Net-zero scenario analysis for finance sector transition planning

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Foreword by HSBC

WWF and HSBC have a rich history of partnering to tackle climate issues, most recently launching the Climate Solutions Partnership in collaboration with World Resources Institute. The partnership brings together our combined knowledge, insight and global networks to help climate solutions break through systemic barriers to become commercial reality and have impact at scale. A key pillar of the partnership is to share learnings and build on collective knowledge, to support new and existing solutions to mobilise the transition to net-zero.

As we enter 2022, partnering with others will continue to play a critical role in driving progress. COP26 made it clear, the planet urgently needs ambitious and lasting action to protect communities, the natural environment and business from the damaging effects of climate change. Whilst government action is imperative to stay within 1.5 degrees of warming, transformation cannot be achieved without finance partnering with multiple stakeholders to build a net zero global economy.

In October 2020 HSBC launched its climate strategy, believing the most significant impact it could have was to partner with customers and support them on their journey to net zero, helping companies to access sustainable finance and expertise, so that they can cut their carbon emissions to net zero. Alongside this, HSBC also aims to achieve net zero in its own operations and supply chain by 2030, or sooner. Expanding the sustainable finance market is not a simple task and it isn't something that can be achieved by any one organisation alone.

Therefore, collaboration is key to accelerating the transition to net zero. Initiatives such as the Glasgow Financial Alliance for Net Zero (GFANZ), The Sustainable Markets Initiative (SMI), the UN's Net-Zero Banking Alliance (NZBA), the Partnership for Carbon Accounting Financials (PCAF) and many others are helping to drive this transition. With the right science-based and internationally recognised guidance, scenario planning and data, there is increasing understanding of how the finance sector can practically align to a 1.5C pathway, and how it can support its clients in their own transition journeys. Together, this is helping to build dynamic, healthier societies that are powered by sustainable, long-term growth.

The world requires a collective effort to drive action, improve data and share learning. It was this shared belief that brought WWF and Guidehouse together with the support of HSBC to create this report and help deliver insight into the sectors that require the greatest support in their journey to net zero. There are many routes to net zero but helping financial organisations to have sight of some of the identified opportunities and challenges is a key step in building a net zero global economy.

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Executive summary

Scenario analysis is both an instrument for stress testing a financial portfolio on climate-related risk, as well as a key part of portfolio alignment with net-zero goals that feeds into the important tasks of setting targets and developing a strategy. Over the past six months, WWF, HSBC and Guidehouse have explored the latter purpose, and through this short report we are sharing our insights to contribute to the growing interest from financial institutions committed to net-zero.

The Intergovernmental Panel on Climate Change (IPCC) was clear, the world is warming due to anthropogenic greenhouse gas (GHG) emissions and to avoid the worst impacts of climate change we need to rapidly decarbonise the global economy towards net-zero around mid-century. Under the Glasgow Financial Alliance for Net Zero (GFANZ), financial institutions commit to net-zero by aligning their portfolio with a no/low overshoot 1.5°C scenario. In the IPCC Sixth Assessment Report (AR6) Working Group I report, scientists estimate that to limit global warming to 1.5°C with 50% probability, leaves only 500 $GtCO_2$ (billion tonnes of carbon dioxide) from 2020 onwards under the condition that non-CO_2 emissions follow deep reductions as well.

The scenario modelling landscape is fast moving and there are over 60 scientific no/low overshoot 1.5°C scenarios at the moment. Financial institutions can select multiple scenarios for their target setting and strategy development, based on, for example, their values, geographical and sectoral exposure. Using specific criteria, grouped into three screening rounds, Guidehouse selected the following four no/low overshoot 1.5°C scenarios to provide HSBC with critical insight to support its net-zero strategy:

Institution	Model	Scenario
International Energy Agency (IEA) Scenario	World Energy Model (WEM) and the Energy Technology Perspective (ETP), coupled with the Greenhouse Gas - Air Pollution Interactions and Synergies (GAINS) and IIASA's Global Biosphere Management Model (GLOBIOM)	Net Zero by 2050 (NZE)
National Institute for Environmental Studies (NIES), Japan	Asia-Pacific Integrated Model/Computable General Equilibrium Model (AIM/CGE)	2.0-SSP1-19
National Institute for Environmental Studies (NIES), Japan	Asia-Pacific Integrated Model/Computable General Equilibrium Model (AIM/CGE)	2.0-SSP2-19
EC-Joint Research Center (JRC)	POLES	Global Energy and Climate Outlook (GECO)

The four selected scenarios (shown in the table above) were assessed to provide deeper understanding of the transition of seven sectors: primary energy, power, automotive, cement, iron and steel, shipping, and agriculture, forestry and other land use (AFOLU). Other scenarios published by the Network for Greening the Financial System (NGFS) were also assessed to expand the analysis of the AFOLU sector.

Scenarios differ in socioeconomic, policy and technology assumptions. Key indicators that show these differences are the projected population growth, GDP growth and the increase of the carbon price as a proxy for future climate policies. The four assessed scenarios show a population growth of 12% to 25% and a GDP growth of 120% to 147% between 2020 and 2050. Carbon prices range from 250 USD to 2350 USD per tonne of CO_2 in 2050, however it's hard to compare this huge difference as the scope and coverage for carbon pricing used in these four climate models varies.

Knowing these underlying assumptions, the scenario analysis focused on understanding the transition of each sector, expressed in reductions in absolute emissions and emissions intensities. The physical emissions intensity metric is often used for setting targets at a sectoral level, for instance by applying the Sectoral Decarbonization Approach (SDA) developed by the Science Based Targets initiative with the support of Guidehouse. The table below summarises the emissions reductions level and key insights for each sector. The global reduction percentages for the period 2020 to 2030 are shown from our scenario analysis, signifying the importance of immediate, rapid and large scale decarbonisation.

Sector	Scope	Absolute emissions reductions 2020-2030	Emissions intensity reduction 2020-2030	Intensity metric	Key sector-specific insight
Primary energy	Scope 3 Use of sold products	-37 to -53%	-28 to -40%	$MtCO_2eq$/ EJ	Each scenario has a different specific energy mix in 2050
Power	Scope 1	-50 to -64%	-63 to -69%	gCO_2/ kWh	Selected scenarios show a fast increase in renewable energy, which presents huge lending and investment opportunities.
AFOLU	Scope 1	-58 to -72%	N/A	N/A	The AFOLU sector represents about 23% of global GHG emissions. The sector is under significant pressure to feed the growing global population, serve as feedstock for bioenergy production and to provide nature-based solutions for emissions removals. Required land for negative emissions through afforestation and reforestation is between 250-470 million hectares.
Cement*	Scope 1+2	-20%	-24%	tCO_2/ tonne of cement	The analysis shows the need to venture into cement blended with other raw materials and Carbon Capture, Utilization and Storage (CCUS) and hydrogen abatement measures in a sector that stays equal in size.
Iron and steel*	Scope 1+2	-28%	-34%	tCO_2/ tonne of steel	The iron and steel industry remains dependent on significant amounts of coal while transitioning to hydrogen combined with CCUS measures.
Shipping*	Scope 1	-12%	-38%	$kgCO_2$/ tonne_ km	Although the shipping industry is predicted to switch to low-carbon fuels such as biofuels, hydrogen, and ammonia, the sector will continue to emit in 2050.
Auto-motive*	Scope 3 Use of sold products	-41%	-46%	gCO_2/ passen-ger-km	The analysis shows that emissions of the sold products of this sector are reduced drastically by electrification, but a residual amount remain unabated by 2050 due to dependency on fossil fuels for some types of vehicles. Battery and grid infrastructure provide huge lending and investment opportunities.

** In the end, only the NZE IEA scenario had available data at the sector level.*

Based on our scenario analysis, we gained the following takeaways:

1. Immediate, rapid, large-scale and sustained actions are required
2. Short-term targets are essential to drive these actions, alongside long-term targets
3. Insights from multiple scenarios can guide these actions
4. Actions should be sector-specific and collaboration with other stakeholders is key
5. Engaging with customers to understand their strategies and support their transitions is essential to finance the right solutions and enable change in the real economy.

1 Introduction

1. Introduction

In November 2021 the UNFCCC COP26 delivered the Glasgow Climate Pact, alongside a plethora of other government and business commitments. The Pact received mixed reactions and does not guarantee a 1.5°C world, but it has kept the prospect of achieving it in reach, by calling on governments to come back later this year at COP27 in Egypt with 'Paris-aligned' near-term targets. It is clear the policy direction remains towards a net-zero future and will likely only strengthen in that respect.

Global financial institutions played a key role at the COP, highlighting the need to go much further in scaling up investments in climate action and to align financing activities with 1.5°C and net-zero targets. The Glasgow Financial Alliance for Net Zero (GFANZ) was front and centre, and on 'finance day' Mark Carney, the UN Special Envoy on Climate Action and Finance and the co-chair for GFANZ, revealed that the capital committed to net-zero was over $130 trillion - up from $5 trillion when the UK and Italy assumed the COP26 Presidency. The Central Banks and Network for Greening the Financial System (NGFS) also reaffirmed their position in participating to meet the objectives of the Paris Agreement by releasing its Glasgow Declaration[1]. Amongst other commitments, this declaration includes a pledge to enhance and enrich its climate scenarios and to increase the work to bridge the data gaps that are currently faced by financial institutions to manage climate associated risks.

It is clear that the urgency and momentum around COP26 has accelerated the finance sector transition towards net-zero. Various activities, including target setting and strategy development based on scenario analysis, have started under GFANZ and other cross-sector initiatives. In 2021, HSBC continued to work through the complexity of aligning finance to climate goals. A critical element of this process was scenario analysis, which was undertaken in collaboration with WWF and Guidehouse.

The aim of this report is to share the key learnings from this scenario analysis for specific sectors and to address a critical component of transition planning by providing insights into the process of selecting and analysing net-zero scenarios.

In this report we analyse 1.5°C-aligned decarbonisation pathways for key sectors such as primary energy, power, cement, iron and steel, shipping, automotive and agriculture, forestry, and other land use (AFOLU). Building on the Practitioner Guide for Banks that HSBC co-authored with 11 other leading banks as part of the Sustainable Markets Initiative - Financial Services Taskforce (FSTF banks), this report deepens the understanding on the selection and use of multiple no/low overshoot 1.5°C scenarios. It also shows the technical steps towards net-zero and the key role of climate scenario analysis for setting science-based targets and climate strategy development.

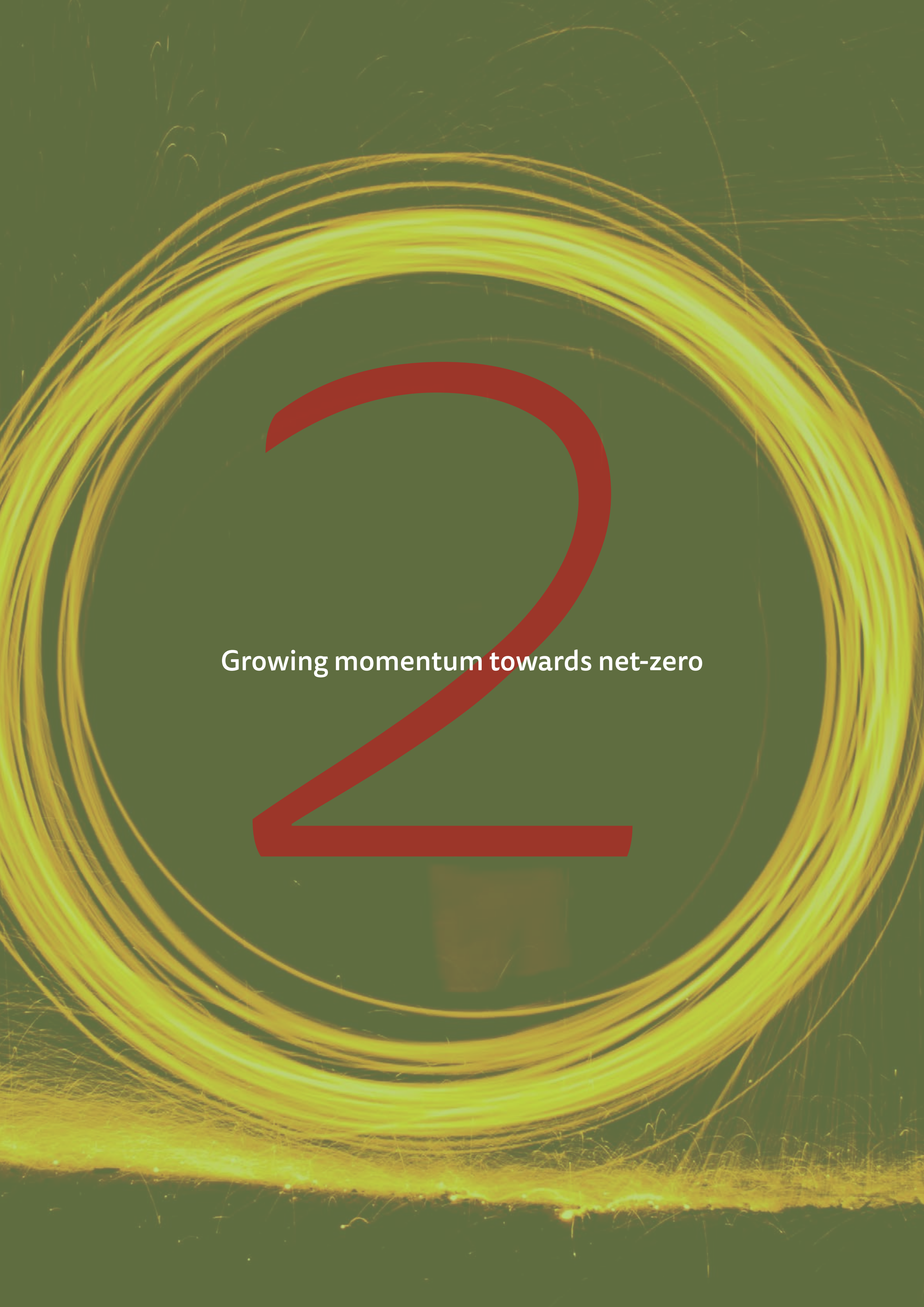
We expect this report will be useful for a wide range of practitioners in financial institutions to inform and develop a transition plan, as recommended by GFANZ and the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD).

1 *Network for Greening the Financial System (NGFS) (2021): NGFS Glasgow Declaration*

The first chapter outlines the relevant topics, context, and the critical need for business to align to net-zero. The subsequent two chapters elaborate on what emission scenarios are, why they are critical for transition planning, and the potential differences among the scenarios. The subsequent chapters are sectoral pathway analyses that derive various conclusions on the differences amongst the scenarios and their implications. Finally, the report ends by providing a list of recommendations to aid financial institutions in developing their transition plans.

This report was developed by Guidehouse together with WWF and HSBC, as part of the Climate Solutions Partnership[2], a collaboration between HSBC, World Resources Institute and WWF.

2 *HSBC (2021): Climate Solutions Partnership*



2

Growing momentum towards net-zero

2. Growing momentum towards net-zero

The Working Group I contribution to the IPCC Sixth Assessment Report (AR6)[3] was clear. There are observed changes in the Earth's climate in every region and across the whole climate system. Many of the changes observed in the climate are unprecedented in thousands, if not hundreds of thousands of years. Some of these are already causing negative climate impacts and some changes already set in motion—such as continued sea level rise and their impacts—are irreversible for centuries to millennia. These changes in our climate are creating systemic risks for human wellbeing, our natural environment, and economic and social activities.

However, immediate, rapid and large-scale reductions in emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) would limit the global temperature rise and associated climate change risks. The GHG emission reductions require a collective effort from all sectors to reach net-zero.

Remaining carbon budget: CO_2 versus non-CO_2

In the recent Working Group I contribution to the IPCC Sixth Assessment Report (WGI AR6), the remaining carbon budget has been updated. Carbon budgets are estimates of the maximum cumulative amount of net anthropogenic CO_2 emissions that would result in a given level of global warming at a given probability. Carbon budgets are expressed in tonnes CO_2, but are provided under the condition that non-CO_2 such as methane (CH_4) and nitrous oxide (N_2O) follow deep reductions as well (see Table 1 and Figure 1).

In the Summary for Policymakers (SPM) of WGI contribution to the AR6[4], the following table shows the remaining carbon budget for different global temperature rise limits and different probability levels. All no/low overshoot 1.5°C scenarios assessed in this report have a probability of 50% and are consistent with a carbon budget of 500 $GtCO_2$ from the beginning of 2020. Knowing that the global CO_2 emissions in 2020 and 2021 are approx. 80 $GtCO_2$ in total, we only have about 420 $GtCO_2$ remaining to have a 50% chance of limiting global warming to 1.5°C.

Table 1. Estimates of remaining carbon budgets

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*[a]					Variations in reductions in non-CO_2 emissions[b]
		17%	33%	50%	67%	83%	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

a This likelihood is based on the uncertainty in transient climate response to cumulative CO_2 emissions (TCRE) and additional Earth system feedbacks and provides the probability that global warming will not exceed the temperature levels provided in the two left columns. Uncertainties related to historical warming (550 $GtCO_2$) and non-CO_2 forcing and response (220 $GtCO_2$) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (20 $GtCO_2$) and the climate response after net zero CO_2 emissions are reached (420 $GtCO_2$) are separate.

b Remaining carbon budget estimates consider the warming from non-CO_2 drivers as implied by the scenarios assessed in SR1.5. The Working Group III Contribution to AR6 will assess mitigation of non-CO_2 emissions.

3 *IPCC (2021): Sixth Assessment Report*

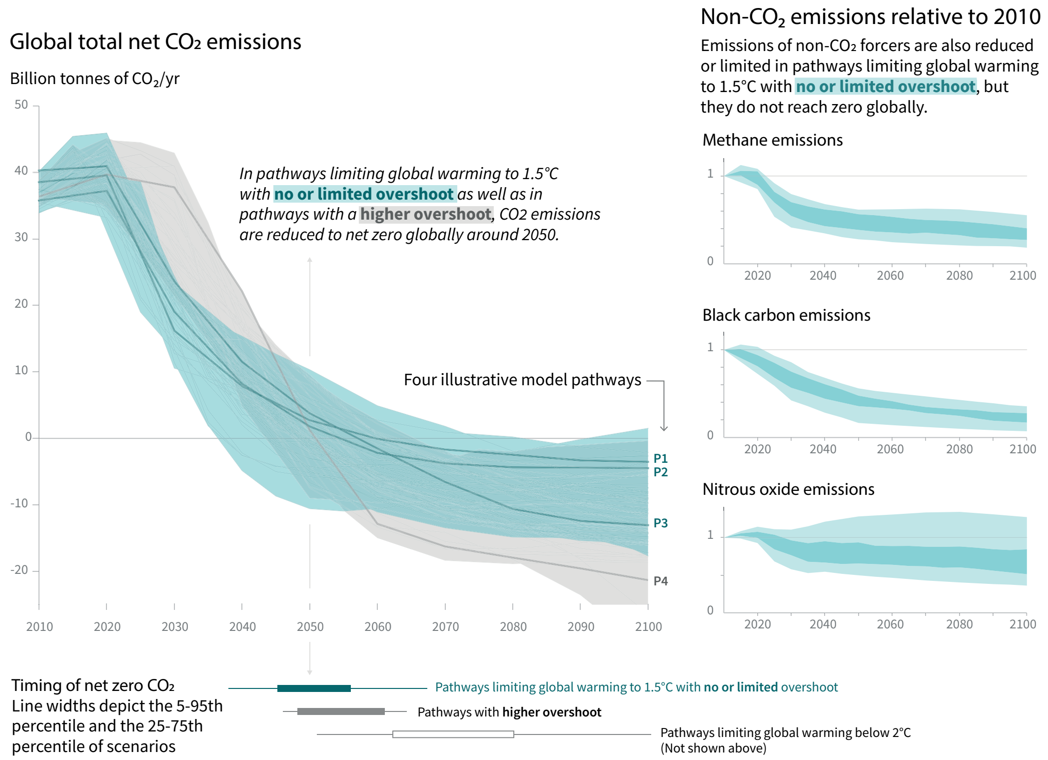
4 *IPCC (2021): Working Group 1 Contribution to Sixth Assessment Report Summary for Policymakers*

What does net-zero mean for financial institutions?

Aligning to a 1.5°C pathway is critical if we are to minimise the risks of climate change. In order to achieve this alignment, global CO_2 emissions need to decline by about 50% relative to 2010 levels by 2030 and continue to reduce towards reaching net-zero by 2050 (Figure 1). Achieving such a pathway requires a targeted, rapid and effective strategy of decarbonising a financial institution's portfolio, and financing the implementation of CO_2 removal solutions to neutralise residual emissions. In addition to a deep reduction of global CO2 emissions, all other non-CO_2 emissions need to be deeply reduced as well.

Figure 1: Global GHG emissions pathway characteristics[5]

General characteristics of the evolution of anthropogenic net emissions of CO_2, and t otal emissions of methane, black carbon, and nitrous oxide in model pathways that limit global warming to 1.5°C with no or limited overshoot. Net emissions are defined as anthropogenic emissions reduced by anthropogenic removals.



IPCC Special Report on Global Warming of 1.5°

A key goal of the Paris Agreement is to steer the global financial flows towards activities that enable low-carbon development. Financial institutions can play a major role in driving the transition towards net-zero by lending and investing capital into activities and technologies that drive deep decarbonisation, and in nature-based solutions that can remove future residual emissions. Financial institutions have the control over allocations of their capital, and ability to speed up the decarbonisation process across all sectors. To achieve low financed emissions, financial institutions will need to actively support their clients in reducing emissions.

However, financial institutions face several challenges in aligning their existing portfolios to a net-zero pathway and to reducing their financed emissions. The portfolios of financial institutions span across an array

5 IPCC (2018): Special Report on Global Warming of 1.5°C Summary for Policymakers

of sectors and geographies and this presents a range of different problems that may each require bespoke solutions. Although the guidance and tools for financial institutions to meet net-zero are growing and several initiatives have been formed in recent years to facilitate the finance sector, there are still significant gaps that need urgently addressing. For example, one of the main challenges for the finance sector is the lack of consistent and credible emission data. So, for financial institutions to develop credible and robust transition plan to align to net-zero, they will need to collaborate with all types of stakeholders (e.g. policy makers, utilities, grid operators) to get access to better data (e.g. energy consumptions data) and to join forces in taking climate action.

The outcomes of COP26 and the run-up to COP27 will see ever-increasing pressure and expectation on the finance sector to align to a 1.5°C pathway. Progress was made at COP26 where GFANZ, under Mark Carney, brought together the Net Zero Asset Owner Alliance, the Net Zero Asset Managers Initiative, the Net Zero Insurance Alliance, and the Net Zero Banking Alliance. Major global financial institutions have announced net-zero commitments. The next step is to align financing with scientific pathways through measuring and setting targets for emissions within portfolios.

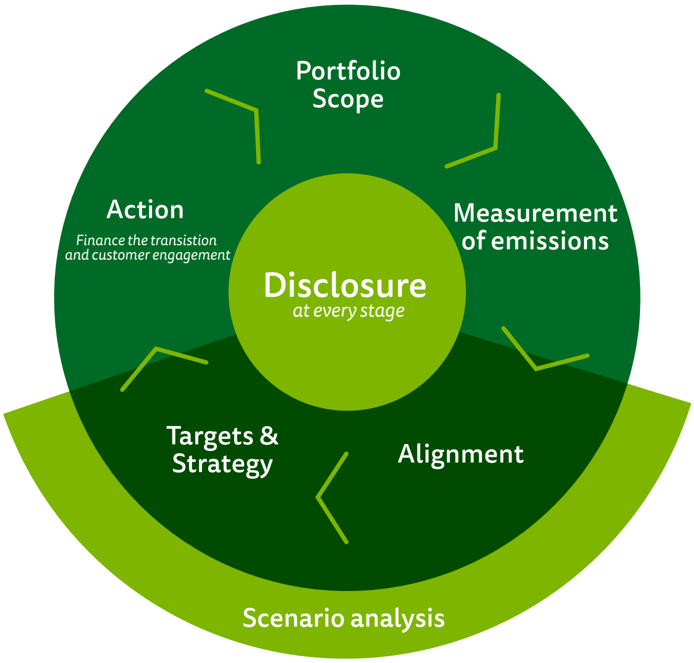
3

Role of scenario analysis and selection

3. Role of scenario analysis and selection

For banks and investors, the process of achieving net-zero consists of seven discrete non-linear steps (see Figure 2)[6].

Figure 2. Position of scenario analysis in journey towards net-zero



Scenario analysis forms a key step in the process towards net-zero that covers both the important tasks of setting targets and developing a strategy. Scenario analysis can be defined as: *A process for identifying and assessing a potential range of outcomes of future decarbonisation pathways under conditions of uncertainty, using forward-looking data.*[7]

Scenario analysis informs the level of decarbonisation for target-setting and the degree of alignment with scientific net-zero trajectories. It can also provide insight into the performance and ambition of companies in a portfolio of a financial institution and thus provide input for the development of a climate transition strategy at the company level. However, it is important to note that scenarios do not provide exact predictions and that they are generally based on a variety of assumptions of events and trends in the future that are impossible to predict accurately. Hence the importance of analysing and selecting a range of common and suitable net-zero scenarios to avoid planning on the basis of just one set of assumptions.

6 *Partnership for Carbon Accounting Financials(PCAF) (2021): Strategic Framework for Paris Alignment and Sustainable Markets Initiative - Financial Service Taskforce (2021): A Practioner's Guide for Banks*

7 *Financial Stability Board Task Force on Climate-related Financial Disclosures (TCFD) (2021): Recommendations of the Task Force on Climate-related Financial Disclosures, Appendix 5: Glossary and Abbreviations*

Net-zero scenarios

Hundreds of climate scenarios have been developed by the global climate science modelling community. A critical question for corporations, including financial institutions, is identifying which scenarios to use to align with net-zero. In all net-zero commitments within the initiatives under GFANZ, financial institutions commit to align their portfolios with a global temperature increase towards 1.5°C with no to low-overshoot.

However, there are still plenty of 1.5°C scenarios available to choose from – meaning there are different ways to deliver on this commitment under GFANZ. In the Science Based Targets initiative's (SBTi) Foundations of Science-based Target Setting paper[8], the initiative has selected 20 low/no-overshoot 1.5°C scenarios out of the full set of 53 Integrated Assessment Modelling Consortium (IAMC) low/no-overshoot 1.5˚C scenarios. For this selection the SBTi applied a distinct set of criteria, such as emissions budget and peak year of emissions.

After the publication of this Foundations paper by SBTi, additional low/no-overshoot 1.5˚C scenarios have been published; for example, by the Network for Greening the Financial System (NGFS), hosted on the International Institute for Applied Systems Analysis' (IIASA) portal[9], the International Energy Agency (IEA) has published their Net Zero by 2050 Roadmap, which is seen by many stakeholders as the current industry benchmark in 1.5˚C scenarios. The scenarios of the IEA have already been used by many initiatives, as they provide detailed physical data on sector level and have been updated annually. More information on these scenarios can be found in the Appendix.

8 *Science Based Targets initiative (2021): Foundations of Science-based Target setting*

9 *NGFS (2021): Scenario portal and data hosted at IASA*

Selection of scenarios

Selecting a scenario requires defining a set of criteria to make an informed decision. Criteria can vary, and depends on the context, ambitions and values of the financial institution. Examples of criteria that financial institutions could consider are:

- **Temperature limit and probability:** considering the end-of century temperature limit of the scenario (e.g. 1.5°C, below 2°C, 2°C or even beyond 2°C following current policies) combined with certain probability levels of staying below the temperature limit (e.g. 50%, 67% or 83%)
- **Science-based:** considering whether the scenario of choice should be scientifically peer-reviewed and developed by Integrated Assessment Models (IAMs)
- **Socio-economic factors:** noting the socio-economic factors that are important for the financial institutions' net-zero journey, for example those that encompass the just transition
- **Geographical coverage**: considering regions and countries that are relevant for the financial institutions' portfolio
- **Sector exposure:** considering the sectors that are relevant to the financial institutions from a greenhouse gas perspective
- **Data types:** being aware of the types of data that financial institutions require for the assessment and whether these are available
- **Other specific conditions:** these could be multiple and could include, for example, that the financial institution prefers a scenario with limited application of technical and nature-based Carbon Dioxide Removal (CDR).

Chapter 4 describes the assumptions of four scenarios and compares them against each other. The scenarios selected for this report are a result of an assessment Guidehouse conducted with HSBC, based on criteria defined by the bank. The criteria were grouped in three screening rounds, as follows:

Scenario selection criteria for first screening:	**Scenario selection criteria for second screening:**	**Scenario selection criteria for third screening:**
• 1.5°C degree scenario • Low/no overshoot in temperature increase • Usage of a global model (IAM) • Peer-reviewed by a reputable source (science-based)	• Regional coverage • Energy breakdown: oil, gas, coal, renewables (incl. bioenergy), nuclear • Time interval of dataset: 5 years or less • Other HSBC priority sectors covered	• Fair transition (Shared Socioeconomic Pathways SSP1 or SSP2) • Different (socioeconomic) assumptions per scenario • Limited Carbon Dioxide Removal (CDR)

The screening exercise resulted in the selection of the four scenarios shown in table 2.

Table 2. Selected scenarios based on a three screening rounds

	Institution	Model	Scenario	Sectors assessed	
1	International Energy Agency (IEA) Scenario	World Energy Model (WEM) and the Energy Technology Perspective (ETP), coupled with the Greenhouse Gas - Air Pollution Interactions and Synergies (GAINS) and IIASA's Global Biosphere Management Model (GLOBIOM)	Net Zero by 2050 (NZE)	Primary energy and power, cement, iron and steel, shipping, automotive, AFOLU	IEA
2	National Institute for Environmental Studies (NIES), Japan	Asia-Pacific Integrated Model/Computable General Equilibrium Model (AIM/CGE)	2.0-SSP1-19	Primary energy, power and AFOLU	SP1
3	National Institute for Environmental Studies (NIES), Japan	Asia-Pacific Integrated Model/Computable General Equilibrium Model (AIM/CGE)	2.0-SSP2-19	Primary energy, power and AFOLU	SP2
4	EC-Joint Research Center (JRC)	POLES	Global Energy and Climate Outlook (GECO)	Primary energy and power	GEC

The following chapter describes these scenarios, and the subsequent chapters (5 to 8) explain the scenario analysis Guidehouse did for HSBC on seven sectors: primary energy, power, AFOLU, cement, iron and steel, shipping, and automotive. To expand the analysis of the AFOLU sector, other scenarios published by the Network for Greening the Financial System (NGFS) were assessed as well.

4 Assumptions in selected scenarios

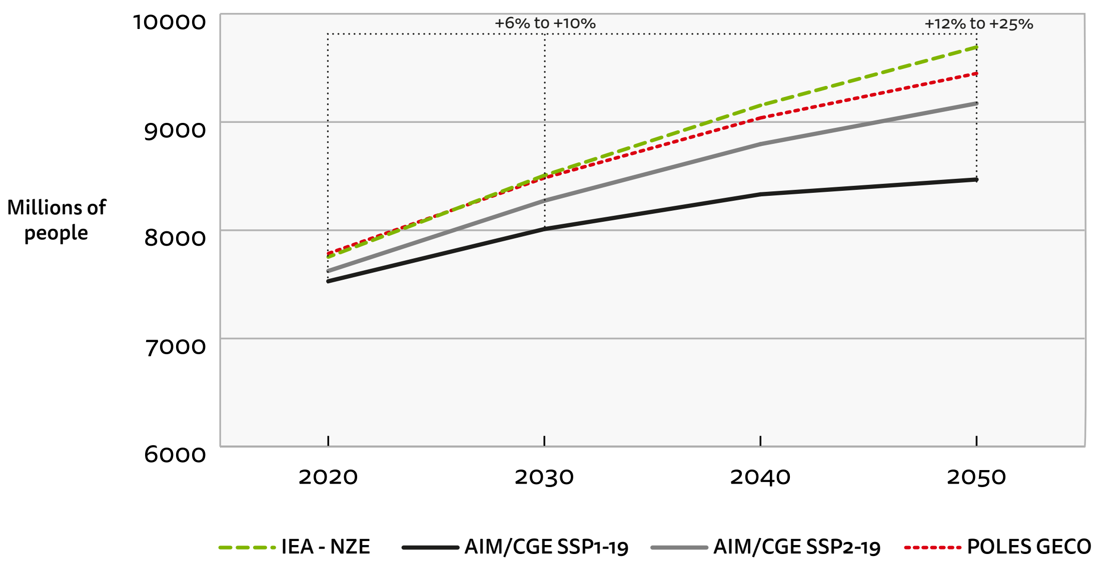
4. Assumptions in selected scenarios

Integrated Assessment Models (IAMs) are computer models used to describe interactions between economic activity, GHG emissions, and climate change. Although IAMs vary in model structure and detail, the core of most IAMs is based on either macroeconomic theory and/or energy systems engineering. Most of the IAMs used to analyse climate policy tend to focus on the energy system, with simpler representations of the climate system, land system, and other emitting systems like air pollution. A growing number of IAMs, however, include detailed representations of some of these non-energy systems[10].

Models are only as good as the assumptions that go into them. Understanding the key assumptions is a prerequisite for obtaining robust and reliable insights from IAMs for use as inputs to target setting and strategy development. Two of the most important assumptions and drivers of emissions are population and GDP growth, as they determine the future demand for energy, goods, and services. In most models, the population and GDP assumptions are based on projections from other leading organizations, such as United Nations (UN) and International Monetary Fund (IMF).

Looking at the four no/low-overshoot 1.5˚C scenarios selected for this report, the difference in population and GDP becomes clear in Figure 3 and 4. In the IEA NZE scenario the population is assumed to grow by 25% between 2020 and 2050, while in AIM/CGE – SSP1-19 scenario this is 12%.

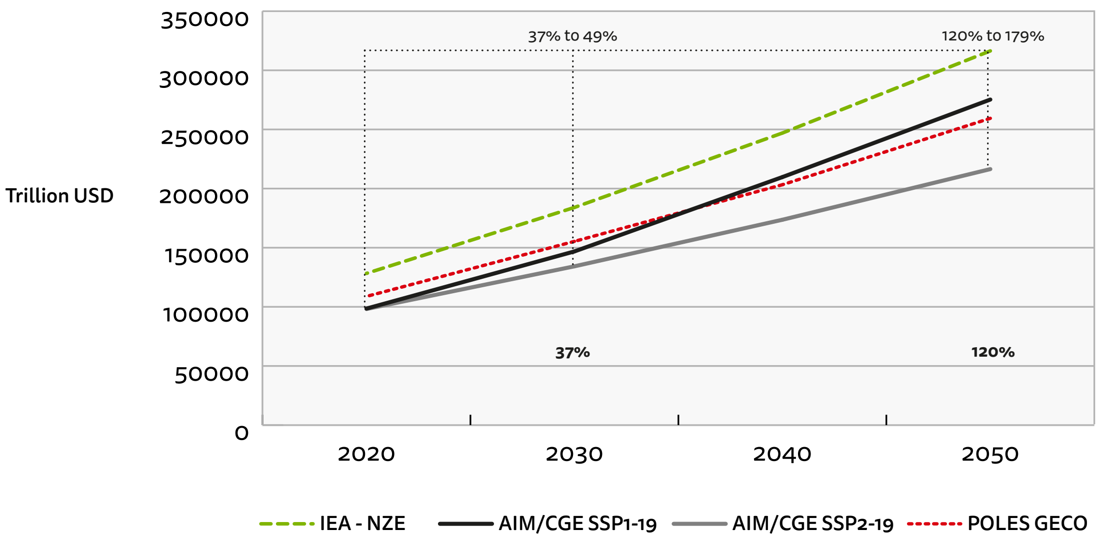
Figure 3. Assumption on population growth for four 1.5˚C scenarios



10 UNEP FI (2021): *Pathway to Paris report*

On GDP growth, the AIM/GCE SSP1-19 scenario assumes the highest growth with a +179% growth between 2020-2050, and the AIM/CGE SSP2-19 scenario predicts a GDP growth of 120% over this period.

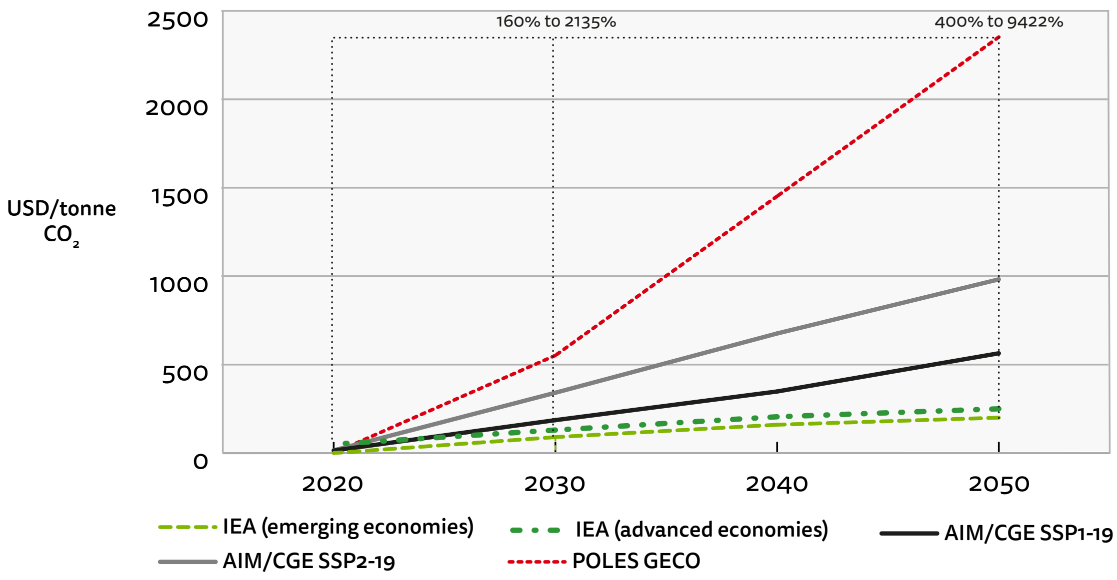
Figure 4. Assumption on GDP growth for four 1.5˚C scenarios



Another important indicator used in these models is the price of carbon. Climate policy in IAMs is often represented via a carbon price. The increase in the carbon price applied in the models to meet certain climate targets (i.e., carbon budget) is also a proxy for the cost efficiency of the mitigation measures applied in these models.

All scenarios show a significant increase in carbon price that ranges between 160% in the IEA-NZE scenario to a 2135% increase in POLES GECO scenario by 2030 (Figure 5). A significant variation in carbon prices is seen across different scenarios. This is because some models use carbon prices in combination with other policy instruments. For instance, the IEA combines carbon prices of electricity and industry with emissions standards for the transport sector which leads to a lower carbon price due to a higher marginal mitigation cost for transport. The variation in scope and coverage used by different models for carbon pricing makes it challenging to make a fair comparison.

Figure 5: Assumed price of carbon across the four scenarios



Understanding that scenarios differ in these key assumptions and indicators is important for further scenario analysis on specific sectors.

The following chapters describe the scenario analysis conducted by Guidehouse in seven sectors: primary energy, power, AFOLU, cement, iron and steel, shipping, and automotive.

5 Primary energy

5. Primary energy

IEA SP1 SP2 GEC

The analysis of the four scenarios shows a rapid and steep decline in emissions generated from primary energy:

- Each scenario has a different specific energy mix in 2050, but the decline of absolute emissions is between -37% to -53% and decline in emissions intensity of the primary energy sector is between -28% to -40% for all selected scenarios from 2020 to 2030
- Use of fossil fuel declines steeply with -42% to -67% for oil and gas, and -64% to -90% for coal by 2050
- In all scenarios oil, gas and coal are still part of the primary energy mix in 2050, however emissions are abated with Carbon Capture, Utilisation and Storage (CCUS).

Despite seeing a growth in global population and GDP from 2020 to 2050, the total amount of primary energy demand remains at similar levels. All scenarios show a decline in primary energy demand between 2020-2030, mainly due to the large application of energy efficiency measures bringing energy demand down. After 2040, primary energy demand grows back towards 2020 levels as continued population and GDP growth require more primary energy and outgrow efficiency measures. Overall, the scenarios show a decline in total global primary energy demand by -2% to -14% by 2050 (Figure 6).

Figure 6: Primary energy demand

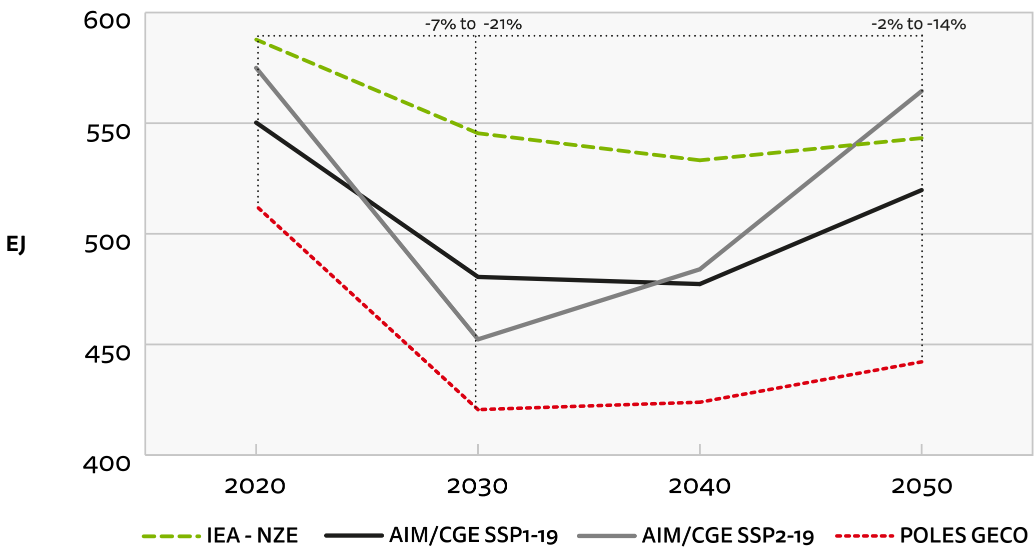
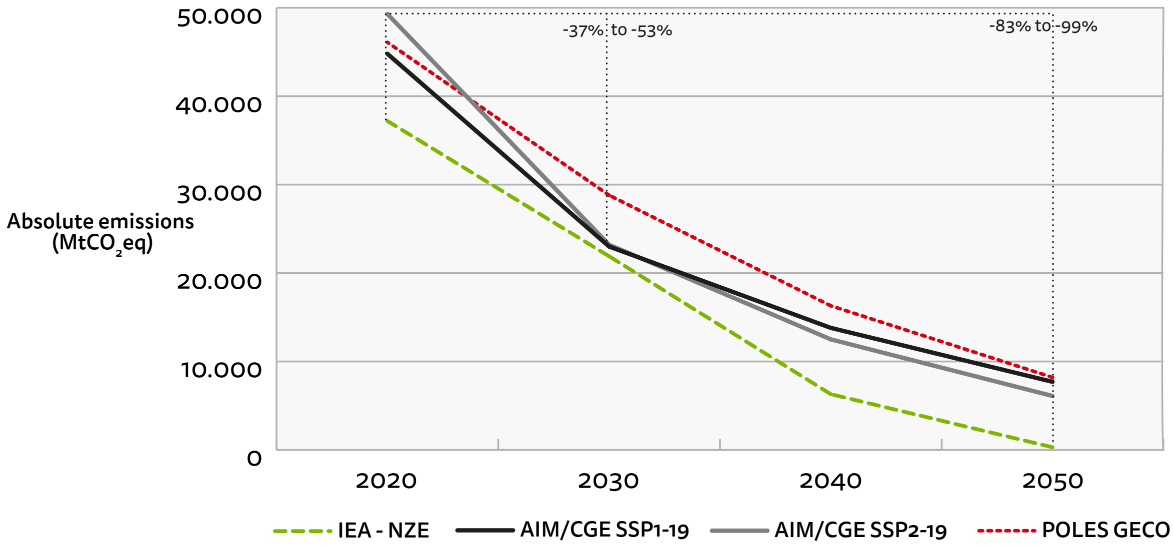


Figure 7: Absolute emissions of primary energy



While primary energy demand stays almost flat, emissions have to decline rapidly (Figure 7). Emission intensity of the primary energy sector declines between 28-40% for all scenarios between 2020 to 2030 (Figure 8). The range of decrease is consistent across all scenarios despite each scenario containing a different energy mix (Figure 9). It is worth noting that scenarios for Asia and other regions show a similar decline in emission intensity for primary energy.

Figure 8: Global and regional
primary energy emission intensity
reductions compared to 2020

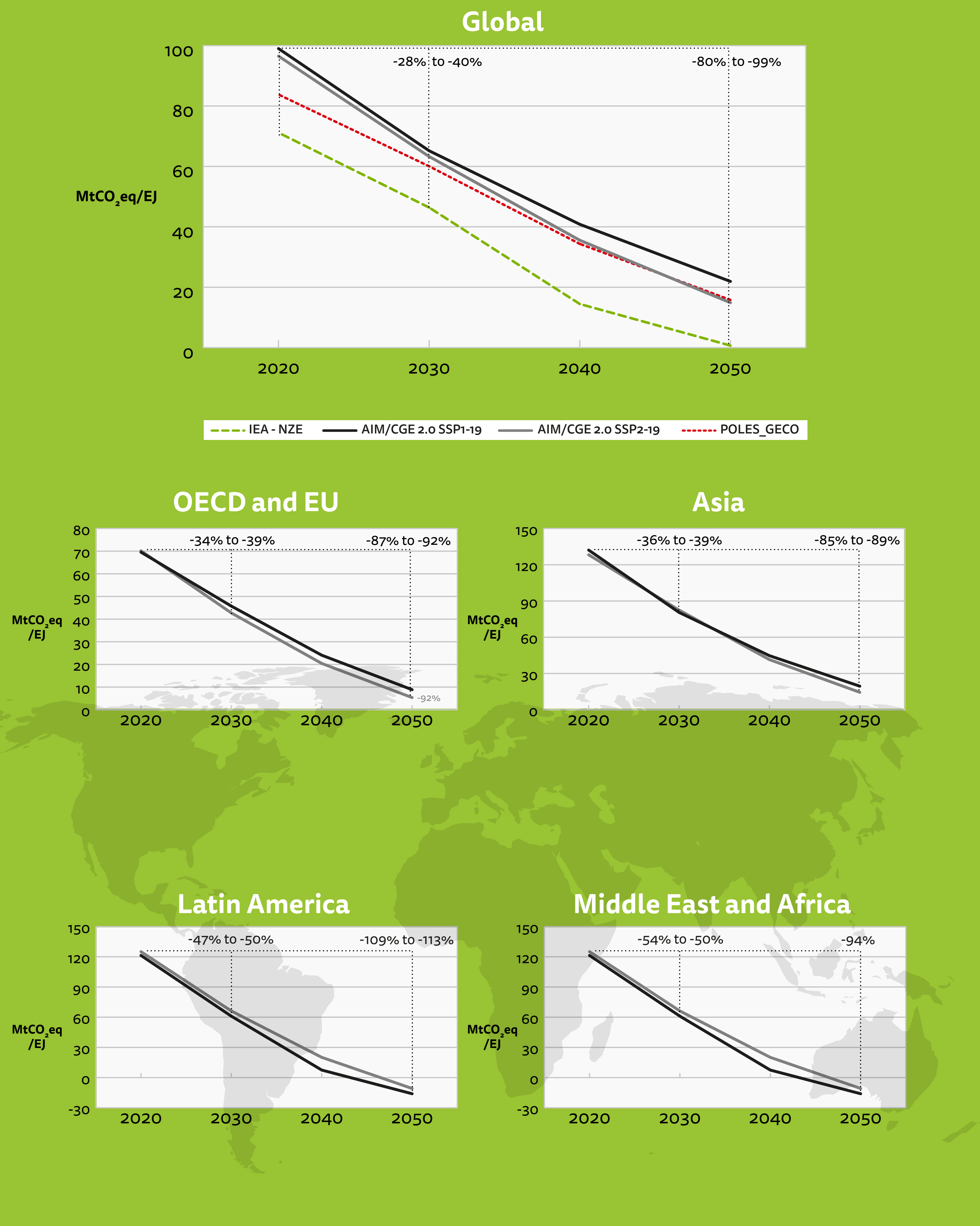
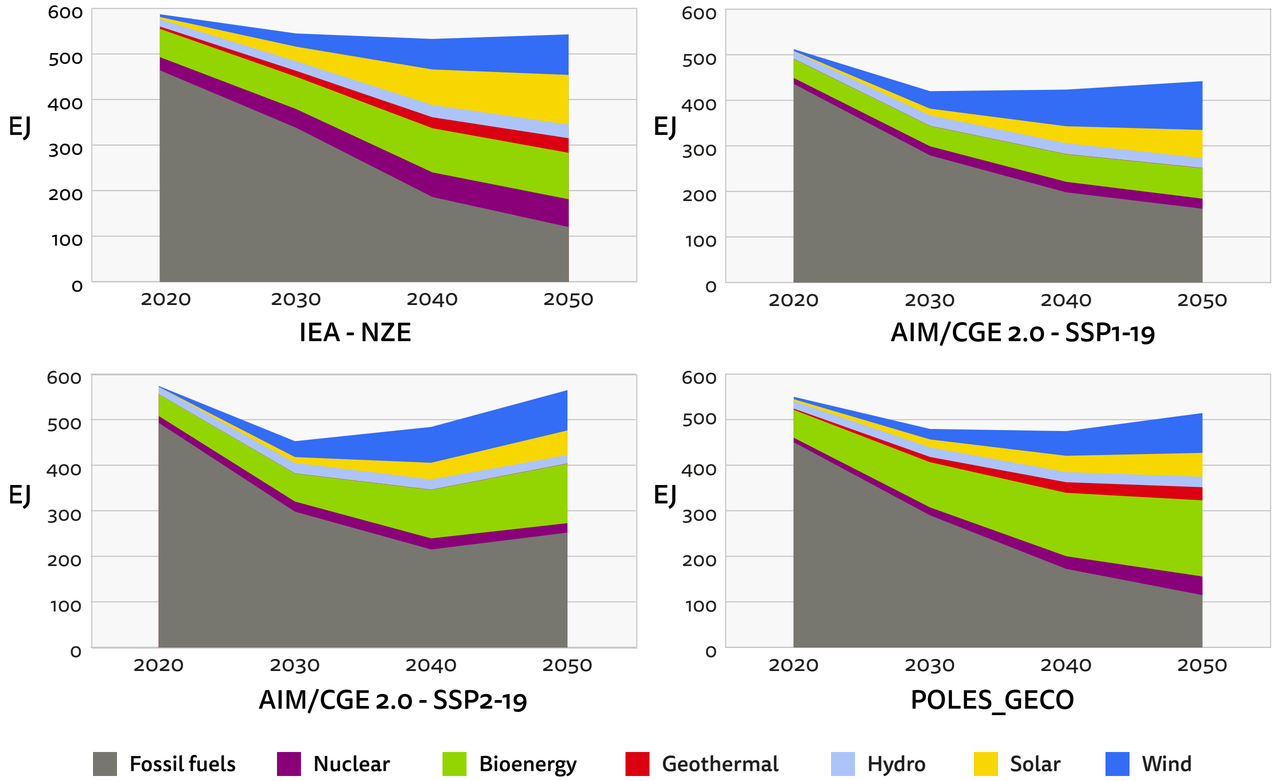


Figure 9: Changes in primary energy demand between 2020 and 2050 across all scenarios



The use of oil and gas, and coal in all scenarios show a steep decline. Oil and gas demand declines between 42% and 67% from 2020 to 2050 (Figure 10). Use of coal for energy production shows the largest decline of between 64% and 90% by 2050 (Figure 11).

Figure 10: Decline of Oil and Gas demand (in % EJ) across all scenarios compared to 2020

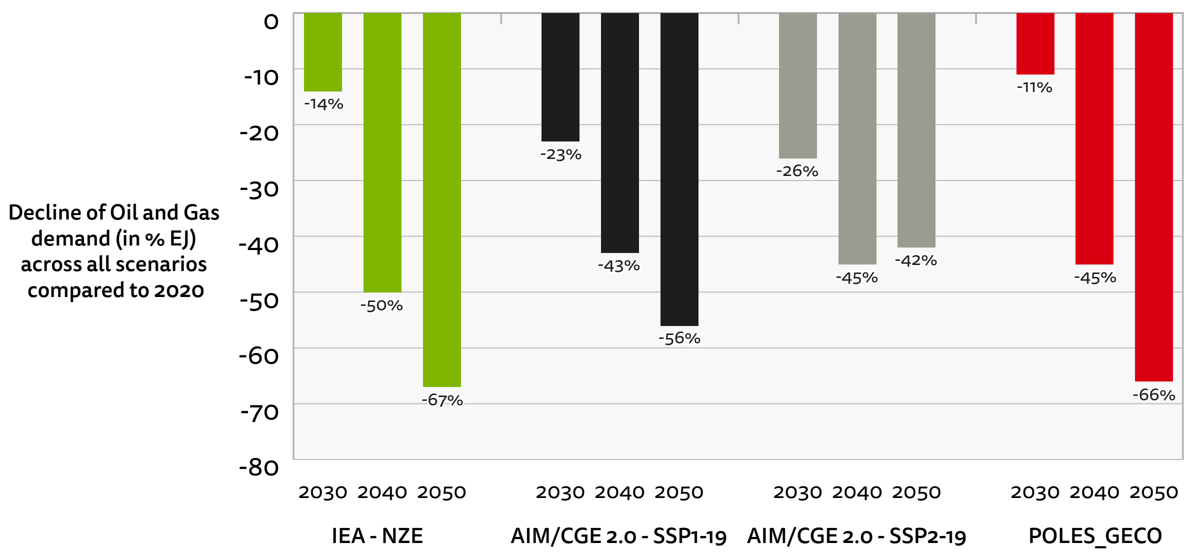
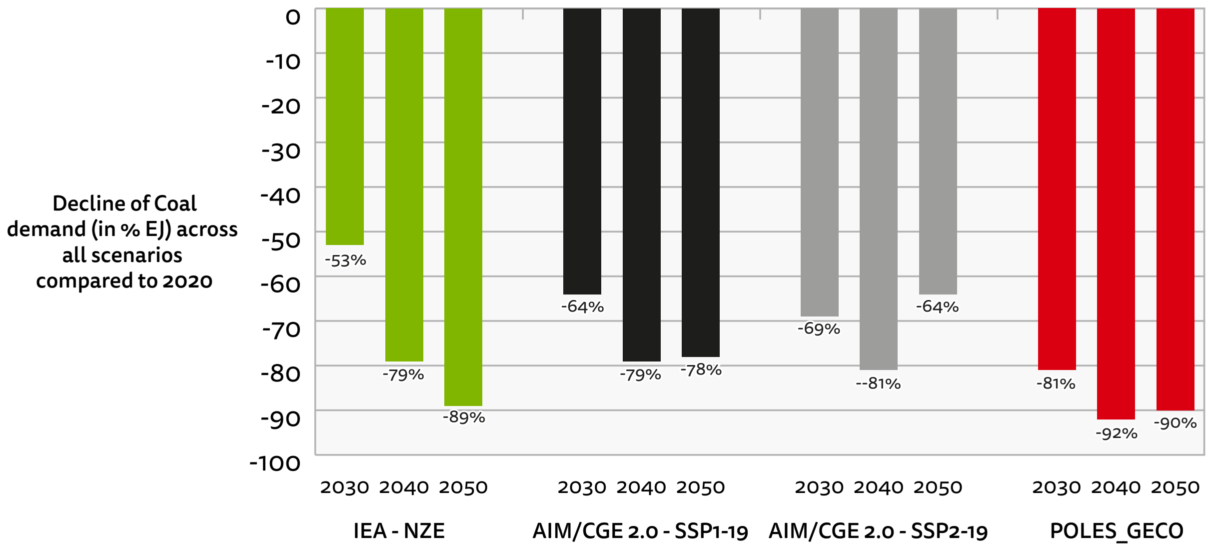


Figure 11: Decline of Coal demand (in % EJ) across all scenarios compared to 2020



As fossil fuels remain in the energy mix by 2050, the residual emissions are assumed to be abated using CCUS technology to capture and store these emissions.

6 Power sector

6. Power sector

IEA SP1 SP2 GEC

The analysis of the four selected scenarios shows a rapid increase in renewable power, which presents huge lending and investment opportunities in the sector.

- Absolute emissions of the power sector decline very rapidly with -50 to -64% and emission intensity (gCO_2/kWh) declines with a –63 to -69% reduction between 2020-2030
- According to the IEA, renewable energy will account for almost 90% of electricity generation by 2050, with 70% coming from wind and solar
- In all scenarios, the use of hydropower increases as one of the largest sources of low-carbon electricity despite the significant known environmental impacts
- The rapid increase in renewable power, combined with grid infrastructure and battery storage, offers huge lending and investment opportunities. Investments in grid networks is expected to triple by 2030.

In the four no/low-overshoot 1.5°C scenarios examined, the power sector is assumed to grow due to further electrification of the economy as well as growth in access to power. Despite the differences in growth of population and GDP, the increase in power production is very similar for the assessed scenarios and ranges between 131% in AIM/GCE SSP2-19 scenario and 166% in the IEA-NZE scenario (Figure 12). Also, the decline in absolute emissions and emission intensity of the power sector is very similar over the four scenarios and shows a similar decline globally as for specific regions (Figures 13 and 14).

Figure 12: The trend in power generation between 2020 and 2050

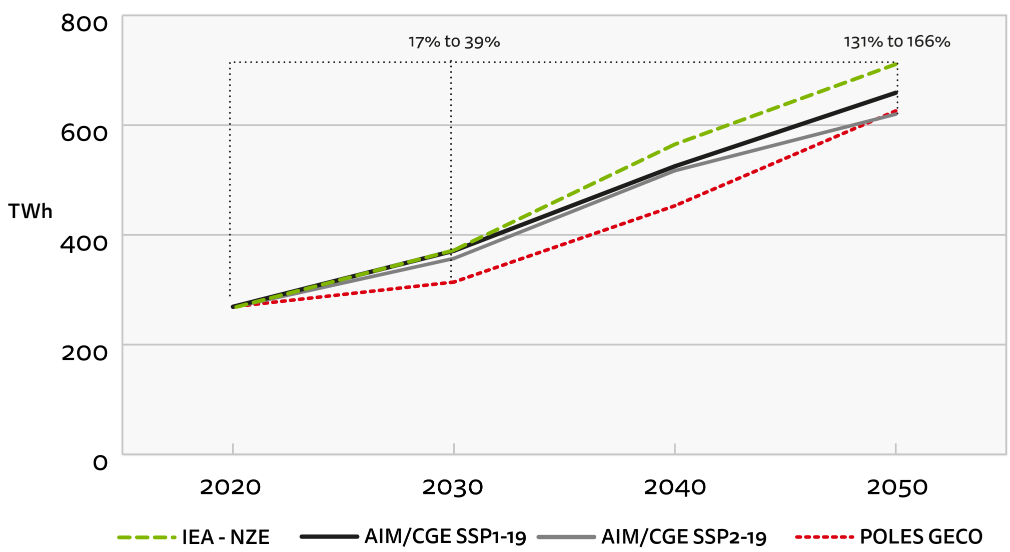
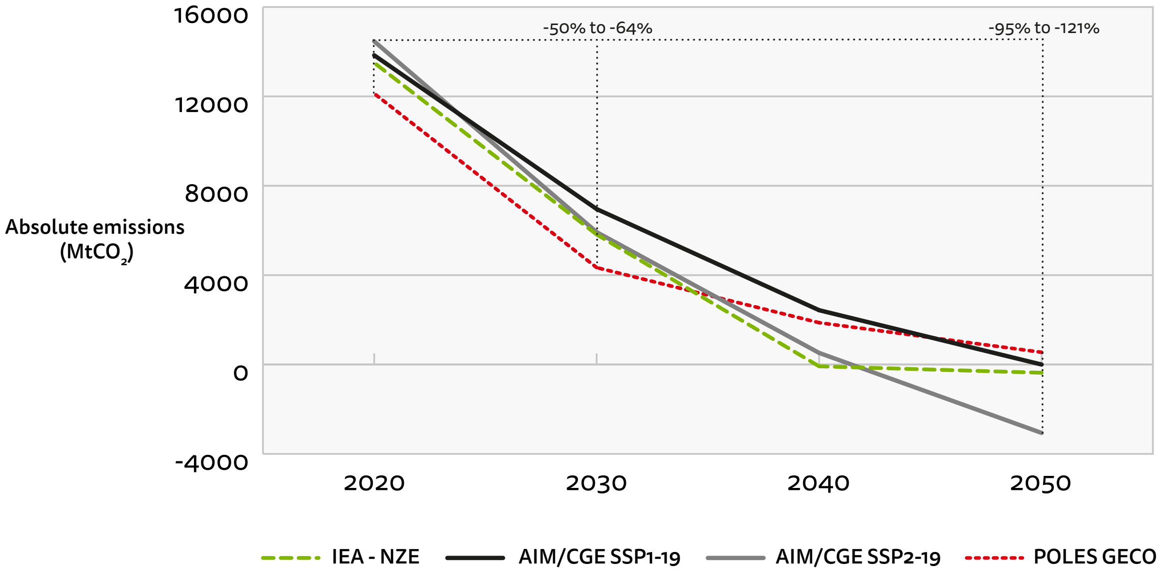


Figure 13: Absolute emissions of the power sector



Renewable energy is expected to account for 90% of electricity generation by 2050 in the IEA's NZE scenario of which 70% is coming from wind and solar. In all scenarios, the use of hydropower increases as one of the largest sources of low-carbon electricity despite the significant known environmental impacts. And the IEA predicts nuclear energy to grow predominantly in developing markets (especially China), and in advanced economies nuclear will mainly remain part of the mix by lifetime extensions of existing plants.

The growth of renewable power will create a significant contribution towards reducing emissions intensity of the power sector which is expected to decline at a range of 63% to 69% between 2020 and 2030 and around 91% to 100% by 2040 (see Figures 14 and 15). The growth of wind power is predicted to be significant between 2020 and 2050 and ranges from a 1030% increase in POLES GECO scenario to 3950% on AIM/CGE scenario. However, solar outperforms on growth with an increase of 1780% to 12742% shown by POLES GECO and AIM/CGE scenarios respectively by 2050 as it becomes the cheapest new source of electricity.

Figure 14: Global and regional **power emissions intensity** reductions compared to 2020

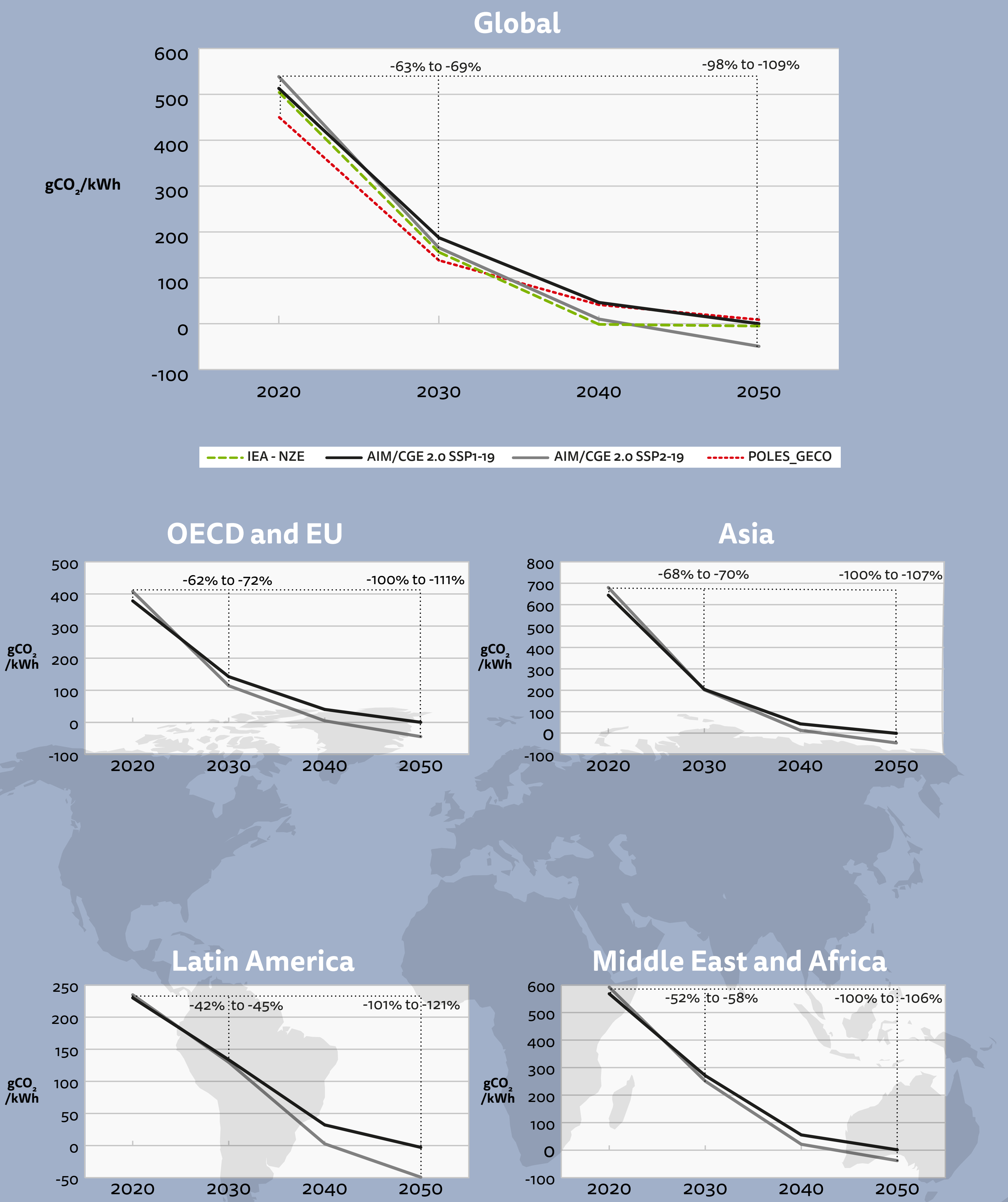
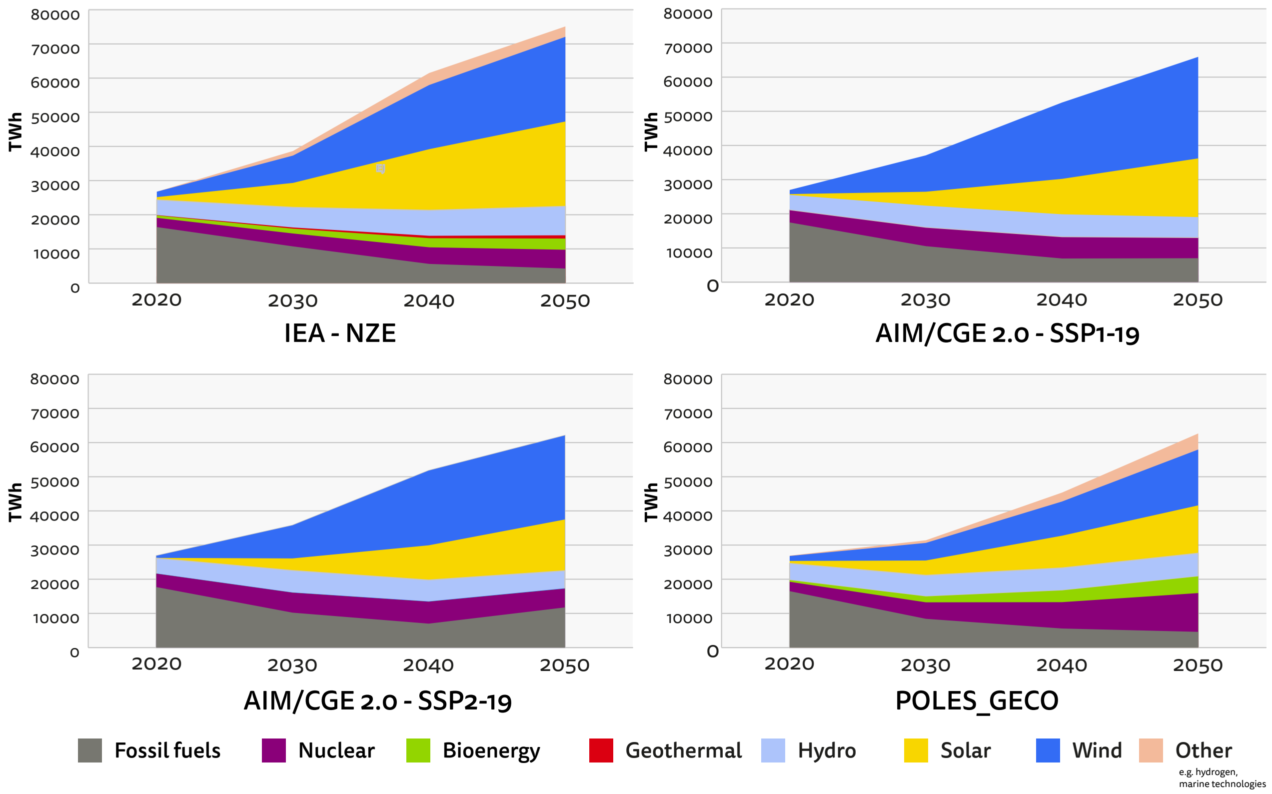


Figure 15: Global future power mix between 2020 and 2050



If the scenarios' predictions are accurate this presents huge lending and investment opportunities in wind and solar power generation, grid infrastructure and battery storage. According to the IEA NZE, electricity network investment is expected to triple by 2030 and remains at a high level until 2050 to meet new electricity demand. Investment in battery storage systems is expected to grow as its coupling with solar power improves flexibility and electricity security.

7

Agriculture, Forestry and Other Land Use (AFOLU)

7 Agriculture, Forestry and Other Land Use (AFOLU)

IEA SP1 SP2 GEC GCA

The analysis of the selected scenarios clearly shows the significant pressure on the sector to feed the global growing population, serve as feedstock for bioenergy production and to provide nature-based solutions for carbon dioxide emissions reduction and removals:

- AFOLU emissions currently represent about 23% of global GHG emissions but drop below zero by 2040 to become a net remover of GHGs through afforestation and reforestation.
- Reliance on bioenergy differs greatly per scenario throughout the pathways. The increase in bioenergy requires a significant increase in land, according to the IEA an increase of 80 million hectares by 2050.
- The required land for the potential sequestration of the AFOLU sector is between 250 and 470 million hectares of land (i.e. about a quarter to half of the size of the United States).

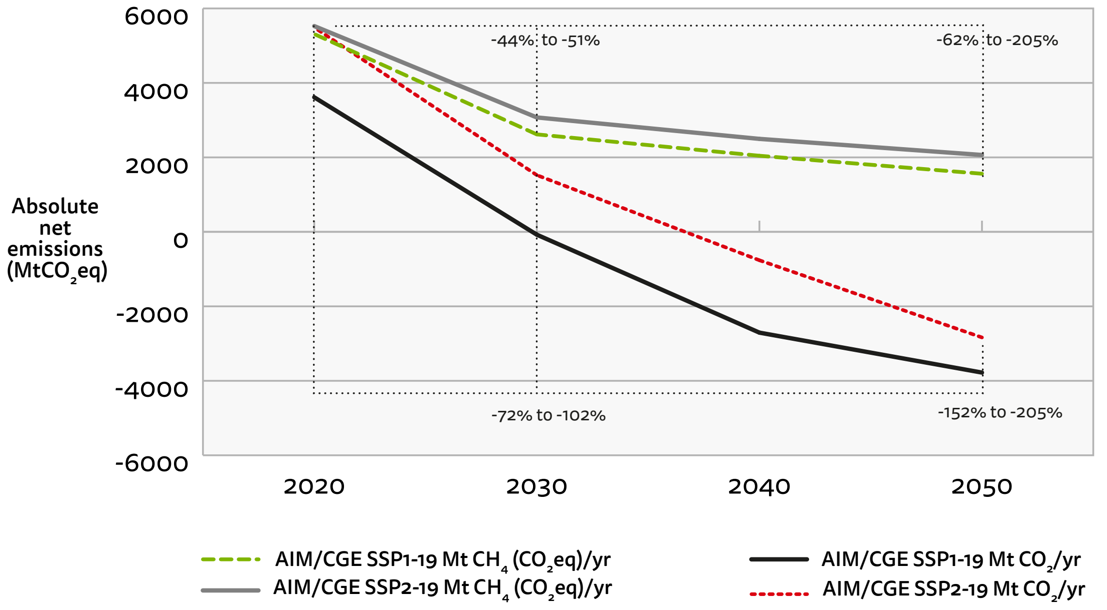
The AFOLU sector is a heavily contributing sector to global emissions representing about 23% of global GHG emissions. Agricultural practices lead to methane (CH_4) emissions from enteric fermentation in ruminant animals such as cattle, sheep, goats, and buffalo, and fermentation of wet rice production. Also the application of fertilizer leads to nitrous oxide (N_2O) in agriculture. Next to this, global deforestation which is to a large extent driven by the expansion of commercial agriculture, has resulted in large amounts of CO_2 released into the atmosphere by cutting and burning of forests and produces around 10% of global GHG emissions each year[11].

Given this, actions to reduce emissions from agriculture and land conversion are an essential solution to climate change. Furthermore, the AFOLU sector also holds the potential to remove emissions from the atmosphere through the protection and restoration of ecosystems such as forests and peatlands, and also through some farming practices (soil carbon sequestration). However, there is significant pressure on this sector to feed the global growing population, serve as feedstock for bioenergy production and to provide nature-based solutions for emissions reductions and removals. This raises the potential for trade-offs between global objectives on climate, food and nature and highlights the need for joined up thinking, approaches that reduce land and water demands, and to maximise emissions reductions to limit the need for removals[12].

According to the AIM/CGE SSP1-19 and AIM/CGE SSP2-19 scenarios, both CO_2 emissions and methane emissions should decline until 2050 as shown in Figure 16 , resulting in a combined reduction of -58 to -72% in 2030.

11 IPCC (2014): *Climate Change Synthesis Report 2014 Summary for Policymakers*
12 WWF UK (2020): *The Triple Challenge*

Figure 16: Absolute net emissions from the AFOLU sector

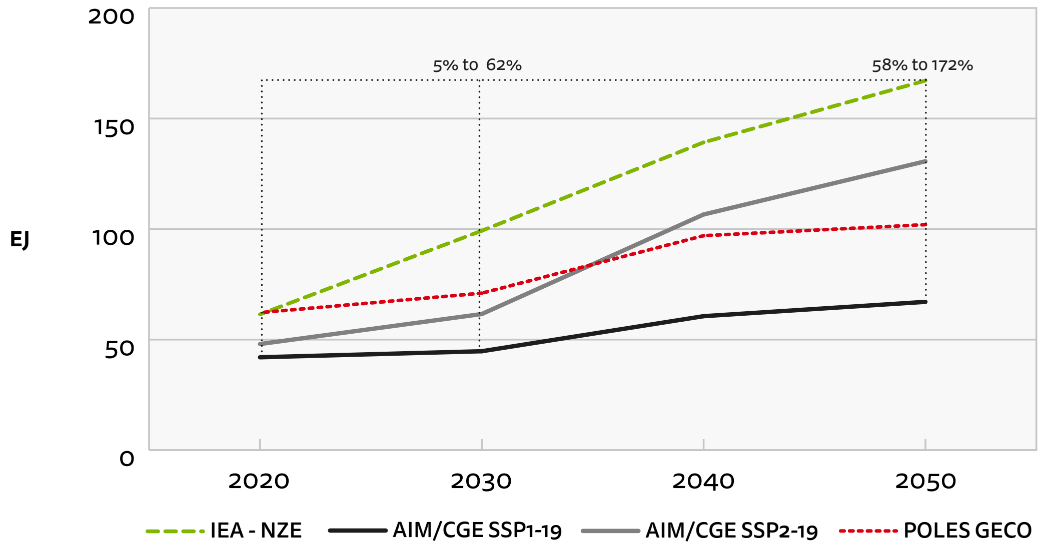


Further analysis of the AFOLU sector has been conducted to support this report focused on the role of bioenergy in each scenario, the potential for nature-based Carbon Dioxide Removals (CDR) and land-cover trade-offs. The analysis on land-cover trade-offs is covered in the box on nature-based solutions (below) and used an additional set of 1.5°C scenarios from the Network for Greening the Financial System (NGFS).

7.1 Bioenergy

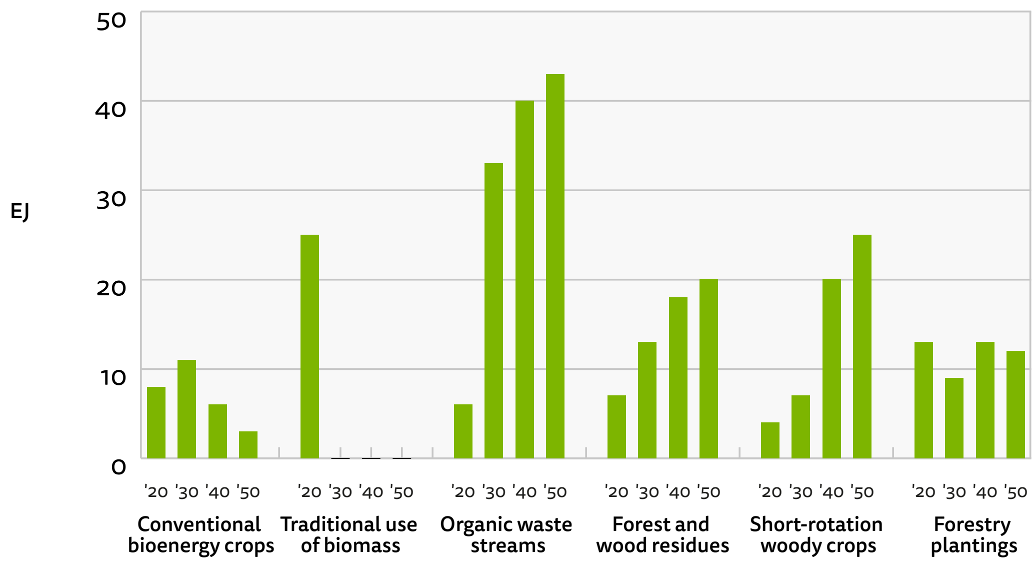
Bioenergy as a primary energy source is predicted to increase across all four selected 1.5°C scenarios (Figure 9). The largest increase of 172% by 2050 is projected by POLES GECO and AIM/GCE SSP2-19 showing a high dependency on bioenergy as part of primary energy generation overall. The scope of POLES GECO encompasses more different types of bioenergy which also results in a relative larger projection of bioenergy in their pathway. The IEA-NZE scenario and AIM/CGE SSP1-19 both show significantly smaller increases (Figure 17).

Figure 17: Growth of bioenergy for primary energy across different scenarios



Demand for bioenergy in the IEA's scenario is concentrated in sectors that are either hard to electrify or require a low-cost dispatchable source of renewable energy including industry, transport, and buildings sector. Most of the biomass included in the IEA's scenario relies on organic waste, forestry residue and industrial waste (Figure 18) – which will help to reduce the risk of land-cover trade-offs. The projection from the IEA also assumes the elimination of fuelwood use by 2030.

Figure 18: Sources of bioenergy between 2020 and 2050 in the IEA scenario



The IEA assumes that the total land area for bioenergy production increases by 80 million hectares (Mha) by 2050. Of the increase:

- 30 Mha are new forests: expanding global forest area by 1% so that bioenergy forest plantations represent 6% of total global forest area in 2050
- 50 Mha remaining is for short-rotation woody bioenergy crops: the 50 Mha increase sees the total land use for both short-rotation woody crops and conventional bioenergy crops rise to 140 Mha in 2050. Of this, 70 Mha are on marginal lands or pastures, and 70 Mha are on cropland.

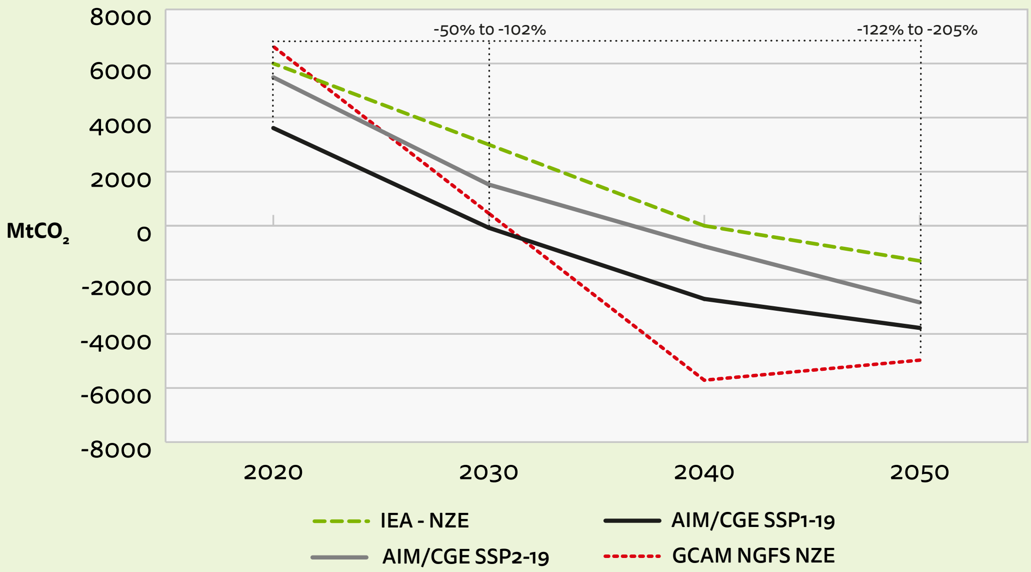
According to the IEA, achieving net-zero emissions without expanding bioenergy land use requires an additional 3200 TWh of solar PV and wind, increasing their capacity by nearly 10% by 2050.

7.2 Nature-based solutions for emission reductions and removals

Nature-based solutions are defined by the IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits[13]." They have grown in prominence as a climate solution following scientific literature demonstrating the large potential for land-based nature-based solutions, in particular, to contribute to climate mitigation through reduced emissions (e.g. avoided conversion of ecosystems) and emission removals (e.g. restoration of ecosystems). They can encompass a range of activities from wetland restoration to regenerative agriculture, but are most commonly represented through reforestation and afforestation in climate modelling.

Figure 19 below displays the CO_2 emission reduction pathway for the AFOLU sector from 2020 until 2050. All 1.5˚C scenarios predict a CO_2 pathway that results in negative emissions by 2050. The largest contribution of negative emissions is projected under NGFS GCAM scenario. This is achieved through an increase in land cover of forest through afforestation and reforestation which subsequently increases the carbon sequestered.

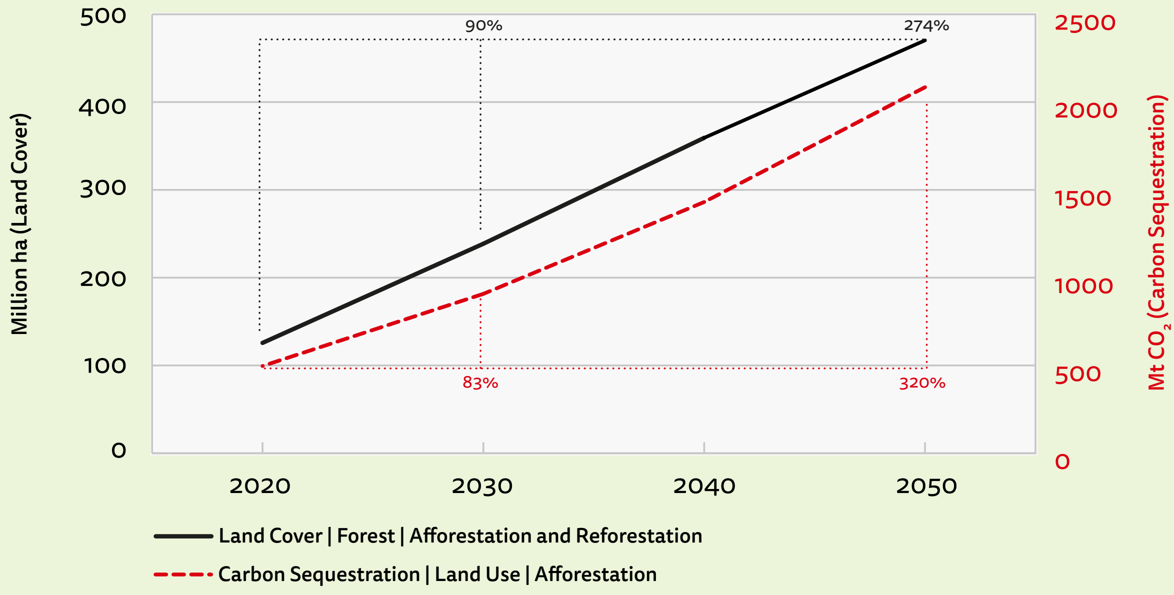
Figure 19: CO_2 emissions from AFOLU under different scenarios



In Figure 20, the NGFS GCAM scenario displays the increase of land coverage for afforestation and reforestation and its respective effects on the carbon sequestration in Mt CO_2. By 2050, the NGFS 1.5˚C scenario requires 470 million hectares of afforestation and reforestation (equal to almost 50% of land-cover of the United States). Also, the IEA – NZE scenario requires 250 million hectares for new forests.

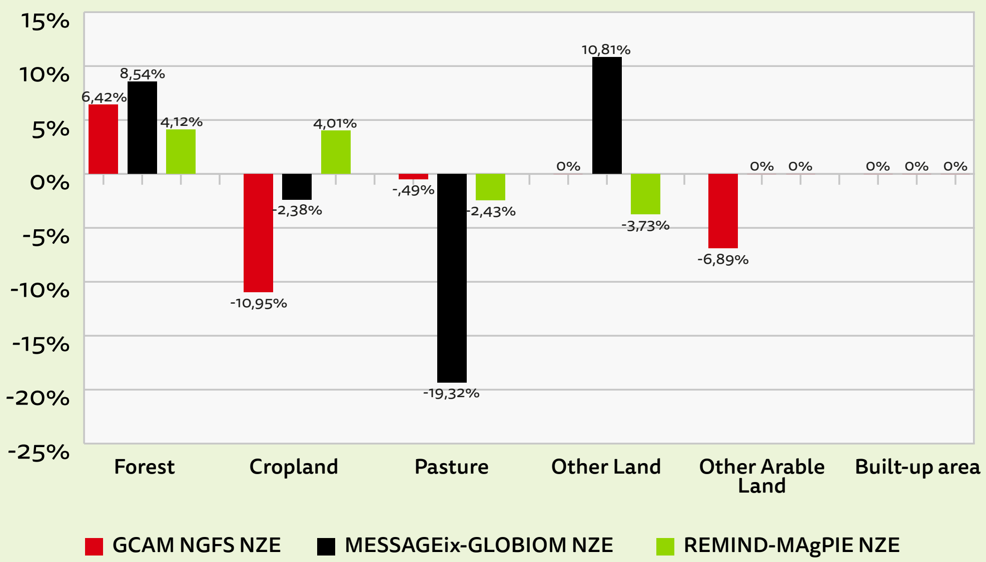
13 IUCN (2020): *Defining Nature-based Solutions*

Figure 20: The land cover and carbon sequestration under NGFS GCAM scenario



The required land for the potential sequestration that the AFOLU sectors hold is not without further implications. Given that we have a finite supply of land, we need to take an integrated perspective on land- based emissions and removals and understand the potential trade-offs in the AFOLU sector. When selecting a scenario and analysing it, it is vital to understand potential consequences, complications and rationales that underly these significant changes. Figure 21 displays the percentage differences in six different land uses that are modelled in the 1.5°C NGFS scenarios. For instance, in one scenario pasture decreases by approximately 19% until 2050 and forests would need to increase by approximately 9% globally as well. This does not necessarily imply that there will be a proportionate reduction in food supply, but highlights the importance of context in interpreting models and scenarios.

Figure 21: Land-use trade-offs in percentage change between 2020 and 2050



The scenarios demonstrate the large role played by nature-based solutions, such as afforestation and reforestation, alongside changes to agricultural land use, at a sector and economy wide level in limiting warming to 1.5°C. But the potential land, water and sea use implications of nature-based solutions at scale also highlights the importance of taking a high integrity approach using guidance from bodies including the IUCN[13], WWF[14] and the Sustainable Markets Initiative[15].

14 WWF (2020): *Beyond Science-Based Targets: A blueprint for corporate action on climate and nature*
15 Sustainable Markets Initiative (2021) - *Financial Service Taskforce: A Practioner's Guide for Banks*

8

Cement sector

8. Cement sector

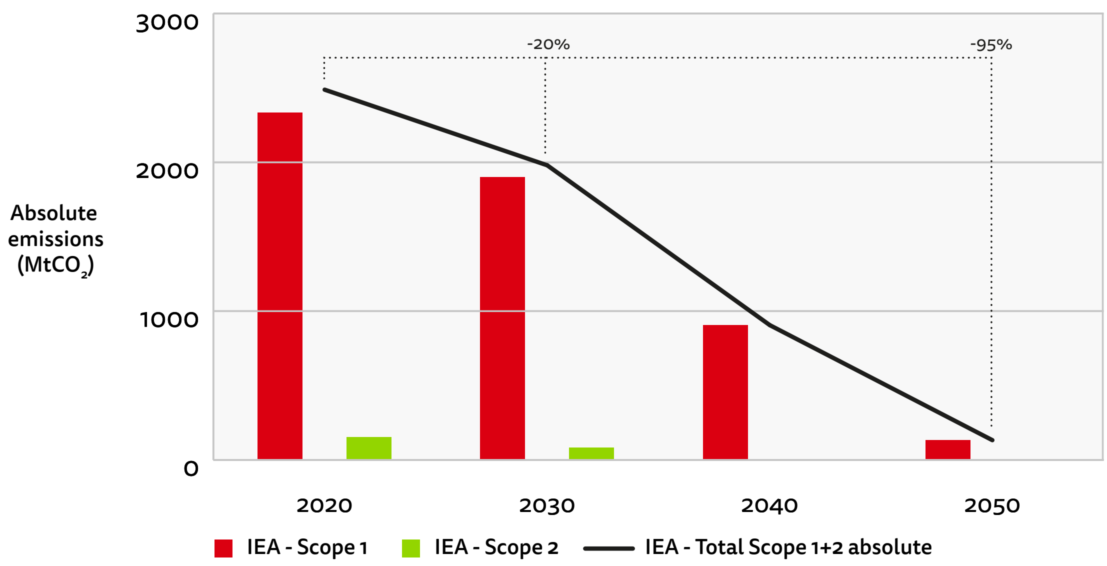
IEA

The analysis of the cement sector uses only the IEA Net Zero by 2050 scenario, as this is the sole scenario that covers this sector. This scenario shows the need to venture into cement blended with alternative materials improving the clinker-to-cement ratio and abatement measures in a sector that remains equal in size.

- Demand for cement remains equal until 2050
- Increased blending of alternative materials into cement to replace a portion of clinker and energy efficiency measures deliver the required emissions reductions by 2030. After 2030, CCUS and hydrogen need to be used to abate emissions from cement
- Absolute Scope 1+2 emissions from cement sector should drop by -20% between 2020 and 2030. The Scope 1+2 emissions intensity (tCO_2 per tonne of cement) should decline by -24% between 2020 and 2030.

The net-zero pathway for the cement sector requires a shift into increased blending of alternative materials into cement to replace a portion of clinker (the active and most emissions-intensive ingredient) and to lower process-related emissions. Alongside this, energy efficiency measures can reduce emissions towards 2030, as shown in Figure 22.

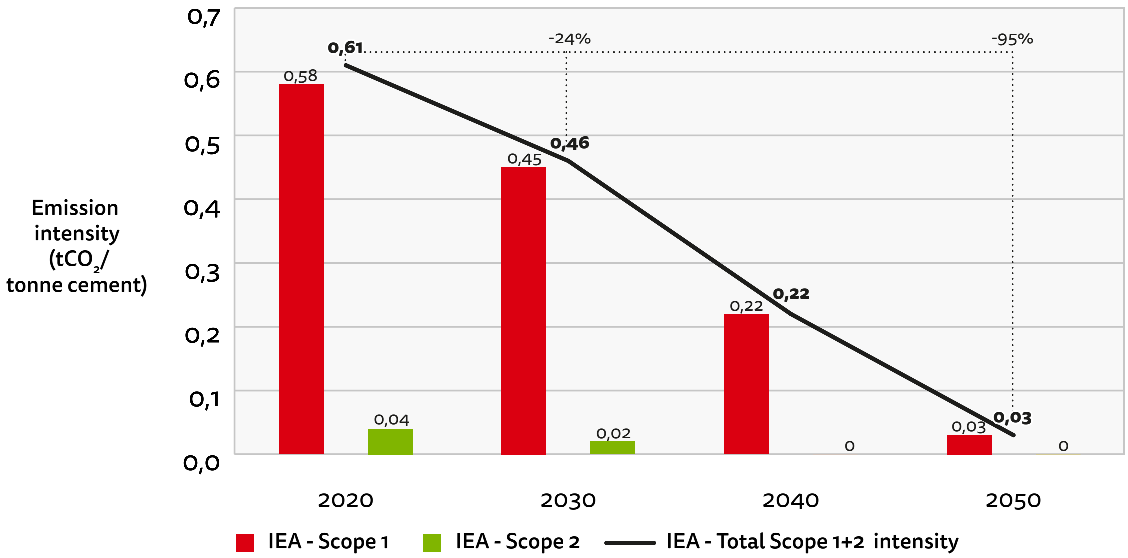
Figure 22: Absolute Scope 1+2 emissions from cement sector



After 2030, the significant drop in direct (Scope 1) emissions from cement is accounted for by the increased implementation of CCUS and hydrogen-based technologies. In the IEA's scenario, coal use is eliminated from cement production by 2050 and replaced by alternative fuels (gas, biomass/waste, hydrogen) combined with CCUS. CCUS technology is projected to account for a 55% emission reduction from cement production in 2050 when compared to 2020.

Under the IEA NZE scenario, between 2020 and 2030, the Scope 1+2 emissions intensity of cement sector is predicted to reduce by -24% (Figure 23). Scope 2 emissions are added to the IEA NZE data by using the electricity emissions intensity (kWh/tonne of cement) from ETP 2017 combined with the power emissions intensity from the IEA NZE.

Figure 23: Global Scope 1+2 emissions intensity of cement sector



9

Iron and steel sector

9. Iron and steel sector

IEA

The scenario analysis for the iron and steel sector also mainly builds on the IEA Net Zero by 2050, as the other scenarios model at a high industry level. The analysis shows the need to focus on iron and steel that does not rely on coal for production but hydrogen combined with CCUS measures.

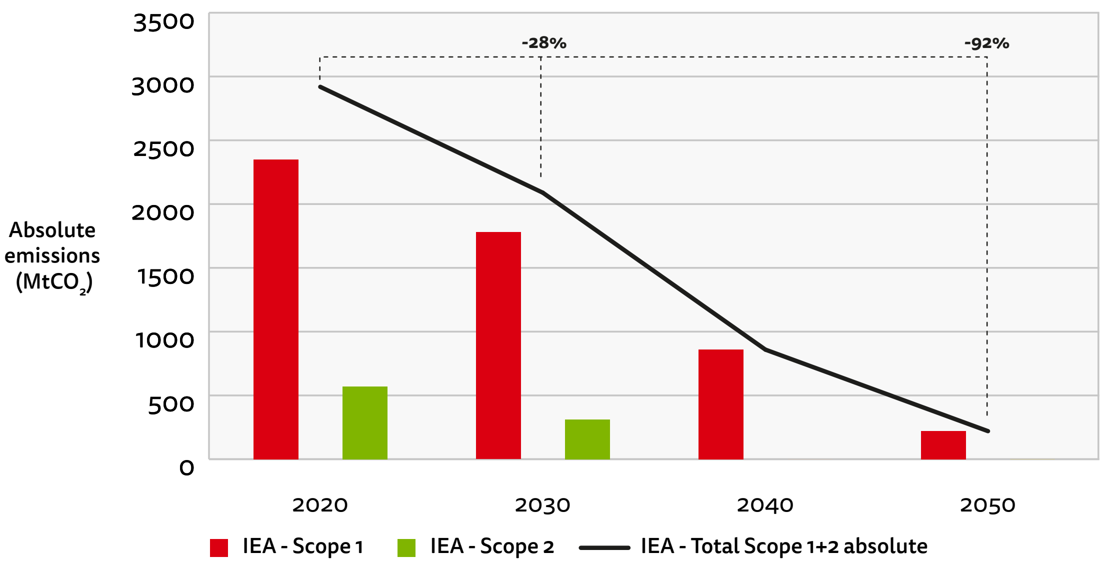
- Global demand for steel in 2050 is predicted to be 12% higher than today as steel is needed to build additional transport infrastructure (roads, cars and trucks) and energy infrastructure.
- The iron and steel industry remains one of the last sectors using significant amounts of coal in 2050.
- After 2030, CCUS and hydrogen play an increasingly important role in reducing CO_2 emissions.

Absolute Scope 1+2 emissions from iron and iron and steel should drop by -28% between 2020 and 2030. The Scope 1+2 emissions intensity (tCO_2 per tonne of steel) should decline by -34% between 2020 and 2030.

In the selected scenarios, it is predicted that the iron and steel sector will continue to release significant CO_2 emissions in 2050 and it is expected to be one of the last industrial sectors that continues to need to use a significant amount of coal as part of the production process. The development and growth of the steel industry is also correlated to the growth of other industries. For example, additional energy and transport infrastructure demand will require an additional 12% more steel in 2050 than today.

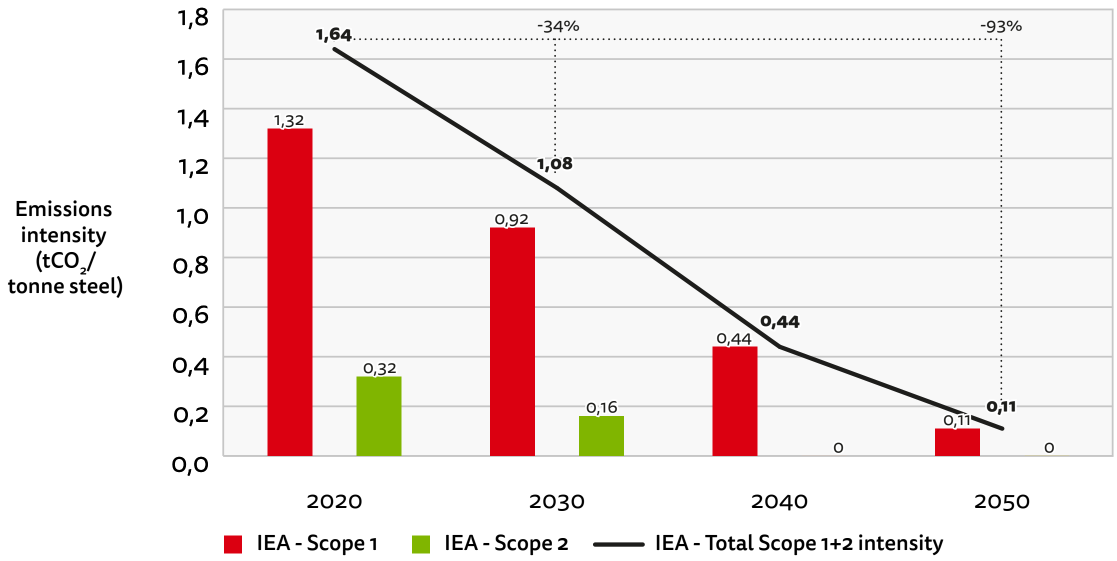
However, the absolute emissions show a gradual decline between 2020 and 2050 (Figure 24). Between 2020 and 2050, the IEA scenario projects a -92% decrease in emissions in the iron and steel sector. The emission savings are created by material efficiency measures accounting for 20% emission reductions.

Figure 24: Absolute Scope 1+2 emissions ($MtCO_2$) from iron and steel sector between 2020 and 2050



The IEA NZE scenario scope 1 emission intensity drops by 30% and scope 2 drops by 50% between 2020 and 2030 from the iron and steel sector, resulting in a total scope 1+2 emission intensity decline of -34%. (Figure 25). Scope 2 emissions are added to the IEA NZE data by using the electricity emissions intensity (kWh/tonne of steel) from IEA ETP 2017 combined with the power emissions intensity from the IEA NZE. After 2030, CCUS and hydrogen play an important role in reducing emissions. This will lead to an increase in demand for hydrogen in the industrial sector from less than 1 Mt to around 40 Mt in 2050.

Figure 25: Global Scope 1+2 emissions intensity of iron and steel sector



10

Shipping sector

10. Shipping sector

IEA

The analysis of the shipping sector is based on the IEA Net Zero by 2050 scenario as well, as this is the only one of the four scenarios that covers this sector. The analysis shows that a significant residual number of emissions remains unabated by 2050 due to the inherent characteristics of the sector that makes it unable to respond quickly to new technologies and sustainable alternatives.

- Significant emission reductions are achieved by switching to low-carbon fuels such as biofuels, hydrogen and ammonia.
- The use of low-emission fuels nudges significant changes in the shipping sector that allows for new investment opportunities.
- Absolute emissions from the shipping sector should drop by -12% between 2020 and 2030. The emissions intensity of the shipping sector (kgCO_2/tonne_km) should decline by -38% between 2020 and 2030.

The shipping sector is one of the transport modes that is predicted to not achieve net-zero emissions by 2050. This is due to an assumed lack of available low-carbon options and the long lifetime of vessels. However, the optimisation of operational efficiency and improving energy efficiency will reduce fuel consumption and contribute towards annual emission reductions of 6% per year until 2050. According to the IEA NZE, in the medium to long-term, significant emission reductions are achieved by switching to low-carbon fuels such as biofuels, hydrogen and ammonia. Around 60% of total energy consumption in shipping will be contributed by ammonia and hydrogen by 2050 (Figure 26). The increase in low-carbon fuels will reduce the carbon intensity of the shipping sector by 38% between 2020 and 2030 (Figure 28).

Figure 26: Global fuel shift of shipping sector

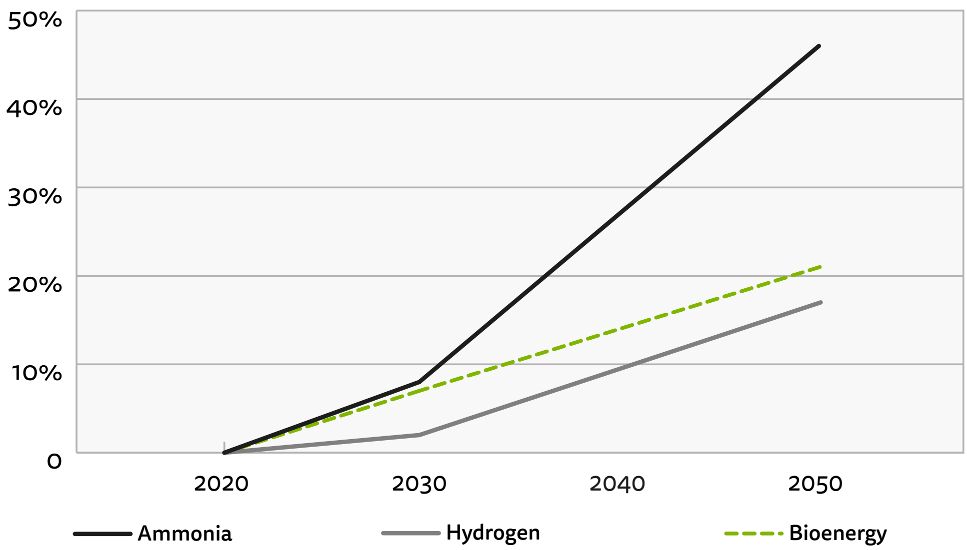


Figure 27: Absolute emissions from shipping sector

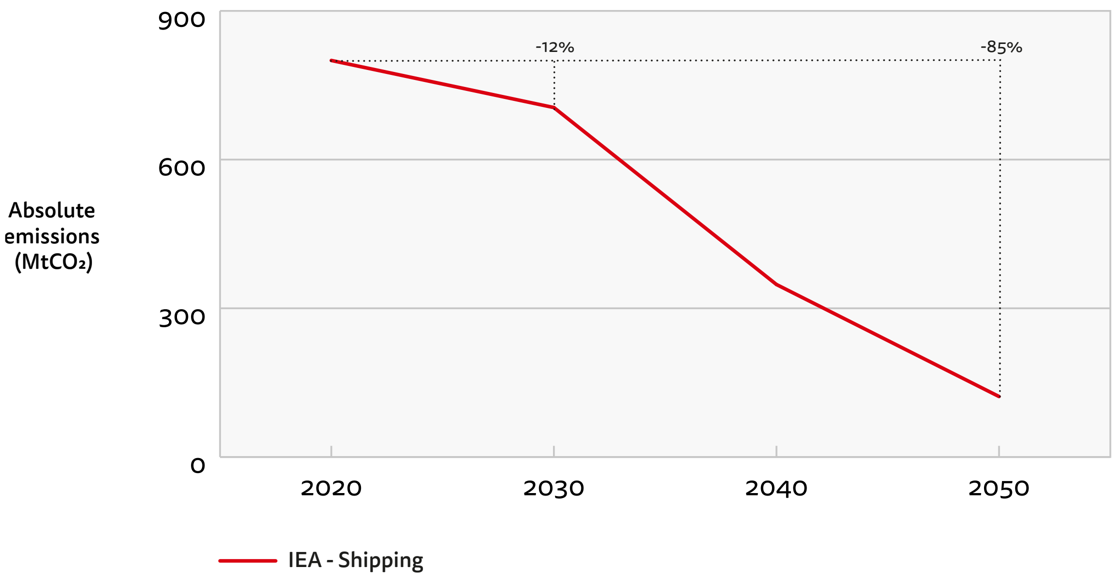
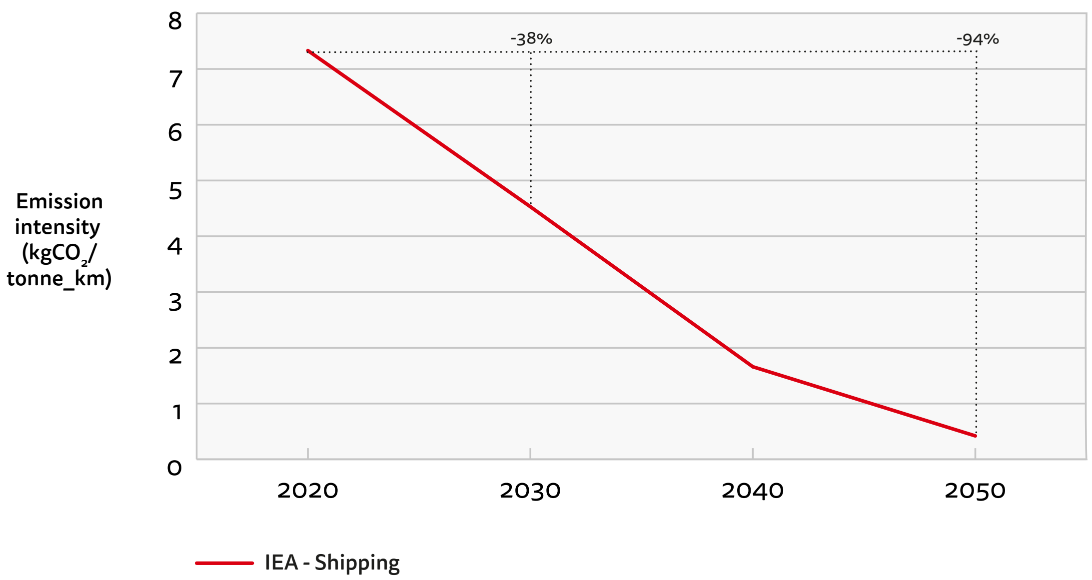


Figure 28: Emission intensity of shipping sector



11

Automotive sector

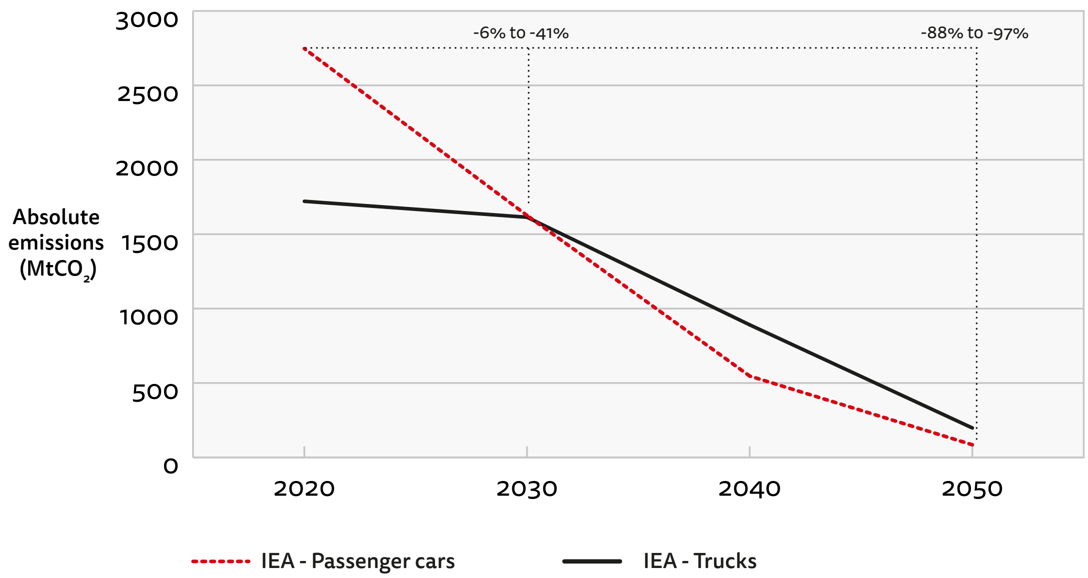
11. Automotive sector

IEA

The analysis of the automotive sector focuses on the emissions of their sold products. The IEA Net Zero by 2050 scenario is used because the other scenarios don't model at specific transport mode level (e.g. passenger cars). The analysis shows that emissions of the sold products of the sector need to reduce drastically between 2020 and 2050, but a residual amount remains unabated by 2050.

- Passenger travel and global passenger car fleet steadily increases.
- No more sales of new internal combustion engine passenger cars from 2035 onwards leads to a rapid shift to electric vehicle sales.
- The increase depends on rapid scaling up of battery manufacturing and the introduction of the next generation batteries between 2025 and 2030.
- Residual unabated emissions are due to dependency on fossil fuels for some types of vehicles.
- Absolute emissions from passenger cars from the automotive sector drop by -41% and emissions intensity (kgCO_2/passenger_km) drops by –46% between 2020 and 2030.

Figure 29: Absolute emissions from products of the automotive sector



The emissions for the sold products by the automotive sector are predicted to reduce significantly between 2020 and 2050. The emission intensity of passenger cars and trucks under the IEA scenario reduces by -46% and -37% respectively as shown in Figure 30 and 31.

Figure 30: Emission intensity of passenger cars between 2020 and 2050

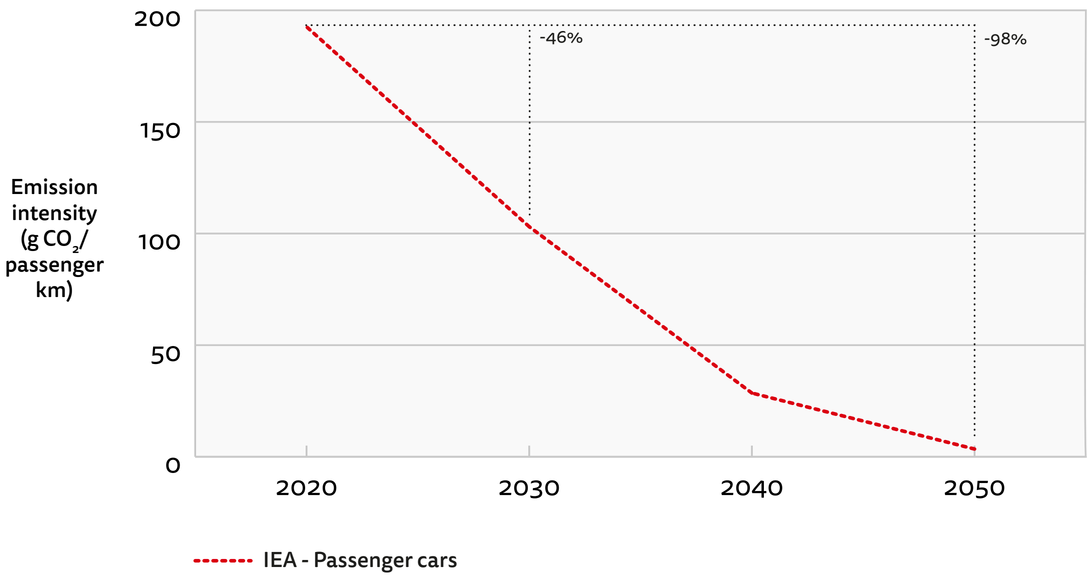
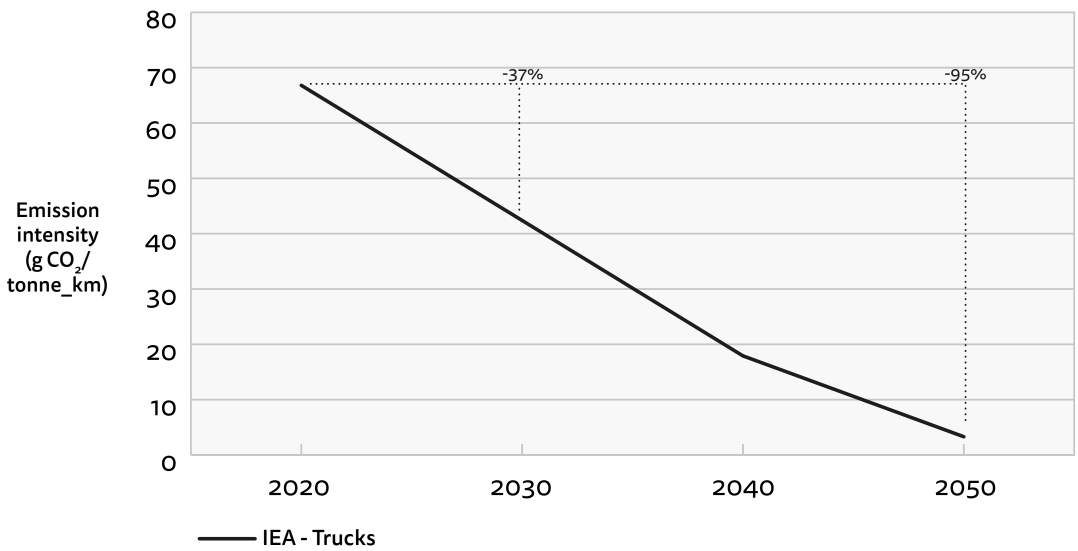
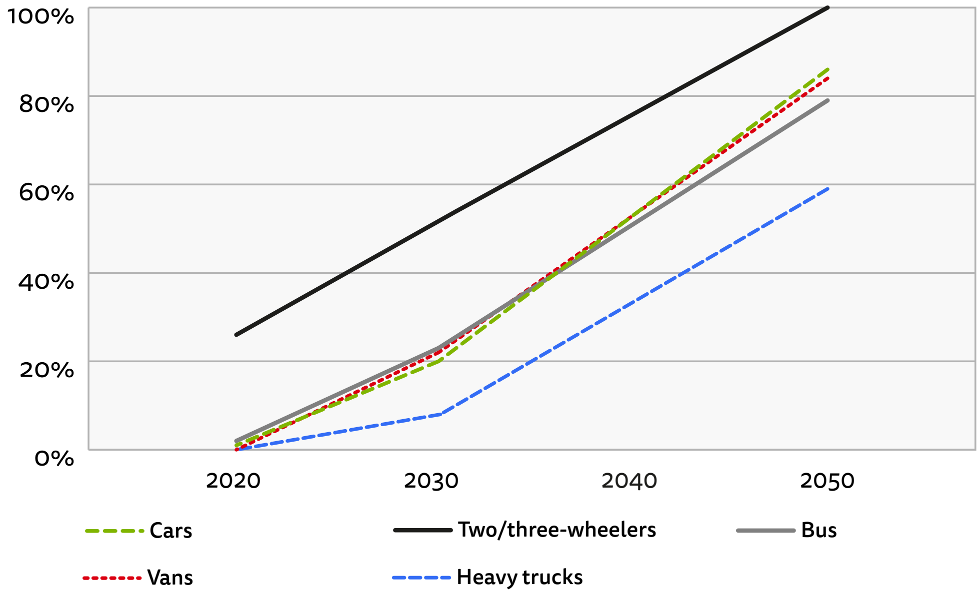


Figure 31: Emission intensity for trucks between 2020 and 2050



Stringent fuel economy standards and the discontinuation of the internal combustion engine (ICE) passenger car sales from 2035 onwards will lead towards a shift in the composition of the global vehicle stock. Electrification of the automotive sector will play a significant role in reducing emissions as EV (Electric Vehicles) are predicted to account for 60% of global car sales by 2030. By 2050, nearly all heavy trucks sold are predicted to be fuel cell or electric under the IEA scenario (Figure 32).

Figure 32: Share of electric vehicles in stock between 2020 and 2050



Along with the increase in electric mobility, operational and technical efficiency, and improvements in energy efficiency contribute significantly towards the decarbonisation of this sector. The IEA's scenario assumes a rapid up-scaling of battery manufacturing and increase in next generation battery technology between 2025 and 2030, which creates huge lending and investment opportunities for the finance sector.

12 Key takeaways for transition plans

12. Key takeaways for transition plans

Based on the scenario selection process and the assessment of the selected no/low-overshoot 1.5°C scenarios, we gained the following takeaways. These takeaways are particularly relevant for institutions that are going through the same process of aligning their portfolio and developing a transition plan, as recommended by the Financial Stability Board's – Task Force on Climate-related Financial Disclosures (TCFD).

1. **Immediate, rapid, large-scale and sustained actions are required:** The IPCC is clear, we need immediate, rapid and large-scale emission reductions to keep 1.5°C within reach. The remaining carbon budget to limit global warming to 1.5°C with a 50% probability is approximately 420 GtCO_2 from 2022 onwards. All selected no/low-overshoot 1.5°C scenarios clearly show immediate emissions reductions are required in all sectors and regions. Lack of sufficient action this decade will mean that it will not be possible to limit global warming to 1.5°C.

2. **Short-term targets are essential to drive these actions:** In order to steer and contribute to immediate deep decarbonisation, short term targets (< 5 years) are crucial, alongside long-term goals. According to our no/low-overshoot 1.5°C scenario analysis, deep emission reductions are required in the coming five to eight years to prevent overshoot of global temperature of 1.5°C. Absolute emissions reductions and emissions intensity reductions for the seven selected sectors between 2020 and 2030 are:

Sector	Scope	Absolute emissions reductions 2020-2030	Emissions intensity reduction 2020-2030	Intensity metric
Primary energy	Scope 3 Use of sold products	-37 to -53%	-28 to -40%	MtCO_2/EJ
Power	Scope 1	-50 to -64%	-63 to -69%	gCO_2/kWh
AFOLU	Scope 1	-58 to -72%	N/A	N/A
Cement	Scope 1+2	-20%	-24%	tCO_2/tonne of cement
Iron and steel	Scope 1+2	-28%	-34%	tCO_2/tonne of steel
Shipping	Scope 1	-12%	-38%	kgCO_2/tonne_km
Automotive	Scope 3 Use of sold products	-41%	-46%	gCO_2/passenger_km

3. **Insights from multiple scenarios can guide the required actions:** The insights from multiple climate scenarios inform the processes of setting targets, developing strategies and creating transition plans. This is important for three reasons: (i) socioeconomic, policy and technology assumptions differ among scenario models, (ii) scenarios can have different purposes (e.g., stress testing, decarbonisation), and (iii) scenarios can offer various views on the transition (e.g., orderly or disorderly transition). A multiple scenario perspective enables a holistic and more informed view on the transition and appropriate targets for each sector.

4. **Actions should be sector-specific:** As decarbonisation pathways of sectors differ and thus emissions reductions per sector differ, scenarios should be assessed at sector-level and actions should be sector-specific, taking interdepencies between sectors (e.g. energy and power, and energy and AFOLU) into account.

5. **Accelerate customer engagement and financing the solutions:** The scenario analysis in this report shows that the transition to a 1.5°C pathway offers huge lending and investing needs and opportunities in all sectors. Engaging with customers to understand their strategies and support their transitions is essential to finance the right solutions and enabling change in the real economy.

The time to act is now. The scenario modelling landscape is fast moving and has already provided key insights to take next steps in the journey towards net-zero. Collaborating with all types of stakeholders is key to drive actions, improve data for steering and reporting, and to enhance further scenario modelling at sector-level. Only through joint efforts, limiting global warming to 1.5°C stays within reach.

13

Glossary

13. Glossary

The following terms and units are used in this report

Black carbon	A type of carbon that is formed through an incomplete combustion of fossil fuels and biofuels.
Carbon budget	The upper limit of carbon dioxide that humanity can emit within the boundaries of a certain temperature goal with a given probability.
Carbon capture, utilisation and storage (CCUS)	The process of capturing carbon dioxide emitted by industrial activities before it enters the atmosphere and consequently storing it elsewhere.
Carbon dioxide (CO_2)	The most common heat-trapping gas of the GHGs which naturally occurs in the Earth's atmosphere but excessively released by human activities.
Carbon dioxide equivalents (CO_2e)	The amount of carbon dioxide (CO_2) that would cause the same integrated radiative forcing (a measure for the strength of climate change drivers) over a given time horizon as an emitted amount of another greenhouse gas or mixture of greenhouse gases.
Carbon Dioxide Removal (CDR)	Anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities.
Carbon price	The application of costs to a unit of carbon dioxide that encourages emitters of carbon dioxide to reduce their emissions.
Carbon sequestration	The process of storing carbon from the atmosphere in a carbon pool through either natural processes or human induced processes.
EJ	Unit of energy: Exajoule (one quintillion (10^{18}) Joule)
Emission intensity	The number of emissions of carbon dioxide equivalents (CO_2e) released per unit of another variable such as gross domestic product (GDP), output energy use or transport.
Gt	Unit of emissions: Gigatonne (one billion (10^9) tonnes)
Greenhouse gases (GHGs)	The seven gases covered by the United Nations Framework Convention on Climate Change (UNFCCC)—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3)
Gross domestic product (GDP)	The monetary total of all final goods and services produced in a specific economy. Often used in the context of one specific nation or globally.
Integrated Assessment Models (IAM's)	A type of scientific modelling that aims to simulate the interactions of human-decision making with the energy system to create a quantitative description of key processes in the earth systems.

Intergovernmental Panel on Climate Change (IPCC)	One of the most well-known intergovernmental bodies of the United Nations to provide policymakers with scientific assessment on human-induced climate change.
Just transition	A Just Transition is a timely, participatory and well-supported transition to a system in which nature and people live in harmony. It is a socially equal and environmentally sustainable transition, consistent with and linked to international climate commitments and the SDGs
Methane (CH_4)	The primary component of natural gas and a common GHG that is also more potent at trapping heat than carbon dioxide.
Mt	Unit of emissions: Megatonne (one million (10^6) tonnes)
Nature-based solutions	Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (IUCN definition)
Network for Greening the Financial System	A network of 83 central banks and financial supervisors that aims to accelerate the scaling up of green finance and develop recommendations for central banks' role for climate change. The NGFS was created in 2017 and its secretariat is hosted by the Banque de France.
Nitrous oxide (N_2O)	Less common of a gas but significantly more potent than carbon dioxide and methane at trapping heat.
No/low overshoot 1.5°C	Climate trajectories that keep global warming consistently below 1.5°C throughout the 21st century or allow a limited "overshoot" of 0.1°C at most
Passenger_km	Unit of passenger transport: representing the transport of one passenger by a defined mode of transport (road, rail, air, sea, inland waterways etc.) over one kilometre.
Primary energy	Energy that is directly harvested from natural sources that has not been subjected to engineered processes.
Tonne	Unit of mass equal to 1,000 kg
Tonne_km	Unit of freight transport: representing the transport of one tonne of goods (including packaging and tare weights of intermodal transport units) by a given transport mode (road, rail, air, sea, inland waterways, pipeline etc.) over a distance of one kilometre.

Appendix

A. Overview of 1.5°C scenarios

	AIM/CGE 2.0	JRC POLES - GECO	NGFS – Orderly*	IEA NZE - 2050
1.5°C aligned	There are multiple 1.5°C degree aligned scenarios by AIM/CGE as pre-selected and filtered in SBTi's foundation paper.	The Joint Research Centre POLES GECO scenario is 1.5°C aligned but also offers a 2°C variant with similar granularity.	The Orderly pathways from NGFS include three 1.5°C scenarios (Net Zero 2050).	NZE2050 refers to a single scenario from the IEA that is 1.5°C aligned and one of the most ambitious and detailed to date.
Geographic granularity	AIM/CGE scenarios are modelled in 17 regions/countries with an emphasis on Asian countries. However, not all data is publicly available.	The POLES GECO scenarios cover 39 world regions and the EU27.	In terms of geographic granularity, the recent NGFS scenarios have the best granularity and data availability. The scenarios have been downscaled to over 170 countries.	This scenario is modelled in various regions, however the data is only available on a global level.
Sectoral granularity	AIM/CGE technical documentation indicates 5 macro-economic sectors next to energy and land use, with industry broken down into 13 production sectors. However data is far less available at sectoral level.	Next to the breakdown of primary energy and power, final energy consumption is available for 10 sectors.	The scenarios offer limited granularity with 7 high-level sector and lack activity data that is needed for intensity calculations, especially for heavy emitting industries.	NZE2050 offers detailed sectoral granularity, including industries like cement and steel, and disclose more activity data for creation of emissions intensity pathways.
Overshoot	The preferred 1.5°C scenarios by SBTi from AIM/CGE are no/low overshoot scenarios with 50% probability.	The POLES GECO 1.5°C scenario was designed with a probability not to exceed their temperature change at the end of the century of 50%.	The NGFS Net Zero 2050 – reaches zero emissions around 2050, giving at least a 50 % chance of limiting global warming to below 1.5 °C by the end of the century, with no or low overshoot (< 0.1 °C) of 1.5 °C in earlier years.	This scenario is a no/low overshoot scenario with 50% probability of limiting the average global temperature rise to 1.5 °C.
Negative emissions technologies	The selected AIM/CGE scenarios in SBTi foundation paper include a range of 6.8-17.9 GtCO_2 for CCS and 4.2-5.5 GtCO_2 removed by land use and afforestation in 2050	In POLES GECO 1.5°C scenario, 4.6 GtCO_2 is captured via CCS and 3.2 GtCO_2 is removed by land use and afforestation in 2050	The three NGFS Net Zero 2050 scenarios give a range of 2.9-5.4 GtCO_2 for Carbon Capture and Storage (CCS) in 2050 and 4.8-5.6 GtCO_2 of Cabon Dioxide Removal (CDR)	IEA NZE2050 includes 7.6 GtCO_2 emissions captured and 1.9 GtCO_2 of emissions removals in 2050

** NGFS scenarios have been generated by 3 different Integrated Assessment Models, namely GCAM, MESSAGEix-GLOBIOM and REMIND-MAgPIE.*

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