- The Inevitable Policy Response Forecast Policy Scenario 2021 (IPR FPS 2021):
- Detailed land use system results

Preparing financial markets for climate-related policy and regulatory risks

December 2021

IPR is commissioned by the Principles for Responsible Investment (PRI), supported by world class research partners and joined by 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 · FitchRatings · 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

INEVITABLE POLICY RESPONSE

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

INEVITABLE POLICY RESPONSE

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
- 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

INEVITABLE POLICY RESPONSE

Executive summary overview

INEVITABLE POLICY RESPONSE

Key findings Food and Land Use

Unlike many scenario models, IPR addresses a major gap by integrating greater detail on the food and land use system in modelling its interaction with the energy system and economy. This reveals how critical often-overlooked assumptions on food and land use emissions and Nature-Based Solutions (NBS) are to achieving climate goals. The analysis finds:

- Meat consumption will peak by 2030 globally and will rapidly decrease after alternatives become cost competitive by 2035. Current pasture and rangelands will be replaced with forests, cropland, and other NBS.
- These changes mean land will be a net CO_2 sink before 2050 and will yield 7 Gt of emissions reductions by 2050. 4.7 Gt will come from NBS that remove carbon from the atmosphere, and the rest will come from avoiding deforestation.
- Together removal and avoided deforestation projects will lead to an industry with an estimated USD167 bn annual revenue by 2050, with China having the highest cumulative NBS deployment to 2050 potential.

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

INEVITABLE POLICY RESPONSE

The land use transition will play a significant role in economic decarbonization, driving both risks and opportunities for financial institutions

	Mitigation potential (GtCO2e/year in 2050) in IPR FPS 2021
Forestry – The forestry sector grows enormously in order to provide carbon sequestration service – Re/afforestation are high-potential, low-cost mitigation sources, with ~3.4 Gt CO_2/year of annual carbon sequestration achievable for less than USD 150/tCO_2 by 2050	3.4 Gt
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 Gt
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 Gt
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 Gt*

Note: *Calculated as the difference between agricultural emissions in 2050 and 2020 in the IPR FPS 2021 scenario.

Source: Vivid Economics

INEVITABLE POLICY RESPONSE

IPR FPS 2021 is based on a number of regulatory, behavioral and technological drivers of change that are expected to accelerate in the land use sectors

Key policy, behavioral and technological shifts in the IPR FPS 2021 related to land use

Regulation:

- Carbon prices will increase the cost of high emitting products and incentivize Nature-based Solutions (NBS)
- Government forestry policy, including creation and enforcement of controls on deforestation and directed re/afforestation programs will lead to a growth in forest land
- Fertilizer taxation will encourage a reduction in fertilizer use, reducing N20 emissions

Shifts in food production:

- Government regulation will increase the cost of animal protein and encourage the production of alternative meat
- Consumer preferences will shift away from animal meat and towards alternative meat due to concerns over sustainability and health
- Technology development will reduce the cost and improve the taste of alternative meat

Bioenergy demand: global demand for bioenergy will increase globally, with regulation implemented to ensure the sustainability of bioenergy and reduce competition with food for land use.

Macroeconomic drivers are also critical to the long-term trajectory of the land system – both global population and GDP are expected to increase significantly over the next 30+ years, putting major pressure on land and food demand.

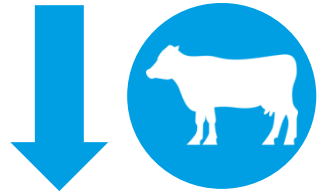
Source: IPR Forecast Policies

Food production shifts in response to climate policy and technology changes with demand shifting to ruminant meat substitutes, posing a major risk for the animal meat-producing sectors

- **Growing alternatives – Companies producing beef substitutes** (both lower emitting meats and animal meat substitutes) will experience substantial benefits from the introduction of stricter climate policies.

Lower-emitting meats and animal meat substitutes

- **Demand declines – animal meat consumption is forecast** to decline by 2050 due to consumer concerns over sustainability, emerging health dietary guidelines (halving of per capita consumption imposed in China), and the increasing price competitiveness of animal meat substitutes



Beef, lamb and pork

- **Supplier risks – stricter regulations and greater consumer awareness are increasing regulatory and reputational risks for companies that contribute to deforestation** and land degradation, particularly around biodiversity hotspots and large carbon sinks, such as the Amazon rainforest. For example, recent fines to AgroSB and JBS in Brazil*

Deforestation-based agriculture

Note: *AgroSB, a Brazilian cattle producer, and JBS, a Brazilian meat-processing company, were fined USD 25 million as their activities were linked to deforestation in protected areas on the Amazonian agricultural frontier. Source: Phillips et al., (2019)

Policy changes, consumer behaviour, and technology drives a change in food production, which varies by region

Demand shape	Consumer preferences	Food technology	Policies
Peak animal meat 2030, 30% fall to 2050	• Consumers already demonstrating willingness to substitute animal meat with alternative meat • Adoption will vary by region, depending on price sensitivity as well as food culture trends	• Technological progress leading to early plant-based meat price and taste parity in lower quality meat markets • Cell-based meat becoming price competitive 2035-2040	• Global support for cellular agriculture with effective policy framework emerging gradually, starting with a few leading countries • Financial incentives for the production of alternative meat

Source: Vivid Economics

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Different animal meat consumption is forecasted depending on the region and type of product (peak year)

Meat type	Europe, North America, Aus and NZ	Brazil, Latin America, Developed East Asia	Mainland China, DPRK, Taiwan, HK and Macau	Sub-Saharan Africa
Non-structured meat e.g. burgers, mince	2025 Saturated markets	2030 Slow-growing markets	2030 Plant-based meat consumption to slow growth	2040 High growth potential
Structured meat e.g. steak, chops	2030 Saturated markets	2030 Slow-growing markets	2035 Market growth as incomes rise	2040 High growth potential

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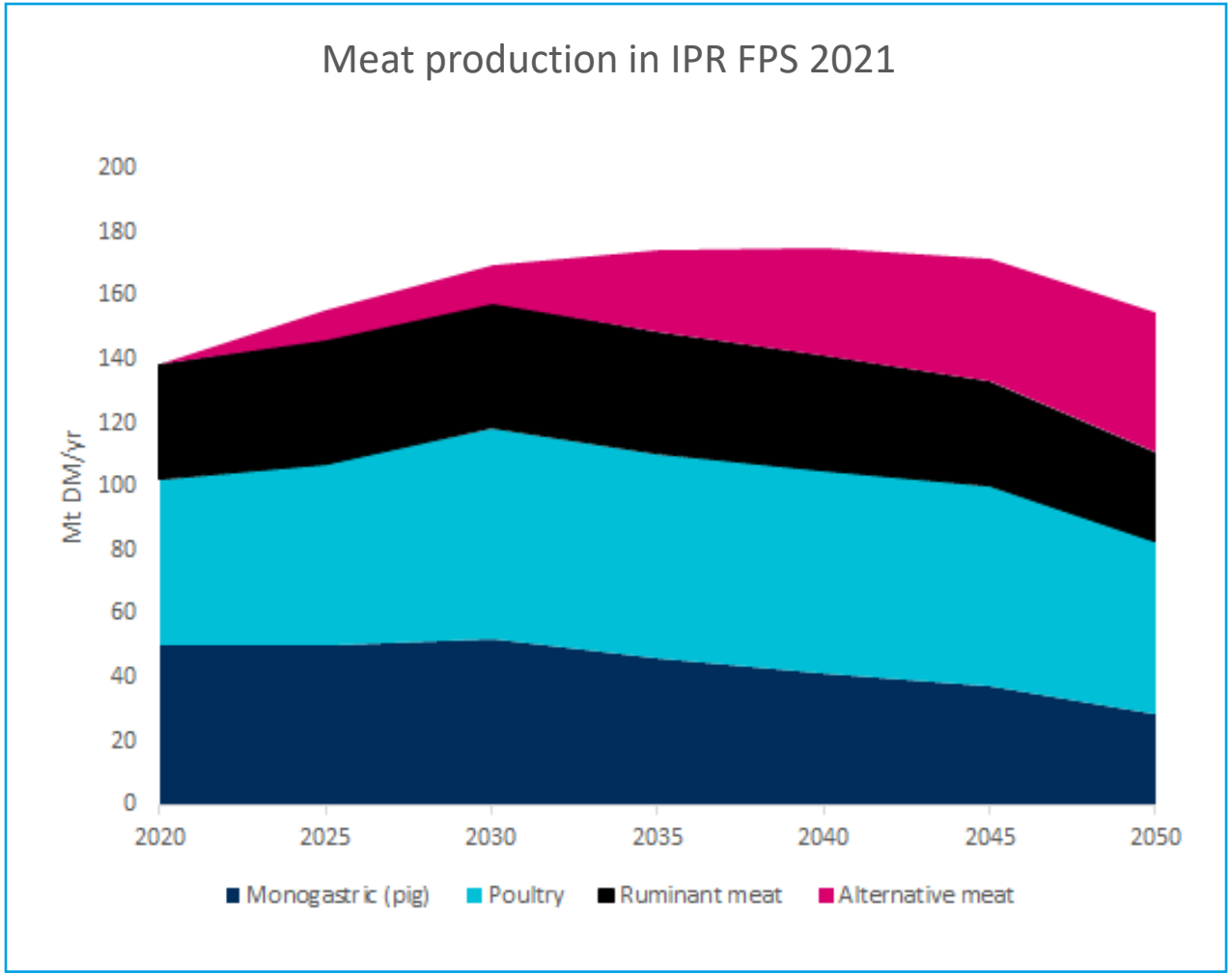
Decline in ruminant meat consumption will give way for alternative meats such as plant-based and cell-based meat



- **30% 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
  - ◊ BAU foresees a 28% increase in animal meat production over the same period
  - ◊ Relatively small decline in poultry production due to lower emissions costs
- Production of alternative meat increases, reaching a 28% market share by 2050
  - ◊ Material market share reached as the cost of cell-based meat becomes more competitive in the 2030s and 2040s
- FPS 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

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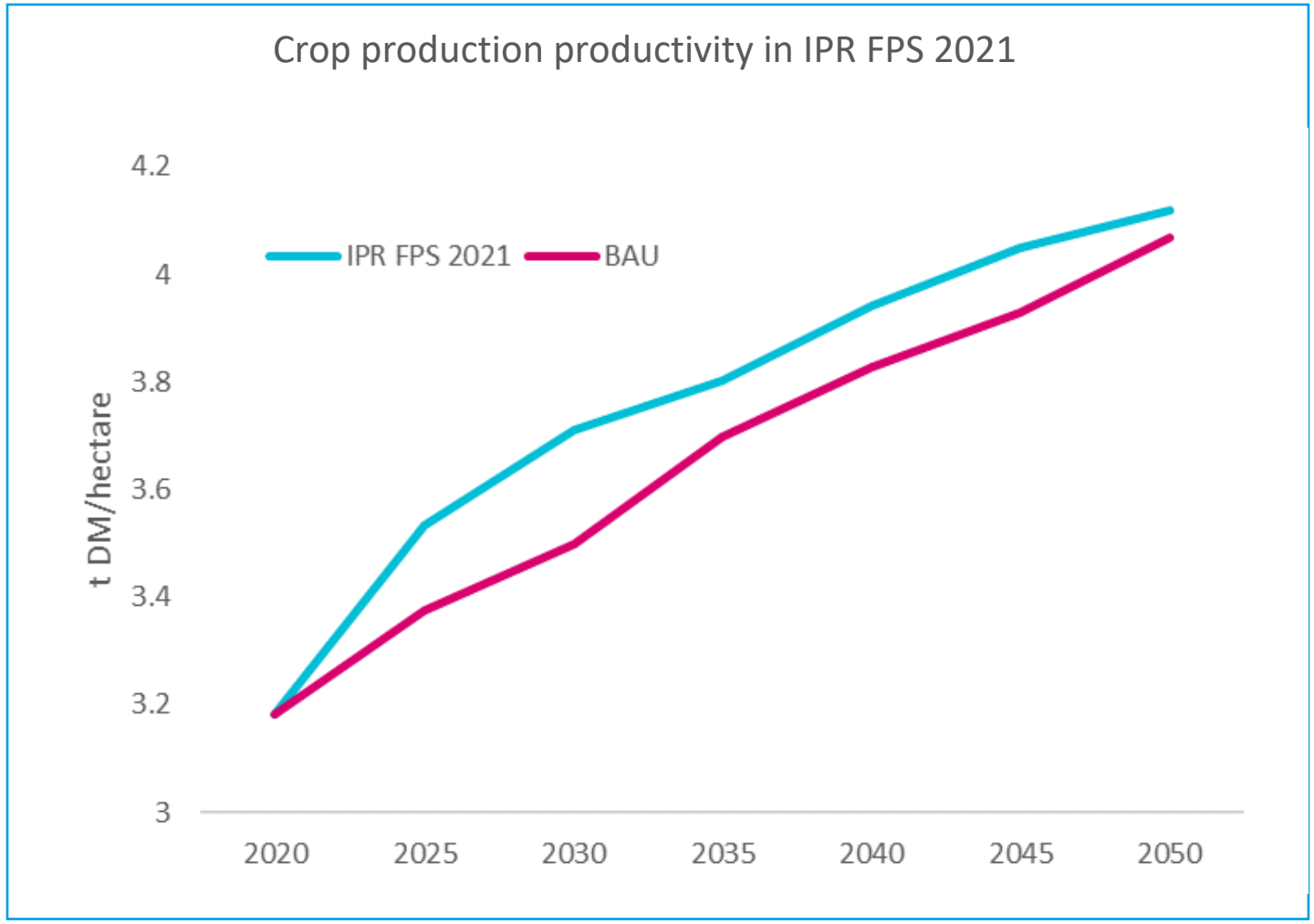
Carbon economics will drive more efficient land use and agricultural practices by raising the cost of land conversion



Producers of commodities that have relied on extending crop and pastureland will need to increase productivity per hectare, while reducing the emissions per unit of production. The winners will be:

- Producers that apply more sustainable practices, including better fertilizer application, regenerative agriculture, and ruminant meat production with reduced methane emissions
- Producers able to sustainably manage water inputs and waste outputs
- Companies that supply technologies that increase productivity while managing emissions
- Midstream and downstream companies able to manage their producer suppliers to improve techniques, especially smaller producers in tropical countries

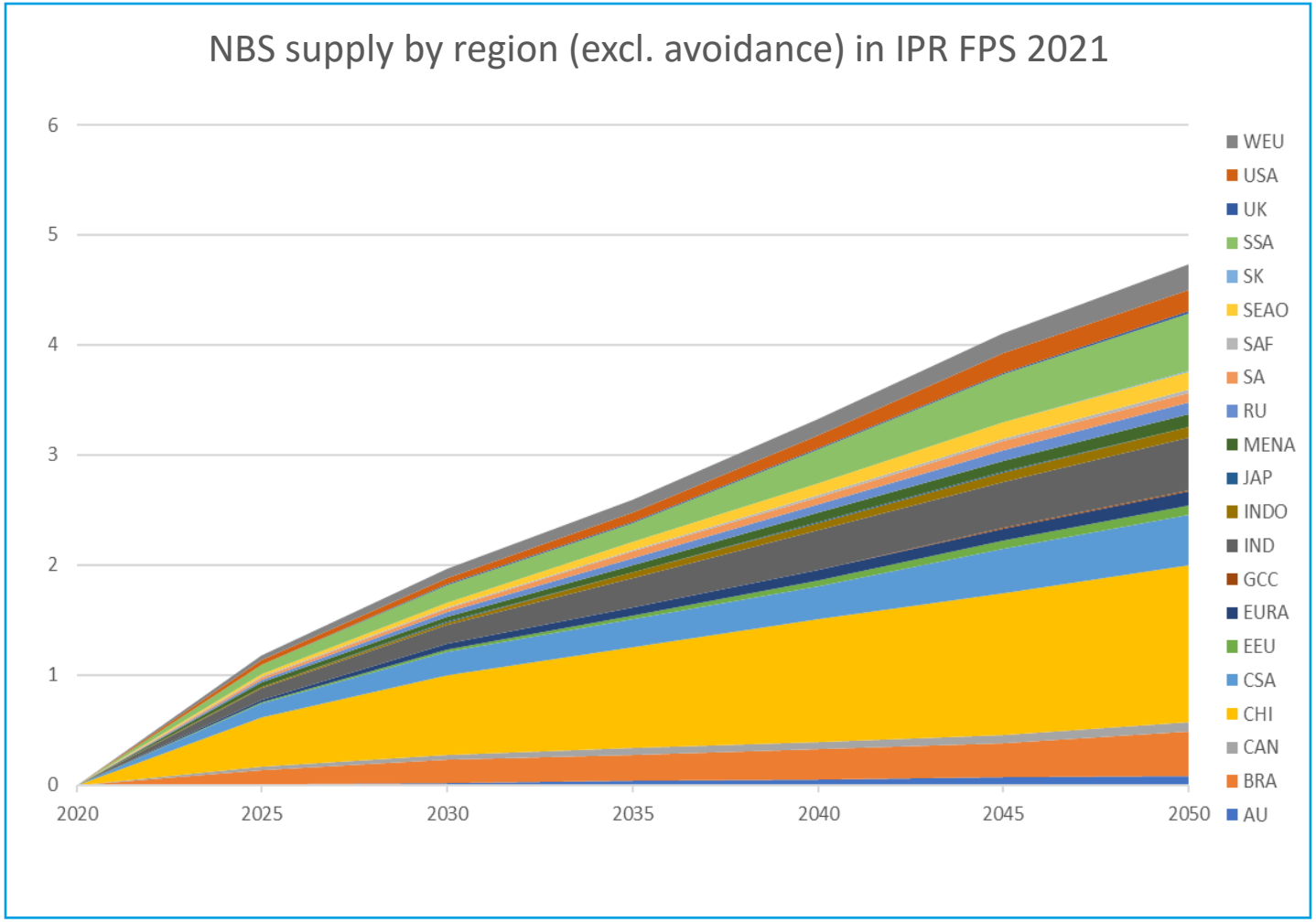
Source: Vivid Economics

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

- Regulation will increase the cost of fossil fuels and promote investment in alternative fuel sources
- Hard-to-abate sectors that can not transition to electrification easily (e.g. heavy industry) will rely on bioenergy as part of their decarbonization plans
- The introduction of emissions pricing in the land use sector will incentivize 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 are scaling 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)

Global removal of GHG with NBS is expected to reach 4.7 $GtCO_2eq$ in 2050, with the greatest sequestration potential occurring in China

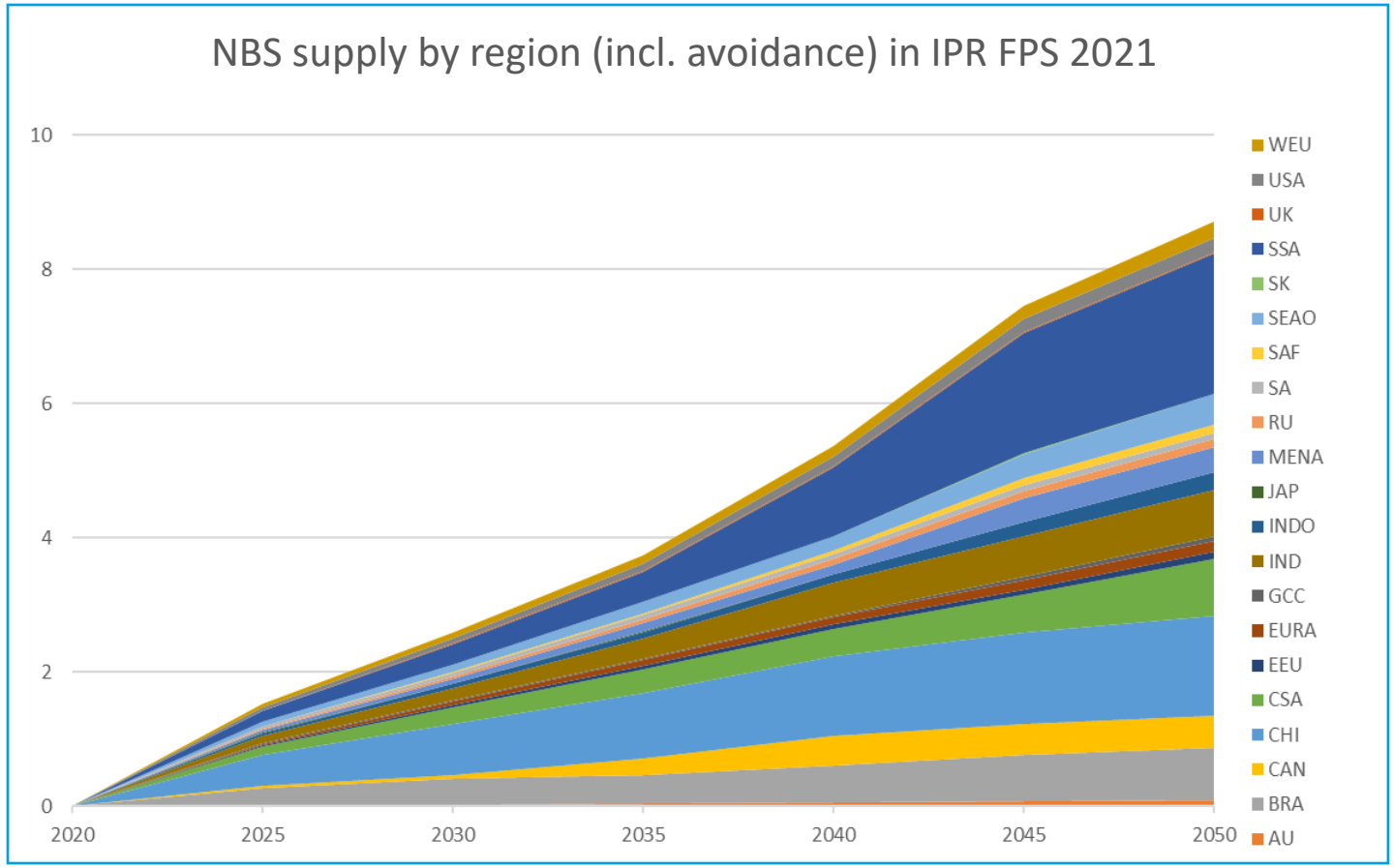


- The greatest sequestration (1.4 Gt) is expected to occur in **China** through **reforestation in the form of NDC and timber plantations**
- **Sub-Saharan Africa** (0.5 Gt) and **Brazil** (0. 4Gt) realise significant GHG removals by deploying **private and governmental reforestation NBS**
- **NDC reforestation and agricultural solutions** drive **India's** NBS supply of 0.5 Gt
- **Europe** will deploy around 0.25 Gt of NBS predominantly in the **agricultural and forestry sectors**

Source: Vivid Economics

INEVITABLE POLICY RESPONSE

Global abatement of GHG with NBS is expected to reach almost 8.7 $GtCO_2eq$ in 2050, including avoided deforestation



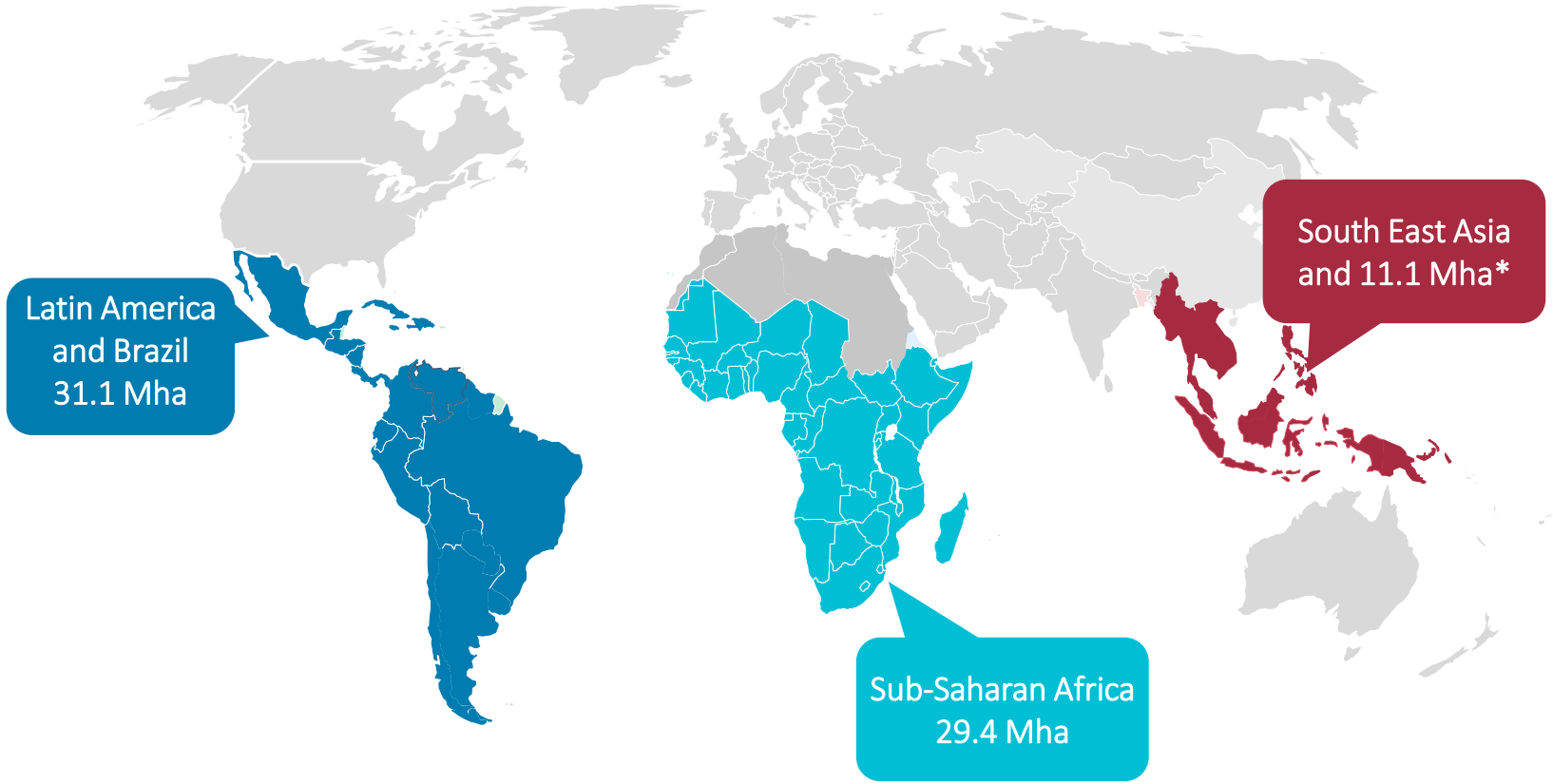
- IPR FPS 2021 expects NBS to ramp up significantly from 2035, with sequestration rising from 3.7 $GtCO_2e$ in 2035 to 8.7 $GtCO_2e$ in 2050.
- **The largest contribution is from a broad set of NBS** that aim primarily to remove CO_2 from the atmosphere, creating negative emissions
- **Large abatement opportunities exist in avoided deforestation**, which is expected to lead to 4 $GtCO_2e$ fewer emissions versus BAU in 2050
- Improved timber management practices are expected to contribute 1 $GtCO_2e$ of abatement in 2050

Source: Vivid Economics

Notes: 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.

INEVITABLE POLICY RESPONSE

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



Carbon prices

Under IPR FPS 2021, a **carbon price of around USD 90** could incentivize re/afforestation of 72 Mha in Latin America, Sub-Saharan Africa and South East Asia

Tropical rainforests

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

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 increase in carbon prices drive a major shift toward nature-based solutions, and carbon sequestration as a valuable forestry sector commodity

- NBS[1] will generate an investible universe worth **USD 898 billion** (in present value terms) by 2050. This number includes NDC and non NDC related investments
- NBS will also generate revenue streams worth **USD 209 billion** by 2050
- This opens up enormous new opportunities for both project developers and investors.

billion USD 2021	2025	2030	2035	2040	2045	2050
Cumulative cost of assets (market size)	140	303	462	639	785	898
Annual total revenue*	16	52	77	122	172	209

Source: Vivid Economics

Note: The cumulative cost of assets 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.
* 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.

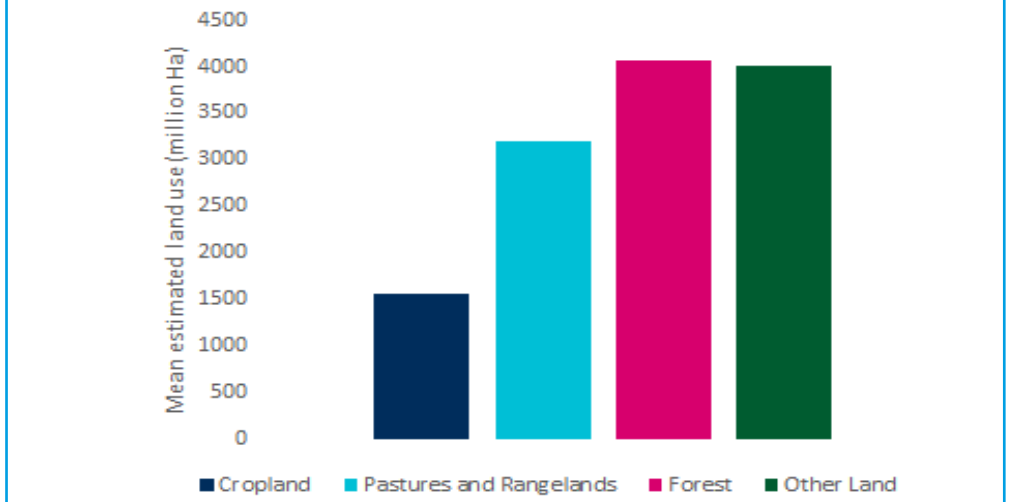
Source:[1] The European Commission defines NBS as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. […]"

INEVITABLE POLICY RESPONSE

Introduction / Baseline

INEVITABLE POLICY RESPONSE

Emissions and land use in forestry and agriculture

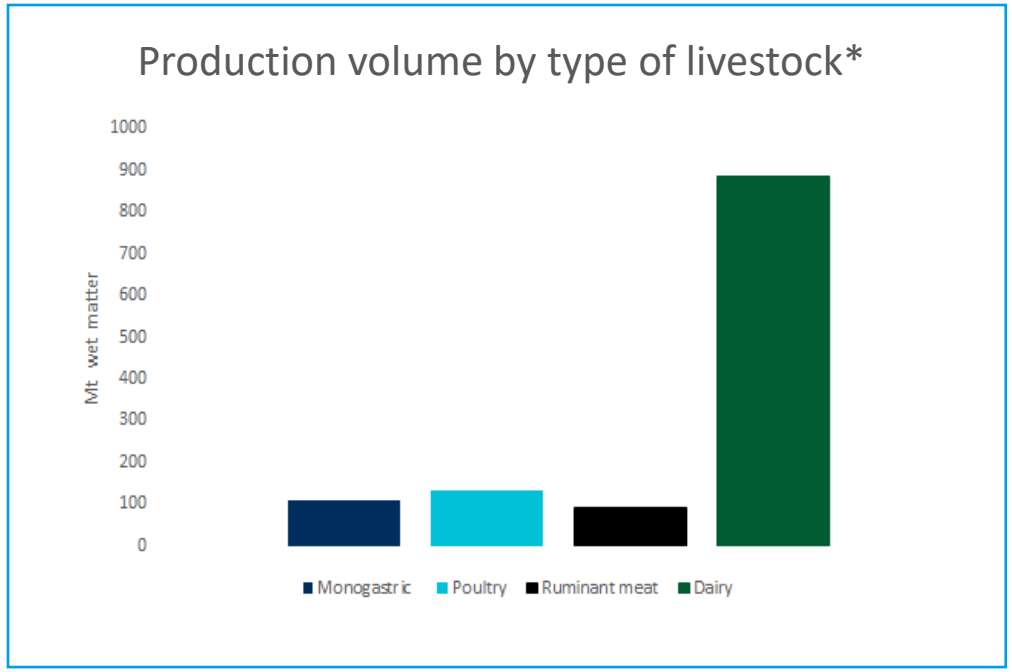


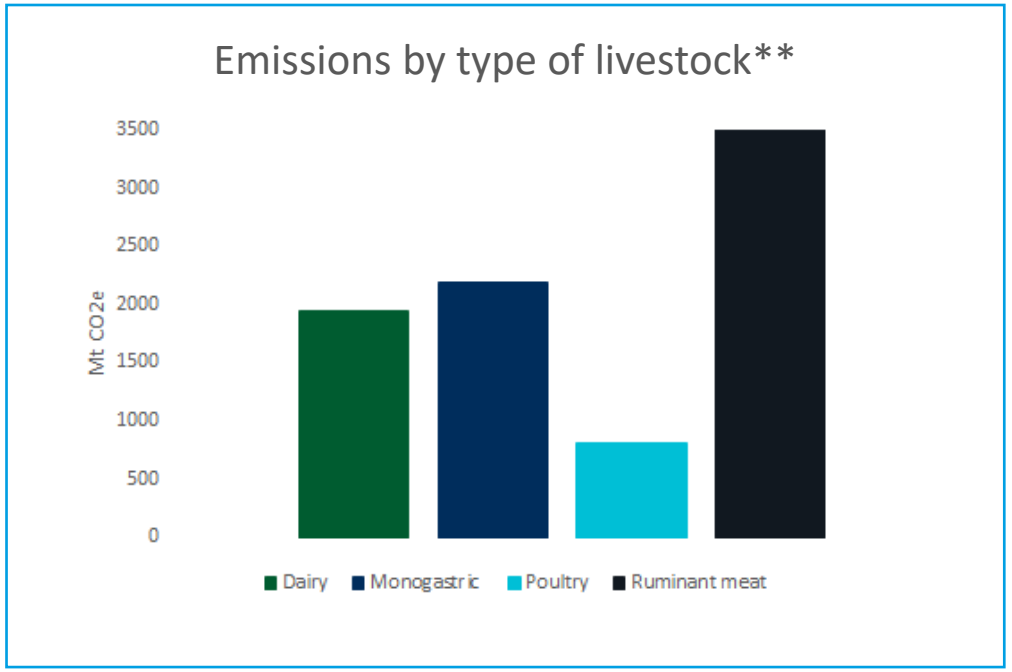
- Emissions from agricultural production constitute the largest proportion of emissions from the land use sector
  - ◊ CO_2 emissions driven by land-use changes e.g. deforestation*
  - ◊ N_20 emissions predominantly a result of fertilizer use in agriculture
  - ◊ CH_4 emissions predominantly related 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



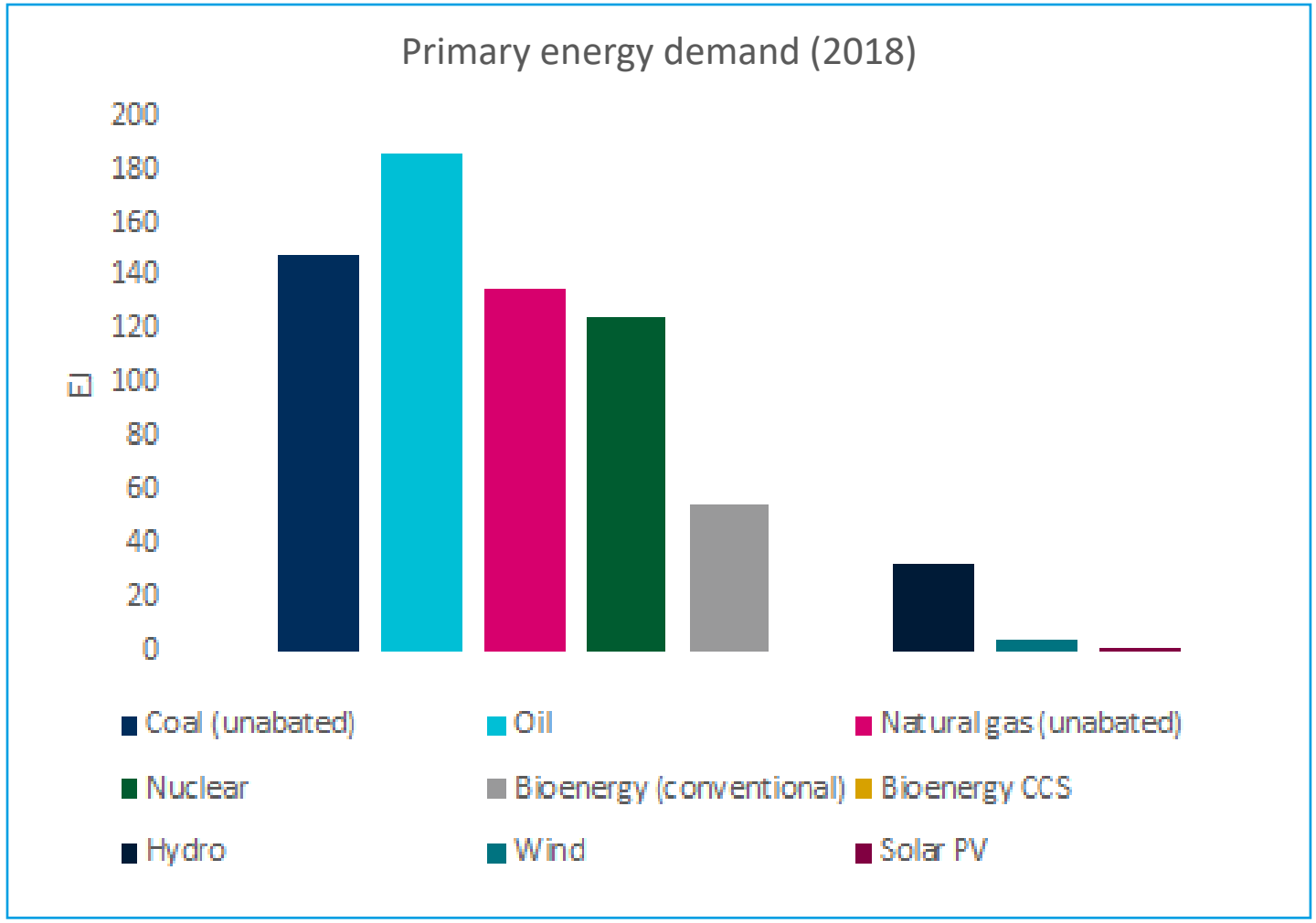


- Ruminant meat makes up around 7% of animal production by weight but constitutes **45% of total land use emissions in the animal protein category*****
- In 2019, poultry production contributed least to land-use emissions (9%)

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

INEVITABLE POLICY RESPONSE

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, 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

INEVITABLE POLICY RESPONSE

Methodology

- 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

Note:

Policy, technology and behavioural expectations

INEVITABLE POLICY RESPONSE

Climate policies will 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 will increase emission costs and apply pressure on:

Agricultural activities which emit carbon through deforestation

Agricultural activities associated with large methane emissions, particularly production of ruminant meat (e.g. beef)

Agricultural activities that use inorganic fertilizers and that are therefore associated with nitrous oxide emissions

The introduction of climate policies will create incentives for:

Reforestation and afforestation activities through rewards for carbon sequestration

Demand for ruminant meat substitutes, such as chicken, plant-based meat substitutes and cell-based meat

Sustainable agricultural systems that use organic fertilisers and capture carbon in the soil

INEVITABLE POLICY RESPONSE

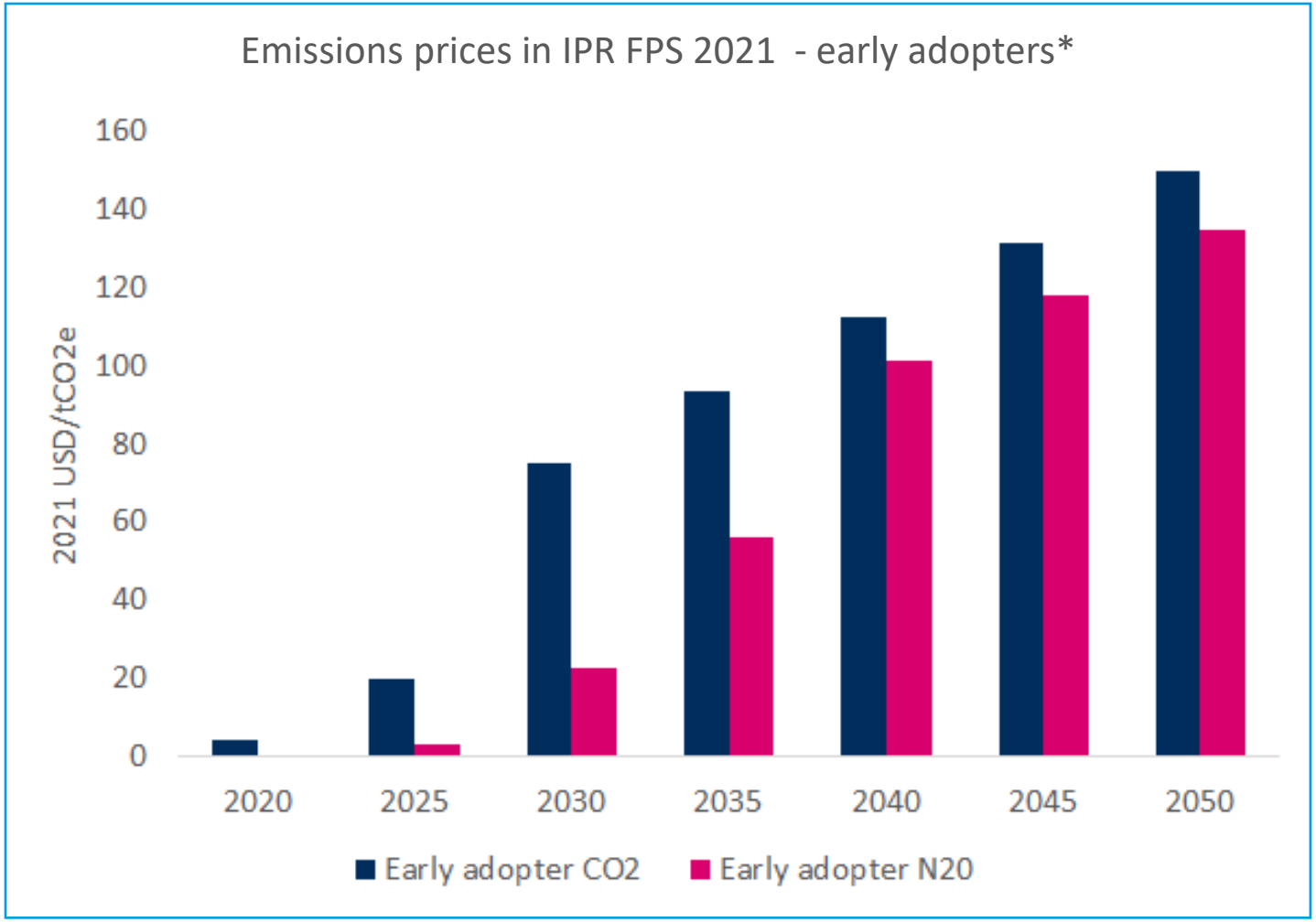
The forecasted policies broadly divide countries and regions into early and late adopters, based on how quickly they adopt sustainable land use policies and carbon pricing in the land use sectors

Early adopters	Late adopters
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 East 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

INEVITABLE POLICY RESPONSE

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

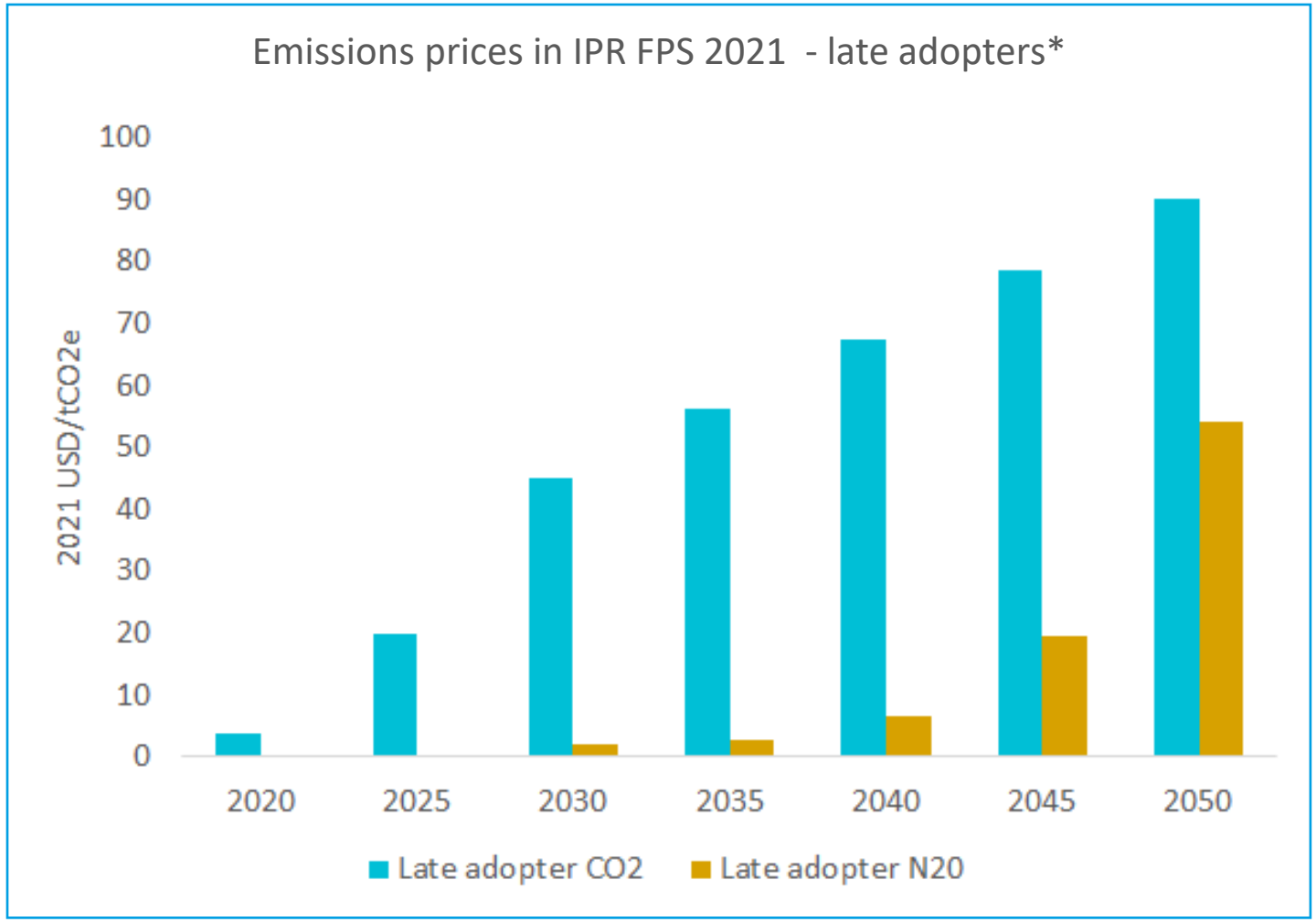


- Land use carbon prices gradually rise to align with the IPR FPS 2021 estimates for carbon price in energy and industry, representing the gradual incorporation of the former into the latter
- There is a price differential between energy and land use until compliance markets start covering land use - until that happens, land use will be covered by voluntary market price
  - ◊ **Land use will be covered by compliance markets in 2025 for early adopters**, with the inclusion of land use in compliance markets expected to be a major component of COP26 negotiations
- 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

Late adopters have a mixture of policies to encourage sustainable land use, and are expected to 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 incorporation of the former into the latter
- The land use sector will begin to be covered by compliance markets in 2030 for late adopters, but will not fully converge to similar markets in energy and industry until after 2050
- For N_2O, the CO_2e prices are expected to be lower to account for the reduced participation agriculture will play in carbon pricing
  - ◊ Late adopters: 60% participation reached in 2050

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 FPS 2021, different meat consumption is forecasted depending on the region and type of product

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

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

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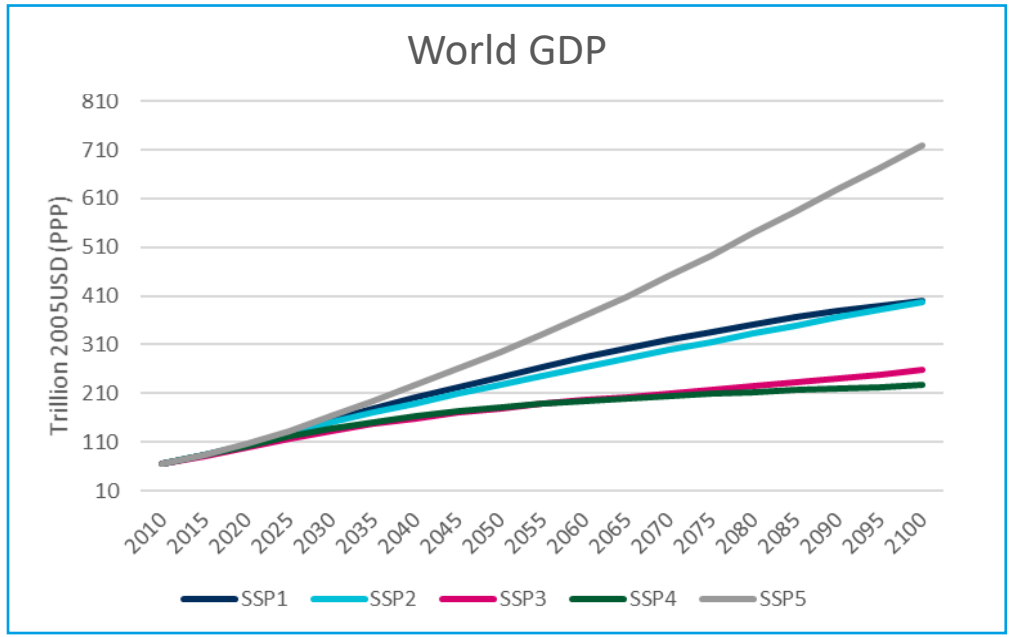
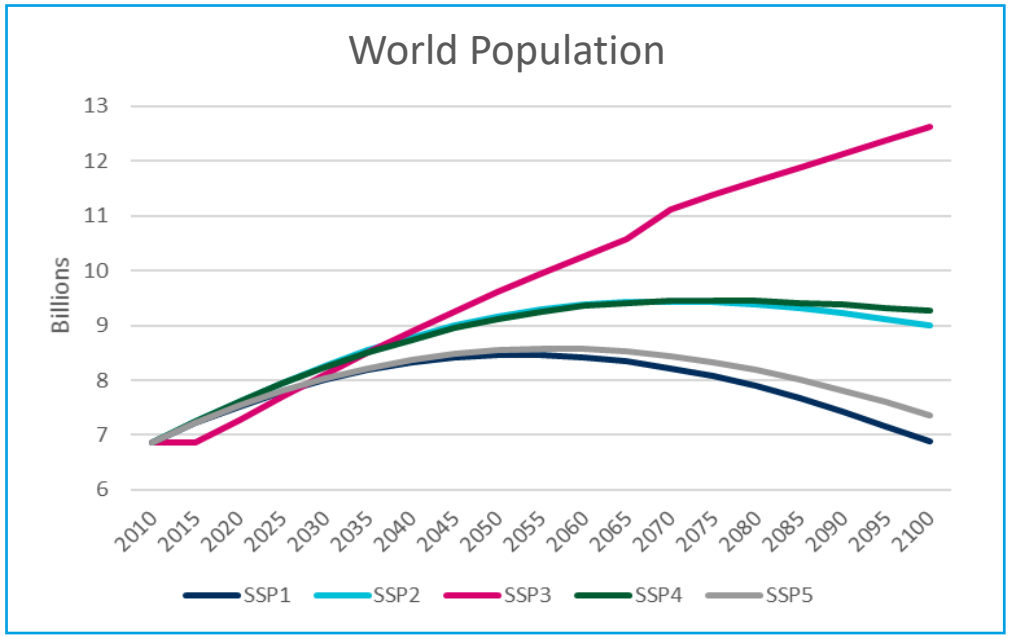
Underlying macroeconomic inputs are sourced from the Shared Socio-economic Pathways (SSP2*) and National Institute Global Econometric Model (NIGEM**)





- 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 2021, with peak around 2070
- GDP (PPP): **Projected to grow to USD 807 trillion (2005 USD) in 2100** for IPR FPS 2021
- NIGEM provides estimations pre-2023 and takes into account COVID-19 implications

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

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Land use and emissions profiles

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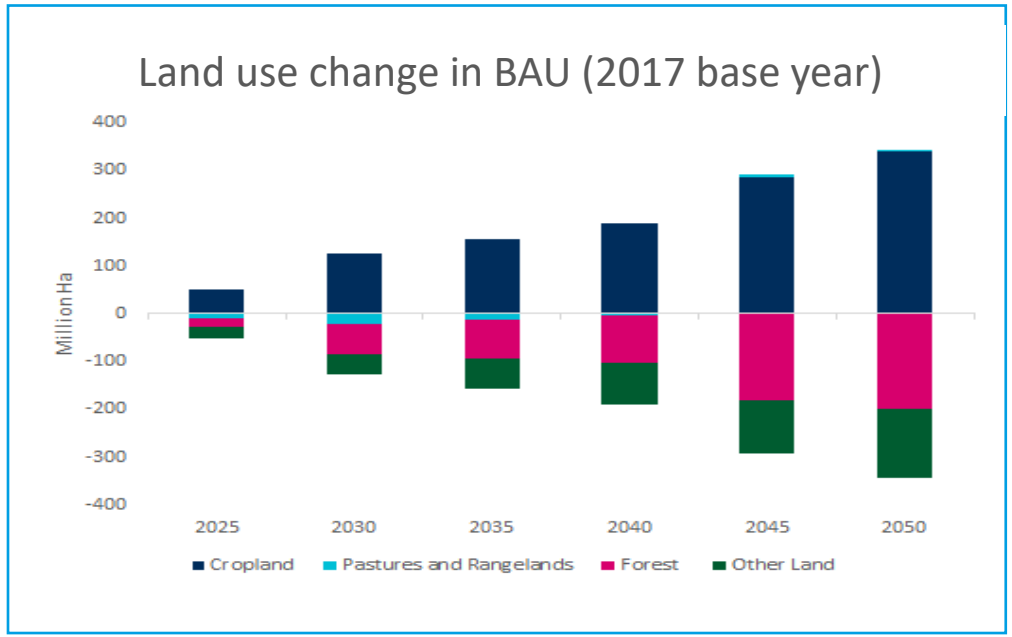
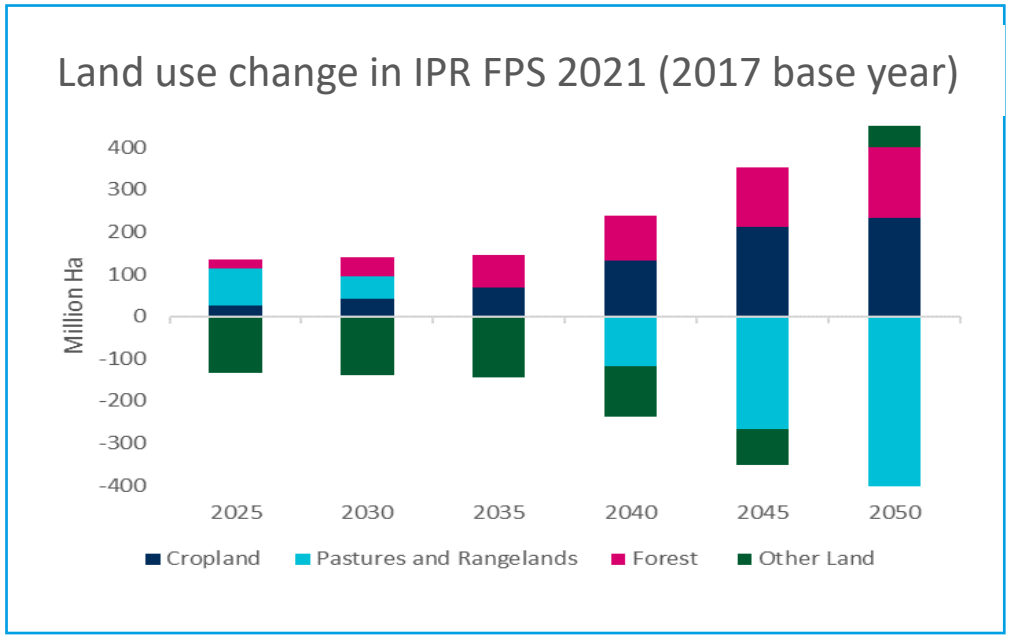
IPR FPS 2021 estimates a decrease in pastures and rangelands, and an increase in forestland which is mainly driven by shifts in food production and incentives for carbon farming





- **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 driven by increases in food demand (from population and income growth) and in bioenergy production
- Large decline in pastures and rangelands land due to shift in food production

Note: Other land is non-productive or marginal land

Source: Vivid Economics with components from FAO

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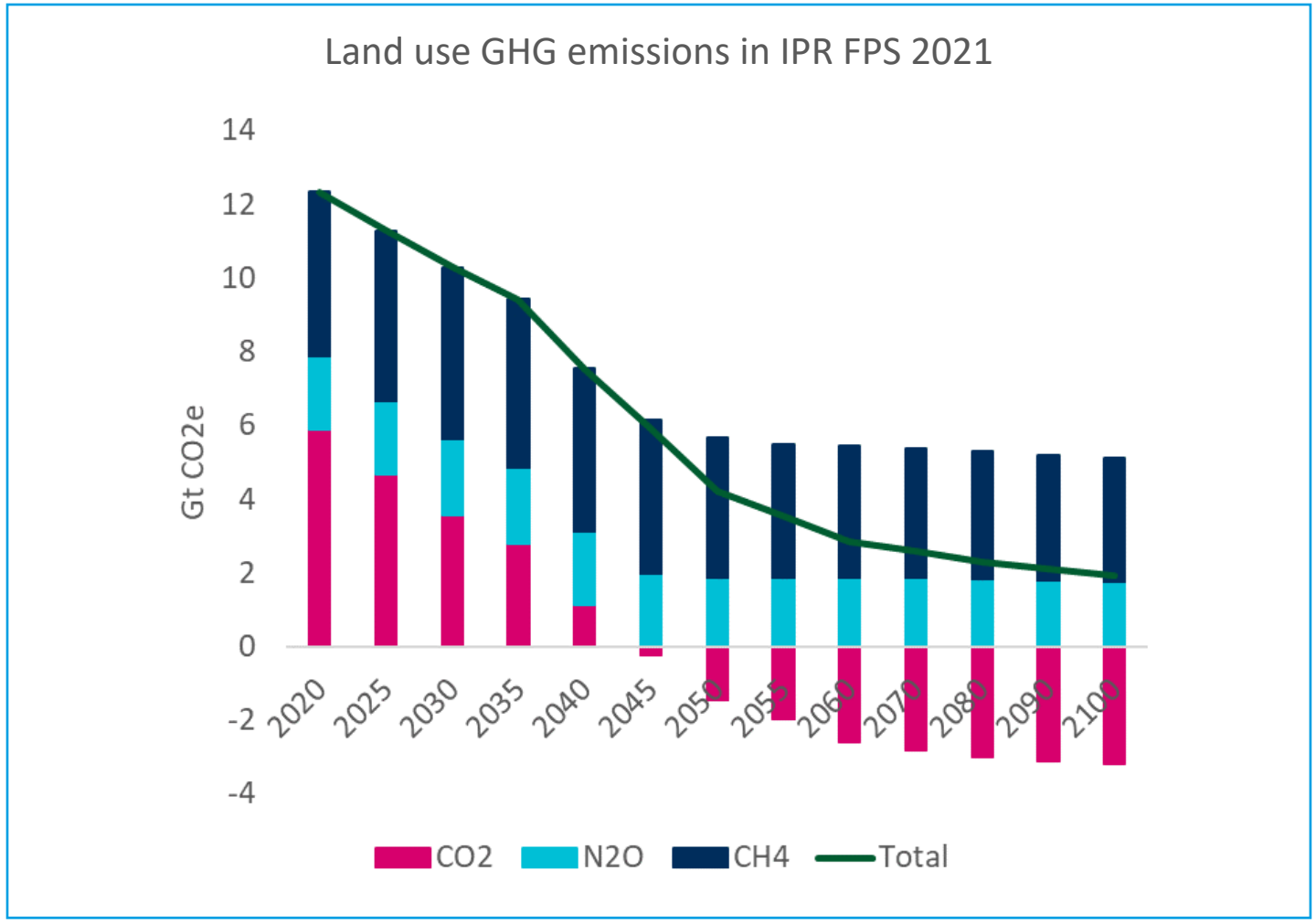
Under IPR FPS 2021, emissions in the land use sector fall to 4.2Gt CO_2e in 2050 and 1.9 Gt in 2100



The land use sector is a net sink for CO_2 around 2045

Emissions linked to deforestation drop due to the introduction of a carbon price in the land use sector, which incentivises afforestation and reforestation. Net deforestation is expected to stop in 2030

N_2O emissions remain relatively constant despite an increase in cropland because of increased productivity that is not driven by fertilizer use

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

Source: Vivid Economics with components from Global Carbon Budget

Agriculture value drivers

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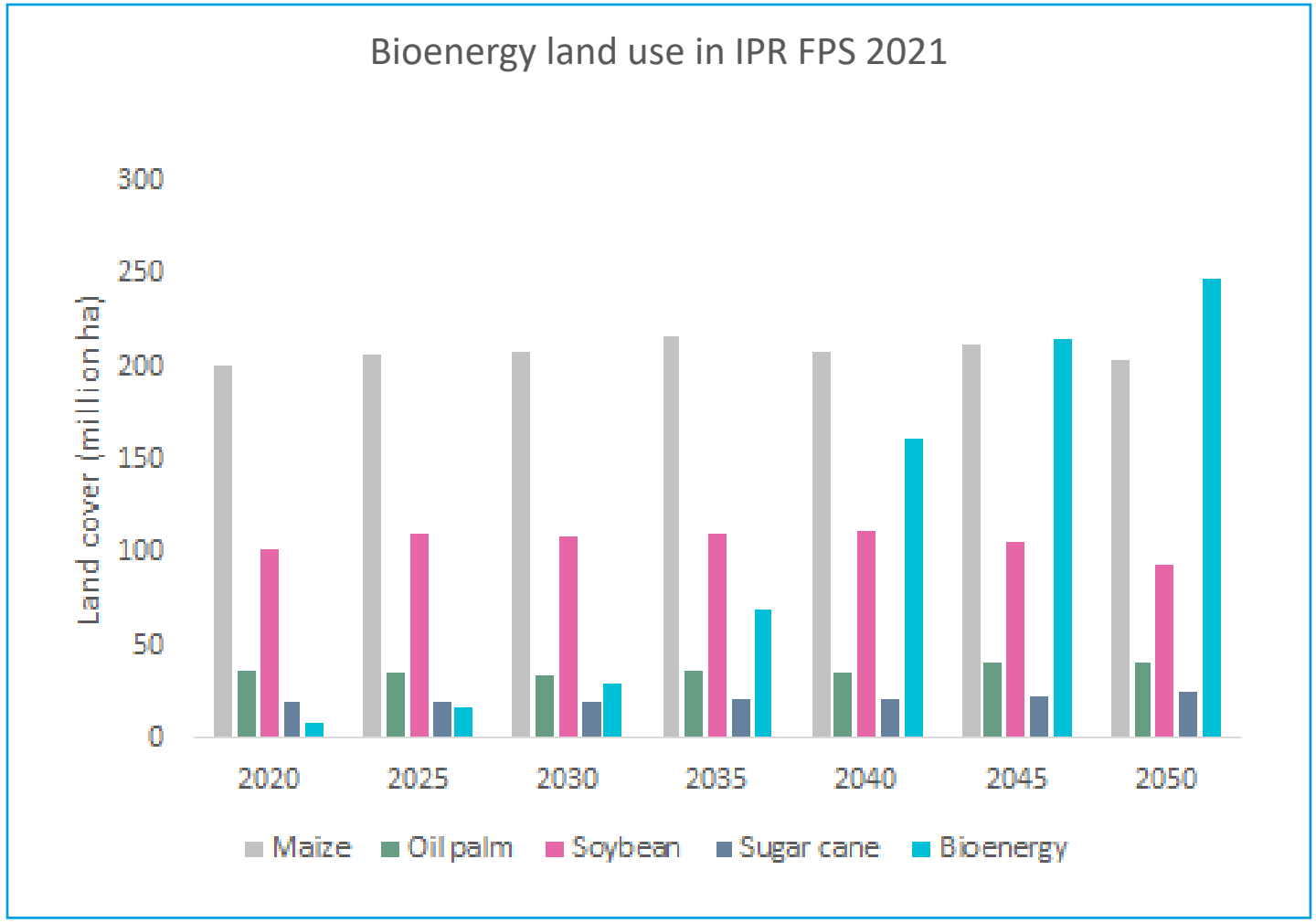
Bioenergy will use 240 million ha in 2050, which is more land than maize currently uses

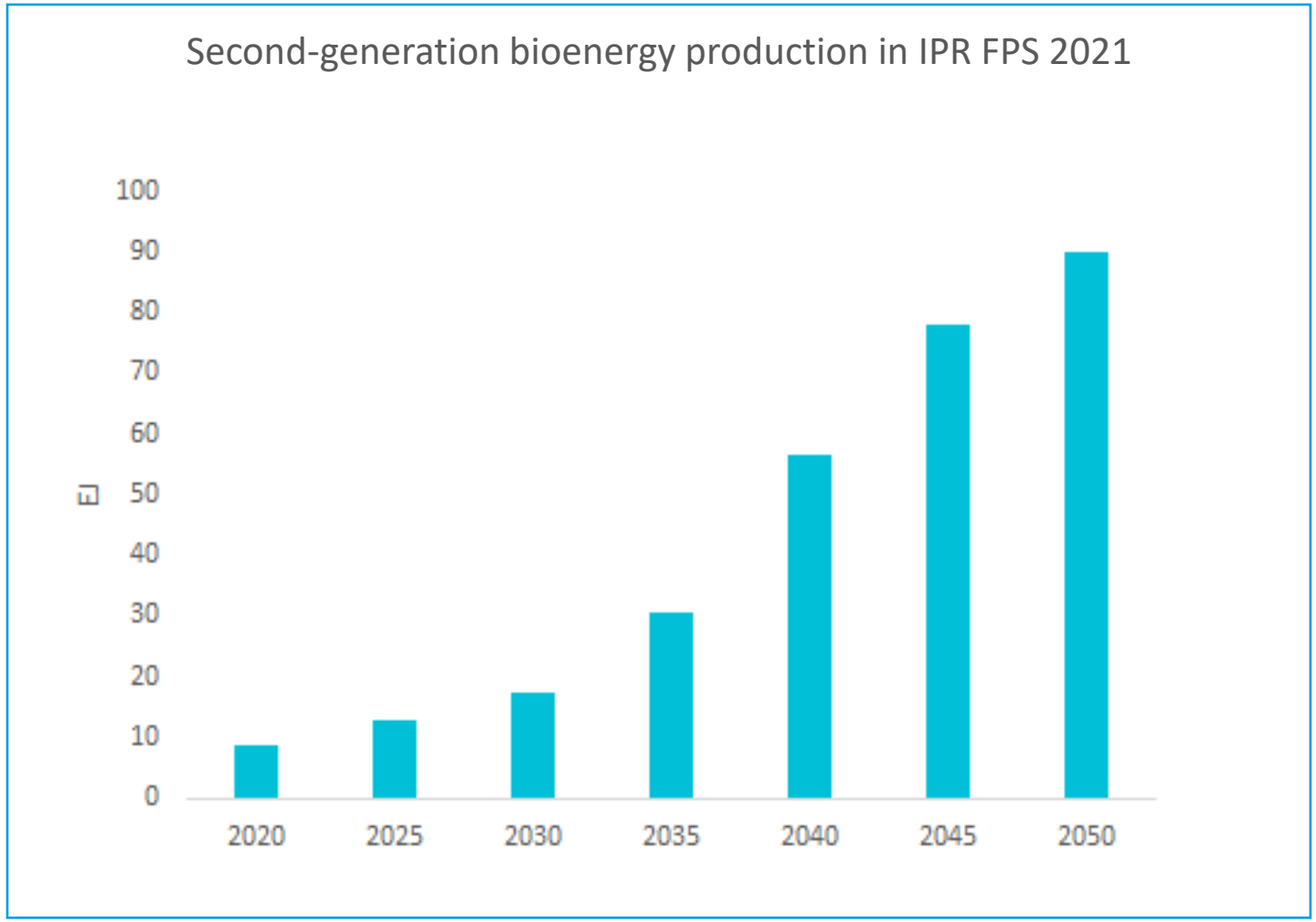


- Second-generation bioenergy crops* will be the **sole source of biomass for bioenergy**
- Production of bioenergy crops grows as farmers find it profitable to shift towards bioenergy production
  - ◊ Growing demand for bioenergy drives up the price of bioenergy
  - ◊ Carbon pricing increases the cost of animal protein production
- **Bioenergy will 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

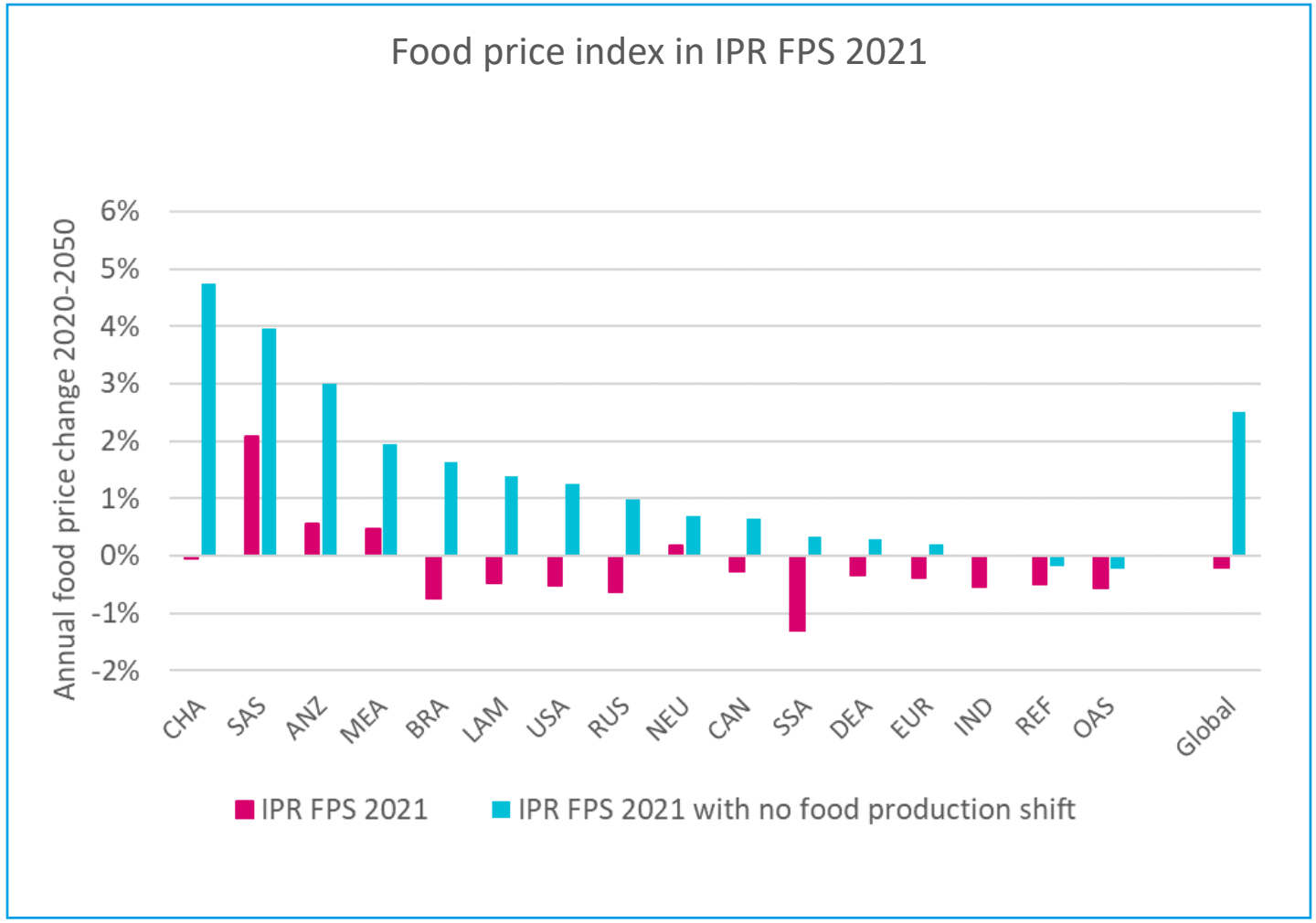
Bioenergy will provide roughly 90 EJ of primary energy, despite being constrained by competition from NBS, concerns about sustainability, and limits to supportive regulation



- **IPR FPS 2021 foresees bioenergy demand of c.90 EJ**, roughly 40m barrels of oil equivalent per day, similar to the IEA's Net Zero scenario
- Bioenergy production is expected to 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 do exist, their extent and scale is expected to be more limited in comparison to alternatives

Source: Vivid Economics

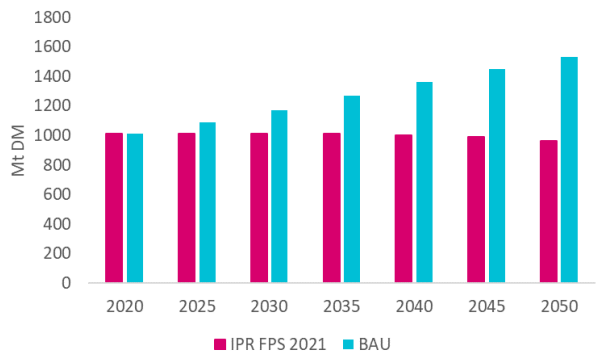
Changes in food production reduce food price pressure and open up resource availability for increased biomass production

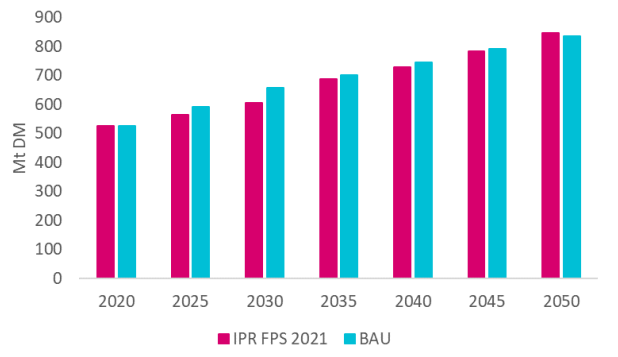


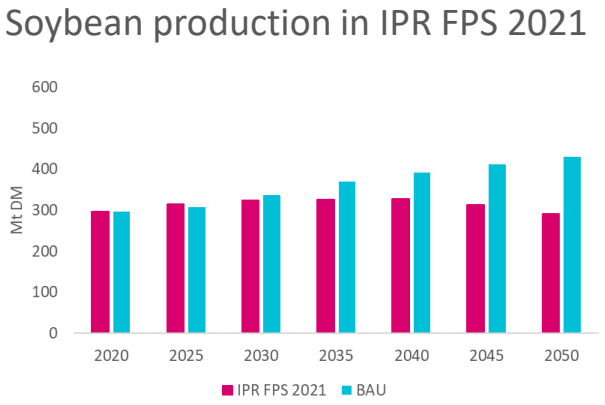
- Competition for land between food and biomass production for energy will decrease, once the food system shifts away from ruminant meat, requiring less land
- Shifts in food production will reduce food price inflation - incorporating a shift in food production reduces food price inflation to -0.2% pa, compared to 2.5% pa in the case of no shift in food production
- Australia and New Zealand (ANZ), China (CHA) and South Asia (SAS) show the highest food price increases driven by bioenergy production

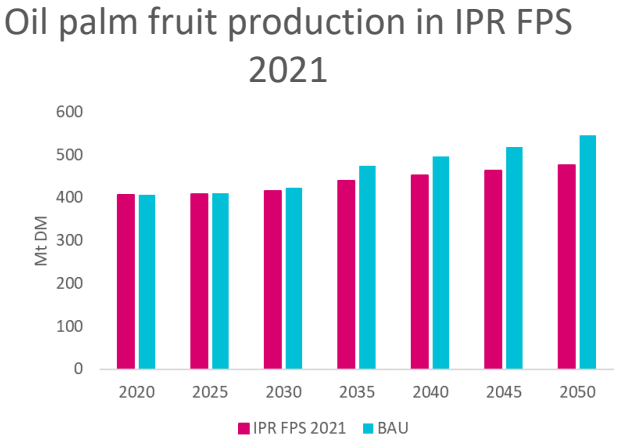
Source: Vivid Economics

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





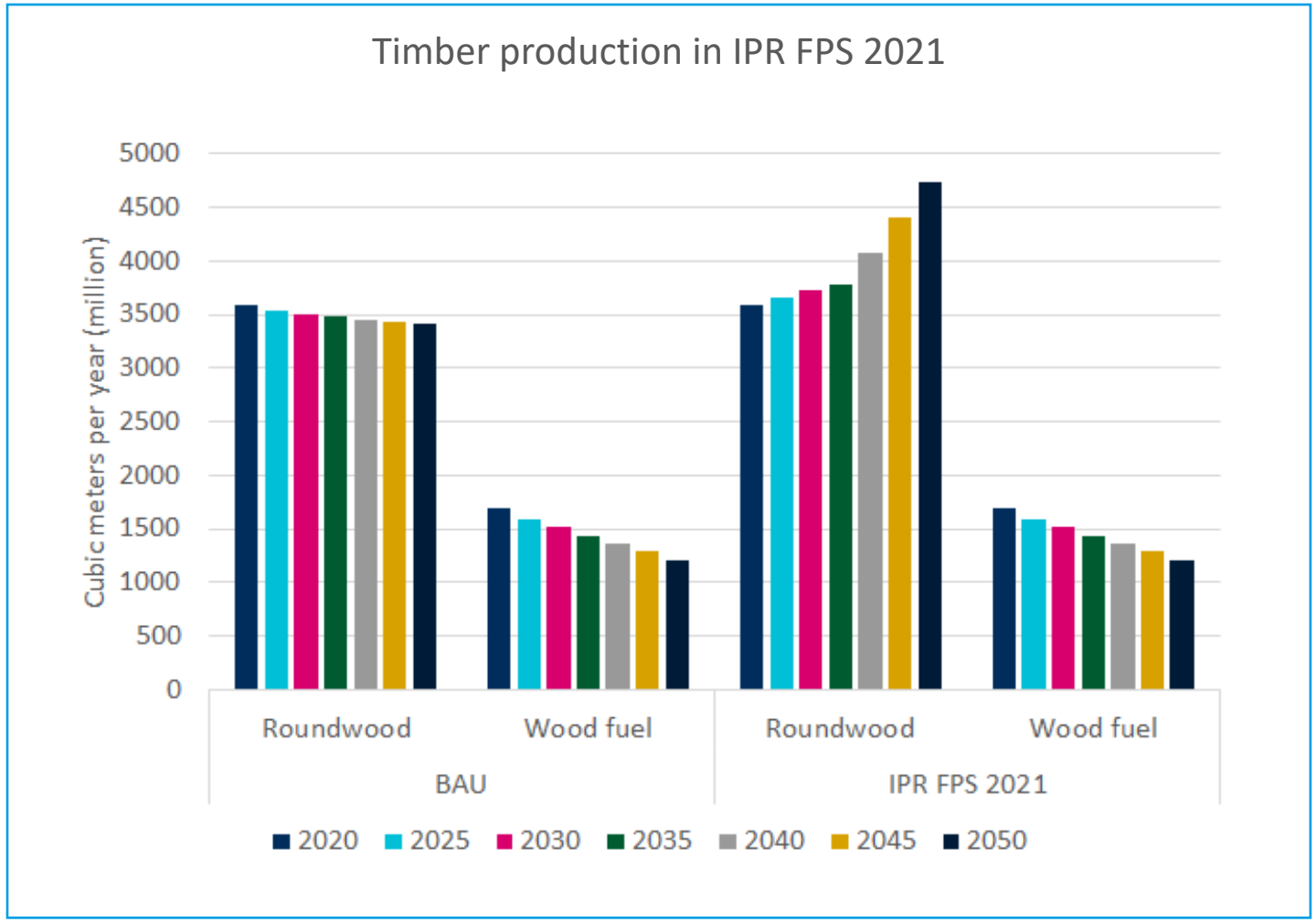




- Maize, used mainly as feed, falls in production due to reduced meat demand
- Sugar cane production rises as consumers shift away from animal protein and toward alternatives
- Oil palm production continues to rise with population growth, but substitution for other oil crops will moderate its growth
- Soybean, used for feed and first-generation bioenergy, falls in line with livestock demand and with first-generation bioenergy phase out by 2050, tempered by food substitution

Source: Vivid Economics with components from FAO

IPR FPS 2021 envisions an increase in roundwood production and a decrease in wood fuel production



- **Construction is expected to use 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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IPR FPS 2021 includes detailed analysis of 10 types of Nature based Solutions

Which NBS are covered in IPR FPS 2021?						
	Forestry	Peatland	Mangroves	Seagrass	Agroforestry	Soil
New deployments	Managed afforestation (NPI and non-NPI); new timber plantations	Peatland restoration	Mangrove restoration	Seagrass restoration		
Avoided impacts	Avoided deforestation of primary and secondary forests	Avoided peatland degradation	Avoided mangrove degradation	Avoided seagrass degradation		Avoided grassland conversion
Improved practices	Switch to sustainable management of timber plantations				Trees in cropland; silvopasture	Cover crops; Legumes and optimal grazing in pasture lands

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].

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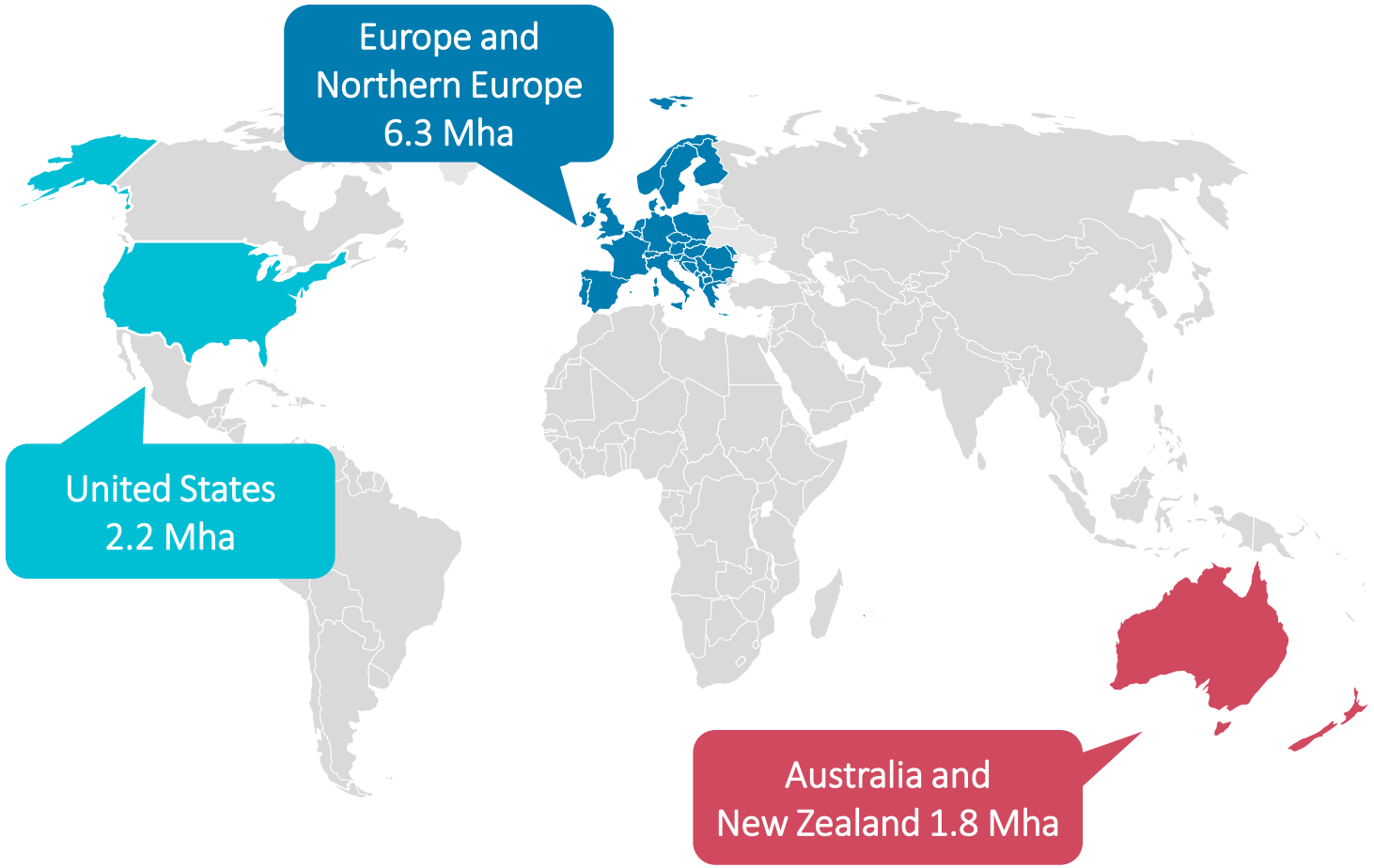
Source: [1] European Commission (no date)

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:

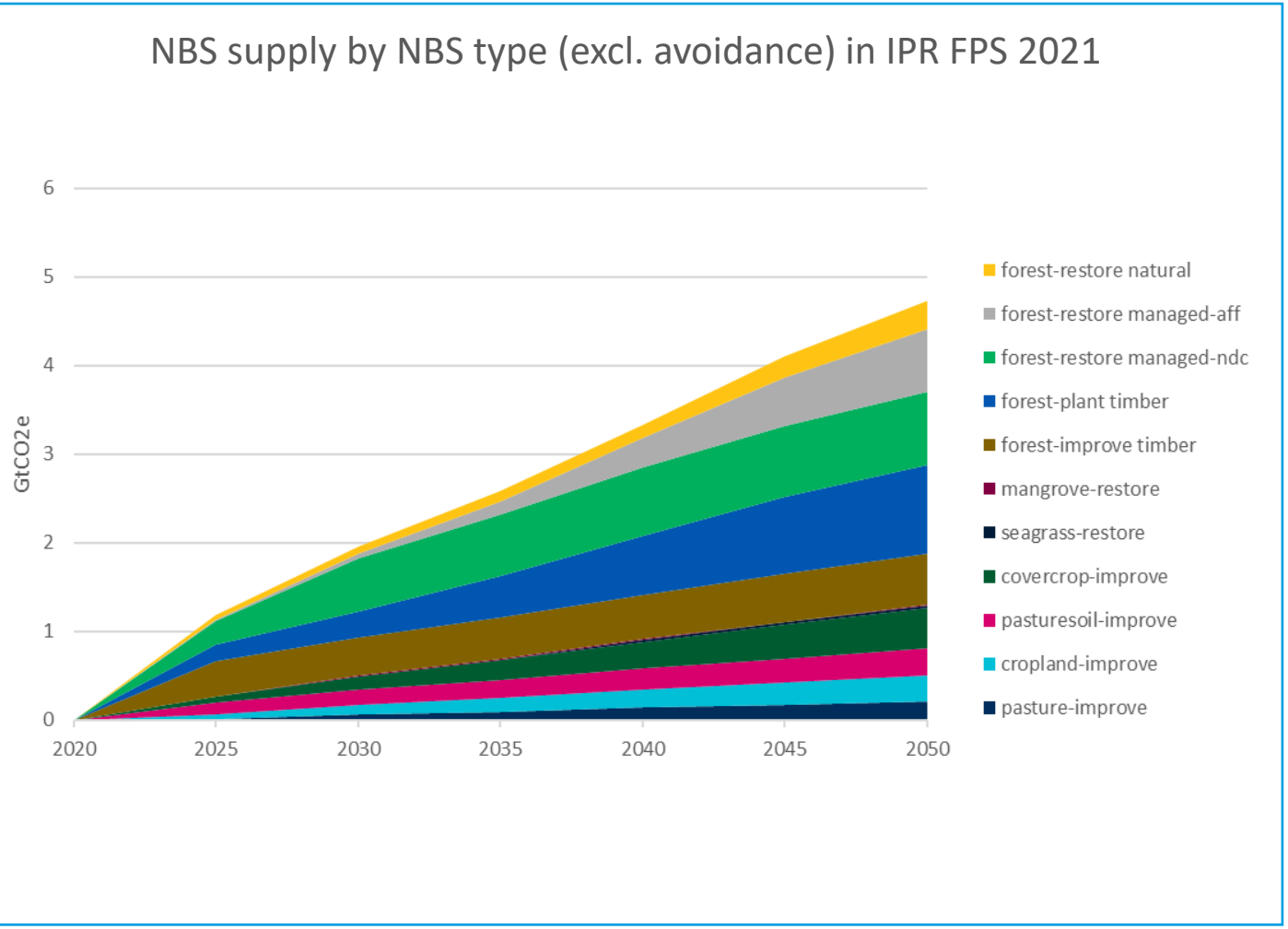
- These countries/regions are not located in tropical areas, so carbon sequestration potentials are lower, thus reducing the sequestration benefits of afforestation
- Their production systems are already efficient, so any additional increase in productivity will be expensive and the investment will be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

Carbon prices

- Under IPR FPS 2021, a **carbon price of around USD 150** could incentivize re/afforestation of 12 Mha in tier 1 countries

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

Forest based solutions have the most potential

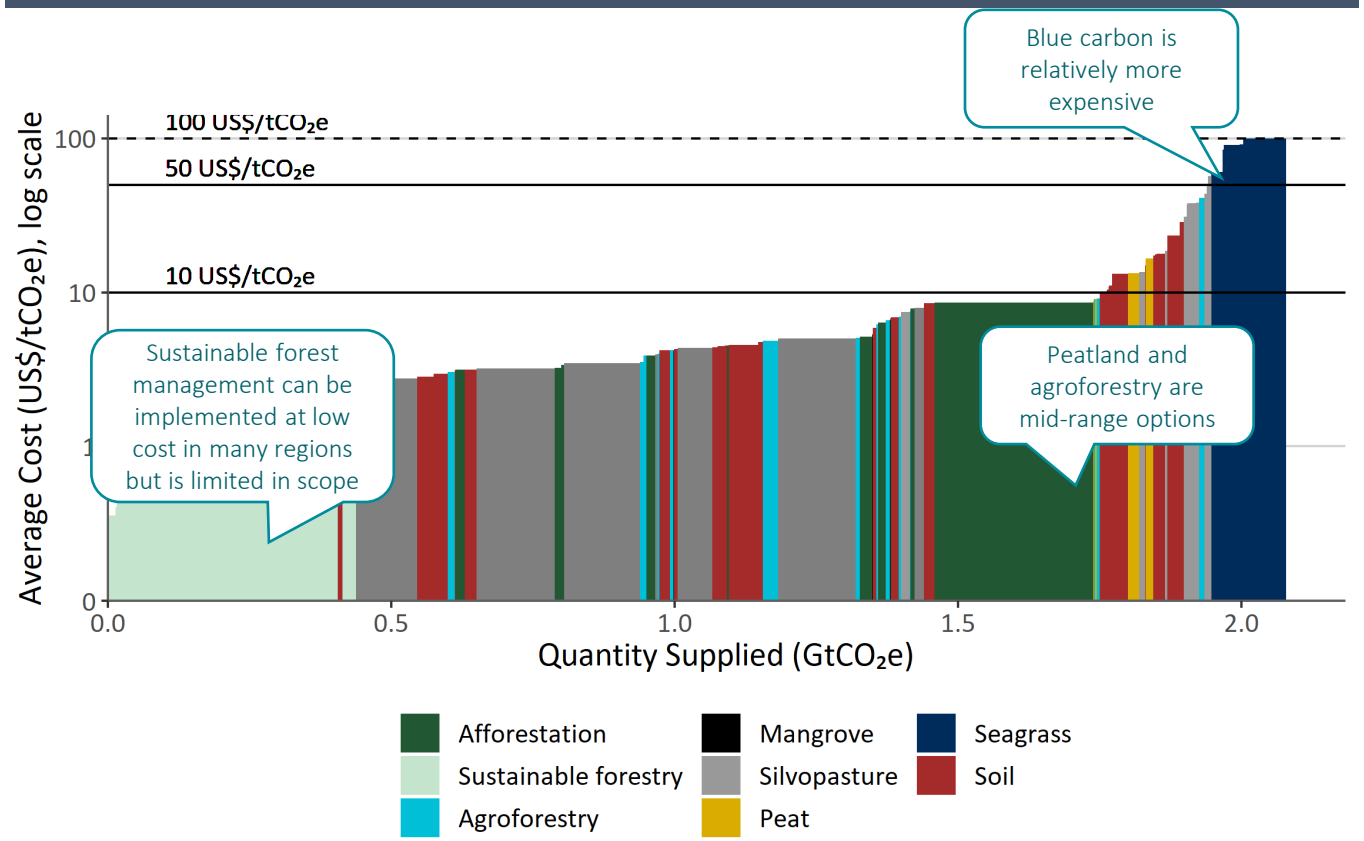


- Forest–based solutions are the most prominent opportunities, accounting for almost three quarters of NBS supply in 2050
- Agriculture makes up 26% of NBS supply in 2050, predominantly through improvements in cover crop
- Mangrove and seagrass constitute less than 1% of NBS supply in 2050

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 FPS 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 likely to be 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 potential for investments in NBS

	Scenario description	Net change in forest cover (2020–50)	Investible universe
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 FPS 2021	• High carbon prices (USD 150/tCO_2e in 2050 in tier 1 countries) • Greater ramp-up of NBS in 2030–40s, accompanied by an end to deforestation and changes in food production • Improvements in agricultural productivity, following returns on technological investments similar to past • Consistent with temperatures stabilizing at c.2°C	+168Mha Deforestation stops by c.2030	USD 898 billion by 2050

Note: The cumulative cost of assets (or investible universe) 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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