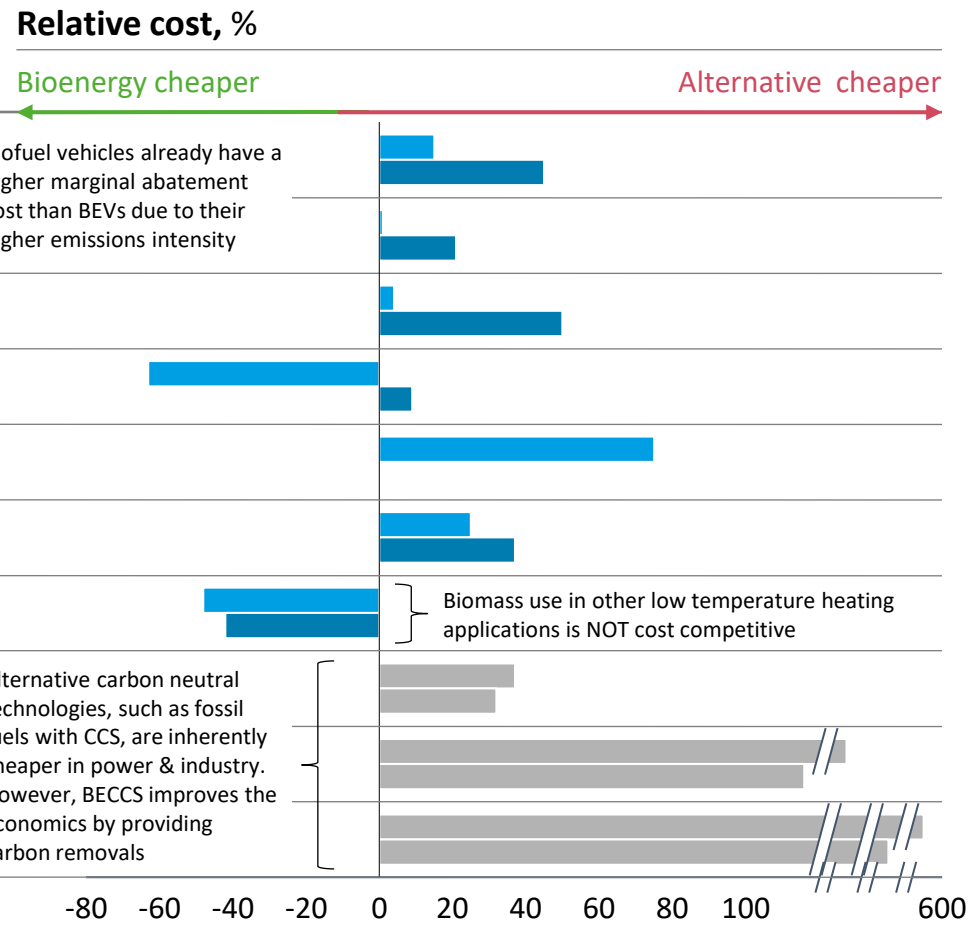
1. Area that has met the sustainability guardrails to avoid nature displacement, deforestation, food competition, and irrigation.
2. Source: Global Power Plant Database . Dataset for 2021 includes power plants that use biomass feedstocks and is non-exhaustive for infrastructure associated with the bioenergy industry (e.g., biofuel refineries).

Bioenergy is a long-term decarbonization option in aviation and some niche uses, a solution for organic waste, but is not cost competitive otherwise

⊗ Unlikely (other than for niche or transition uses) ✓ Likely 2030 2050

SELECTED END USES, NOT EXHAUSTIVE

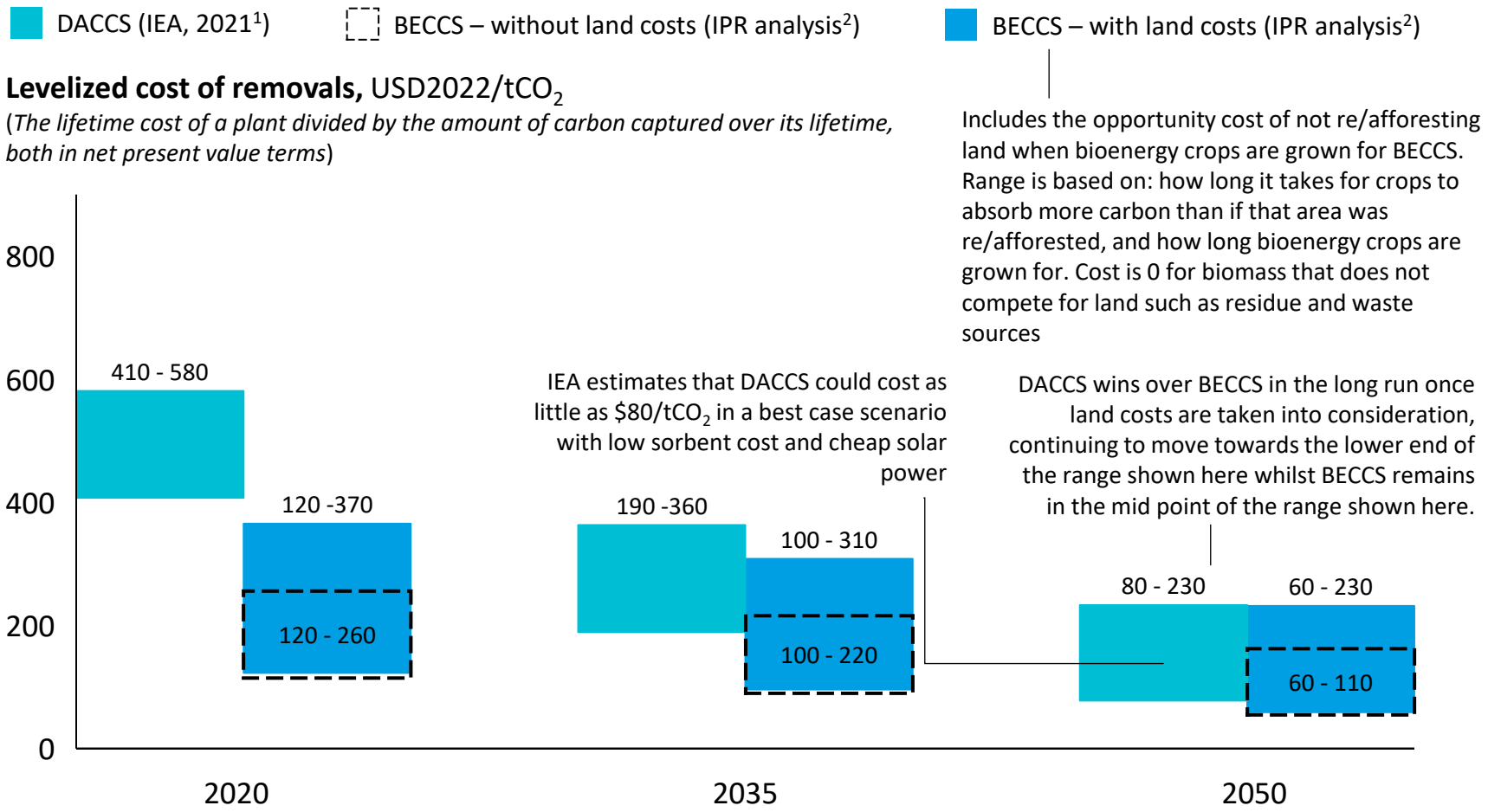
Sector	End use	Feedstock: Current	Feedstock: Future	Alternative	Long-term option
Transport	Light-duty vehicles[1]	1G crops	N/A	BEV	⊗
	Heavy-duty vehicles[1,2]	1G oil crops	Residues	BEV	⊗
	Shipping[1]	1G oil crops	N/A	Ammonia	⊗
	Aviation	1G oil crops	Residues	Synfuels	✓
Buildings	Space heating[3]	Wood residue	N/A	Electrification	⊗
Industry	Iron & steel (no CCS)	Wood pellets	N/A	H2DRI EAF	⊗
	Pulp and Paper process heating[4]	Wood residue	Wood residue	Electrification	✓
	BECCS for cement	Wood pellets	2G crops	Gas CCS	✓
	BECCS for other high T industry	Wood pellets	2G crops	Gas CCS	✓
Power	BECCS for power	Wood pellets	2G crops	CCGT CCS	✓



Note: BECCS technologies are compared here against alternative focused only on end use, and as such relative costs do not incorporate any possible payment for removals. See next sub-section for further comparison against alternative emissions removals options

Source: 1. ETC, 2021, Bioresources within a Net-Zero Emissions Economy; 2. Transport and Environment, 2020, How to decarbonise the UKs freight sector by 2050; 3. Khan et al, 2023, Life cycle cost analysis (LCCA) of Stirling-cycle-based heat pumps vs. conventional boilers (assuming biogas boiler); 4. Pulp and paper is one application of low temperature process heating, and is the only industrial application in which biomass is lower cost than other low carbon alternatives because it can self-supply the wood residues

Once land-based costs are considered, DACCS is expected to be more attractive than BECCS by 2050



BECCS is unlikely to experience significant cost reductions as it applies a relatively mature technology

BECCS costs increase if the land impact of growing biomass is considered.

Direct Air Carbon Capture and Storage (DACCS) could see rapid cost reductions as today's demonstrator plants scale, and with access to low-cost renewable energy

1. Primarily based on IEAGHG Technical Report, 2021, Global Assessment of Direct Air Capture Costs. Assumes FOAK is 2020 and NOAK is 2050. Range is from base case (lower) to very ambitious (upper)
2. No land cost estimates in line with Fuss et al, 2018, Negative emissions—Part 2: Costs, potentials and side effects. Land costs calculated based on how long it takes for crops to absorb more carbon than if that area was re/afforested: the carbon payback period (CPP), and how long bioenergy crops are grown for: the removal period . Lower bound = 75-year removal period with 5-year CPP, upper bound = 50-year removal period with 15-year CPP
3. BECCS and DACCS represent two of the most often discussed technology-based removals, however other approaches such as biochar or enhanced weathering also offer potential for removals.

Investment Implications: the Opportunity Side of Transition

Electrification of everything	Decarbonization of land-use	Decarbonization of food	Removal of emissions
• Energy production: Solar, heat pumps, geothermal, hydrogen, biodiesel (if using organics waste) • Infrastructure / last mile to user: grids, batteries, materials	• Ag tech to reduce land use per unit • Nature-tech / carbon tech for land planning & policy enforcement • Sustainable biomass, as a solution for organics waste	• Food tech to increase nutrients per unit / reduce methane per unit (cow/ sheep) • Incumbents demonstrating first mover advantage in decarbonizing own Scope 3	• Only Nature can remove carbon reliably, permanently and profitably: NBS • New tech is emerging - CCS, DACCs, BECCs

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