The Inevitable Policy Response 1.5°C Required Policy Scenario 2021 (IPR 1.5°C RPS 2021): Detailed land use system results

Preparing financial markets for climate-related policy and regulatory risks

December 2021

IPR was commissioned by the Principles for Responsible Investment (PRI), supported by world class research partners and leading financial institutions

PRI Principles for Responsible Investment

PRI commissioned the Inevitable Policy Response in 2018 to advance the industry's knowledge of climate transition risk, and to support investors' efforts to incorporate climate risk into their portfolio assessments

:vivideconomics putting economics to good use

Energy Transition Advisors ETA

A research partnership led by Energy Transition Advisors and Vivid Economics conducts the initiative's policy research and scenario modelling and includes 2Dii, Carbon Tracker Initiative, Climate Bonds Initiative, Quinbrook Infrastructure Partners and Planet Tracker

The consortium was given the mandate to bring leading analytic tools and an independent perspective to assess the drivers of likely policy action and their implications on the market

Planet Tracker | quinbrook infrastructure PARTNERS | 2° investing initiative | Carbon Tracker Initiative | Climate Bonds Initiative

Who supports the Inevitable Policy Response ?

Leading financial institutions joined the IPR as Strategic Partners in 2021 to provide more in-depth industry input, and to further strengthen its relevance to the financial industry

BlackRock · Fitch Ratings · nuveen A TIAA Company · ROBECO The Investment Engineers · BNP PARIBAS ASSET MANAGEMENT · Goldman Sachs Asset Management · NewForests

Core philanthropic support since IPR began in 2018. The IPR is funded in part by the Gordon and Betty Moore Foundation through The Finance Hub, which was created to advance sustainable finance and the ClimateWorks Foundation striving to innovate and accelerate climate solutions at scale

Gordon and Betty Moore Foundation · The Finance Hub · climateworks Foundation

The IPR helps the financial sector navigate the climate transition

Markets inconsistently price transition risk

- Policies will continue interacting with new technologies to deeply disrupt established industries and economies
- Financial institutions need to deepen their understanding of this unfolding environment to manage their assets effectively
- Yet the scenarios currently available provide limited intelligence about the realistic risks and opportunities most critical to the financial sector, and omit the land sector

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The IPR offers a range of applications to help navigate the climate transition

IPR Policy Forecast

A **high-conviction policy-based forecast** of forceful policy response to climate change and implications for energy, agriculture and land use

IPR Forecast Policy Scenario (FPS)

A **fully integrated climate scenario** modelling the impact of the forecasted policies on the real economy up to 2050, tracing detailed effects on all emitting sectors

IPR 1.5°C RPS Scenario

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. This can be used by those looking to align to 1.5°C

IPR value drivers

A set of publicly available **outputs from the FPS and 1.5°C RPS** that offer significant granularity at the sector and country level allowing investors to assess their own climate risk

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IPR's FPS value add

A high conviction policy-based forecast, anchored in realistic policy and technology expectations rather than hypothetical 'optimal' pathways

Complete forecast includes macroeconomic, energy and land use models linking crucial aspects of climate across the entire economy

Transparent on expectations for policy and deployment of key technologies, such as Negative Emission Technologies

Covers all regions of the world, with specific policy forecasts for key countries and regions

Applicable to TCFD reporting and regulatory stress testing

Fully integrating land-use to examine the full system impacts of policies, and highlight the critical role of land

A '**1.5°C Required Policy Scenario'** (1.5°C RPS) has been developed, building on the IEA NZE, deepening analysis on land use, and deriving polices required to reach a rapid net zero 2050 outcome

Note: IPR does not model physical risk

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IPR 2021 reports

A series of new IPR reports have been released in 2021. Please visit the PRI website here for more information

Glossary

- AgTech - Agriculture technology
- BECCS - Bioenergy with carbon capture and storage
- BNEF - Bloomberg New Energy Finance
- CAGR - Compound average growth rate
- CCS - Carbon capture and storage
- CDR - Carbon dioxide removal
- CH_4 - Methane
- CO_2 - Carbon dioxide
- CPS - Current Policies Scenario
- DAC - Direct air capture
- LT-DAC - Low temperature solid sorbent
- EV - Electric vehicle
- FPI - Food Price Index
- FPS - Forecast Policy Scenario
- GHG - Greenhouse gas
- ICE - Internal Combustion Engine
- IEA - International Energy Agency
- IPR - Inevitable Policy Response
- N_2O - Nitrous oxide
- NDC - Nationally determined contributions
- NEO - New Energy Outlook
- NETs - Negative emission technologies
- NPS - New Policies Scenario
- P1 - An IPCC 1.5°C scenario
- P2 - An IPCC 1.5°C scenario
- 1.5°C RPS - 1.5°C Required Policy Scenario
- SDS - Sustainable Development Scenario
- STEPS - Stated Policies Scenario
- TCFD - Task Force on Climate-related Financial Disclosures
- ULEV - Ultra low emission vehicles
- WEO - World Energy Outlook

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Executive summary overview

Food and Land Use: Key Findings

IPR addresses a major gap in climate change analysis by integrating food and land use systems with the energy system and economy. Land use emissions and Nature-Based Solutions (NBS) are critical to achieving climate goals but are usually overlooked. Our analysis finds:

- Under a required policy scenario (RPS), meat consumption – which contributes to 14% of total global emissions – should peak by 2030 globally and decrease rapidly by 40% through 2050, once alternatives become cost and taste-competitive. Pasture and rangelands will be replaced with forests, cropland, and other NBS
- Land will need to become a net CO_2 sink before 2050, yielding - 8.3 Gt of emissions reductions compared to a 2020 baseline value of 5.9 Gt. 4.9 Gt will come from NBS that remove carbon from the atmosphere, and the rest will come from changes in food production and bioenergy.
- NBS must become its own industry, with an estimated USD841 bn cumulative value of assets by 2050, with China having the highest cumulative NBS deployment potential through mid-century
- Deforestation stops in 2025 in RPS, avoiding 38 Gt of cumulative emissions (2020-2050) compared to a scenario in which deforestation emissions remain at 2020 levels.

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Note: The Model of Agricultural Production and its Impact on the Environment (MAgPIE) is the main source of insight for the calculations in this chart section (unless indicated otherwise). More info on the model can be found here: https://www.pik-potsdam.de/en/institute/departments/activities/land-use-modelling/magpie

The RPS demands more and faster action than FPS, especially in food production transformation, and would result in 30% greater emission reduction compared to FPS

	Mitigation (GtCO2e/year in 2050)	
	IPR FPS	RPS 2021
Forestry – The forestry sector grows enormously in order to provide carbon sequestration services – Re/afforestation are high-potential, low-cost mitigation sources, with ~3.6 Gt CO_2/year of annual carbon sequestration achievable for less than USD 150/tCO_2 by 2050	3.4	3.6
Food production change – Food production transforms away from products and production processes with high GHG costs – Shifting away from animal protein sources, particularly beef and lamb, will reduce non-CO_2 (methane and nitrous oxide) GHGs associated with livestock and fertilizer for feed. Importantly, this includes a tipping point toward alternative meat products	0.8	2.1
Low carbon agriculture – New techniques to sustainably intensify production and to reduce agricultural emissions are deployed to make agriculture more GHG efficient – Major improvements are possible in developing countries, particularly in the tropics where forest carbon stocks are dense. More broadly, options exist to reduce methane reduction of remaining ruminant production	1.3	1.3
Bioenergy – Land availability and demand for bioenergy as a low-carbon fuel source will drive increased production of second-generation bioenergy - including the use of bioenergy with carbon capture and storage	1.0	1.3

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Source: Vivid Economics

IPR 1.5°C RPS 2021 is based on additional regulatory and technological drivers of change than FPS 2021

Policy lever	FPS 2021	IPR 1.5°C RPS
GHG prices	Land use carbon prices gradually rise to align with carbon price in energy and industry, representing the gradual incorporation of the former into the latter.	Greater integration of agriculture in carbon pricing schemes
Food production	Peak meat in 2030; 30% fall to 2050 due to. • Policy-driven increases in the cost of animal meat, encouraging the production of alternative meat • Consumer preferences will shift towards alternative meat for sustainability and health reasons • Technology development will reduce the cost and improve the taste of alternative meat; cell-based meat becomes price/taste competitive 2035-2040	Faster reductions in traditional meat consumption • Strong consumer preference for lower environmental impact influenced by public education and marketing by alternative protein companies. • Technological progress accelerated by government support, with plant-based meat reaching cost and taste-parity with low grade meat in 2025. Cell-based meat becomes price and taste competitive in 2030. • Highly interventionist regulation, approval of cellular agriculture globally
Bioenergy	90 EJ production by 2050	99 EJ production by 2050
Deforestation	End to deforestation in 2030	End to deforestation in 2025

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IPR designed the 1.5°C RPS to demonstrate how aggressive policies and actions have to be to keep global warming below 1.5°C

Main message

- IPR 1.5°C RPS is driven by stronger interventions than the IPR FPS 2021
- **Strong government intervention anticipated in the animal meat market,** with substantial support for the cellular agriculture industry (e.g. subsidies) alongside regulation which limits animal protein consumption
- Environmental impact will be a primary concern for consumers when making consumption choices, following government education programs.

Demand shape	Consumer preferences	Technology availability	Regulation
Peak animal meat 2030, 40% fall by 2050 globally	Strong consumer preference for lower environmental impact influenced by government education leads to shift away from animal meat consumption	High rate of technological progress accelerated by government support, with plant-based meat reaching cost parity with low grade meat in 2025 and cell-based meat becoming price competitive in the 2030s	Highly interventionist regulation, approval of cellular agriculture globally

Ending deforestation by 2025 in 1.5°C RPS, compared to the IPR FPS 2021 assumption of ending it in 2030, will require immediate policy action

Deforestation of natural forest halted through strong and effective command and control policy

Countries/regions like CAN, GCC, JAP, SA, SK, UK have virtually zero net deforestation

End of deforestation

	2020	2025	2030	Change in forest cover 2020-2050 (m ha) IPR FPS 2021	IPR 1.5C RPS
AU		FPSRPS		3	3
BRA		RPS	FPS	12	16
CAN	FPSRPS			1	1
CHI		RPS	FPS	92	92
CSA		RPS	FPS	10	14
EEU		FPSRPS		4	4
EURA		RPS	FPS	1	2
GCC	FPSRPS			0	0
IND		RPS	FPS	13	13
INDO		RPS	FPS	2	6
JAP	FPSRPS			0	0
MENA		RPS	FPS	-1	1
RU		RPS	FPS	1	2
SA	FPSRPS			0	0
SAF		RPS	FPS	0	1
SEAO		RPS	FPS	3	11
SK	FPSRPS			0	0
SSA		RPS	FPS	0	15
UK	FPSRPS			1	1
USA		FPSRPS		17	17
WEU		RPS	FPS	11	12

Carbon pricing and NDC commitments combine to stop net deforestation by 2030. Biggest changes need to occur in BRZ, CSA, INDO, SEAO, SSA

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Achieving 1.5°C RPS animal meat consumption reductions requires a shift in policy acceleration of five years compared to the IPR FPS 2021

						Reduction in per capita meat consumption* 2020-2050 (%)	
	2020	2025	2030	2035	2040	IPR FPS 2021	IPR 1.5C RPS
AU		RPS	FPS			42	51
BRA		RPS	FPS			38	48
CAN		RPS	FPS			43	52
CHI				FPSRPS		35	45
CSA		RPS	FPS			34	45
EEU		RPS	FPS			40	50
EURA			RPS	FPS		30	42
GCC			RPS	FPS		25	37
IND			RPS	FPS		0	14
INDO			RPS	FPS		18	31
JAP		RPS	FPS			40	50
MENA			RPS	FPS		28	39
RU		RPS	FPS			36	46
SA			RPS	FPS		6	22
SAF			RPS	FPS		-13	6
SEAO			RPS	FPS		20	33
SK		RPS	FPS			40	50
SSA					FPSRPS	-13	6
UK		RPS	FPS			41	50
USA		RPS	FPS			42	51
WEU	RPS	FPS				40	50

*kcal per person

All regions need to reduce and/or reverse the growth of animal meat consumption

Large drop in SSA happens post 2035

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Animal protein consumption trends are derived by region and type of product; 5-year differences in reaching "peak meat" between FPS and RPS are material drivers of resulting emission profiles

Peak year for traditional meat consumption by region and category

Meat type	Europe, North America, Aus and NZ, Developed East Asia	Brazil, Latin America	Mainland China, DPRK, Taiwan, HK and Macau	Sub-Saharan Africa
Non-structured meat e.g. burgers, mince	Saturated markets FPS & RPS: 2025	Slow-growing markets FPS: 2030 RPS: 2025	Plant-based meat consumption to slow growth FPS & RPS: 2030	Plant-based meat to slow animal meat demand growth in 2030s FPS & RPS: 2040
Structured meat e.g. steak, chops	Saturated markets FPS: 2030 RPS: 2025	Slow-growing markets FPS & RPS: 2030	Animal meat replaced with cell-based meat FPS: 2035 RPS: 2030	High growth potential FPS & RPS: 2040

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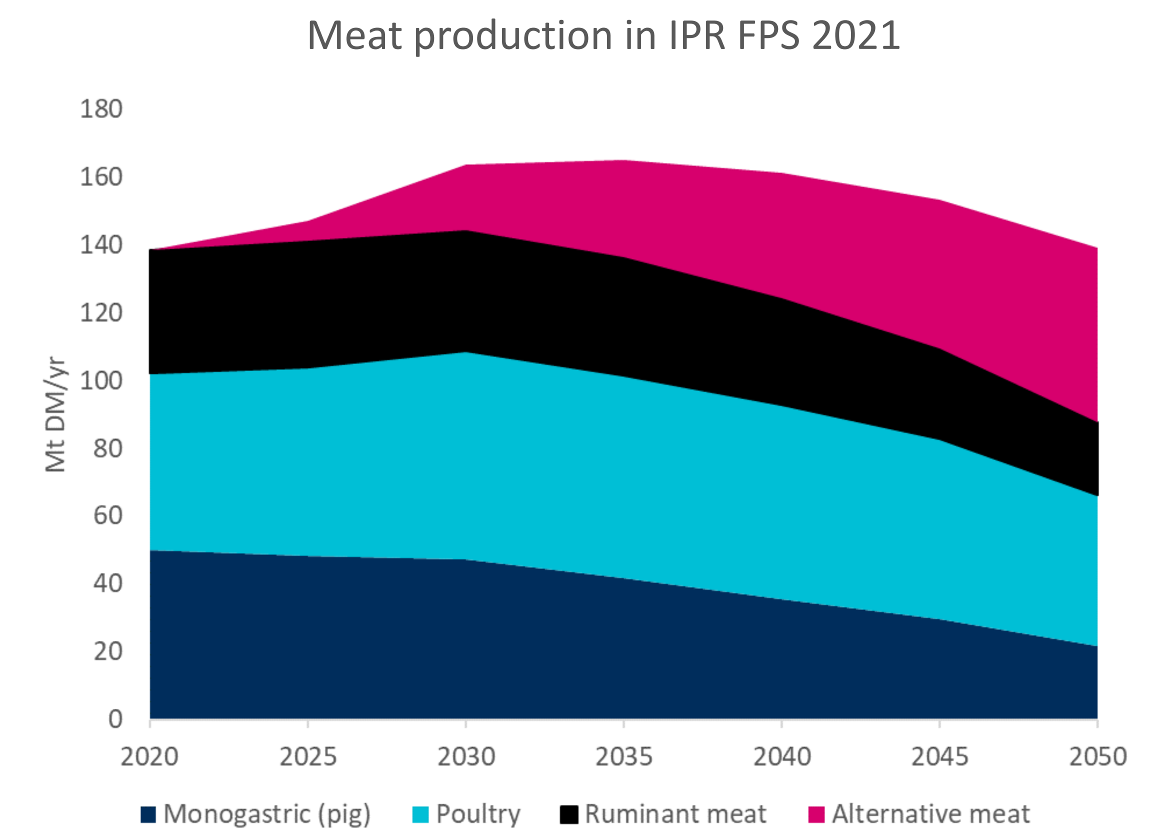
Alternative meat takes substantial share of the protein market in 2050 in both FPS and RPS, though RPS suggests it will become the dominant protein



- **RPS requires a 39% reduction in animal meat production between 2030 and 2050**, as a result of rising prices and changing consumer preferences
  - ◊ Reduction in per capita meat consumption led by tier 1 countries, in addition to China and Brazil
  - ◊ Relatively small decline in poultry production due to lower emissions costs
  - ◊ This compares to a drop of only 30% forecasted in FPS
- **Alternative protein reaches a market share of 37% in 2050**, making it the largest type in the meat category
  - ◊ Share of ruminant meat falls from 26% to 16% as consumers switch away from animal meats with a large environmental impact
  - ◊ Under FPS, the predicted alternative meat share amounts to 29%
- **RPS estimates an 8% decrease in food waste compared to 2020 values. Food waste reductions are driven by lower demand for animal feed, slightly more expensive food and behavioural changes driven by awareness campaigns**

Source: Vivid Economics with components from FAO
Note: See annex for FPS values.

Second generation, more sustainable bioenergy production grows in response to climate policy

- Regulation increases the cost of fossil fuels and promotes investment in alternative fuel sources
- Hard-to-abate sectors that cannot transition to electrification easily (e.g., heavy industry) must rely on bioenergy as part of their decarbonization plans
- The introduction of emissions pricing in the land use sector incentivizes a shift away from first-generation and toward second-generation energy crops, and particularly toward producers that can demonstrate very high-standards for the sustainability of production
- Governments scale up support for bioenergy as a low-carbon fuel source
    - The US Department for Energy announced USD 61.4m in support for the development and demonstration of bioenergy projects in April 2021[1]

Source: [1] Biomass Magazine (2021)

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IPR FPS 2021 includes detailed analysis of 7 types of Nature based Solutions

Which NBS are covered in IPR RPS 2021?

	Forestry	Peatland	Mangroves	Seagrass	Agroforestry	Soil
New deployments	Managed afforestation (NPI and non-NPI); new timber plantations	Peatland restoration	Mangrove restoration	Seagrass restoration		
Improved practices	Switch to sustainable management of timber plantations				Trees in cropland; silvopasture	Cover crops; Legumes and optimal grazing in pasture lands
Avoided impact	Avoided deforestation of primary and secondary forests	Avoided peatland degradation	Avoided mangrove degradation	Avoided seagrass degradation		Avoided grassland conversion

What are Nature-Based Solutions (NBS)?

- The European Commission defines NBS as “solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. […]”[1]
- Avoided impacts are accounted separately because they always rely on a counterfactual scenarios (for example BAU), which makes comparability with removals difficult

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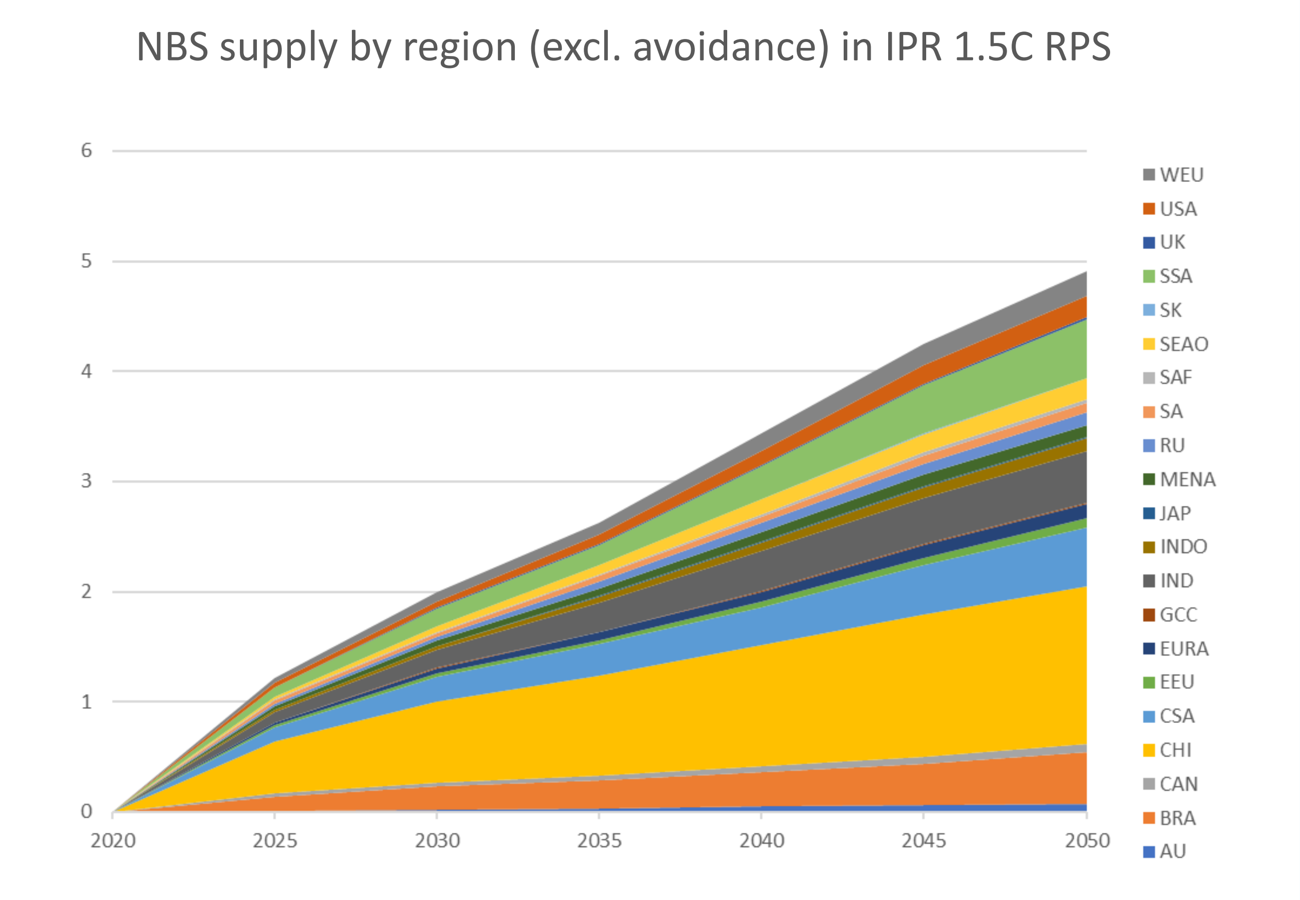
Source: [1] European Commission (no date)

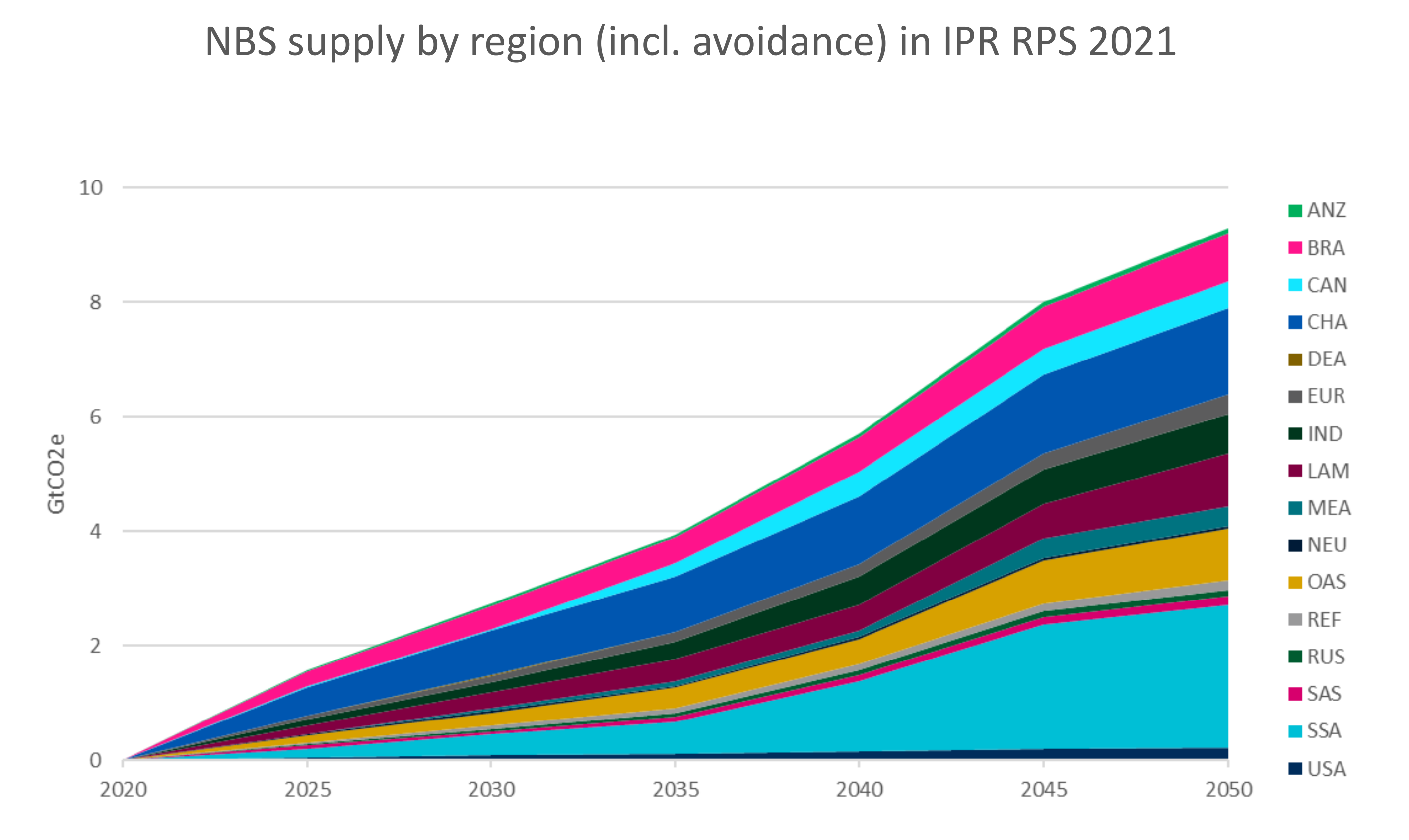
Global NBS GHG reaches 4.9 $GtCO_2eq$ by 2050 under RPS, compared with 4.7 $GtCO_2eq$ for FPS, with the greatest sequestration potential occurring in China



- The greatest sequestration (1.4 Gt) occurs in China, mostly through **reforestation in the form of NDC implementation and timber plantations**
- Significant GHG removals (0.6 Gt) are achieved in Sub-Saharan Africa by deploying **private and governmental reforestation NBS**
- **NDC reforestation and agricultural solutions** drive **India's** NBS supply of 0.5 Gt
- In Europe and the USA, strong contributions are made through forestry and improved agricultural solutions.
- Deforestation stopping in 2025 **avoids 38 Gt of cumulative emissions (2020-2050)** compared to a scenario in which deforestation emissions remain at 2020 levels.

Source: Vivid Economics

Global abatement of GHG with NBS is expected to reach almost 9.2 $GtCO_2eq$ in 2050, including avoided deforestation



- This chart **adds avoidance NBS** to the removal NBS show in the previous slide
- IPR RPS 2021 expects NBS to ramp up significantly from 2035, with sequestration rising from 3.9 $GtCO_2e$ in 2035 **to 9.2 $GtCO_2e$ in 2050** (compared to 8.7 Gt in FPS)
- Moving forward the end of deforestation to 2025 **increases avoidance NBS in 2025 and 2030 compared to FPS**

Source: Vivid Economics

Note: Avoidance numbers in this slide are calculated against a BAU scenarios that assumes historical trends will be extended to 2050. This provides an estimate of the overall envelope of potential avoided emissions. Each country will need to establish an agreed reference level – usually at an international level – to enable the generation of avoided emissions credits. There remains a high level of uncertainty around these reference levels, and hence estimates of the scale of avoided emissions markets both globally and within specific countries or regions remains very uncertain.

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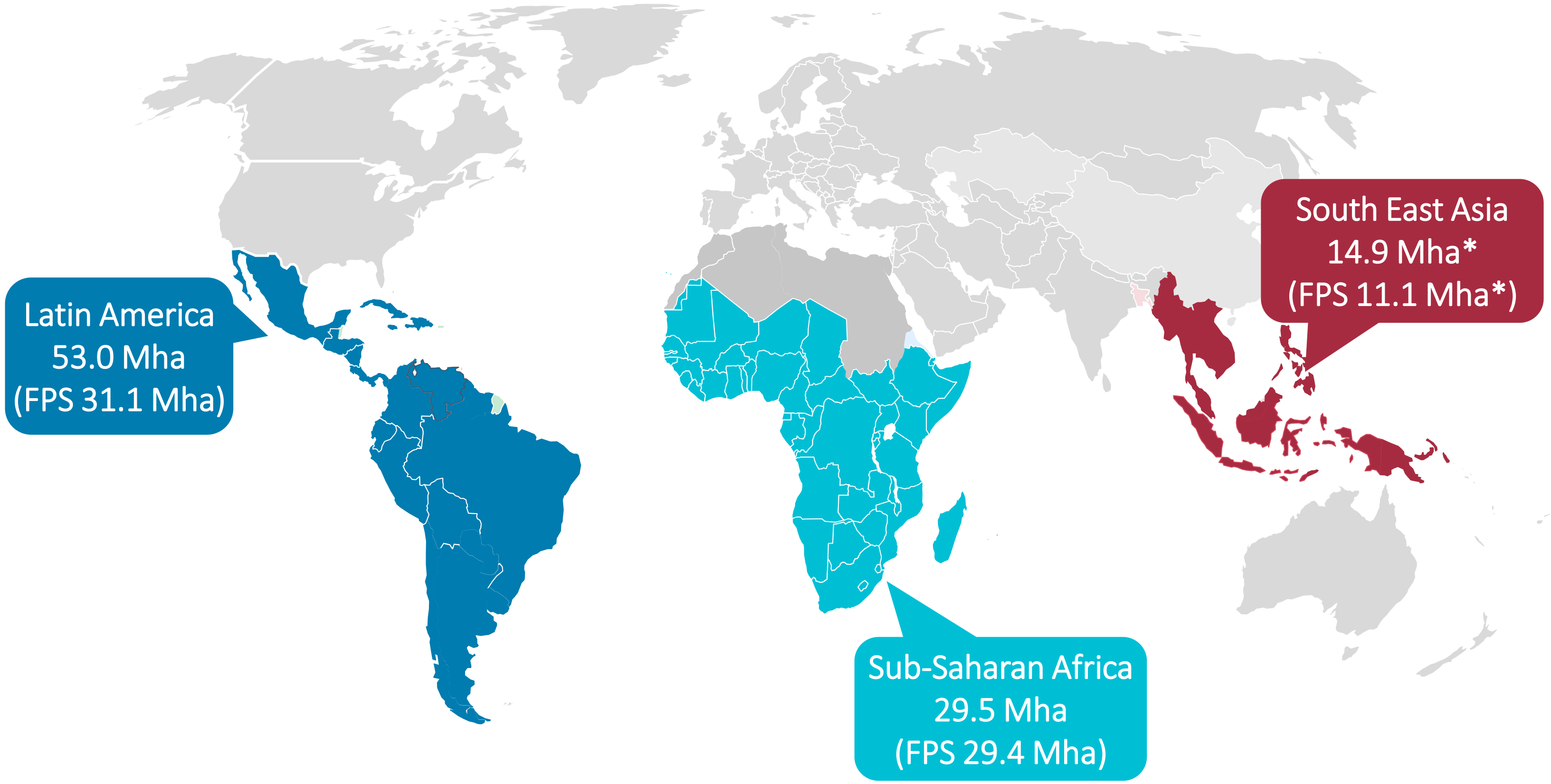
In the forestry sector, tropical afforestation and reforestation offer inexpensive sequestration at large scale up to 1 Gt CO_2



Carbon prices

Under IPR RPS 2021, a **carbon price of around USD 90** could incentivize re/afforestation of 97 Mha in Latin America, Sub-Saharan Africa and Southeast Asia

Tropical rainforests

NBS opportunities are geographically concentrated in regions with both dense carbon sinks and high existing rates of deforestation

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Note: *South East Asia includes territories located in Oceania, except for Australia and New Zealand. Regional values represent reforestation and afforestation between 2020 and 2050

Source: Vivid Economics

Directed government reforestation programs, the gradual extension of offset markets, and increases in carbon prices drive a major shift toward nature-based solutions, and carbon sequestration as a valuable forestry sector commodity

billion USD 2021	Scenario	2025	2030	2035	2040	2045	2050
Cumulative cost of assets (market size)	RPS	132	271	419	587	725	841
	FPS	140	303	462	639	785	898
Potential annual revenues*	RPS	18	61	93	150	271	269
	FPS	16	52	77	122	172	209

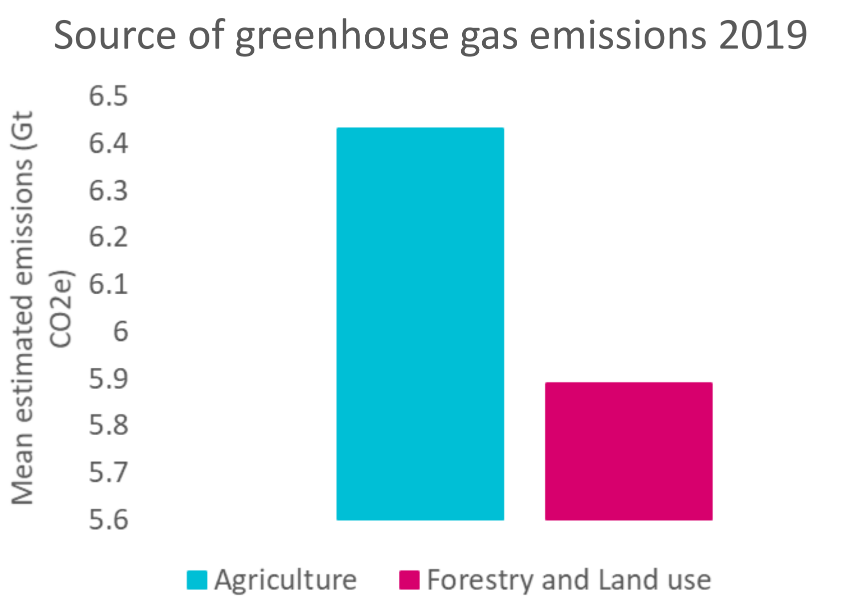
Source: Vivid Economics

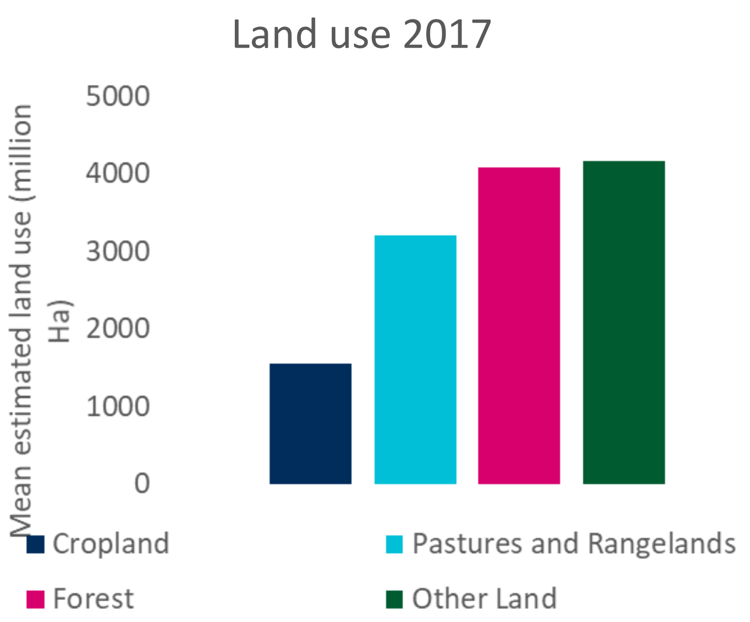
- NBS[1] generate assets worth **USD 841 billion** (in present value terms) by 2050 under RPS. This number includes NDC and non-NDC related investments
- The **cost of assets is lower in RPS** because land competition is more intense in FPS and therefore land prices are higher
- However, **revenues are higher in RPS**. This opens up enormous new opportunities for both project developers and investors

Note: The cumulative cost of assets is the amount of money required (CAPEX+OPEX) to set up and maintain the required NBS assets. Figures are discounted to 2021 using regional discount factors.
* Revenues are calculated simply as the quantity of emissions sequestered multiplied by the prevailing carbon price. It is unclear how much of the total value of carbon will be used by government to meet their NDC and how much will be left to the market. So this estimate does not necessarily represent market revenues.
Source:[1] The European Commission defines NBS as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. […]"

Introduction / Baseline

Emissions and land use in forestry and agriculture





Emissions from agricultural production constitute the largest proportion of emissions from the land use sector

- CO_2 emissions driven by land-use changes e.g. deforestation*
- N_2O emissions predominantly a result of fertilizer use in agriculture
- CH_4 emissions predominantly related to ruminant meat production

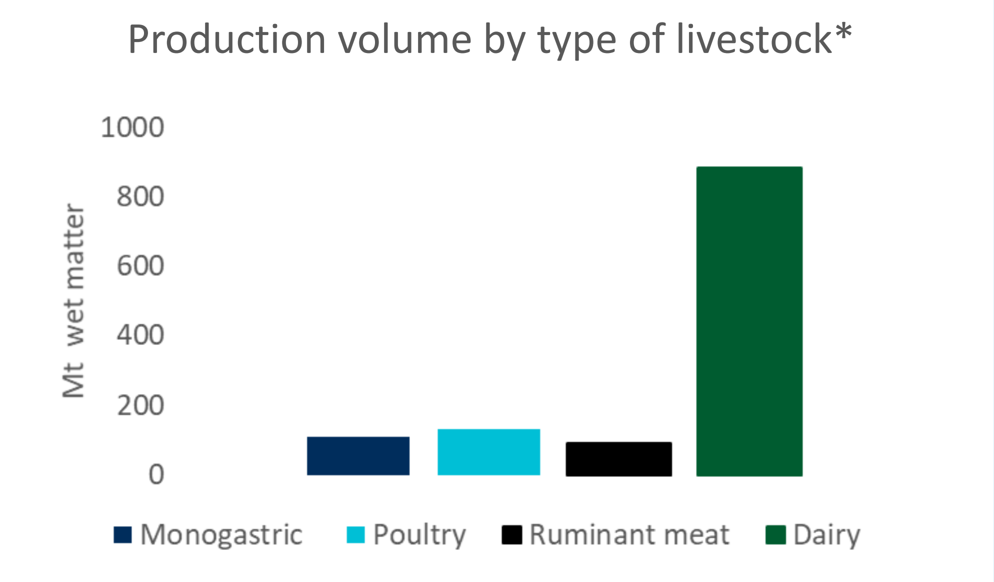
Forestland and non-productive land employ most area globally

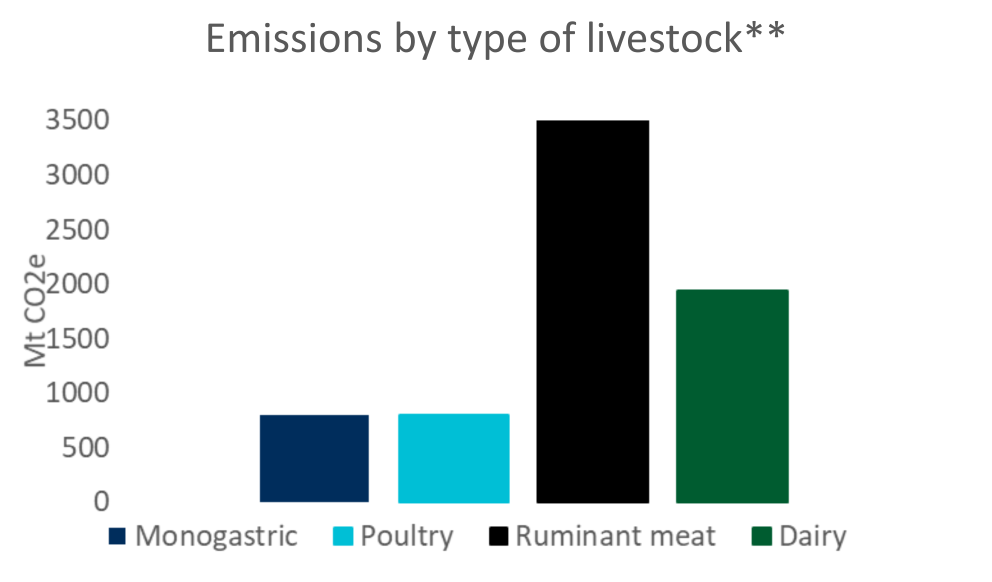
- Cropland: land used to grow crops
- Pastures and rangelands: land used covered by grass, often used to grow animals
- Forests: covered by natural or managed forests
- Other Land: non-productive or marginal land

Note:*The Global Carbon Project estimate an uncertainty of ± 0.7Gt for land-use change emissions

Sources: FAO, IPCC, Global Carbon Project, PIK, CIAT

Ruminant meat: smallest by production but dwarfs other livestock by emissions





- Ruminant meat makes up around 7% of animal production by weight but constitutes **45% of total land use emissions in the animal protein category*****
- In 2019, poultry production contributed least to land-use emissions (9%)
- Food waste in 2020 is around 650 kcal/cap/day, ranging from 403 in SSA to 1074 in the US

Notes: *Ruminant meat consists of beef, buffalo, goat, sheep and camel, which is the full categorization of ruminant meat as reported by the FAO
**Ruminant meat consists of beef and sheep, which represents almost all of the ruminant meat in production as reported by the FAO. FAO data on land use emissions is not available across food types. Dairy land use emissions calculated as total land use emissions from milk production and cheese production, weighted according to their overall share of dairy production
***Land use emissions include CO2, CH2, CH3, CH4, N20, NH3, NH4+, NOX, N and P emissions from land use change, crop production and livestock production
Source: Animal protein production - FAO, with Vivid calculations; Emissions by livestock type – Our World in Data with Vivid calculations

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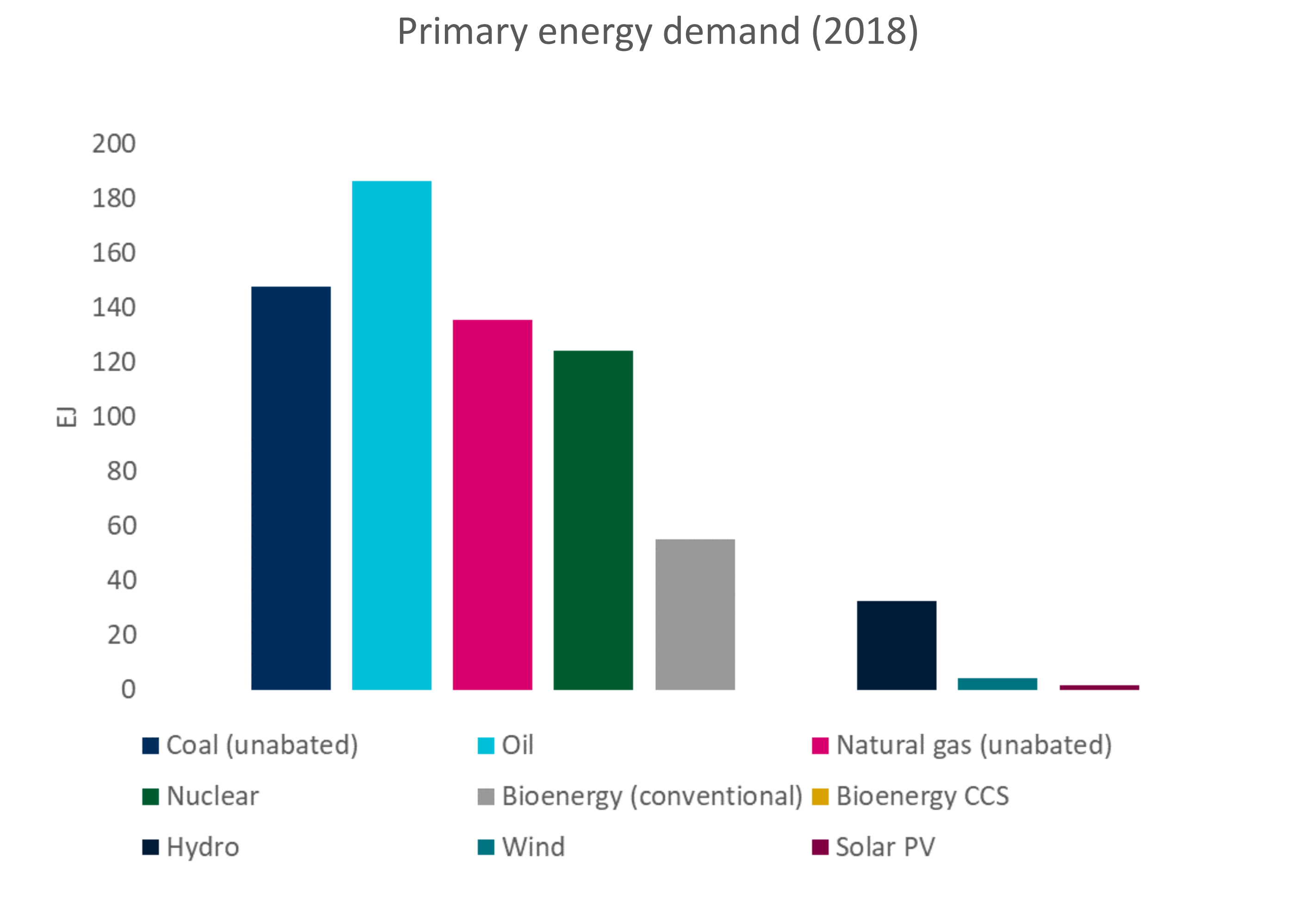
Global bioenergy today is nearly 55 EJ with the vast majority ‘traditional’ or modern ‘first generation’



- There was 55 EJ of bioenergy demand in 2018, accounting for 8% of primary energy demand
- A large proportion of this energy was through traditional biomass (e.g. wood heat and cookstoves), which is polluting and can create deforestation, alongside modern first-generation biomass
- There is currently no bioenergy carbon capture and storage (BECCS)

Sources: Bioenergy production - Vivid Economics with components from Frank et al. (2021); Primary energy demand – IEA World Energy Balance

Methodology

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Methodology

- Analysis using the Model of Agricultural Production and its Impact on the Environment (MAgPIE) is the main source of insight for the calculations in this chart pack (unless indicated otherwise)
- More information on the model can be found here: https://www.pik-potsdam.de/en/institute/departments/activities/land-use-modelling/magpie

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Note:

Policy, technology and behavioural expectations

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Climate policies must transform the land-use sector by increasing the cost of GHG emissions and creating demand for new products to reduce those emissions

The introduction of climate policies increases emission costs and apply pressure on:	The introduction of climate policies creates incentives for:
Agricultural activities which emit carbon through deforestation	Reforestation and afforestation activities through rewards for carbon sequestration
Agricultural activities associated with large methane emissions, particularly production of ruminant meat (e.g., beef)	Demand for ruminant meat substitutes, such as chicken, plant-based meat substitutes and cell-based meat
Agricultural activities that use inorganic fertilizers and that are therefore associated with nitrous oxide emissions	Sustainable agricultural systems that use organic fertilizers and capture carbon in the soil

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Developed countries must adopt climate policies in land-use sectors early, followed by developing countries

Developed countries	Developing countries
Europe	India
Australia and New Zealand	Latin America
Developed East Asia (Japan and Korea)	Sub-Saharan Africa
USA	Middle East Asia*
Canada	South East Asia**
Northern Europe	Brazil
	Reforming economies***
	South Asia
	Mainland China, DPRK, Taiwan, HK and Macau

Note: *Middle East Asia includes Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, the UAE, Western Sahara and Yemen **South East Asia includes territories located in Oceania, except for Australia and New Zealand ***Reforming economies are based in Eastern Europe and Asia and are predominantly former Soviet Union states

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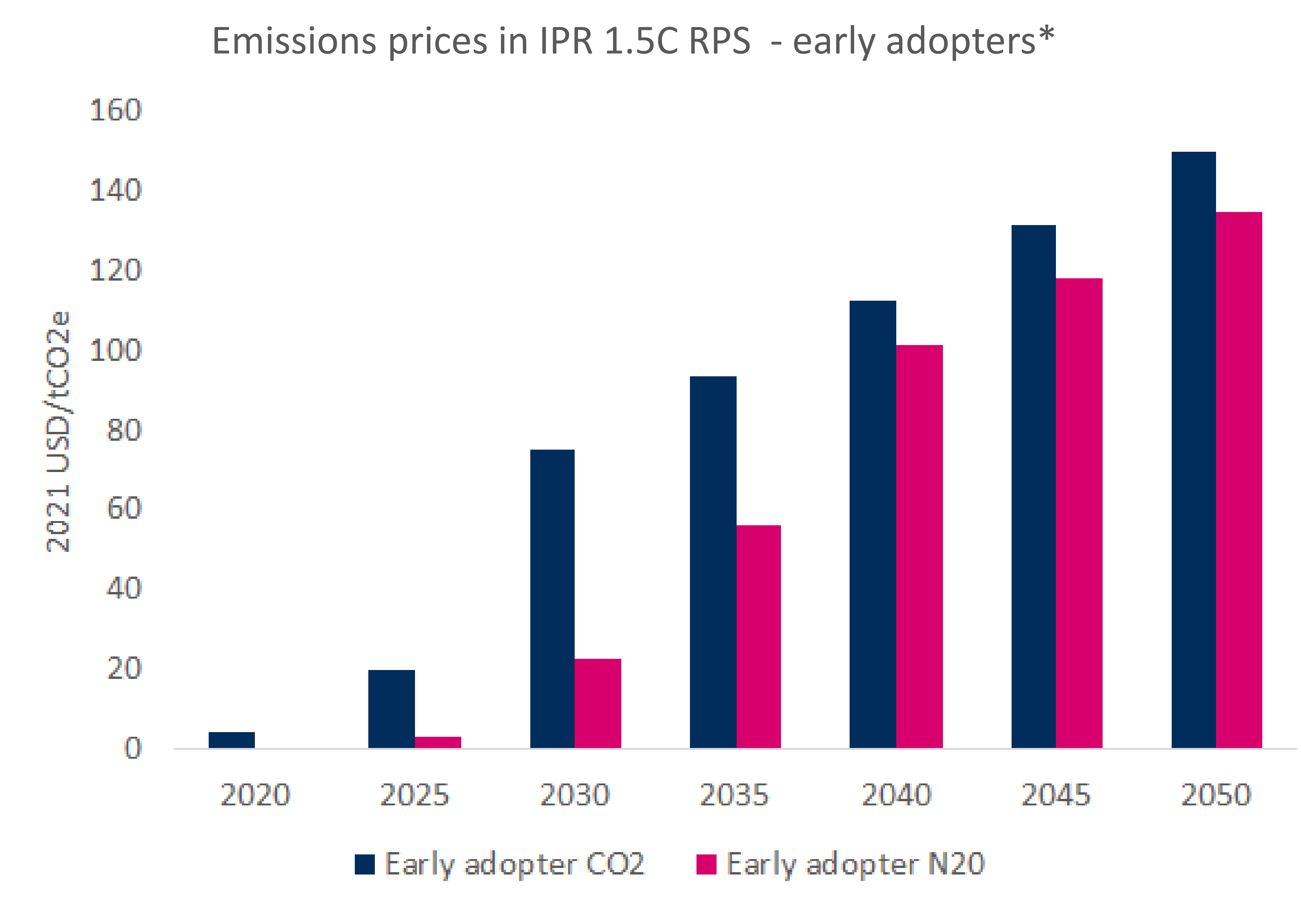
Developed countries are already putting in place broad policies to encourage sustainable land use, and must cover the land use sector in compliance-based carbon pricing by 2030, with prices converging to energy and industry sectors in 2040

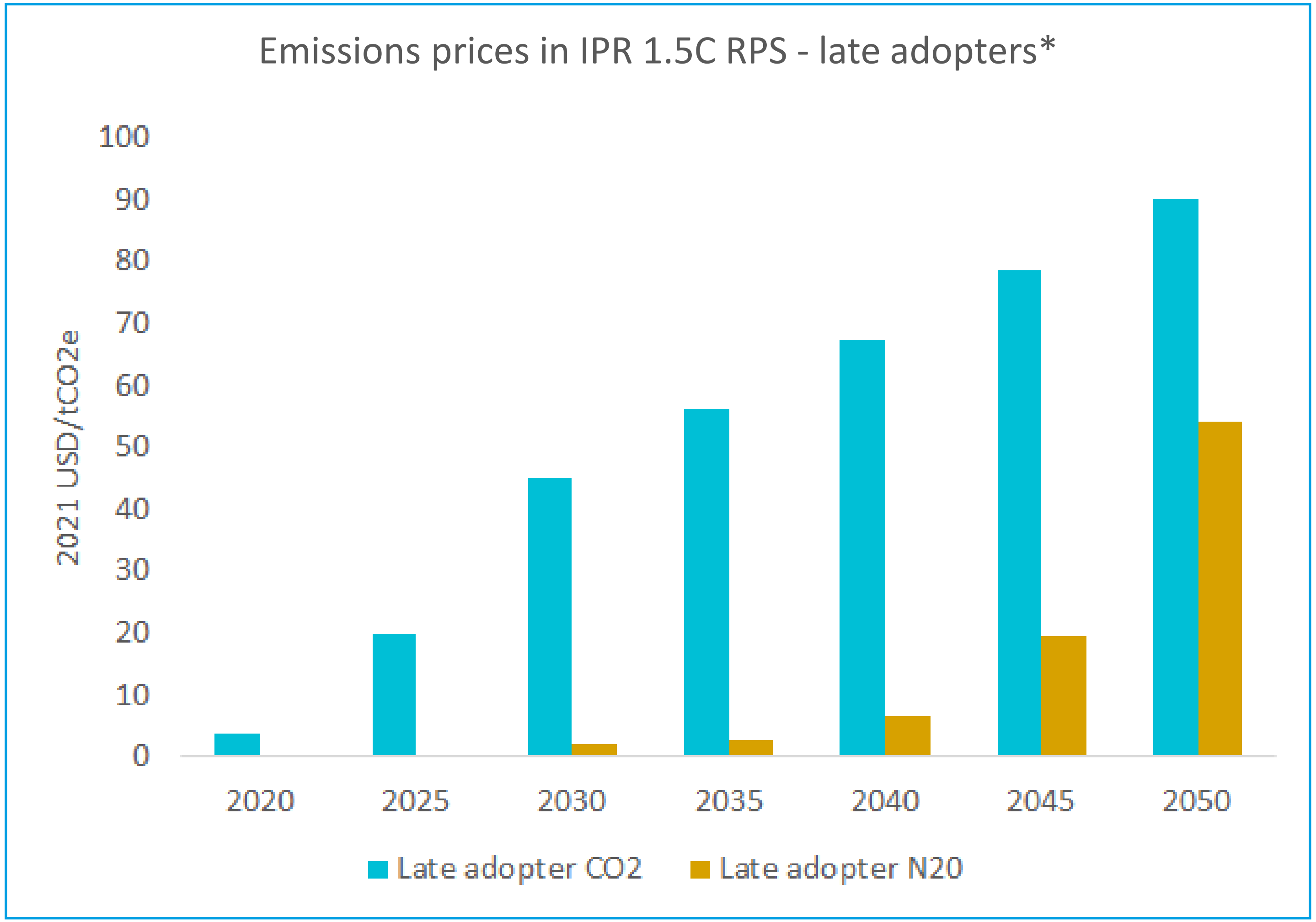


- **Land use carbon prices gradually rise to align with the IPR FPS 2021 estimates for carbon price in energy and industry**, representing the gradual alignment of the former with the latter, as governments seek lowest cost abatement opportunities across land and energy
- There is a price differential between energy and land use until government programs align on the carbon price and until compliance markets start to more extensively cover land use (until that happens, land use will be covered by voluntary market price)
- **Land use must be increasingly covered by compliance markets from 2025 for early adopters.** Carbon pricing for BAU (used as a comparator in this presentation) is 0 in line with no carbon pricing systems covering AFOLU
- For N_2O, CO_2 prices are scaled to account for the reduced participation agriculture will play in carbon pricing

Note: *Early adopters correspond to the policy forecast tier 1 countries for carbon pricing, with gradual convergence of land-use sectors to energy and industrial sector prices as the markets are gradually integrated

Source: Vivid Economics

Developing countries have a mixture of policies to encourage sustainable land use, and may cover the land use sector in compliance-based carbon pricing more slowly with prices converging to energy and industry sectors beyond 2050



- Land use carbon prices gradually rise to align with the FPS estimates for carbon price in energy and industry, representing the gradual alignment of the former with the latter
- **The land use sector must begin to be covered by compliance markets from 2030 for late adopters, but prices may not fully converge to similar markets in energy and industry until after 2050**
- For N_2O, the CO_2e prices are lower to account for the reduced participation agriculture will play in carbon pricing
- For N_2O, CO_2 prices are scaled to account for the reduced participation agriculture will play in carbon pricing

Note: *Late adopters correspond to the policy forecast tier 2 and 3 countries for carbon pricing, with gradual convergence of land-use sectors to energy and industrial sector prices as the markets are gradually integrated
Source: Vivid Economics

For IPR 1.5C RPS, different meat consumption is required depending on the region and type of product

Peak year for traditional meat consumption by region and category

Meat type	Europe, North America, Aus and NZ, Developed East Asia	Brazil, Latin America	Mainland China, DPRK, Taiwan, HK and Macau	India	Middle East Asia*	Russia	South East Asia	Reforming economies**	South Asia (ex. India)	Sub-Saharan Africa
Non-structured meat e.g. burgers, mince	2025 Saturated markets	2025 Slow-growing markets	2030 Plant-based meat consumption to slow growth	2030 Slowly replaced by plant-based meat	2030 Moderate growth as incomes rise	2030 Slow-growing market	2030 Slowly replaced by plant-based meat	2030 Moderate growth as incomes rise	2030 Slowly replaced by plant-based meat	2040 High growth potential
Structured meat e.g. steak, chops	2025 Saturated markets	2030 Slow-growing markets	2030 Animal meat replaced with cell-based meat	2035 Market growth as income rise	2035 Market growth as incomes rise	2030 Potential for slow market growth	2035 Market growth as incomes rise	2035 Market growt h as incomes r ise	2035 Market growth as incomes rise	2040 High growth potential

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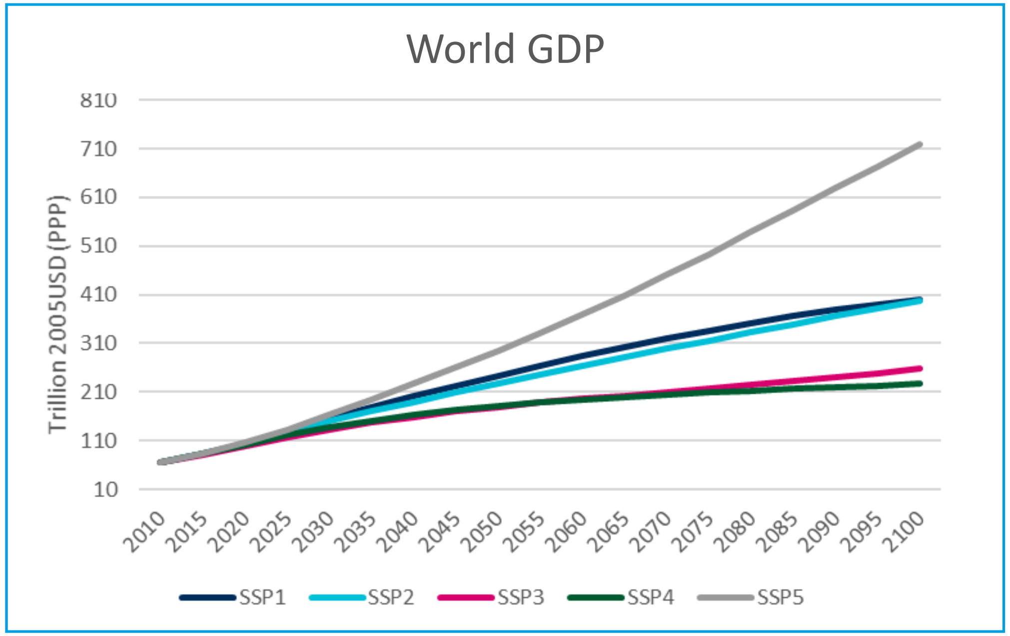
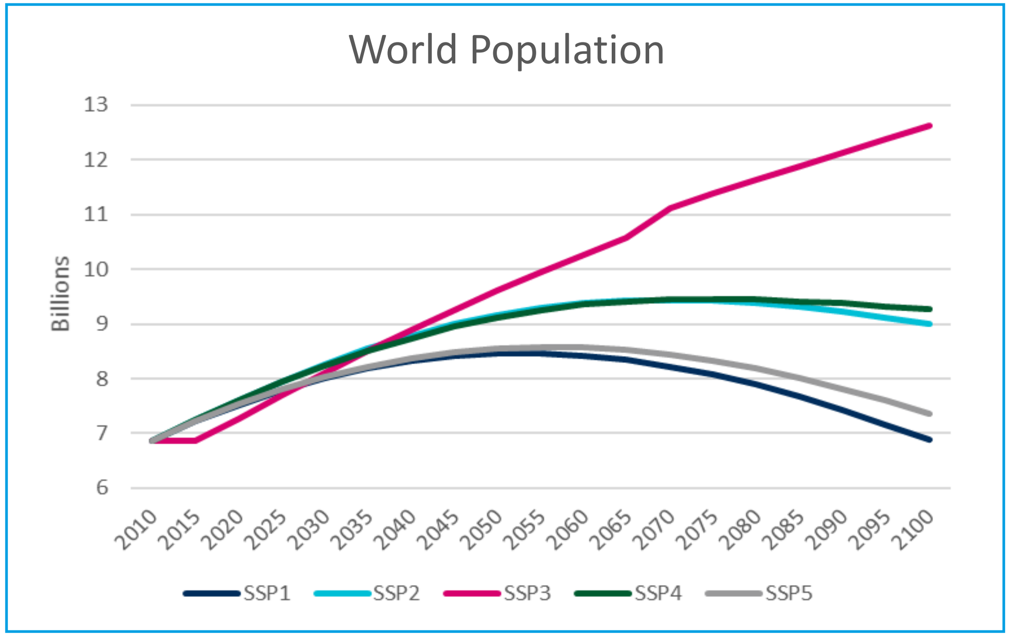
Note: *Middle East Asia includes Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, the UAE, Western Sahara and Yemen **Reforming economies are based in Eastern Europe and Asia and are predominantly former Soviet Union states

Underlying macroeconomic inputs are sourced from the Shared Socio-economic Pathways (SSP2*) and National Institute Global Econometric Model (NIGEM**)





- SSP2 is the socioeconomic pathway most commonly used in the analysis of transition pathways (e.g. by the NGFS and IEA)
- It is based on a world where the broad, underlying social, economic and technological trends do not shift markedly from historical patterns
- Population: **Projected to grow to 8.89 billion in 2100** for IPR FPS and IPR 1.5 RPS 2021, with peak around 2070
- GDP (PPP): **Projected to grow to USD 807 trillion (2005 USD) in 2100** for IPR FPS and IPR 1.5 RPS 2021
- NIGEM provides estimations pre-2023 and takes into account COVID-19 implications

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Notes: *SSP2 is a specific socioeconomic pathway used in climate change modelling, and most commonly used in climate transition scenarios
**NIGEM is a model developed by the National Institute of Economic and Social Research (NIESR)
Sources: Vivid Economics and IIASA

Land use and emissions profiles

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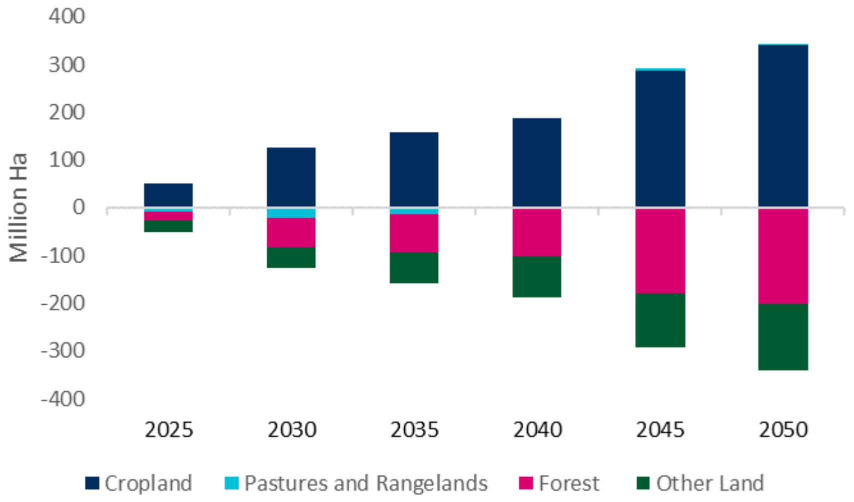
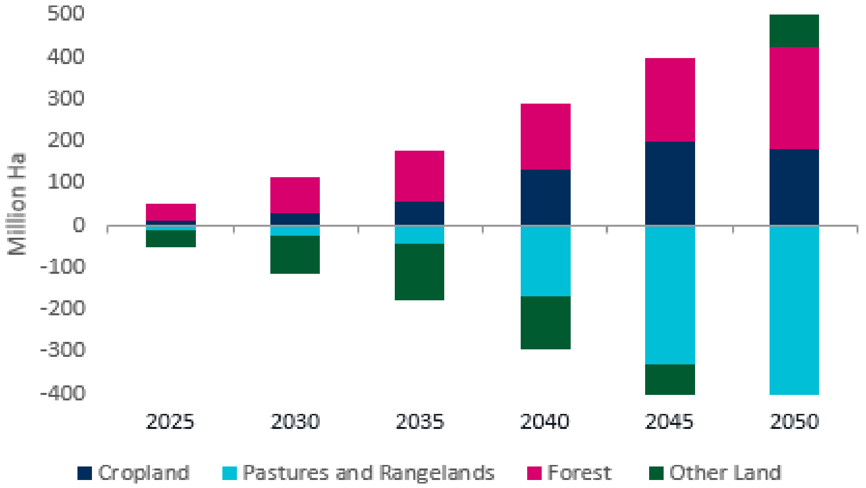
IPR 1.5C RPS sees a decrease in pastures and rangelands, and an increase in forestland which is mainly driven by shifts in food production and incentives for carbon farming

Land use change in BAU (2017 base year)



Land use change in IPR 1.5C RPS (2017 base year)



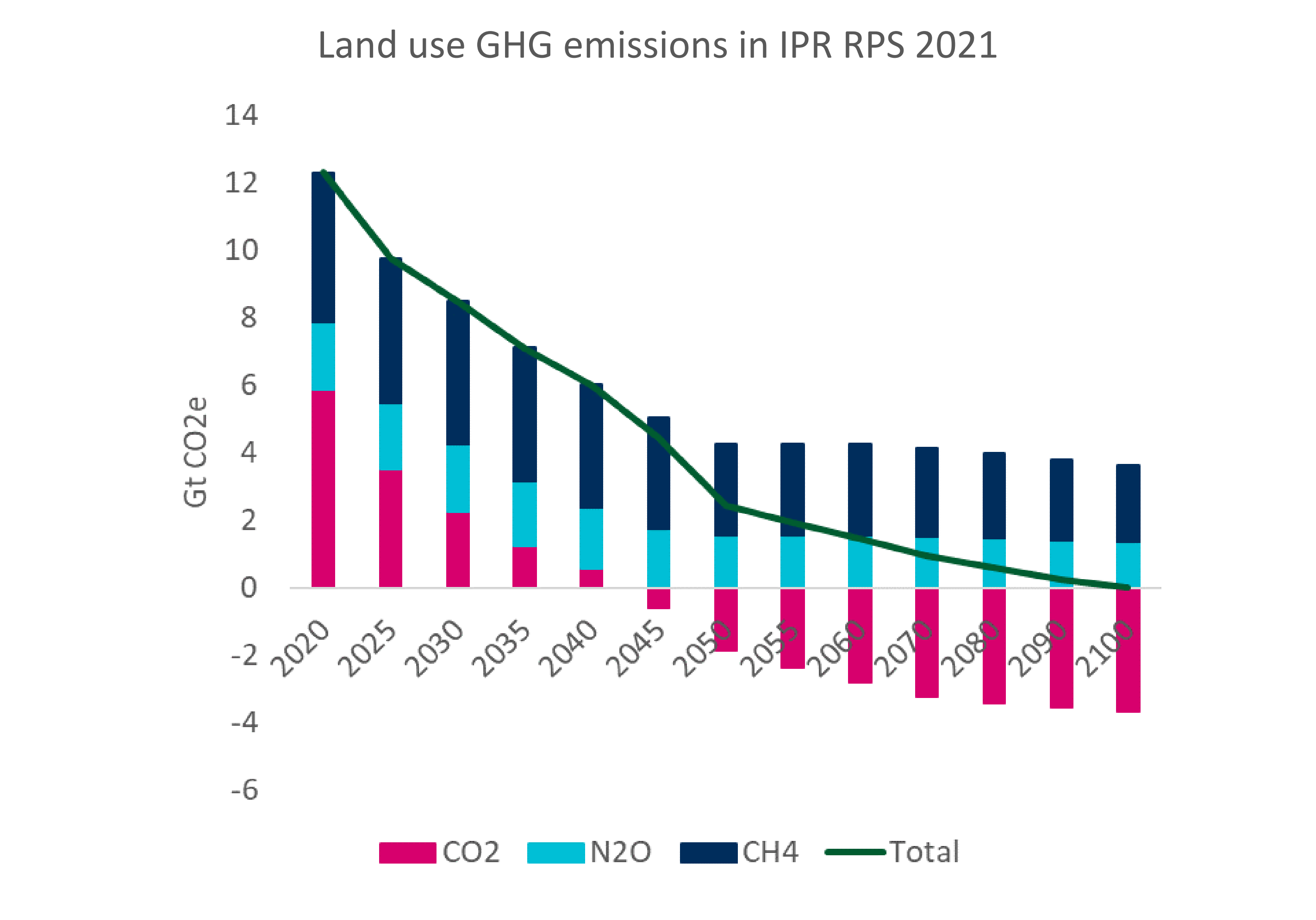
- **Steady drop in forestland**
- Marked increase in cropland driven by increases in food demand (from population and income growth)

- **Sharp increase in forestland** as an increasing carbon price drives reforestation and afforestation
- Increase in cropland to 2050 driven by increases in food demand (from population and income growth) and in bioenergy production.
- Large decline in pastures and rangelands after 2025 due to shift in food production

Note: Other land is non-productive or marginal land

Source: Vivid Economics with components from FAO

Under IPR RPS 2021, emissions in the land use sector must fall to 2.3Gt CO_2e in 2050 and 0.01 Gt in 2100



The land use sector must become a net sink for CO_2; under RPS this happens around 2045

Emissions linked to deforestation drop due to the introduction of a carbon price in the land use sector, which incentivizes afforestation and reforestation. Net deforestation is expected to stop in 2025

N_2O emissions decrease slowly despite an increase in cropland because of increased productivity that is not driven by fertilizer use

CH_4 emissions fall consistently due to a decline in ruminant meat production and food waste

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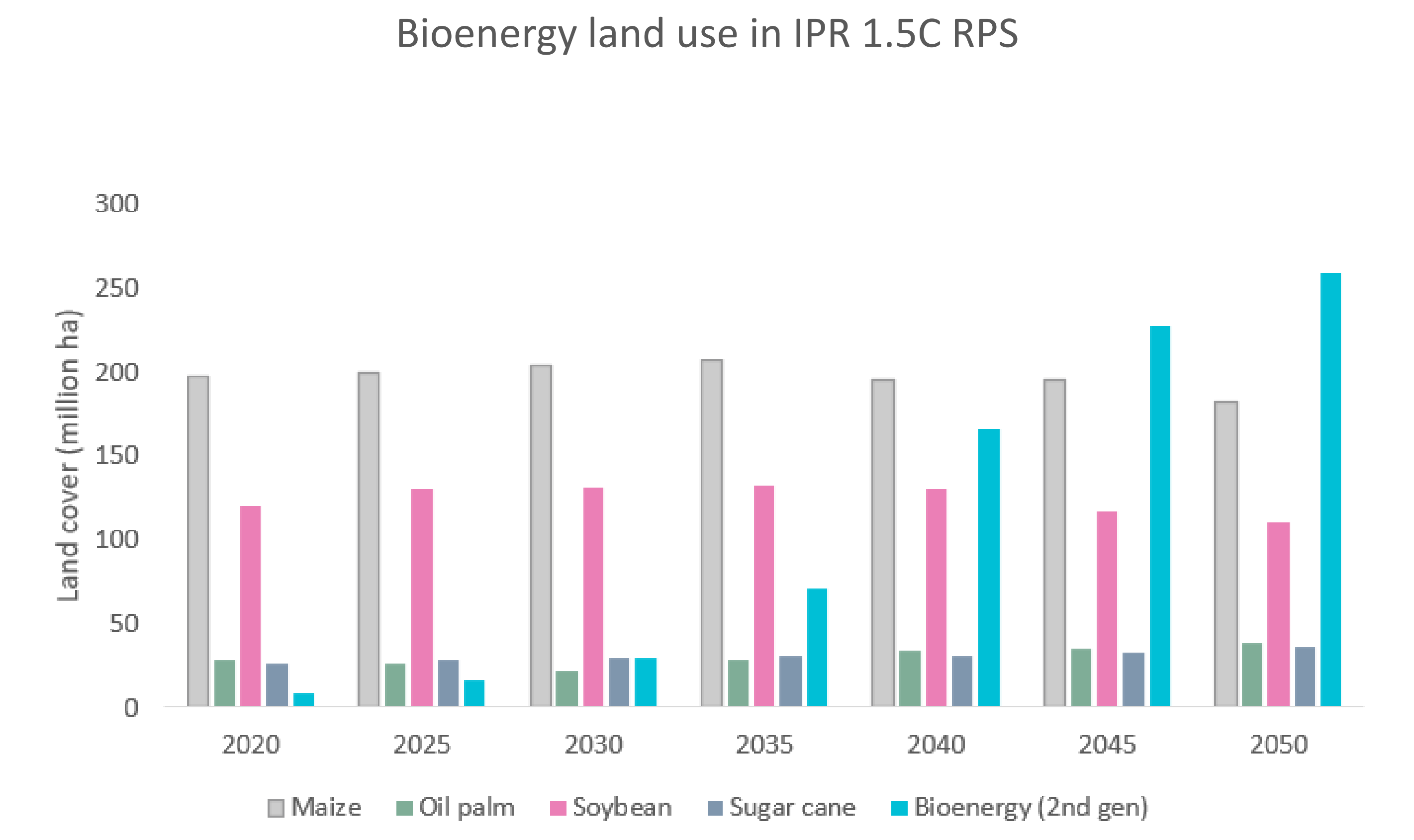
Source: Vivid Economics with components from Global Carbon Budget

Agriculture value drivers

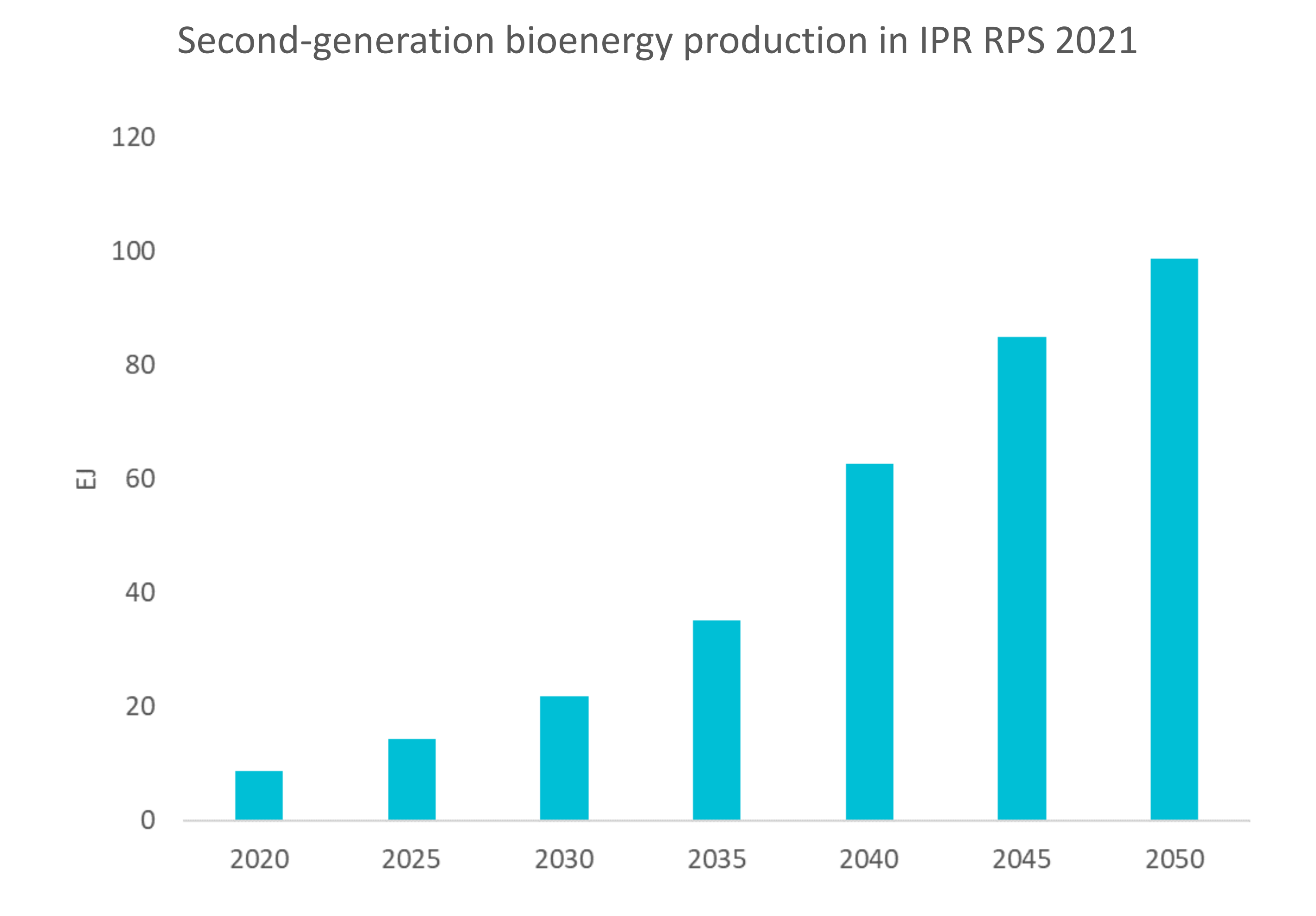
Bioenergy will use almost 260 million ha in 2050, which is more land than maize currently uses



- Second-generation bioenergy crops* should be the **sole source of biomass for bioenergy by 2040**
- Production of bioenergy crops grows as farmers find it profitable to shift towards bioenergy production
  - ◊ Growing demand for bioenergy drives up the price of bioenergy
  - ◊ Carbon pricing increases the cost of animal protein production
- **Bioenergy should use more land than maize by 2045**
- Most other crops (apart from feed crops) show little change in land required as productivity improvements offset demand increases from income and population growth

Note: *Second generation (grassy) bioenergy crops include switchgrass, miscanthus. Second-generation woody biomass sources include poplar and eucalyptus
Source: Vivid Economics

Bioenergy should provide roughly 99 EJ of primary energy, despite being constrained by competition from NBS, concerns about sustainability, and limits to supportive regulation

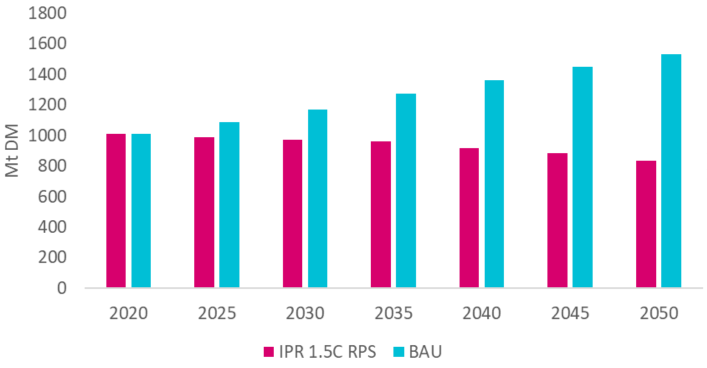


- **IPR RPS 2021 requires bioenergy demand of c.99 EJ**, roughly 44m barrels of oil equivalent per day, similar to the IEA's Net Zero scenario
- Bioenergy production should be large across major regions, including Latin America, China, the United States and Sub-Saharan Africa
- Scaling up bioenergy will be constrained by various factors:
  - **Concerns about sustainability:** seen as threatening planetary boundaries in comparison to alternatives
  - **Relative competitiveness of NBS:** which will reduce the incentive to scale up bioenergy and the land available for biomass production
  - **Regulation:** although significant supporting policies should be in place, their extent and scale may be more limited in comparison to alternatives

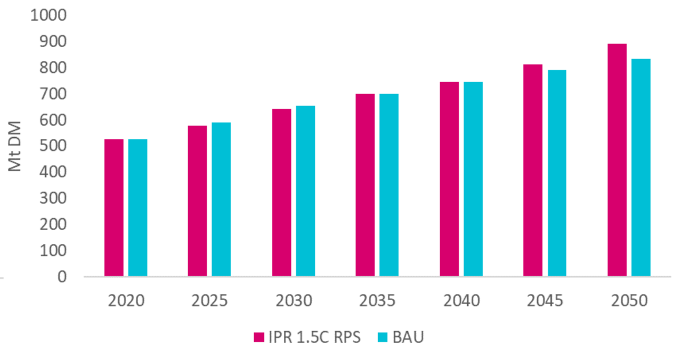
Source: Vivid Economics

Production of key crops is linked to livestock production and bioenergy production

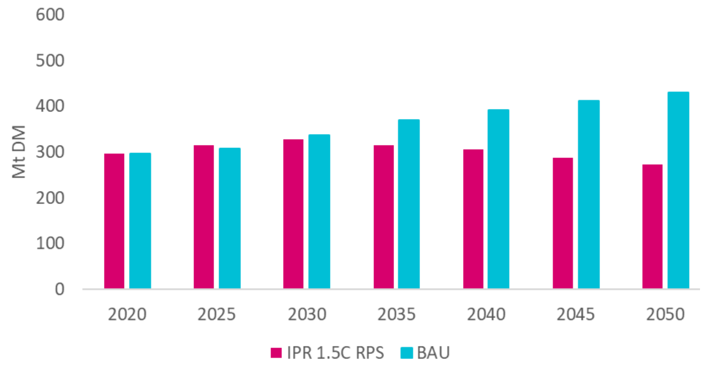
Maize production in IPR 1.5C RPS



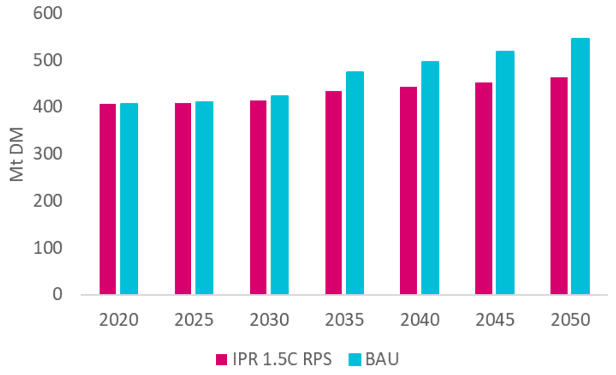
Sugar cane production in IPR 1.5C RPS



Soybean production in IPR 1.5C RPS



Palm oil fruit production in IPR 1.5C RPS



- Maize, used mainly as feed, falls in line with livestock. This movement is more pronounced in RPS as shift away from livestock is more abrupt
- Sugar cane production rises more under RPS as consumers shift faster away from animal protein and toward alternatives
- Oil palm production continues to rise with population growth, but stronger substitution for other oil crops will moderate its growth
- Soybean, used for feed and first-generation bioenergy, falls in line with livestock demand and with first-gen bioenergy phase out, tempered by food substitution. This effect is stronger in RPS as phase out occurs in 2040 compared to 2050 in FPS

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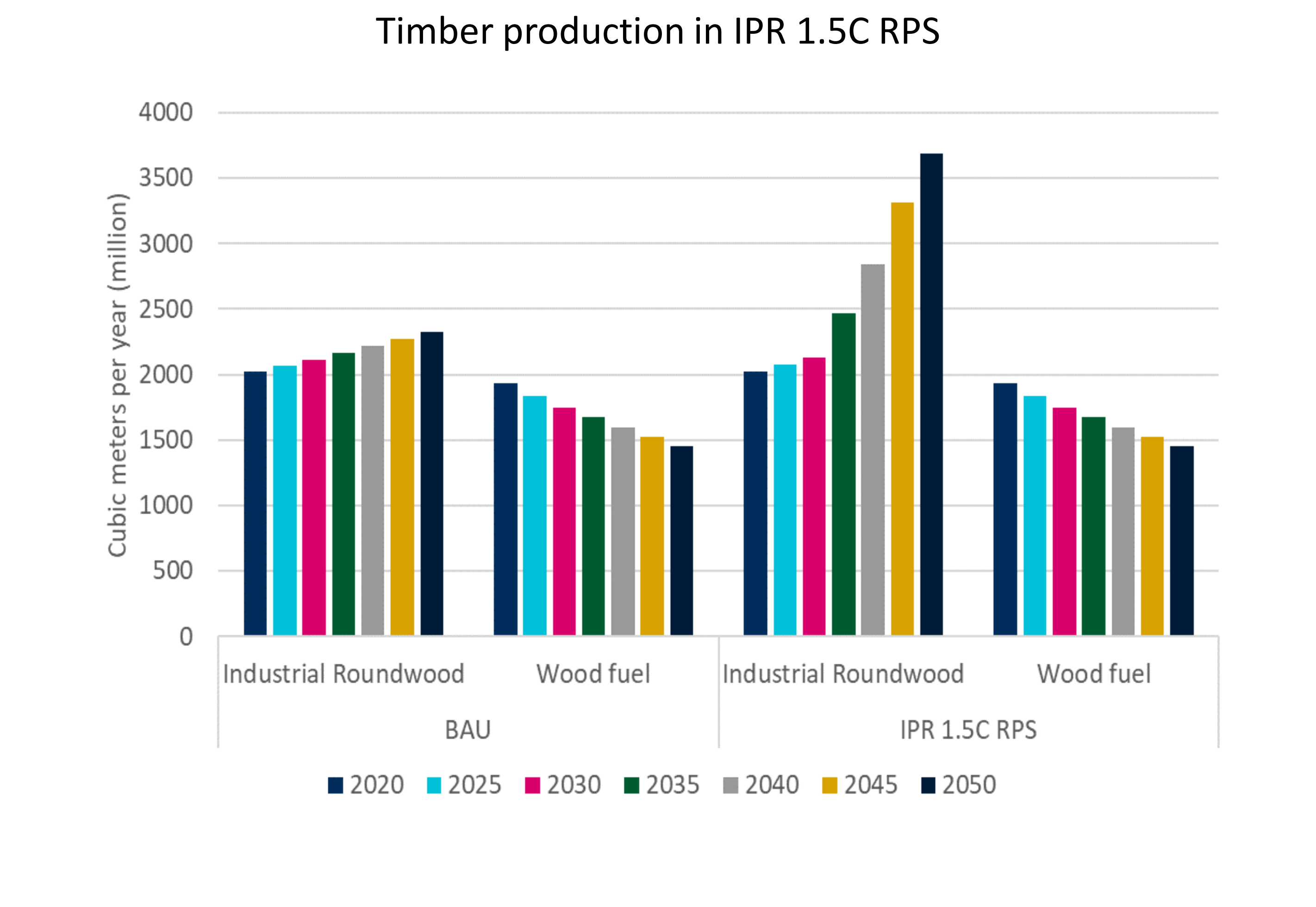
Source: Vivid Economics with components from FAO

IPR 1.5C RPS entails an increase in industrial roundwood production and a decrease in wood fuel production



- **Construction uses more roundwood**, responding to changes in consumer preferences in developed countries as well as construction booms in developing countries with high rates of economic growth and increasing levels of urbanisation
- Conversely, **wood fuel will be substituted by grassy biomass for bioenergy production**. This responds to lower costs of production of grassy biomass, especially in Sub-Saharan Africa, China and Latin America
- Higher carbon prices generate incentives to create plantations that exploit both timber and carbon

Source: Vivid Economics

NBS value drivers

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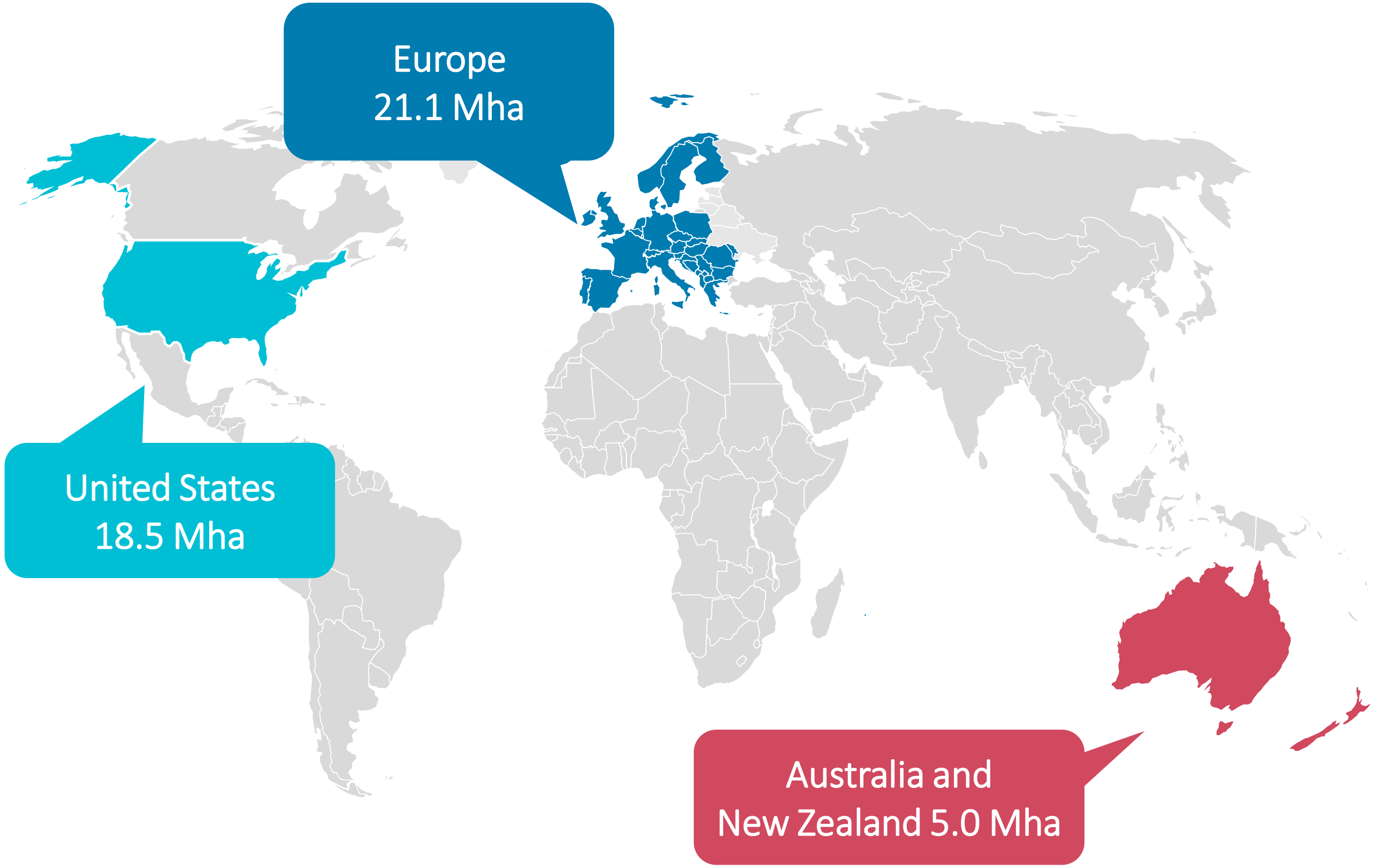
Afforestation & reforestation costs are significantly higher in tier 1 countries, on average



Developed countries

In developed economies, carbon sequestration through re/afforestation will require a significantly higher carbon price because:

- These countries/regions are not located in tropical areas, so carbon sequestration potentials are lower, thus reducing the sequestration benefits of afforestation
- Their production systems are already efficient, so any additional increase in productivity will be expensive and the investment will be justified only by high carbon revenues/prices

Carbon prices

- Under IPR RPS 2021, a **carbon price of around USD 150** would incentivize re/afforestation of 44 Mha in tier 1 countries

Note: Regional values represent reforestation and afforestation between 2020 and 2050
Source: Vivid Economics

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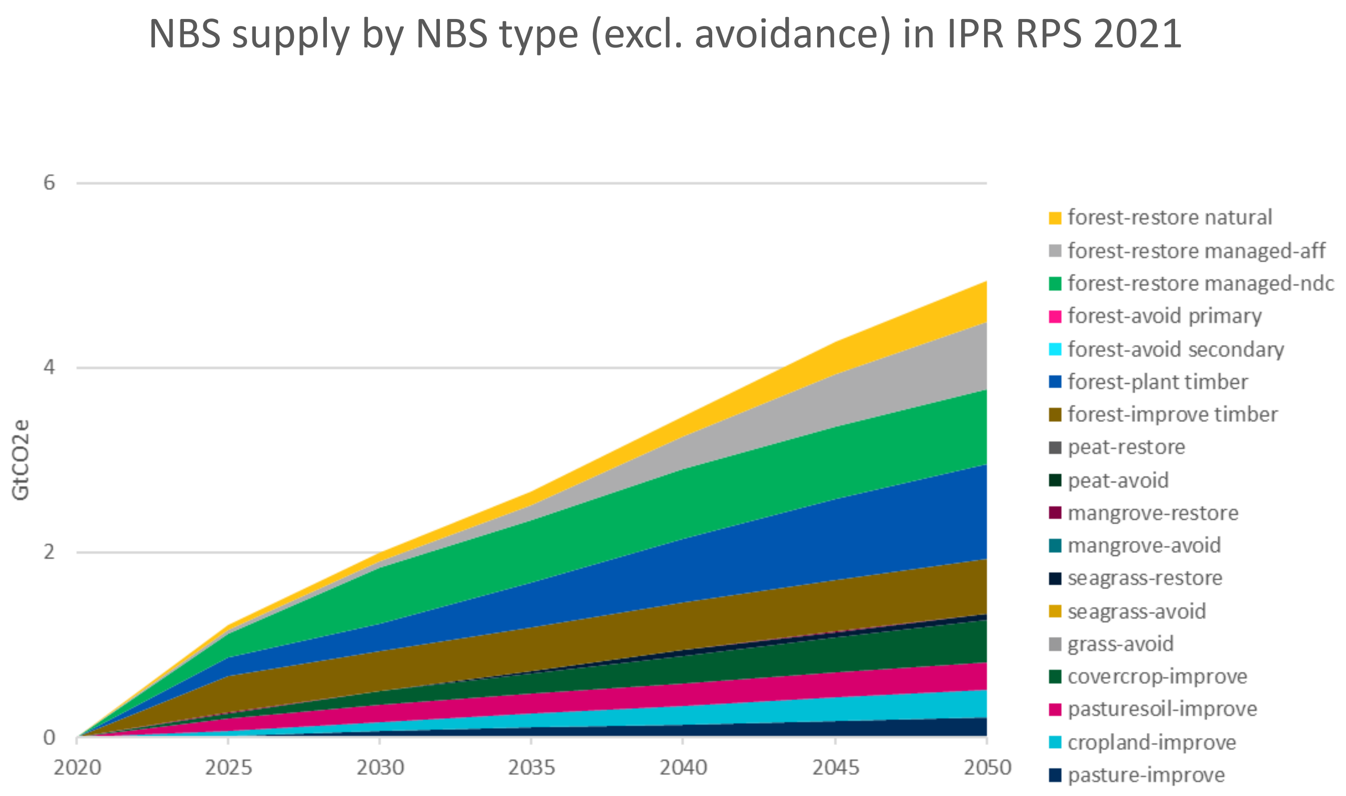
Forest-based solutions must become a major NBS source under RPS, as they have the greatest scaling potential

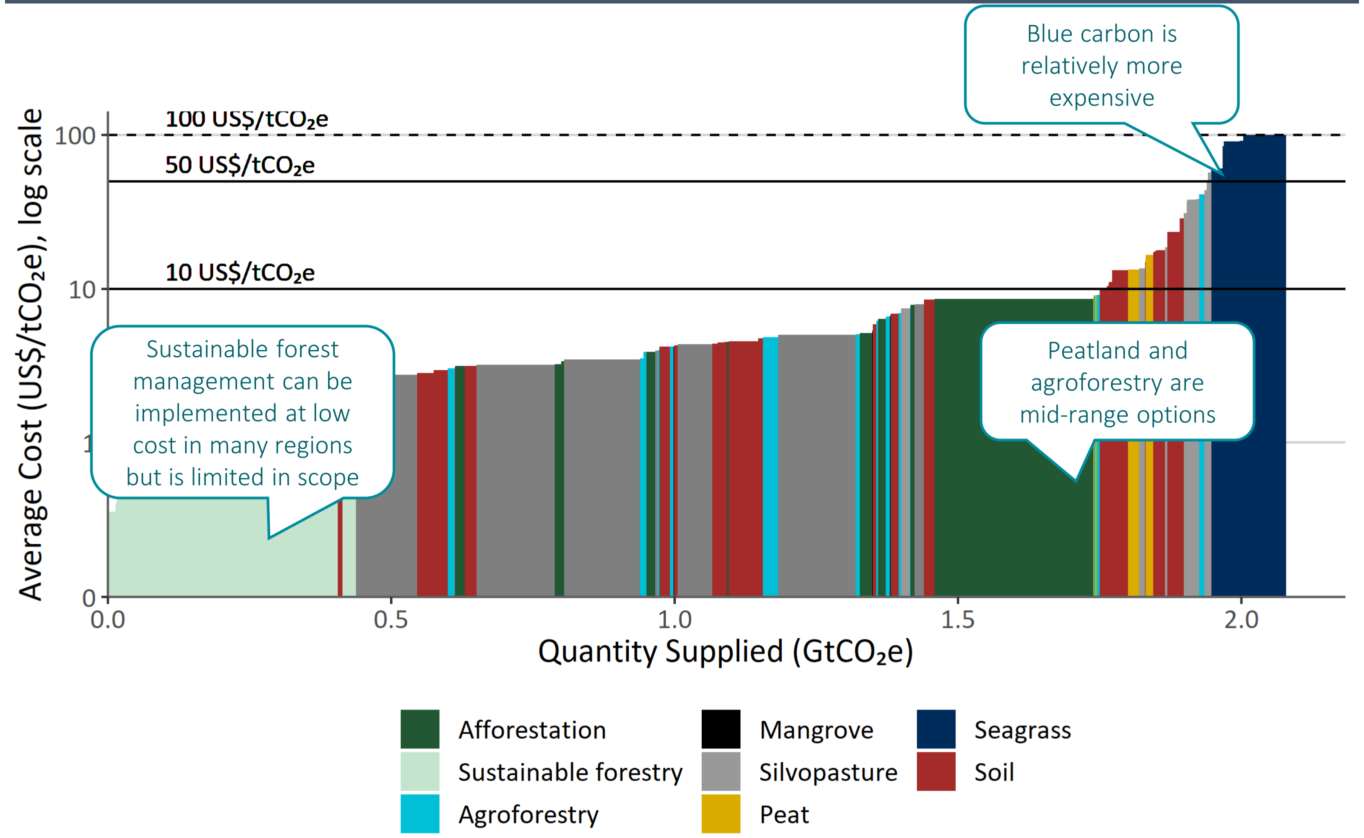


- Forest–based solutions are the most prominent opportunities, accounting for approximately three quarters of NBS supply in 2050
- Agriculture makes up 16% of NBS supply in 2050, predominantly through improvements in cover crop
- Peatland, mangrove and seagrass make up the remaining 7% of NBS supply in 2050

Source: Vivid Economics

Forest based solutions in Africa, Brazil and Asia-Pacific have most options below USD 10 USD per tCO_2e, while blue carbon (seagrass) has less volume and higher costs

NBS average cost curve in 2030 in IPR RPS 2021



Main message

- **NBS can supply substantial sequestration (in GtCO2e) at relatively low cost**, while higher-cost options offer relatively less abatement potential
- A variety of NBS options can be offered at **very low cost**, particularly **avoidance** projects and **sustainable forest management** practices
- **Mid-range options** are feasible as well, for example **peatland** and **agroforestry** projects
- Depending on demand, **more costly** options may be considered. These include **blue carbon (seagrass)** restoration and avoidance options

Note: Costs are in USD 2020 terms
Source: Vivid Economics

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In comparison to a business-as-usual scenario, there is very large growth for investments in NBS

	Scenario description	Net change in forest cover (2020–50)	Asset value
4°C Business as Usual	• Currently implemented policies only • Value realisation from carbon sequestration is minimal • Extensive expansion of agriculture based on relatively cheap land availability • Consistent with a 3–4°C global temperature increase	–200Mha Deforestation continues up to 2100	Negligible
IPR 1.5C RPS	• High carbon prices (USD 150/tCO_2e in 2050 in tier 1 countries) • Greater ramp-up of NBS in 2030–40s and substantial changes in food production • Improvements in agricultural productivity, following returns on technological investments similar to past • Consistent with temperatures stabilizing at c.1.5°C	+241Mha Deforestation stops by c.2025	USD 841 billion by 2050

Note: The cumulative cost of assets (publicly or privately owned) is the amount of money required to meet the equilibrium quantity demanded in each year. Figures are discounted to 2021 using regional discount factors. Market revenue is calculated as the undiscounted price multiplied by quantity sold.

Source: Vivid Economics

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Thank you!

Please see PRI website for further details:

https://www.unpri.org/climate-change/what-is-the-inevitable-policy-response/4787.article

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