CGE Training materials - Mitigation Assessment

Module B

Mitigation Options by Sector

Consultative Group of Experts (CGE)

United Nations
Climate Change Secretariat

Outline

I. General considerations

II. Energy supply

III. Transport

IV. Buildings

V. Industry

VI. AFOLU

VII. Cross-cutting

Module objectives and expectations

The objective of this session is to provide the participants with review of the key sectors related to greenhouse gas (GHG) mitigation as well as cross-sectoral opportunities for GHG mitigation including:

- Emissions sources, trends, and drivers
- Impacts of climate change on the sector
- Mitigation technologies and strategies
- Policies and measures for their adoption and implementation
- Common barriers and potential solutions

Expectation: Participants will have a broad but sound understanding of the key sectors and cross-cutting opportunities for GHG mitigation actions.

MODULE B1

GENERAL CONSIDERATIONS

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The urgency of climate action

- Module A provided an overview of the impacts of climate change on the Earth's processes and subsequent effects on human lives
- Although global emissions must be cut almost in half before 2030 to enable temperature increase to remain below 1.5°C, they are on track to rise by 14%
- Under current Nationally Determined Contributions (NDCs), the world is headed for 2.8 degrees of global heating by the end of the century (UNEP Gap Report 2022)
- Continuing on this path will lead to catastrophic impacts, especially on the most vulnerable populations
- Only an urgent system-wide transformation can avoid an accelerating climate disaster

…the clock is ticking.
We are in the fight of our lives.
And we are losing.

United Nations Secretary-General António Guterres

Fundamental distinctions in mitigation actions

Technologies and practices that reduce GHG emissions ← enabling — **Policies and instruments that lead to the use of these technologies and practices**

- Efficiency (demand, supply)
- Substitution (fuels, feedstock, products)
- End-of-pipe (carbon capture and storage-CCS)
- Practices (farming, land clearing, change in mobility patterns, etc.).

- Economic and financial instruments (e.g. taxes and incentives, markets, trade policy)
- Regulatory approaches (e.g. standards, required practices)
- Information (e.g. labelling, campaigns)
- Capacity building (e.g. institutions, skilled workforce)
- Research & development

← Strengthening institutions & stakeholder engagement

A national enabling environment for successful mitigation

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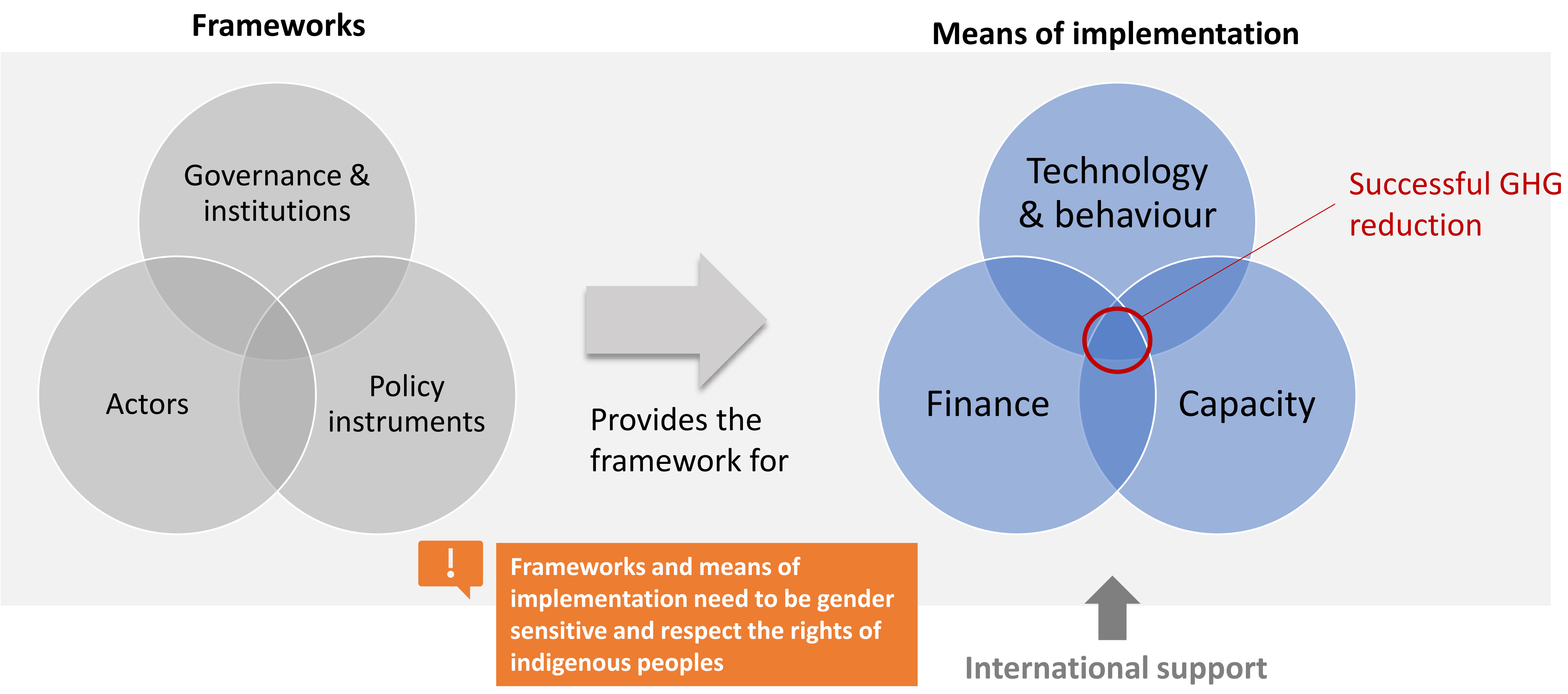

Linkages between mitigation and adaptation

LINKAGES WITH INTERNATIONAL AGENDAS

CONVENTION ON BIOLOGICAL DIVERSITY

Decision V/3 on marine and coastal biodiversity, and decision VIII/30 on synergies between biodiversity and climate change

UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION

Article 10 of UNCCD on measures to mitigate the effects of drought (early warning systems, assisting environmentally displaced persons, food security systems and alternative livelihood projects).

FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS

FAO strategy on climate change (focusing on food security, forestry agriculture and fisheries)

MITIGATION & ADAPTATION LINKAGES WITHIN THE UNFCCC

CONVENTION

Article 2: Mitigation actions to allow adaptation of ecosystems and sustainable development

Article 4: Taking climate change into account in social, economic and environmental policies

KYOTO PROTOCOL

Article 12: Clean Development Mechanism (CDM) to achieve sustainable development

PARIS AGREEMENT

Article 2: Climate change in the context of sustainable development

Article 5: Joint adaptation and mitigation for sustainable management of forest management

Article 4: Mitigation co-benefits from adaptation and/or economic diversification

Article 7: Link between need for adaptation and level of mitigation

KEY RELEVANT COP DECISIONS

1/CP.21, paragraph 108: Recognizing the social, economic and environmental value of voluntary mitigation actions and their co-benefits for adaptation, health and sustainable development

4/CP.23: Koronivia joint work on agriculture

1/CP.21, paragraph 127: Identifying adaptation actions that could enhance economic diversification and have mitigation co-benefits

9/CMA.1, annex, bullet f: Including adaptation actions that result in mitigation co-benefits into the elements of adaptation communications

SUSTAINABLE DEVELOPMENT GOALS

RESOLUTION 70/1 OF THE UNITED NATIONS GENERAL ASSEMBLY, LIST:

- **GOAL 1:** No Poverty
- **GOAL 2:** Zero Hunger
- **GOAL 3:** Good Health and Well-being
- **GOAL 4:** Quality Education
- **GOAL 5:** Gender Equality
- **GOAL 6:** Clean Water and Sanitation
- **GOAL 7:** Affordable and Clean Energy
- **GOAL 8:** Decent Work and Economic Growth
- **GOAL 9:** Industry, Innovation and Infrastructure
- **GOAL 10:** Reduced Inequality
- **GOAL 11:** Sustainable Cities and Communities
- **GOAL 12:** Responsible Consumption and Production
- **GOAL 13:** Climate Action
- **GOAL 14:** Life Below Water
- **GOAL 15:** Life on Land
- **GOAL 16:** Peace, Justice, and Strong Institutions
- **GOAL 17:** Partnerships for the Goals.

Different levels of mitigation potential

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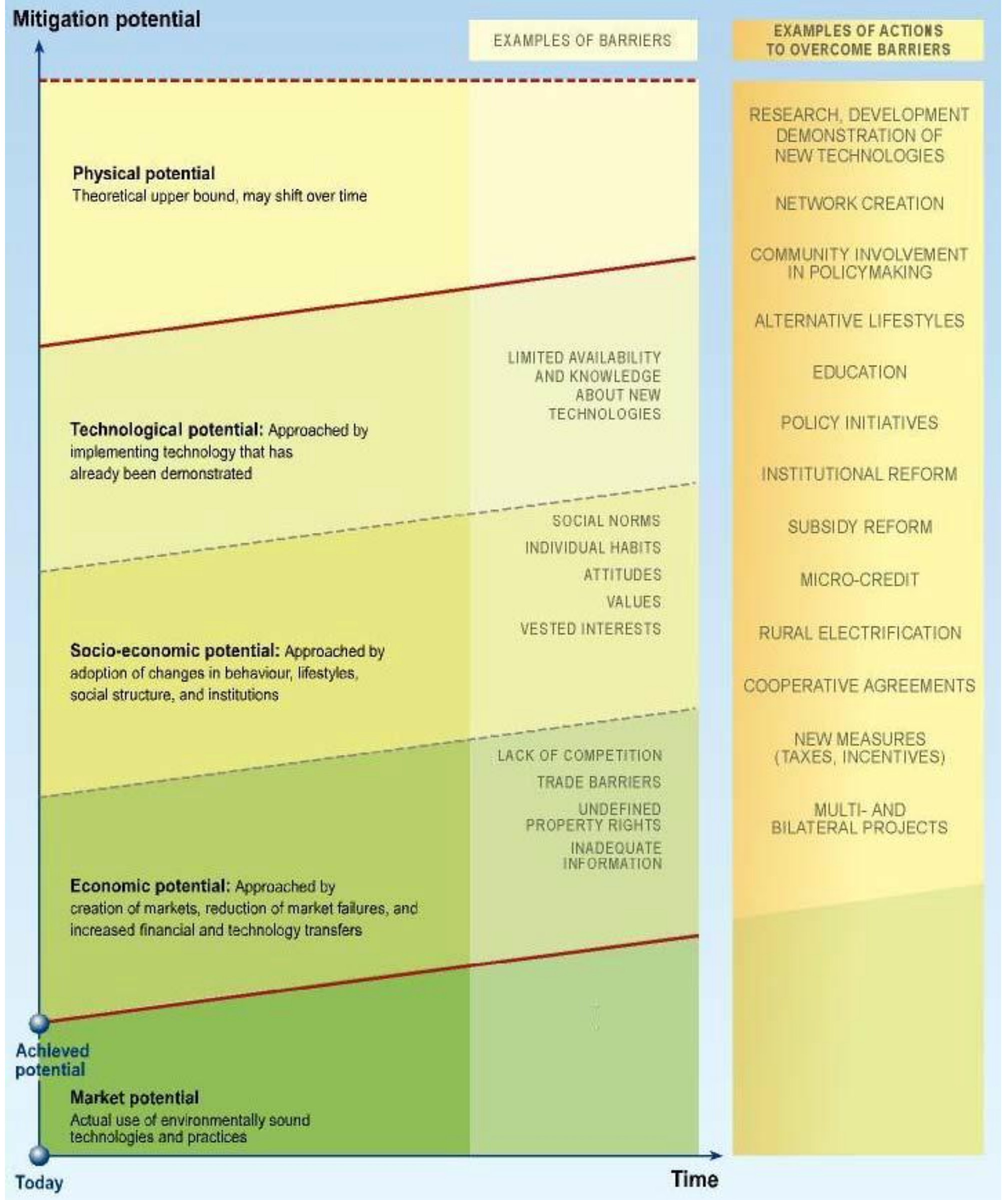
The share of the theoretically possible mitigation potential that is achieved on the ground, is limited by several barriers:

- Currently demonstrated **technology** does usually not cover the full physical potential (top red line).
- The **technological potential** is not fully deployed through availability and knowledge.
- The implementation of solutions is further reduced by **socio-economic factors** that limit adoption of technologies and practices.
- The structure of markets does not always ensure that measures that benefit the **overall economy** are implemented.
- The **market potential** reflects potential that is financially viable and most likely to be achieved (bottom red line).



Examples of barriers to tap the full technological potential

- Insufficient access to financial and technical support to facilitate technology development and transfer (TDT)
- Lack of a regulatory environment and enabling policies concerning climate technologies
- Lack of private sector involvement in the process of TDT (lack of business case or value proposition)
- Lack the infrastructure needed for technology innovation and development
- Slow pace of licensing climate technologies
- Intellectual property rights that can act as a barrier to deploy where it is needed
- Market barriers often either incentivize or disincentivize uptake of climate technologies
- High (upfront) costs associated with some climate-related technologies, especially if they are new
- Lack the institutional capacity at national level to turn technology needs assessments into bankable projects
- Lack of awareness and understanding of climate technologies that could be feasible in terms of national circumstances
- Lack of political will and championing in both developed and developing countries on TDT

! **Specific barriers for individual sectors will be highlighted in the sectoral submodules**

Action areas to overcome barriers

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Innovation
There is a need to rally stakeholder and build the infrastructure needed to support innovation and research and development of climate technologies that will suit the developing country context and technology assessment needs.

Implementation
Developing countries need very clear modalities and processes from which they can access financial and technical support to enhance TDT.

Support
More financial and technical resources need to be mobilized to support climate technology development

Enabling environment & capacity development
Sound, robust institutional arrangements and the legal frameworks at national level are needed to support TDT and give direction to stakeholders such as the private sector to deploy climate technologies. Building national capacity of technology experts nationally can help with TDT.

Collaboration & stakeholder engagement
A broad range of stakeholders needs to come together to achieve the needed TDT. Very often stakeholders have diverging and converging interests to the national agenda on climate change and it takes a lot of relationship-building to unlock the cooperation needed.

Clarifying concepts: net-zero vs. neutrality

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At the **global scale** the concepts are equivalent

Net-zero: Emissions and removals **within** the direct control or territorial responsibility of a country or entity

Neutrality: Includes emissions and removals **outside** the direct control or territorial responsibility of a country or entity

CO_2 only	Net-zero CO_2 emissions	Carbon neutrality
All GHGs	Net-zero GHG emissions	GHG neutrality

"Commitments to net zero are worth zero without the plans, policies and actions to back it up"

United Nations Secretary-General António Guterres

Include 'scope 3' or 'value chain' emissions and are usually used for companies, commodities and activities, and can include offset mechanisms.

Clarifying concepts: net-zero/neutrality vs. zero emissions

Zero emissions
=
Reducing ALL emissions to zero

Challenges

In some sectors emissions are very difficult to reduce, such as:

- Process emissions in industry
- CH_4 and N_2O emissions in agriculture

Action needs to happen everywhere (all countries, all sectors) rapidly.

Net-zero / carbon neutrality
=
Compensating remaining emissions with carbon dioxide removals

Challenges

- Reliance on carbon removal technologies that are largely unproven at large scale
- Reliance on fast-cycle carbon sequestration in vegetation and soils to replace slow-cycle fossil storage
- Reliance on offsets from other countries and sectors becoming increasingly difficult with more ambitious NDCs from all countries
- Vegetation-based carbon removals can threaten the rights, cultures, and food security of Indigenous Peoples and local communities

Transformative vs. incremental action

- Incremental change will modify current systems in via simple and minor changes at a time.
- Transformative change will lead to a fundamental system change, often requiring a change of goals.
- Both types of change are needed:
  - Some sectors or areas of action will require more **transformational thinking**.
  - For other areas or in some countries incremental steps can be successful, **if they are sufficient in ambition, timing and scale.**

Transformative action is required where decisions today can lead to lock-in of infrastructure or habits or where existing infrastructure needs to be replaced fast

Incremental action needs to enable that overall decarbonisation goals are achieved within the required timeframe. Actions need to have a clear timeline of increasing ambition levels.

"Yes, decarbonization implies transformational change and will require massive investments … but our return on investment will be recouped many times over in socioeconomic benefits, jobs and welfare."

Andrea Meza, Deputy Executive Secretary of the United Nations Convention to Combat Desertification (UNCCD)

General considerations for mitigation strategies

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- Overcoming barriers requires a wide variety of policies, measures and instruments.
- Taking advantage of capital stock turnover and periods of rapid social change can minimize disruption and mitigation costs.
- National responses to climate change can be more effective if deployed as a portfolio of policy instruments to limit or reduce GHG gas emissions.
- Effectiveness can be enhanced when climate policies are integrated with the non-climate objectives of national and sectoral policy (e.g., air pollution, energy access, industrial competitiveness).
- Coordinated actions among countries and sectors may help to reduce mitigation costs, address competitiveness concerns and carbon leakage.

Governance & institutions

Climate governance challenges include:

Strong and reliable institutions and processes are essential to motivate private sector investment and tap into climate finance

Ensuring coordination

- High-level coordination bodies help better coordinate intra-governmental processes.
- Institutional arrangements need clear authority and legal mandate for setting directions.
- Coordination needs to be ensured across all levels of government.

Building consensus

- Institutions are needed to mediate differing interests and build trust and consensus on future pathways.
- Credible institutions can help to provide knowledge to support consensus.
- Winners and losers of the transition need to be on the table.

Setting strategy

- The needed transformation requires long-term strategic intent.
- Deliberate and lasting institutions and processes that provide this guidance will enable the transformation.
- Integrating international development priorities will foster support.

Actors in the political process

- A broad array of actors are engaged in shaping mitigation policy processes, including politicians and political parties, corporate actors, citizen groups, indigenous peoples' organizations, labour unions, academic institutions, national agencies and international organizations.
- Subnational actors play a crucial role in developing, delivering and contesting decarbonisation pathways.
- Some actors are directly involved in political decision-making (politicians and political parties), while others aim to influence such decisions, with the interests of their respective constituencies in mind.
- Actions to influence policy take many forms: direct influence on politicians, information generation and dissemination, boycotts, strikes, protests, and legal action (litigation).
- Media is another platform for various actors to present, interpret and shape debates around climate change and its governance, but it can also be a useful tool to build public support for measures that accelerate mitigation action.
- Partnerships, e.g. among private and public, or transnational and subnational entities, can enable better mitigation results.

Types of policy instruments for GHG mitigation

Economic

Carbon taxes, GHG emissions trading, fossil fuel taxes, tax credits, grants, renewable energy subsidies, fossil fuel subsidy reductions, offsets, R&D subsidies, loan guarantees, direct investment from public budgets

Regulatory

Energy efficiency standards, renewable portfolio standards, vehicle emission standards, ban on SF6 uses, biofuel content mandates, emission performance standards, methane regulations, land-use controls

Other

Information programs, voluntary agreements, infrastructure, government technology procurement policies, corporate carbon reporting

Only a stable policy framework will trigger private sector investment and behaviour change

The ‘Avoid-Shift-Improve’ framework

There is high untapped potential of demand-side mitigation options if considered holistically using the ‘avoid-shift-improve’ approach. This applies to all demand sectors.

Avoid
Reduce activity levels

→

Shift
Move behaviour to more sustainable solutions

→

Improve
Enhance efficiency and technological performance

! Policies currently focus more on efficiency and ‘improve’ options and relatively less on ‘shift’ and ‘avoid’ options.

Types of barriers and options to overcome them

Barriers	Options to overcome barriers
Governance, actors and policy instruments	
• Conflicting goals • Uncertainty of long-term policy framework • Inadequate enforcement • Unclear responsibilities and lack of coordination • Counter-acting subsidies or taxes • Missing or counterproductive regulation • Undefined property rights • Principle-agent issues • Inadequate information • Vested interests	• Creating an integrated, long-term strategy, involving all stakeholders • Implementation of coordinating bodies or institutions • Put in place missing legislation or adapt existing legislation • Establish institutional and legislative systems to gather required data at the required level of detail, frequency and quality
Technology barriers	
• Lack of access to technologies • Low quality of local technology products • Limited availability of monitoring technology (e.g. satellite monitoring) • Lack of standardization	• Strengthen national research and development (R&D) activities • Incentivize national technology production • Strengthen education and training • Support standardization, e.g. through industry round tables

Types of barriers and options to overcome them

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Barriers	Options to overcome barriers
Capacity constraints	
• Limited number of experts in-country • Limited local R&D • Limited awareness about technical solutions • Limited knowledge on related benefits of mitigation technologies • Lack of technical personnel for installation and maintenance • Lack of personnel for monitoring and enforcement • Unavailability of detailed information on wind potentials and solar irradiation • Lack of training and education capacity	• Strengthen education and training system, e.g. introduction of formal training programmes for selected technologies • Increase R&D investment • Awareness campaigns • Pilot/demonstration projects • Develop strategic partnerships with international funders
Financial constraints	
• High up-front investment cost • Access to loans at competitive interest rates • Short-term perspective of investors • Continuity of finance • Unclear risk assessment and management	• Governmental incentive schemes with low interest rates • Information and awareness campaigns • Develop consistent, clear and long-term strategies to reduce investor risk perception

Adoption of instruments in different sectors

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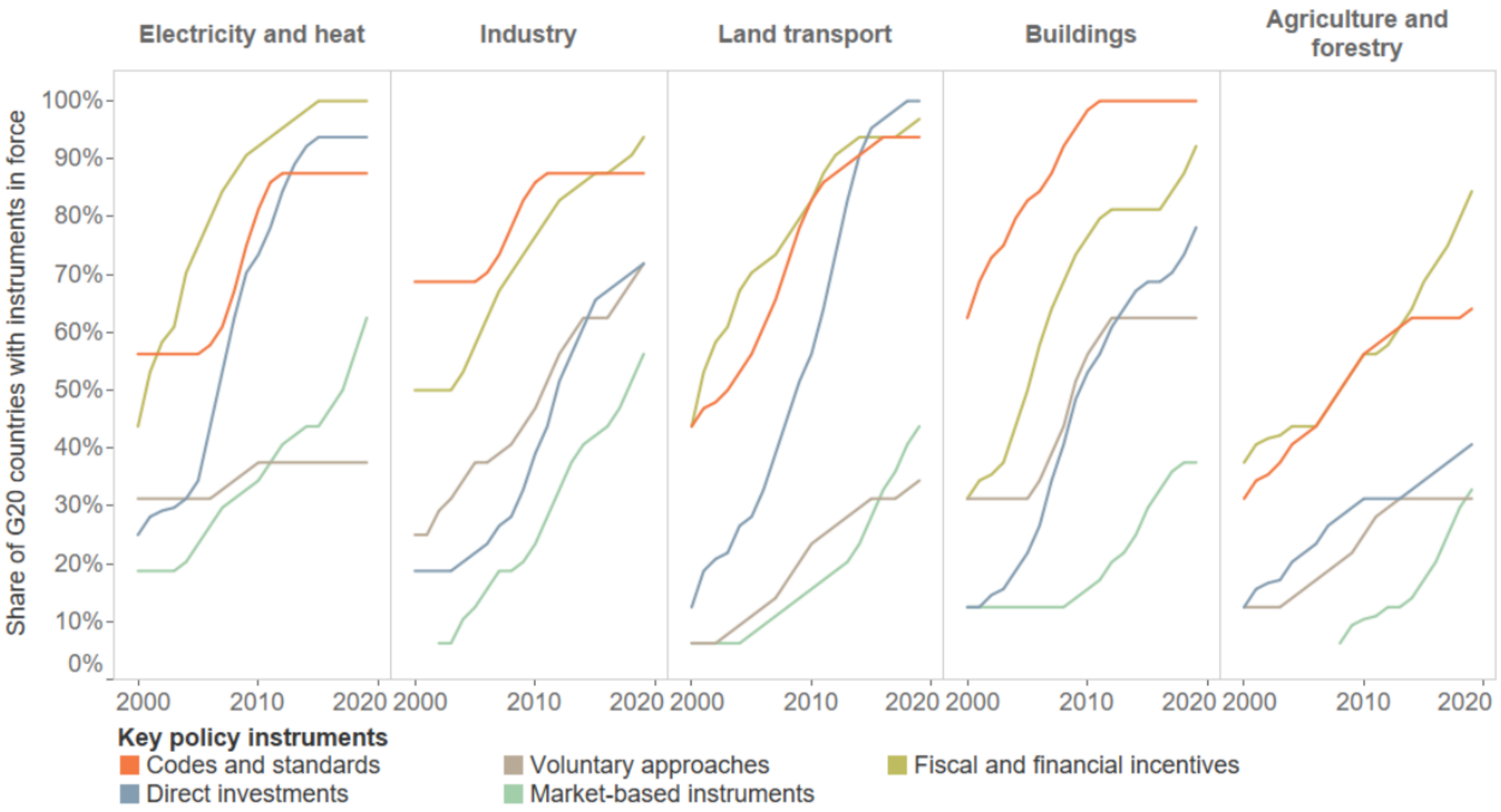
- Analysis of policy instruments in G20 countries shows a steady increase over the past two decades.
- There are sectoral differences in the number of policies in place, as well as the composition, i.e. which types of policies are implemented.
- Only a small share of non-CO_2 emissions are subject to mitigation policies.



MODULE B2

ENERGY SUPPLY

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Energy supply: Key challenges

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- Meeting increasing demand for energy services while minimizing climate and environmental impacts.
- Dominance of fossil fuels in electricity generation.
- Long lifetime of capital stock, especially fossil-fuel based power generation infrastructure.
- Complexity of managing grids with increasing shares of variable renewable energy.

> *"The wide range of energy sources and carriers that provide energy services need to offer long-term security of supply, be affordable and have minimal impact on the environment.... three... goals [that] often compete."*
>
> *IPCC (2007) AR4 WGIII*

Status: Energy demand is a key driver for GHG emissions

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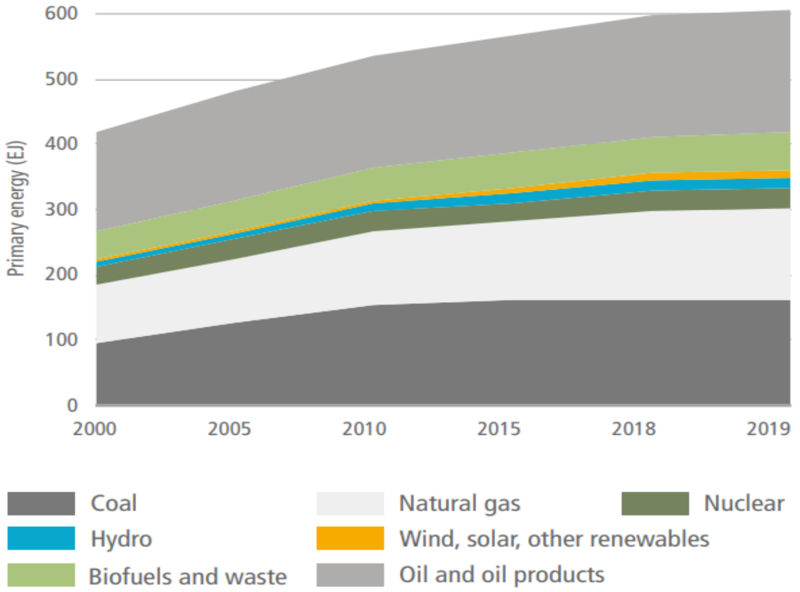
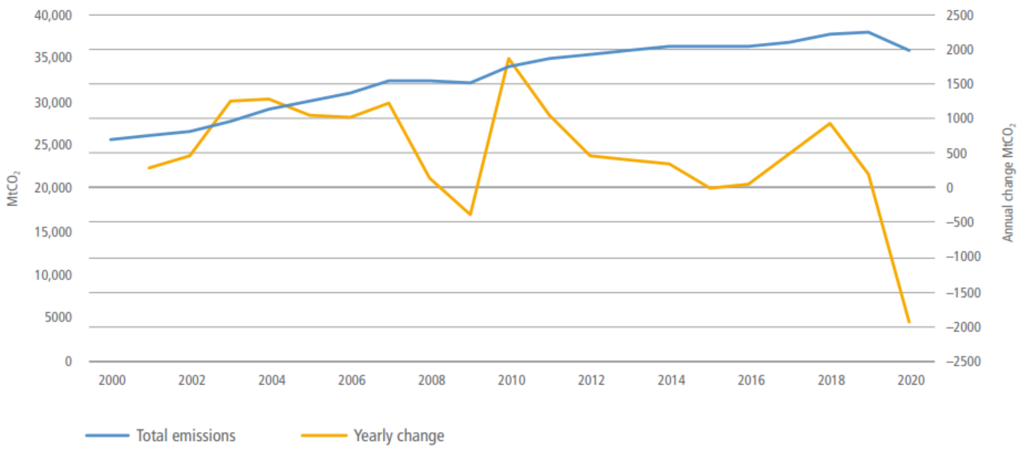
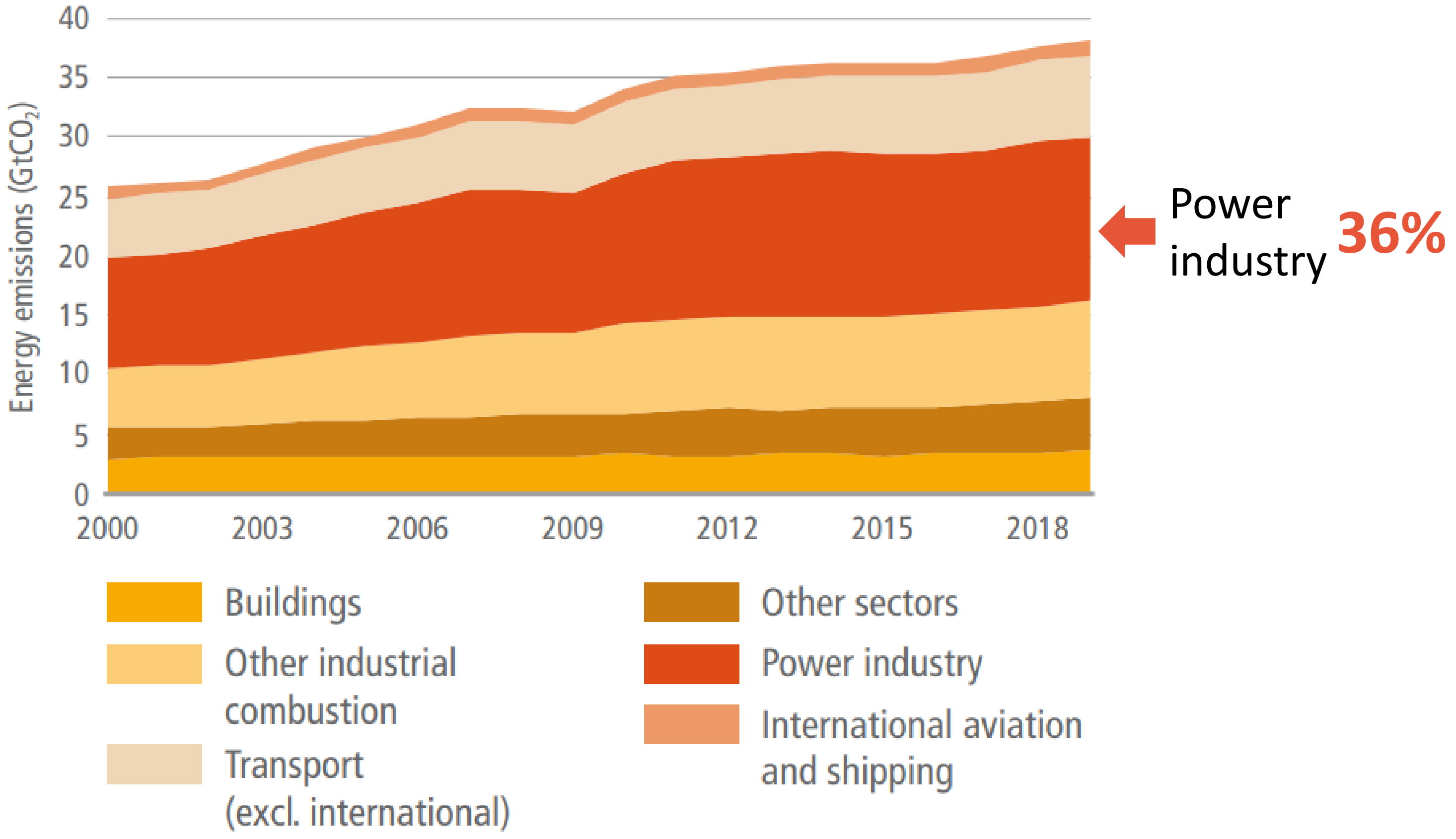
- Global energy system fossil fuel CO_2 emissions grew by 4.6% between 2015 and 2019, reaching 38 Gt CO_2 in 2019.
- Total primary energy supply (TPES) for the energy system grew by 6.6% over the same period.
- Fossil fuel energy supply and use account for around two thirds of total GHG emissions.
- Coal, gas and oil have been the key primary energy sources for the past decades, but natural gas consumptions grew most quickly between 2015 and 2019.
- Modern renewable energy (excl. hydro) had the highest growth, but their share in TPES remains negligible at 2.2%.
- Oil products used for transport accounted for 41% of total final energy consumption (TFC) in 2019.





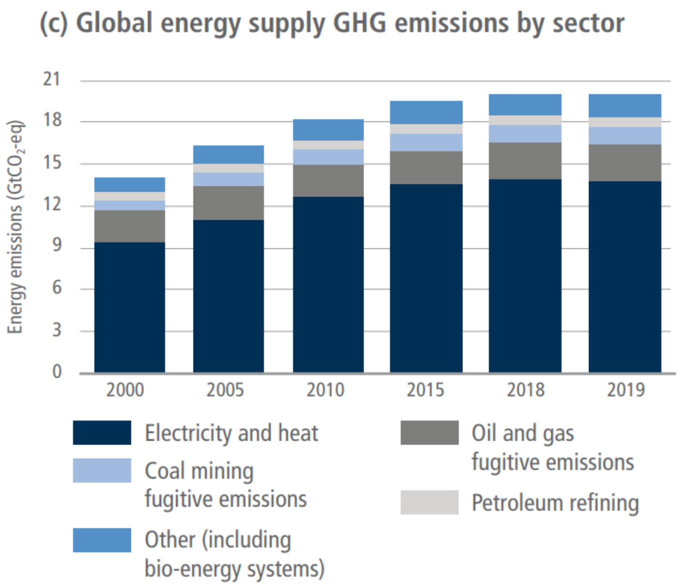
Power generation remains the largest emitter

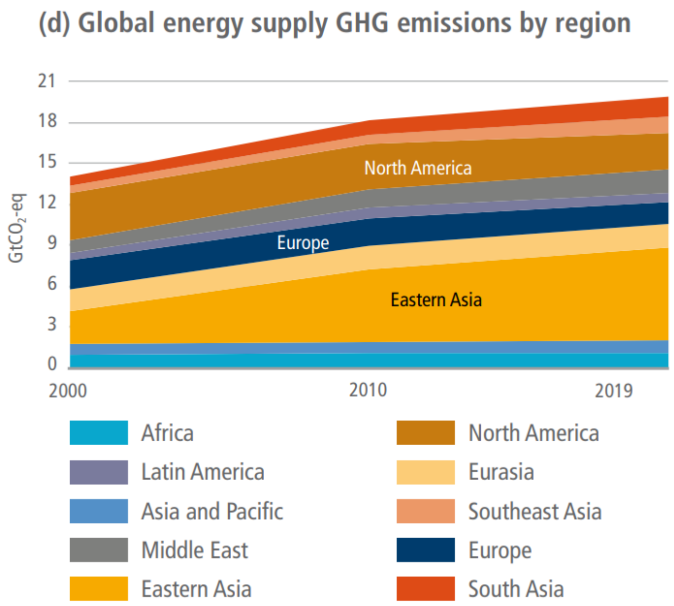
- The electricity sector remains the single largest source of energy sector CO_2 emissions.
- Electricity sector emissions continue to rise despite rapid deployment of wind and solar power



Energy supply emissions: Past trends

- Energy supply GHG emissions increased by 2.7% from 2015 to 2019.
- Electricity and heat generation was responsible for around 69% of energy supply GHG emissions in 2019.
- 18% were from non-CO_2 gases, mostly fugitive emissions linked to oil and gas production and coal mining.
- Global energy sector GHG emissions have been driven by rising emissions in some large developing and emerging countries.
- Per capita emissions in these countries remain well below those in developed countries.





Non-climate drivers for energy system changes

Energy access

The share of the population with access to electricity increased from 73% to 90% between 2000 and 2019.

Energy security

Energy security is perceived as a national security issue and often prioritized over climate concerns.

Air pollution

In some places, the prospect of reducing local air pollution remains more salient to policymakers and the public than climate mitigation.

Technological progress

Technology development enables new solutions and decreases costs, such as for renewable technologies or batteries over the last years.

Energy system supply projections under current policies

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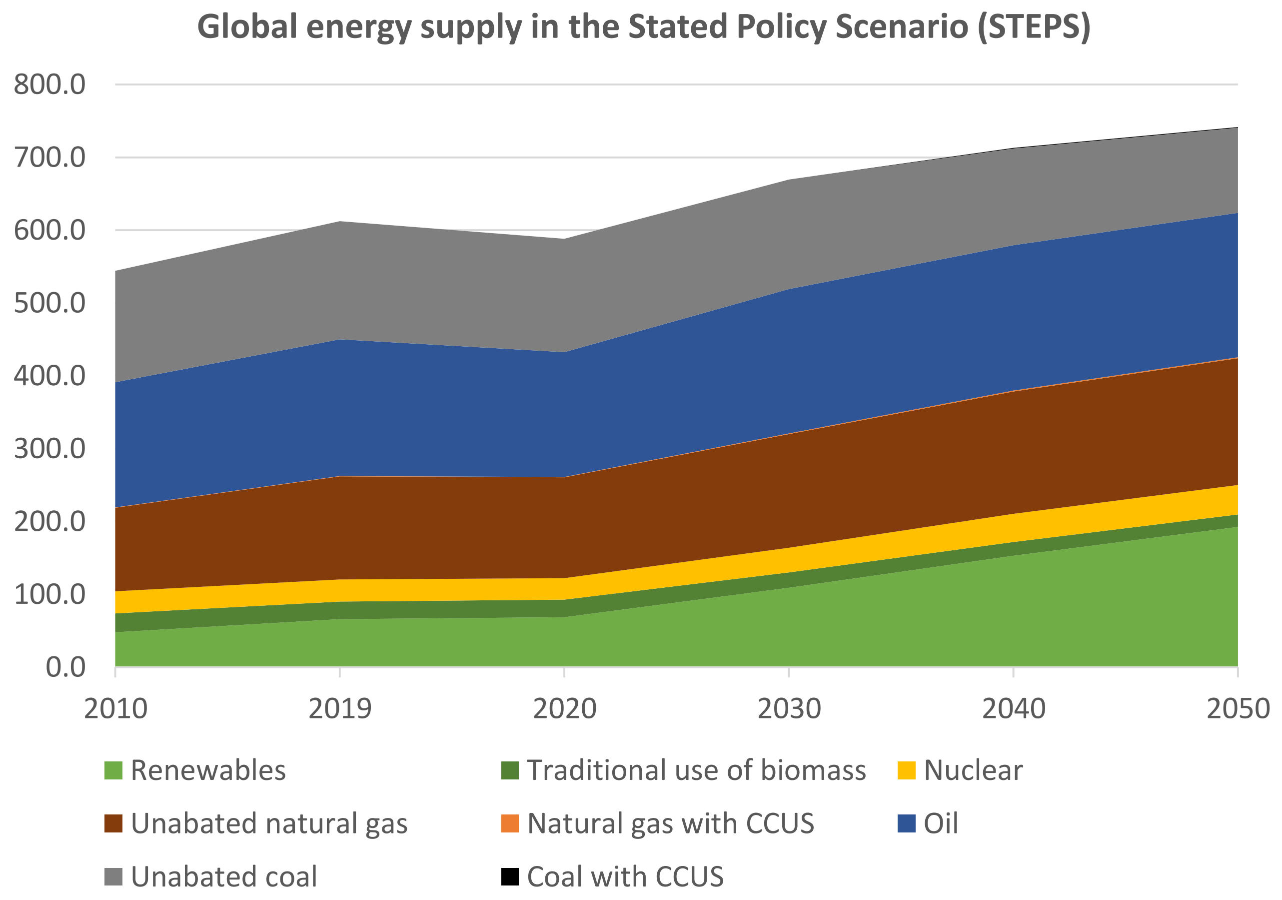
- Global total energy system supply is projected to grow by 1.3% annually up to 2030 (IEA, WEO 2022).
- Renewables (excl. traditional biomass) grow by 4.8% annually up to 2030.
- The total share of renewables remains low at 16% by 2030 and 26% by 2050.
- Coal demand declines significantly after 2025.
- Oil demand continues to rise until 2030 and then plateaus.
- Gas demand continues to increase until 2050.



Possible net zero energy systems

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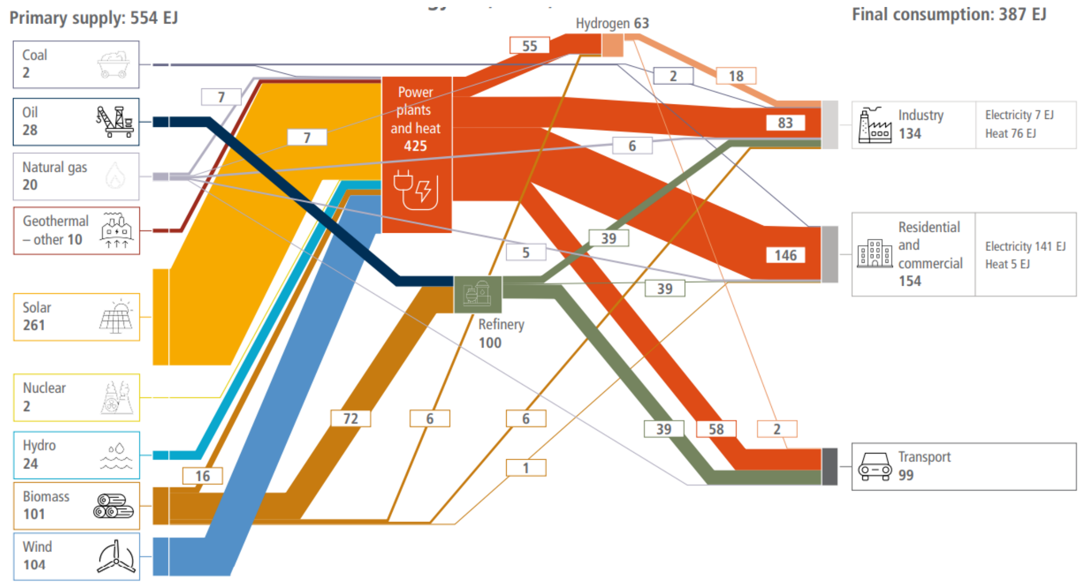
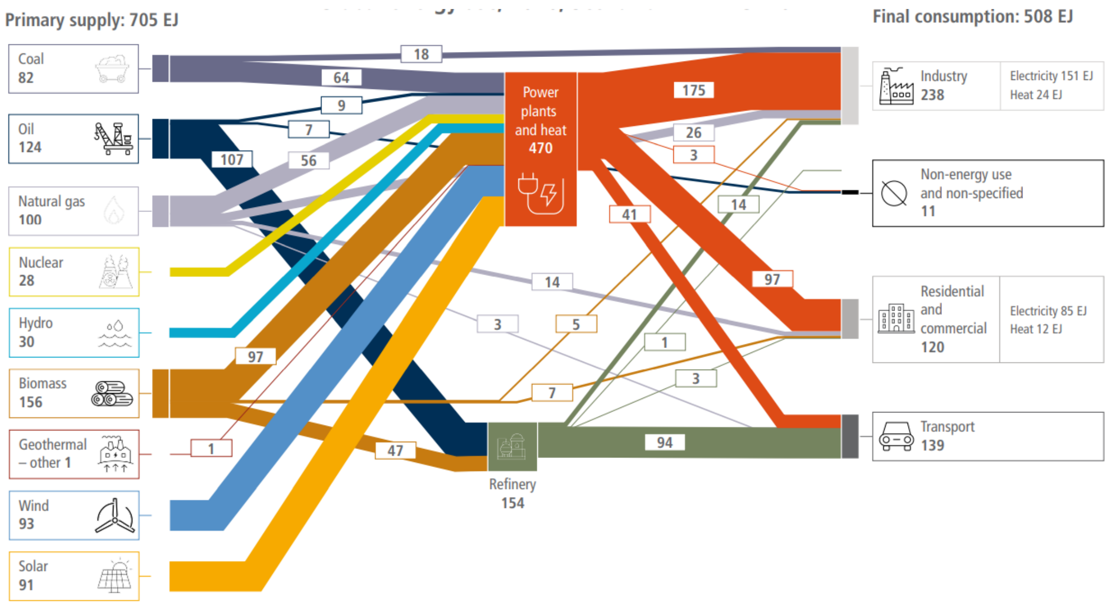
There are very different net zero energy systems possible, depending on:

- The level of energy efficiency assumed.
- Choices on fuel types.
- The level of CDR.

They also differ in the year they achieve net zero emissions:

- The illustrative pathway in the top graph achieves this in 2060.
- The illustrative pathway in the bottom graph achieves this in 2070.





Timing of net-zero emissions for electricity generation

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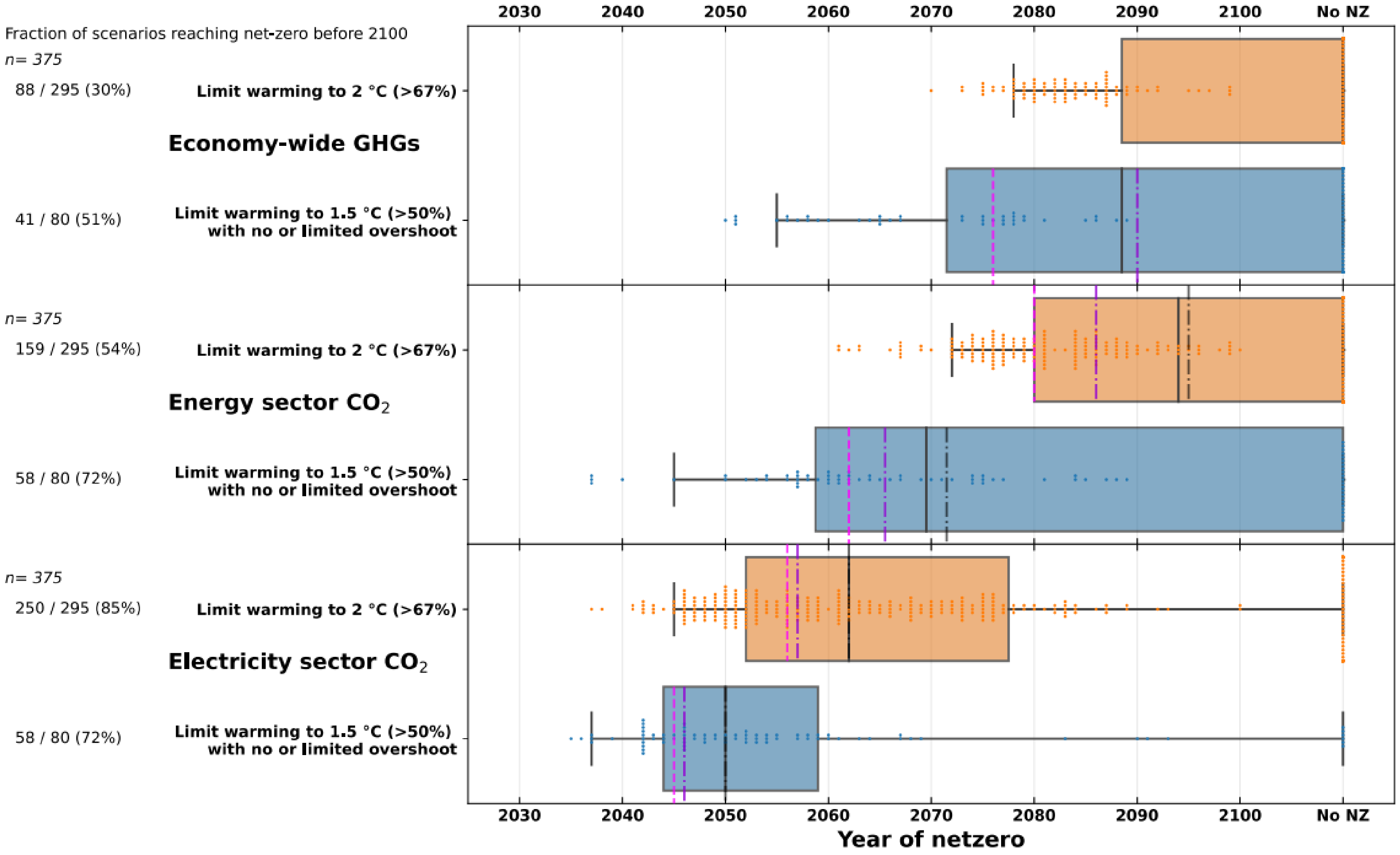
The electricity generation sector will need to fully decarbonise faster than other sectors..

This is especially important as other sectors move towards higher electrification, such as electric vehicles, heat pumps, etc.



Climate change impacts on the energy supply system

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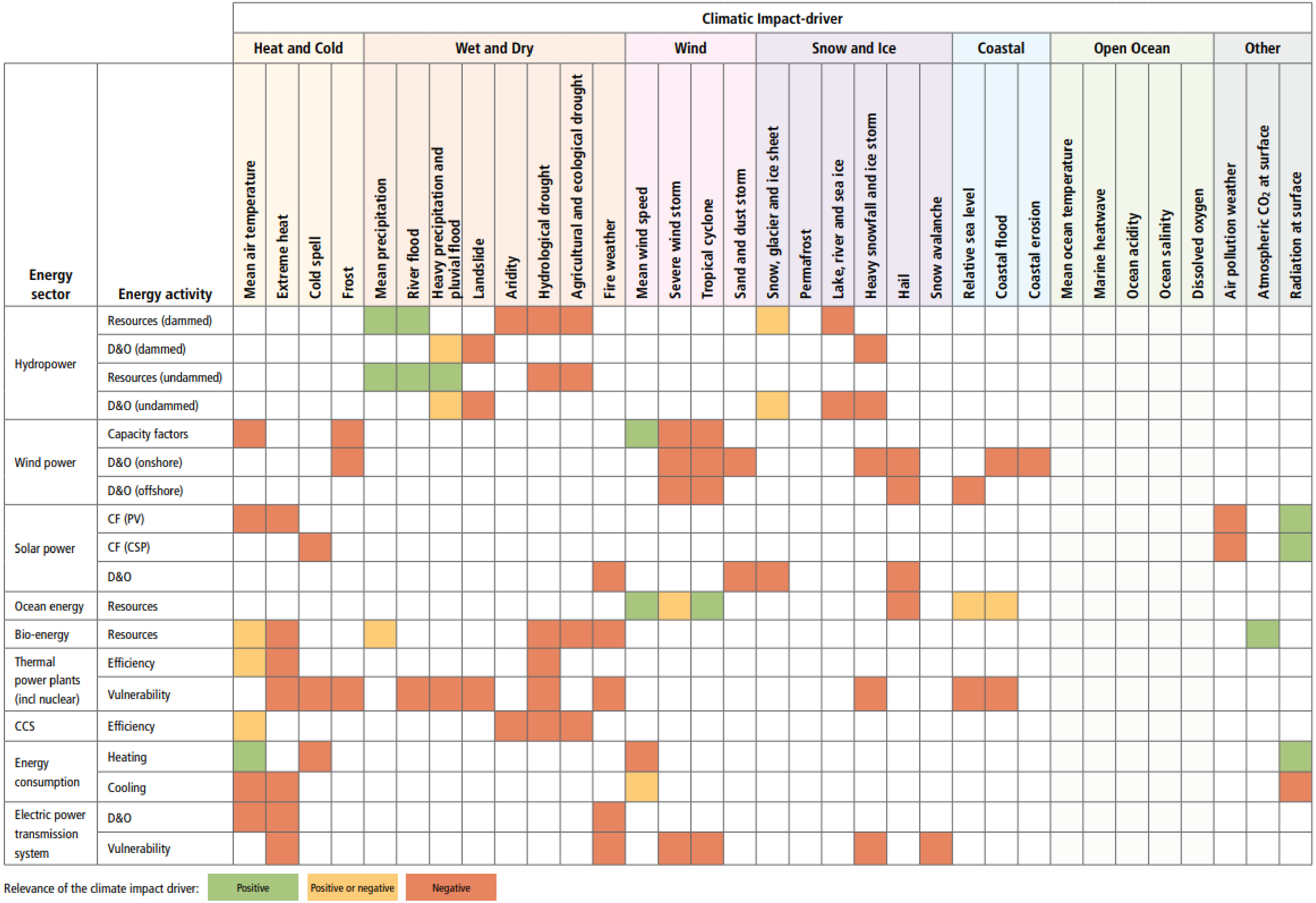
- Local impacts could be significant.
- Thermal power plants are affected most severely.
- Effects need to be considered in energy system and mitigation planning.



Energy supply mitigation technologies

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Some of the mitigation options will require the application of carbon capture and storage (CCS) or carbon dioxide removals (CDR) in the long-term to achieve full decarbonisation, as they continue reliance on fossil fuels.

Fuel production

- Reduction and use of fugitive emissions from mining & extraction
- Efficiency of operations

Fuel type

- Shift to renewable sources:
  - Wind
  - Solar
  - Hydro
  - Ocean
  - Geothermal
  - Bioenergy
- Shift to low-carbon sources:
  - Nuclear energy

Conversion

- Enhance plant efficiency
- Shift to other technologies

Storage

- Enhanced storage to enable variable renewables
- Carbon dioxide removal (CDR)

Transport & transmission

- Reduction in transmission & transport losses
- Decentralisation
- Hydrogen

Energy system integration

- Flexibility technologies
- Advanced control systems

Carbon dioxide removal in net zero energy systems

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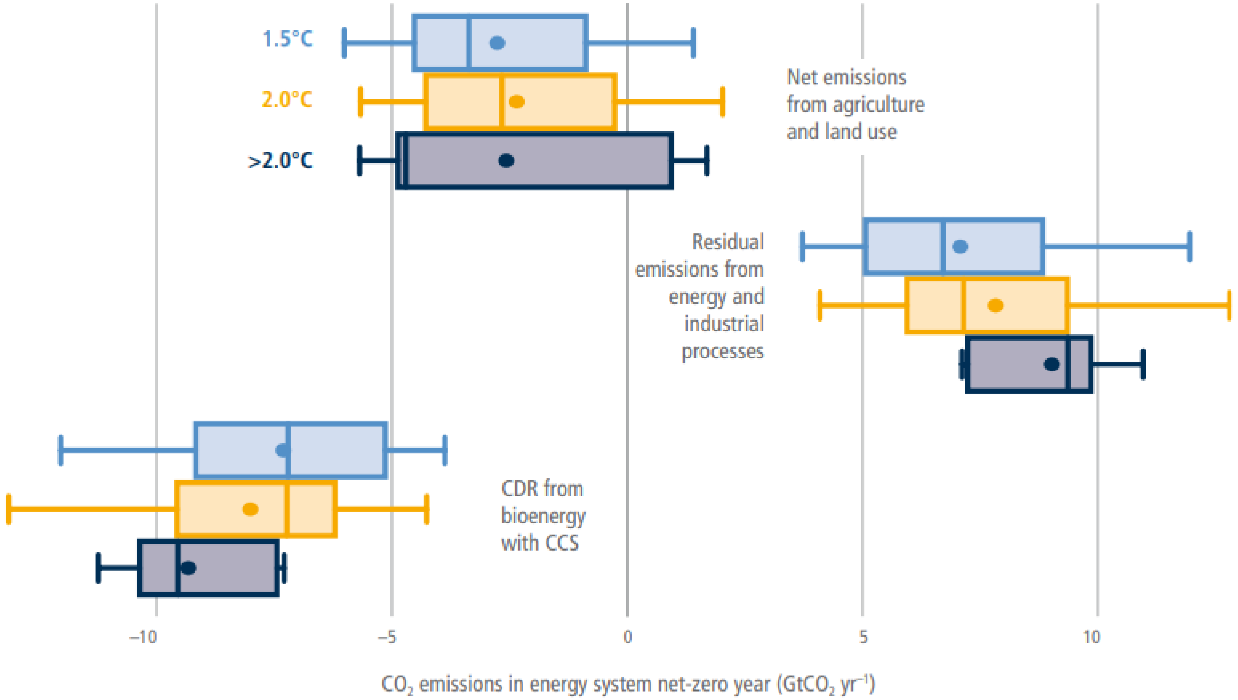
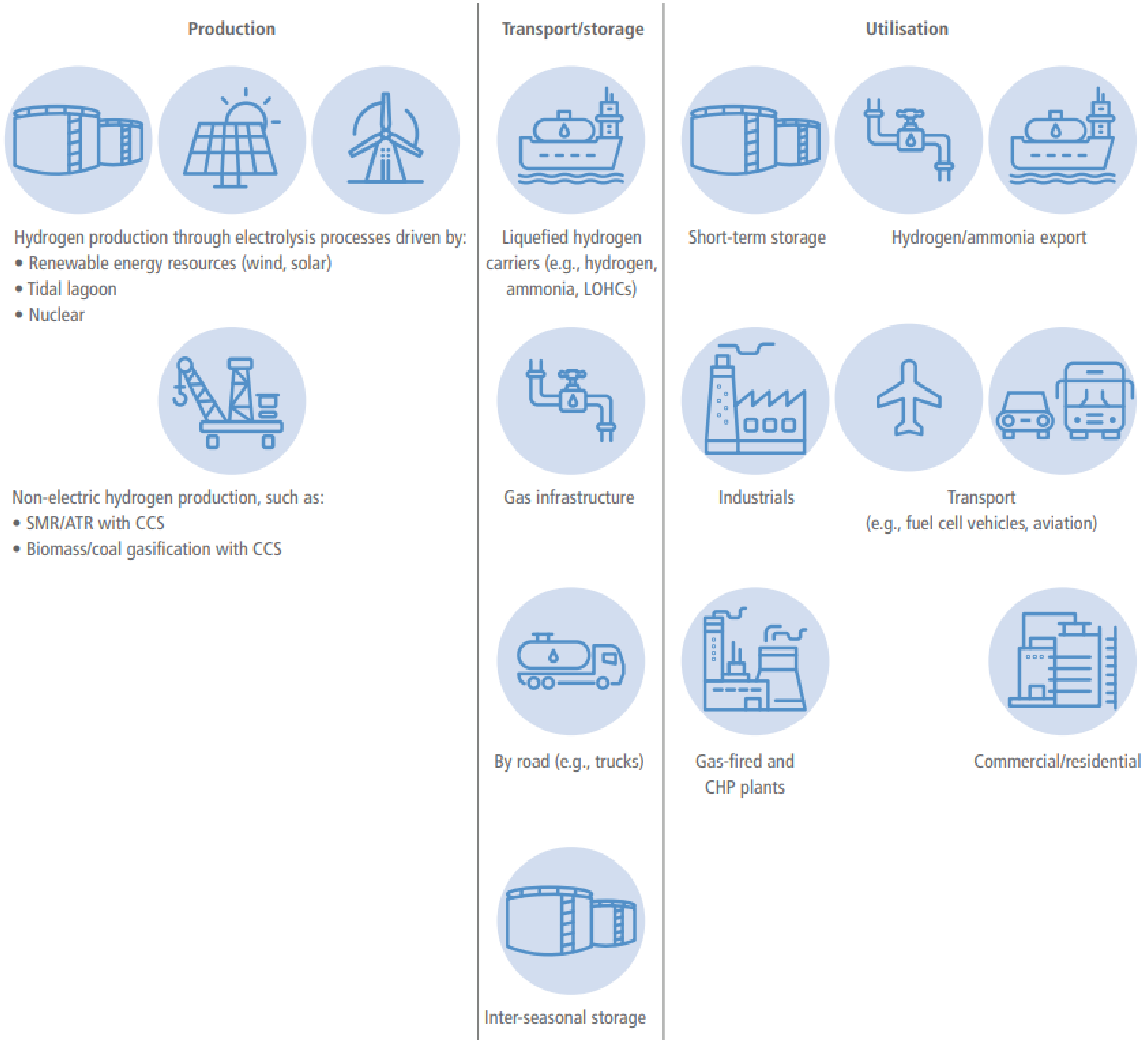
- Remaining GHG emissions would need to be compensated:
    - Within the sector through technical solutions, such as CCS and BECCS.
    - Outside the sector through biological methods or technical solutions, such as DACCS.
- Some forms of CDR require energy, so would increase total energy demand.



Hydrogen as a low-carbon energy fuel

- Hydrogen can be produced by various means and input and fuel sources.
- These processes have different emissions implications.
- Hydrogen can be transported by various means and in various forms.
- It can be stored in bulk for longer-term use.
- It has multiple potential end uses.



Hydrogen is not automatically climate-friendly

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Green: Produced through water electrolysis process by employing renewable electricity. ➡ No CO_2 emissions.

Blue: Produced from fossil fuel, with CO2 capture and storage underground (carbon sequestration). ➡ No CO_2 is emitted during production.

Gray : Produced from fossil fuel and commonly uses steam methane reforming (SMR) method. ➡ CO_2 is produced and released to the atmosphere.

Black or **brown**: Produced from coal. The colours refer to the type bituminous (black) and lignite (brown) coal. The gasification of coal is a method used to produce hydrogen. ➡ CO_2 and carbon monoxide are produced.

Turquoise: Extracted by thermal splitting of methane via methane pyrolysis. The experimental process removes the carbon in a solid form. ➡ No CO_2 emissions.

Purple: Production using nuclear power and heat through combined chemo thermal electrolysis splitting of water. ➡ No CO_2 emissions.

Pink: Generated through electrolysis of water by using electricity from a nuclear power plant. ➡ No CO_2 emissions.

Red: Produced through the high-temperature catalytic splitting of water using nuclear power thermal as an energy source. ➡ No CO_2 emissions.

White: Naturally occurring hydrogen. ➡ No CO_2 emissions.

Hydrogen itself is a colourless gas but there are around nine colour codes to identify hydrogen. The colours codes of hydrogen refer to the source or the process used to make hydrogen.

Benefits and drawbacks of different mitigation options

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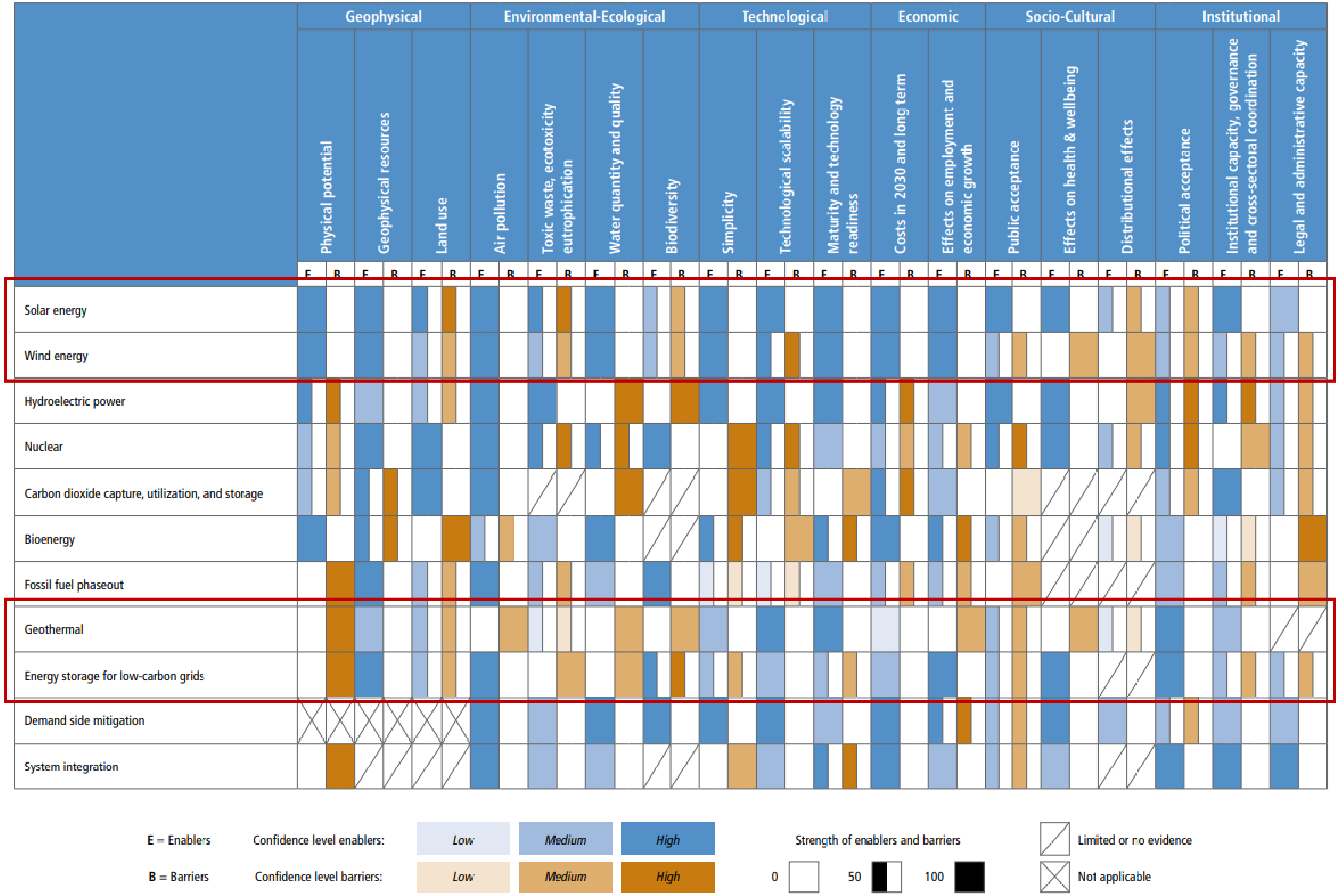
Some options have strong enablers and face limited barriers

Other options still face substantial barriers



Mitigation cost

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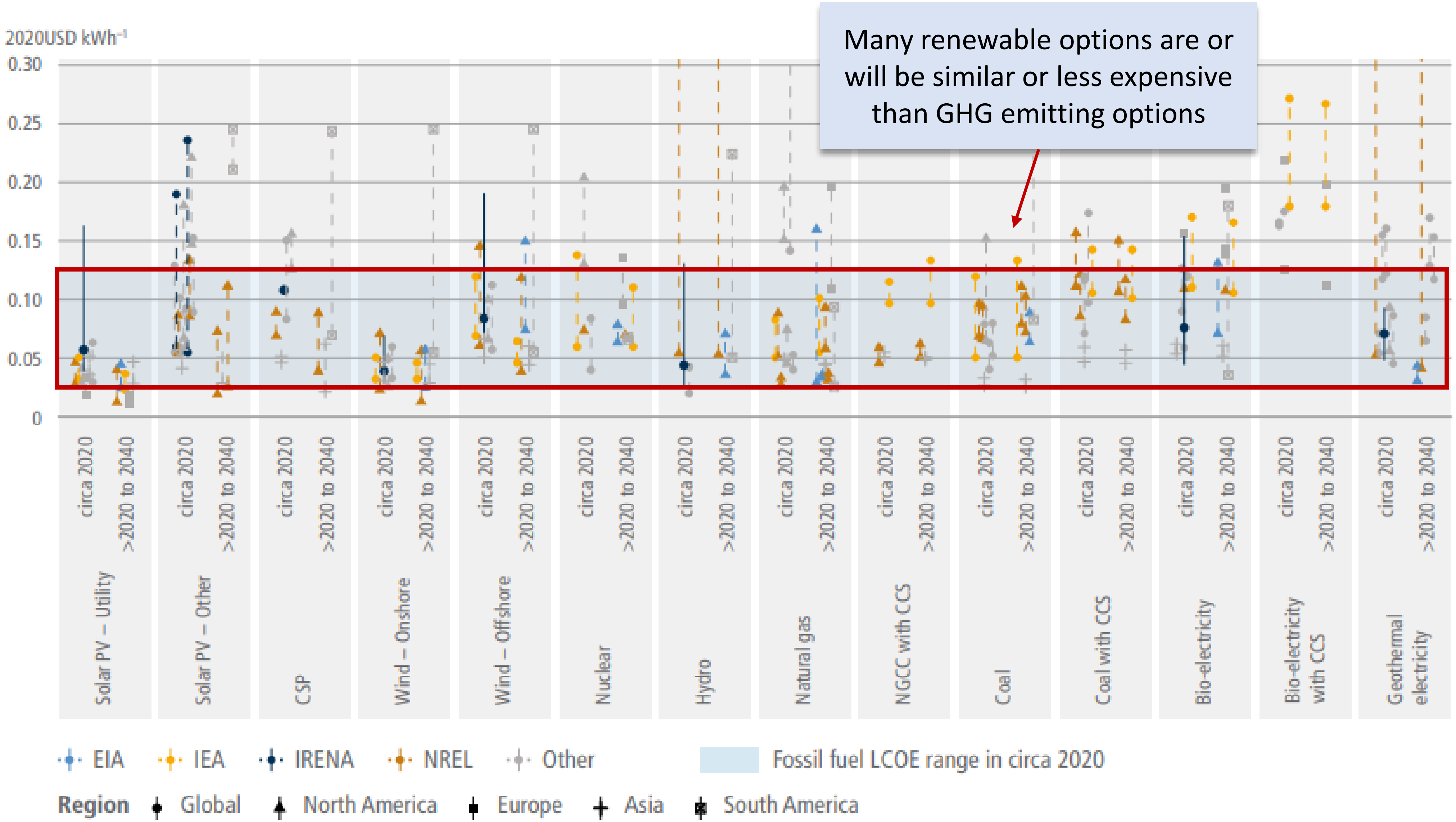


NGCC = Natural gas combined cycle CSP = Concentrated solar power CCS = Carbon capture and storage

Policy instruments

Technology readiness	**Economic & financial**	**Regulatory**	**Information**	**Capacity building**	**Research & development**
Mature	• Revision of energy market design • Emission trading • Renewable portfolio standards	• Efficiency standards • Specification of allowed fuels and/or technologies	• Information campaigns	• Roll-out of training activities to standard education & training	
Early adoption	• Tariff structures • Taxes and subsidies • Direct investment	• Transmission tariff structure • Transmission access	• Voluntary agreements	• Design of training programmes • Training of teaching institutions	• Local applicability studies • Business model development
Development		• Enabling frameworks for research and demonstration	• Support for research networks		• Research subsidies • Demonstration projects

Example: Net metering

Features

- Net metering is an easy-to-implement instrument providing financial incentive to install renewables, mostly solar rooftop PV.
- Buildings with renewable electricity generation capacity that are connected to the grid pay electricity tariffs only for the difference between the electricity delivered into the grid and the electricity drawn from the grid.

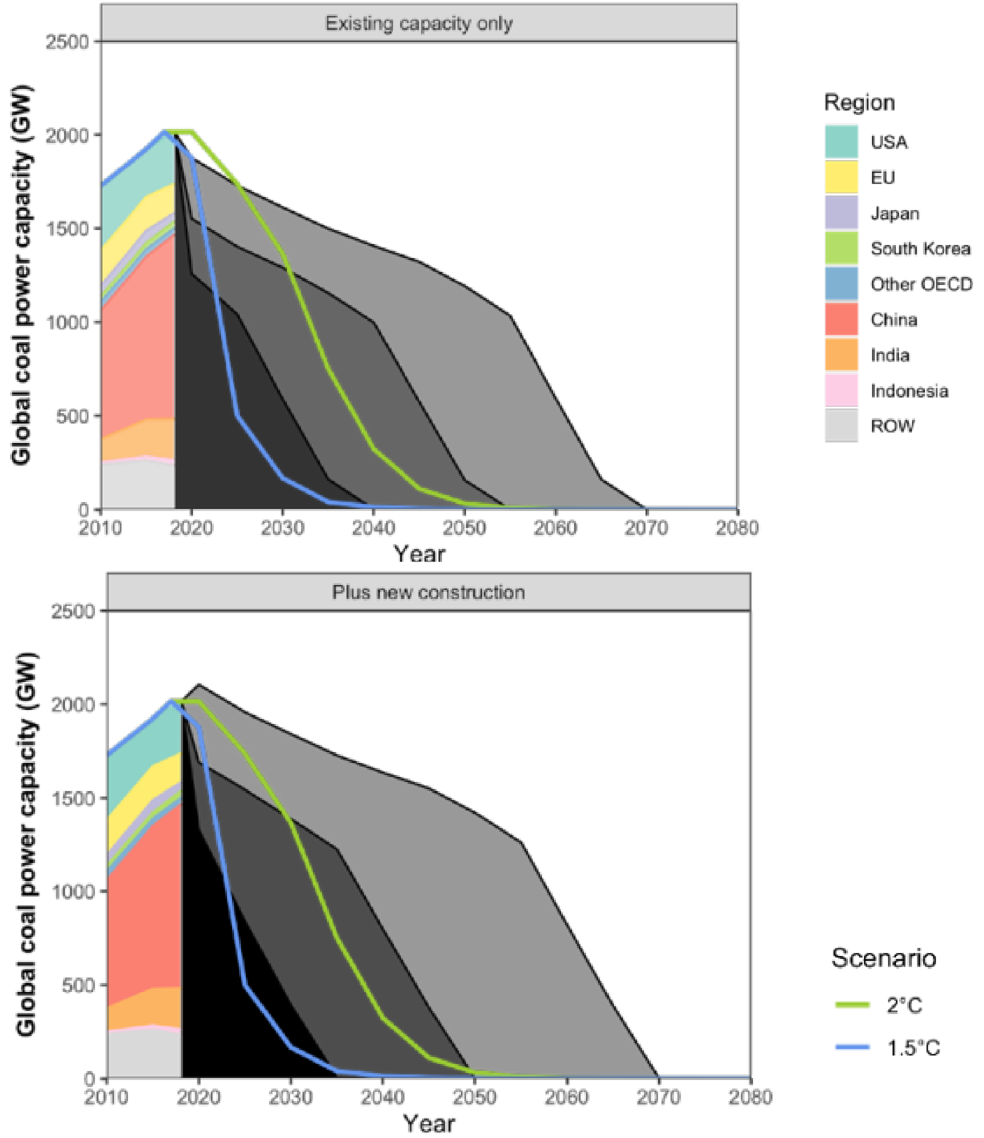
Lessons

- It serves best in early stages of renewable deployment and is usually replaced by other schemes in more developed electricity markets.
- The incentive provided through net metering depends on the level of electricity tariffs.
- To support larger installations that also feed in substantial power to the grid, additional instruments are needed.

Status and challenges of a coal phase-out

- Between 2015 and 2019, global coal power capacity grew by 146 GW, or 7.6%.
- Limiting global warming to 2ºC or below requires a rapid shift away from unabated coal consumption (coal without CCS) in the energy system by 2050.
- To limit warming to 2ºC or below, and without new builds, existing coal plants will need to retire 10 to 25 years earlier than the historical average operating lifetime.
- Completing all planned projects will further reduce the viable lifetime of all plants by 5 to 10 years.
- An increasing number of countries and regions have committed to or operationalised coal phase-outs.

➡ The Glasgow Climate Pact calls on Parties to accelerate efforts to phase down unabated coal power!



Energy system lock-in and path dependence

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Physical energy system

Through:

- Fossil power generation infrastructure
- Fossil resource exploration
- Infrastructure in demand sectors, such as:
  - Buildings
  - Industrial production facilities
  - Transport infrastructure

Committed carbon emissions are unevenly distributed. Infrastructure in emerging economies is comparatively young, due to rapid growth in recent years.

Societal and institutional inertia

Through for example:

- Habits
- Complexity of politics
- Institutional learning needs
- Vested interests
- Informational deficits

Low-carbon transitions involve cultural changes extending beyond purely technical developments, including changes in consumer practices, business models, and organizational arrangements

Stranded assets through decarbonisation

There are two types of stranded assets:

- **Fossil-fuel resources that cannot be burned**: About 30% of oil, 50% of gas, and 80% of coal reserves will need to remain unburned if likely warming is limited to 2°C (more for 1.5°C).
- **Premature retirement of fossil infrastructure**: About 200 GW of fossil fuel electricity generation per year will likely need to be retired prematurely after 2030 to limit likely warming to 2°C, even if countries achieve their NDCs.

➡ The risk from climate change impacts and climate action are increasingly considered in investment decisions!

Stronger near-term mitigation will reduce premature retirements of fossil infrastructure:

- If likely warming is limited to 2°C, strengthening the NDC pledges beyond their 2015 levels could decrease stranded electricity sector assets by more than 50%.
- By contrast, if countries fail to meet their NDCs and continue to build fossil infrastructure, mitigation will need to be accelerated beyond 2030, resulting up to double the amount of stranded electricity generation capacity, if warming is to remain limited to 2°C.

Key resources for energy supply information

Information

Open Energy Info (OpenEI):

http://en.openei.org/

IEA Policies and Measures Databases:
https://www.iea.org/policies

Renewables Global Status Report:

https://www.ren21.net/reports/global-status-report/

Bloomberg New Energy Outlook:

https://about.bnef.com/new-energy-outlook/

Enerdata Global Energy Trends:
https://www.enerdata.net/publications/reports-presentations/world-energy-trends.html

Key expertise

International Energy Agency (IEA):

http://iea.org/

World Energy Council:
http://www.worldenergy.org/

The International Renewable Energy Agency (IRENA):

https://www.irena.org/

Topics for discussion

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- How is energy sector planning approached in your country?
- How are GHG mitigation and adaptation opportunities integrated into this process?
- What policy instruments have had the most significant impact in promoting renewable energy so far?
- What are the key challenges you are facing in decarbonising your energy system?

MODULE B3

TRANSPORT

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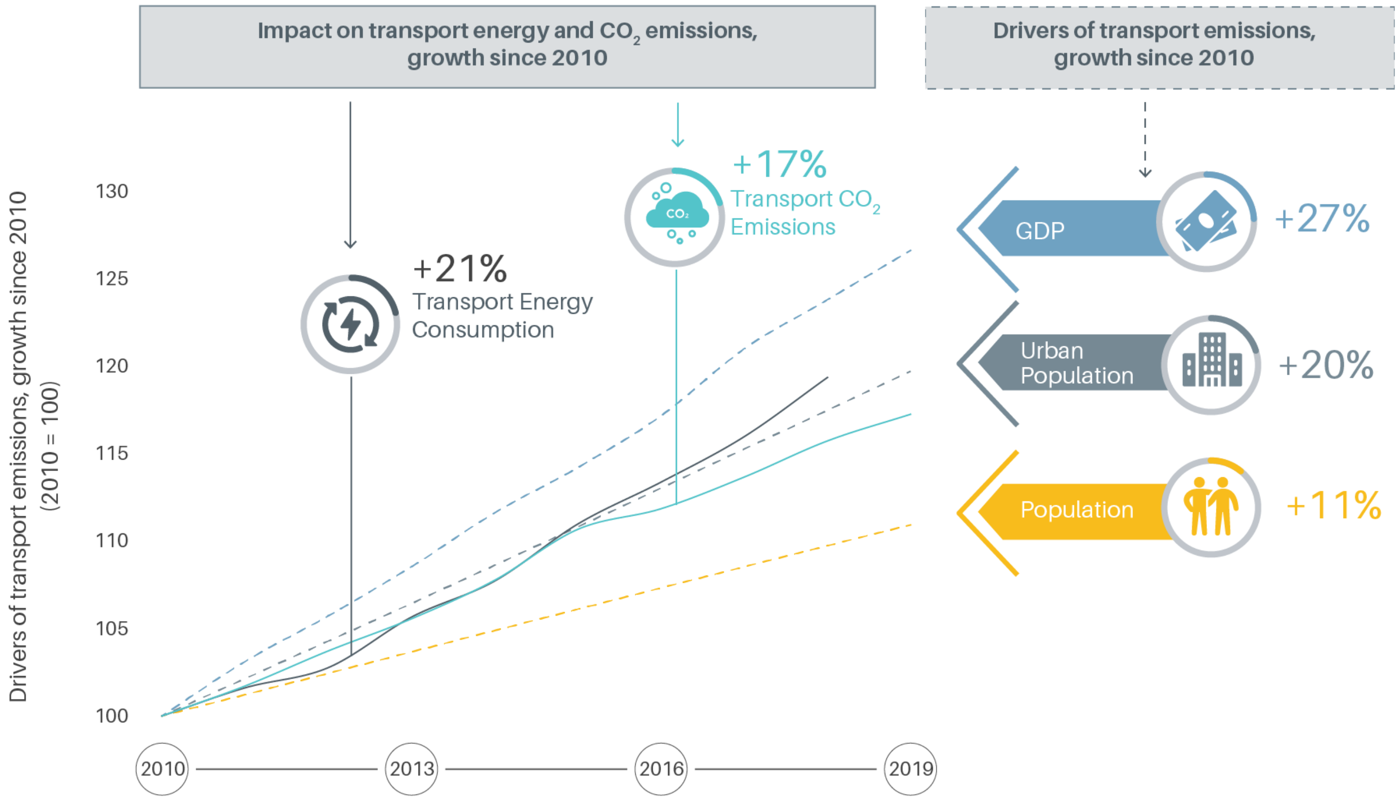
Transport: Key challenges

- Meeting rising transport demand due to population and economic growth while preventing further increasing individual motorisation.
- Long life of infrastructure that favours motorised transport demand based on fossil fuels and long infrastructure planning and construction times, that can effectively lock-in high-emitting modes of transport.
- Strong dependency on individual behaviour for the implementation of solutions.
- Strong fragmentation of policies and governance structures, with many decisions taken at the local and regional level, calling for tailored solutions that enable action at all levels.

Population and economic growth drive transport demand

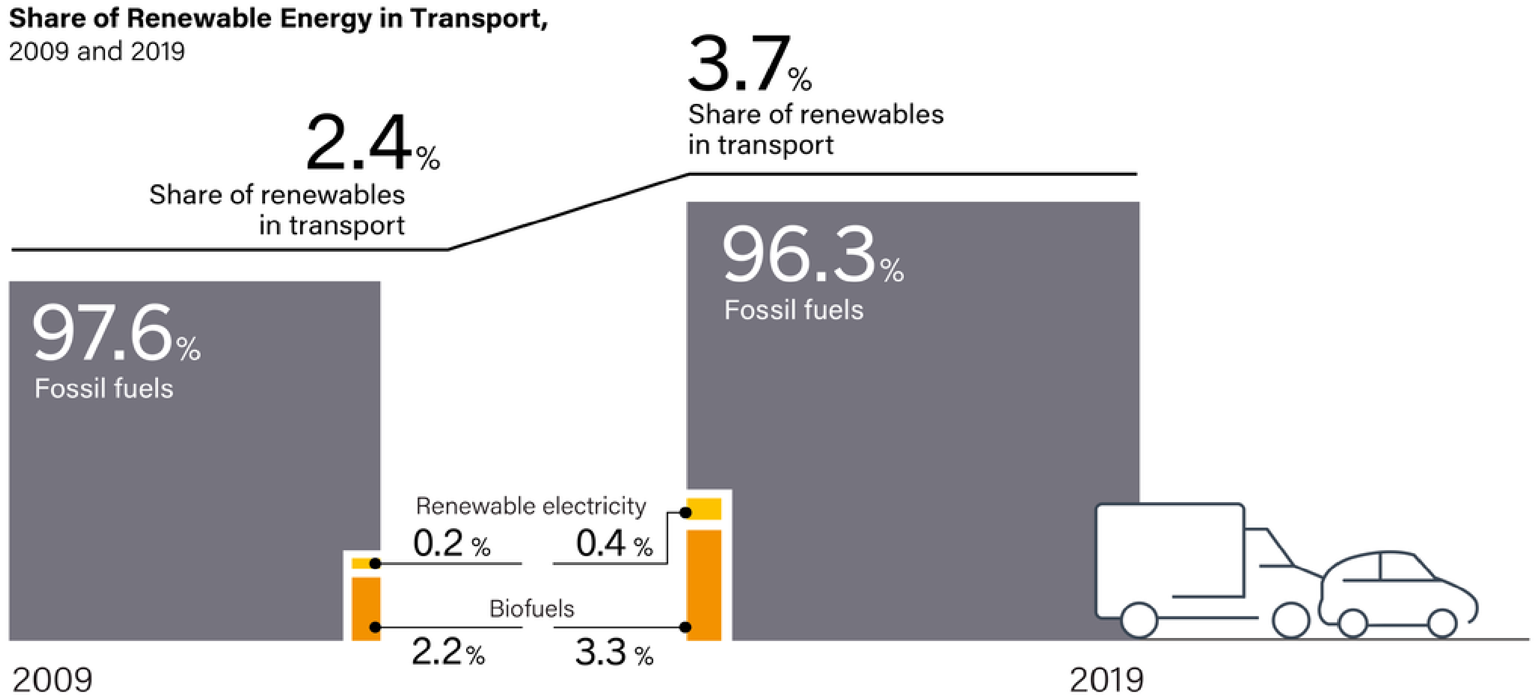
- Global population increased 12% between 2010 and 2020, to an estimated 7.7 billion people, and the urban population grew nearly 20% over this period.
- Global GDP grew 27% between 2010 and 2019 (average annual rate of 3%) and 2.2% in 2019, but it fell an estimated 4.3% in 2020 due to the impacts of COVID-19.
- Together, this resulted in a 21% increase in energy consumption from the sector between 2010 and 2019.
- In 2019, direct GHG emissions from transport accounted for 23% of global energy-related CO_2 emissions (IPCC, 2022).



Source: SLOCAT, TCC-GSR 2022

Transport is dominated by fossil fuels

- Transport remains dominated by petroleum products
- 0.9% of energy needs were met by fossil-fuel based electricity
- Globally, 3.3% of energy used in 2019 were biofuels



Note: ICE = internal combustion engine

Source: Based on IEA data.

REN21 RENEWABLES 2022 GLOBAL STATUS REPORT

Road transport shows the largest emission growth

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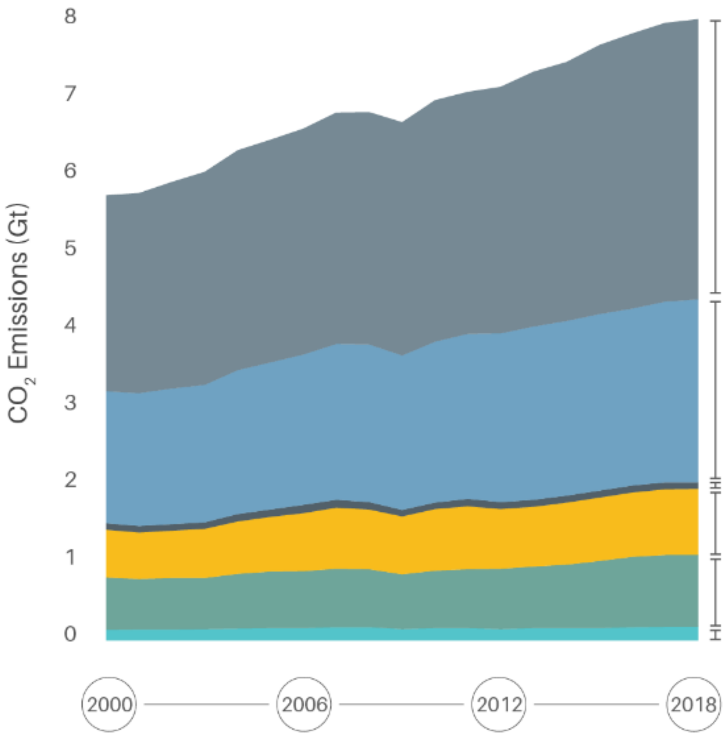
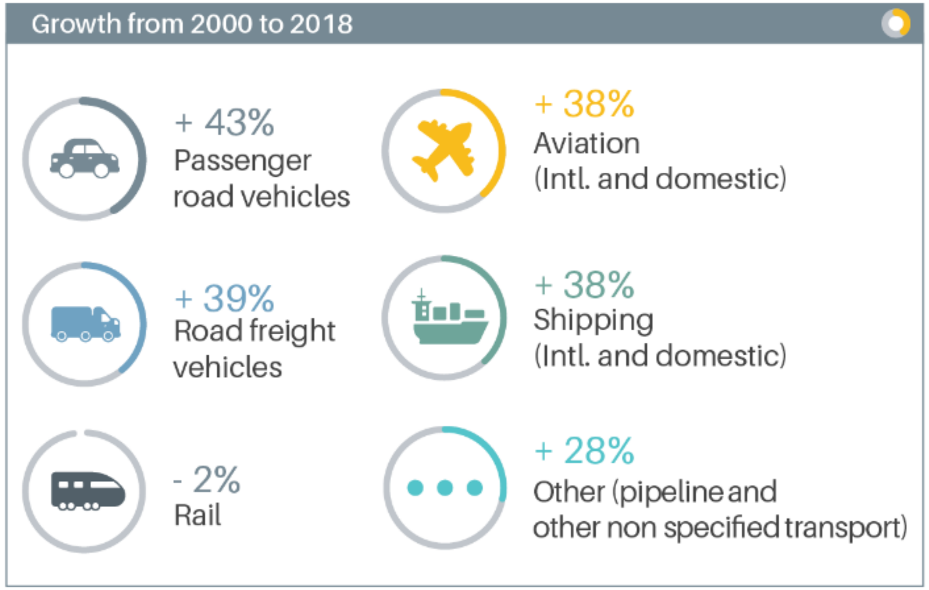
- Transport sector emissions grew by 17% between 2010 and 2019
- Road transport was responsible for 74% of the sector's emissions in 2019
- Freight was responsible for around 40% of emissions in 2019
- Since 2010, sector's emissions have increased faster than for any other end-use sector, averaging +1.8% annual growth





Growth is not equally distributed across the globe

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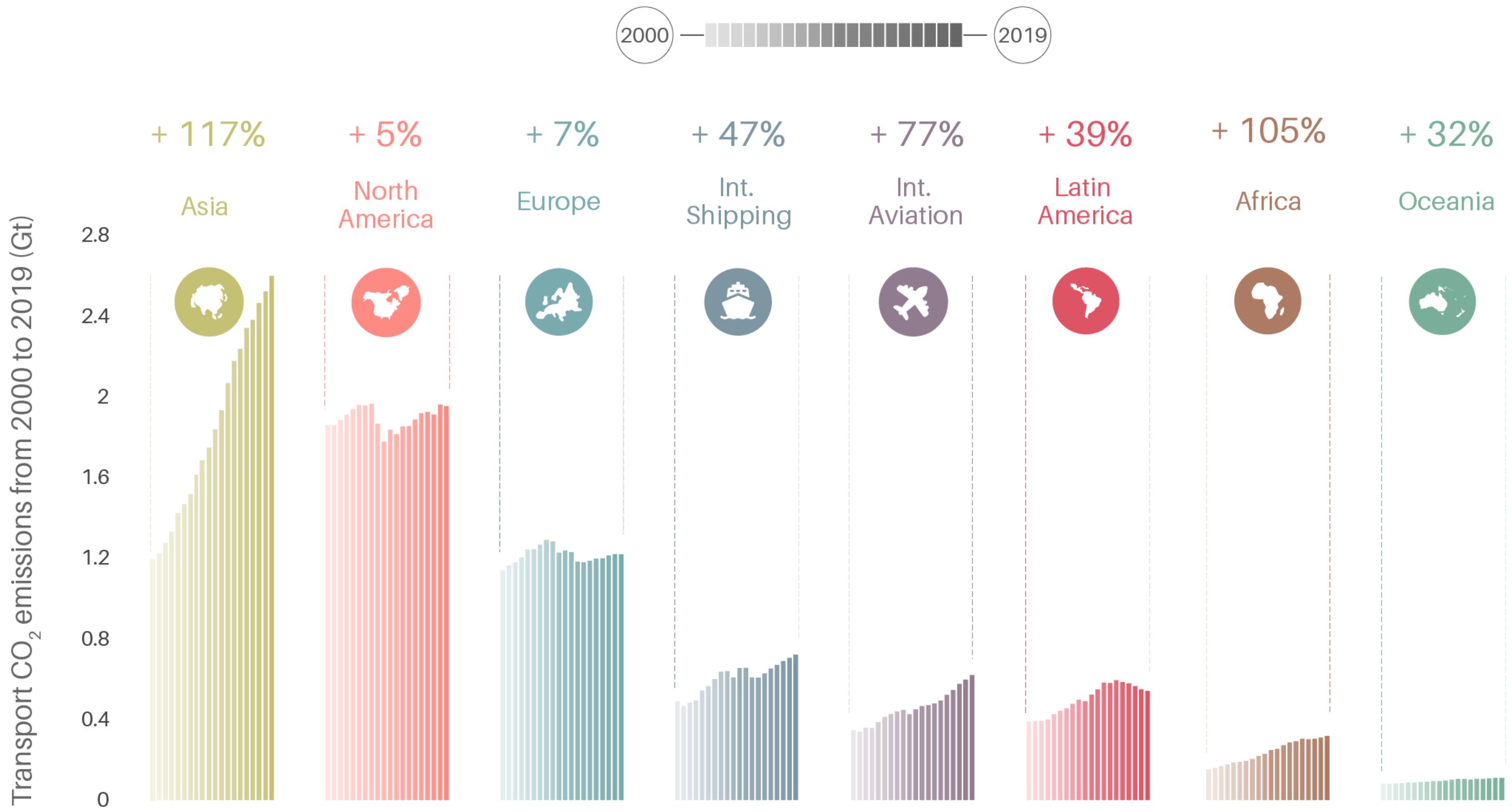

➡ Rapid action is needed in fast growing regions, such as Asia, but also at the multilateral level for international shipping and aviation.

- Asia experienced the largest growth with 117% between 2000 and 2019 and 41% from 2010 to 2019 in line with economic growth
- Only Europe decreased emissions slightly over that period, but also increased compared to 2000 levels
- International aviation and shipping emit more than Latin America, Africa and Oceania

Non-climate drivers for transport system changes

Activity levels

Transport activity in passenger and freight grew by 73% between 2000 and 2018.

Industrial policy

Existing industries in the sector may oppose change, but new opportunities arise from new technologies.

Air pollution, etc.

Increasing concerns over air quality, congestion levels and safety shape transport policy.

Urbanisation

Between 2015 and 2050, demand for urban passenger transport is poised to more than double.

Non-climate drivers: Rapid motorisation

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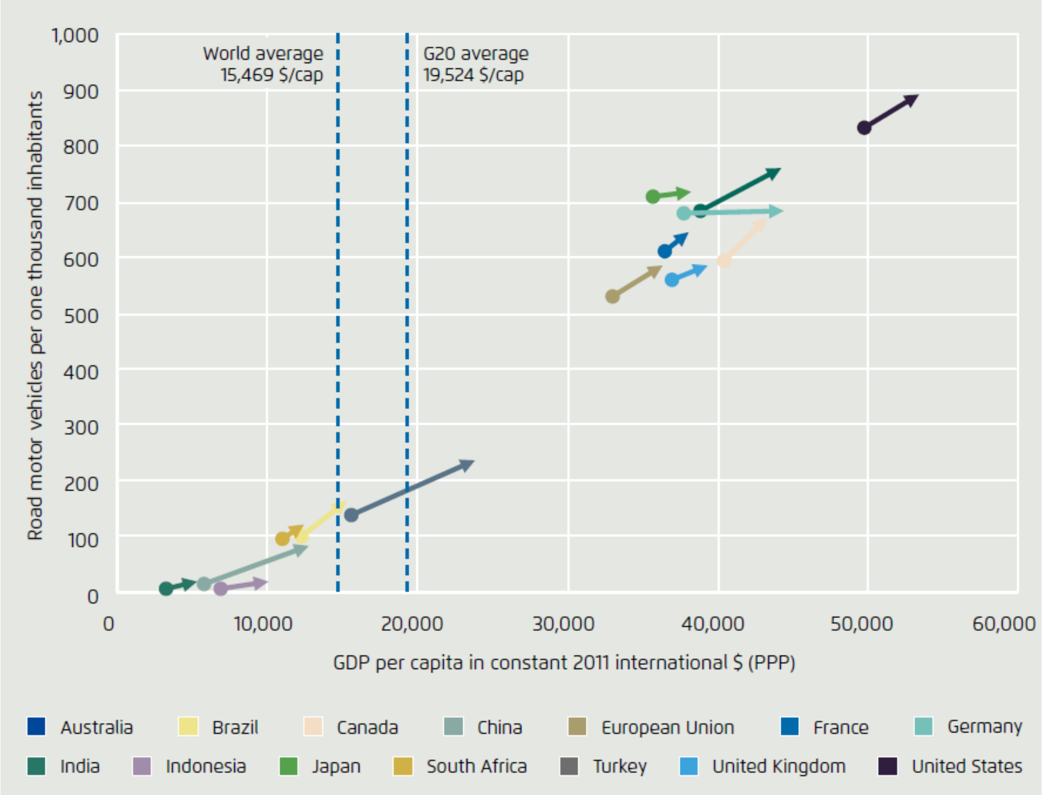
- The trend towards greater private vehicle ownership in conjunction with population growth is resulting in increased travel by car.
- The trend towards greater overall travel distances can be observed in all countries, despite the large differences in growth.
- Together with increasing vehicle weight, this counteracts gains from improved efficiency of motors.

➡ For low-carbon development in the sector, the share of individual travel must be reduced through increased use of shared mobility options



Emission projections: Current policies leave a large gap

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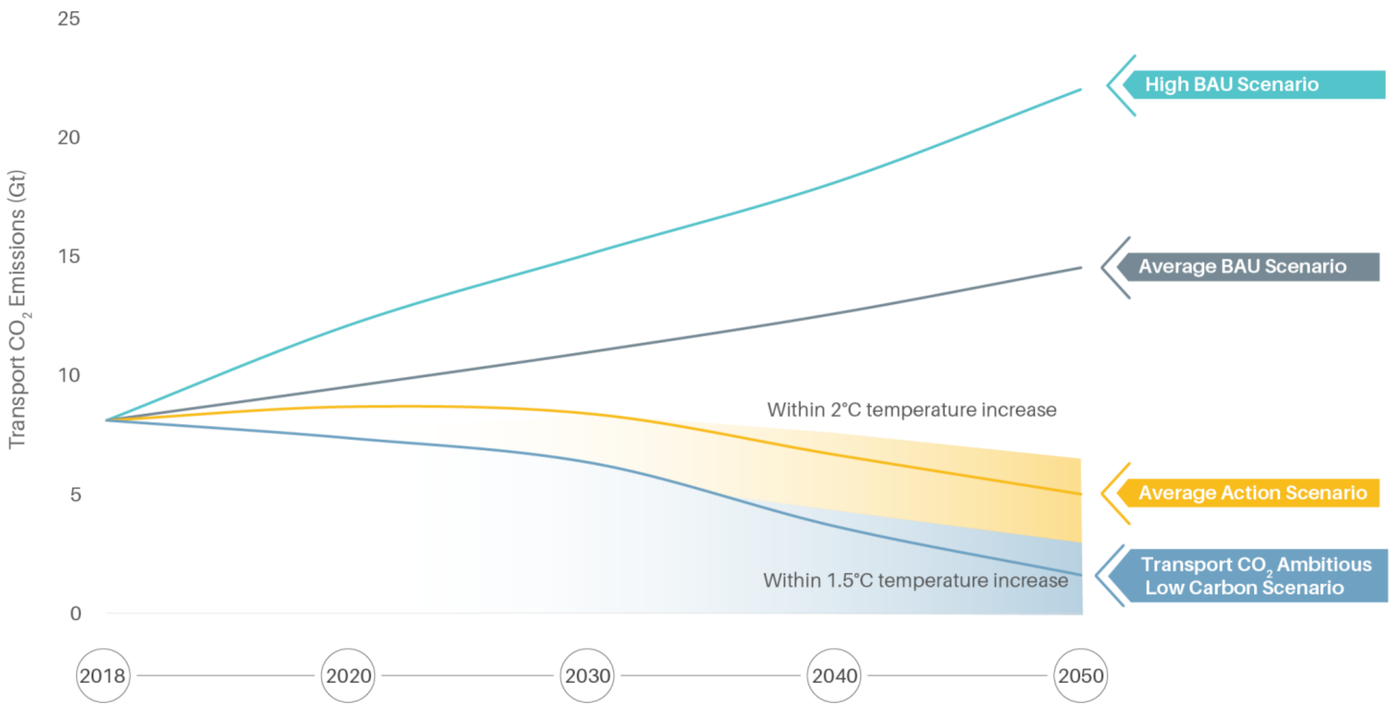
Scenarios from bottom-up and top-down models indicate that without intervention, CO_2 emissions from transport could grow substantially by 2050.

Average baseline 2050: 15,4 Gt CO_2

Below 2°C compatible: 5 Gt CO_2

Below 1.5 °C compatible: 2-3 Gt CO_2

! The emissions gap in 2050 is larger than global transport sector emissions in 2019!



Emissions from freight need to be tackled

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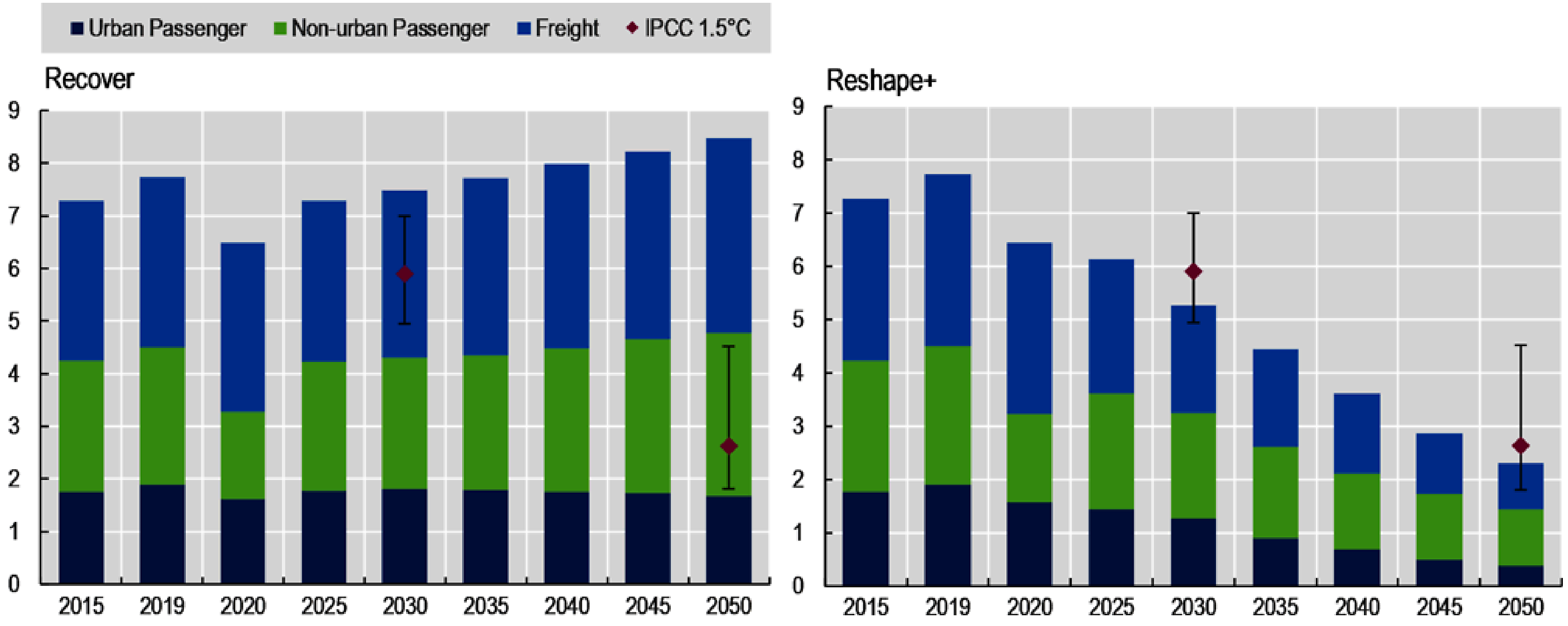
- Freight is responsible for more than 40% of all transport CO_2 emissions.
- Trucks currently emit 65% of all freight CO_2 and will remain the dominant mode of surface transport under current policies.
- With decisive actions freight transport's CO_2 emissions could be 72% lower in 2050 than in 2015



Energy pathways for low-carbon transport

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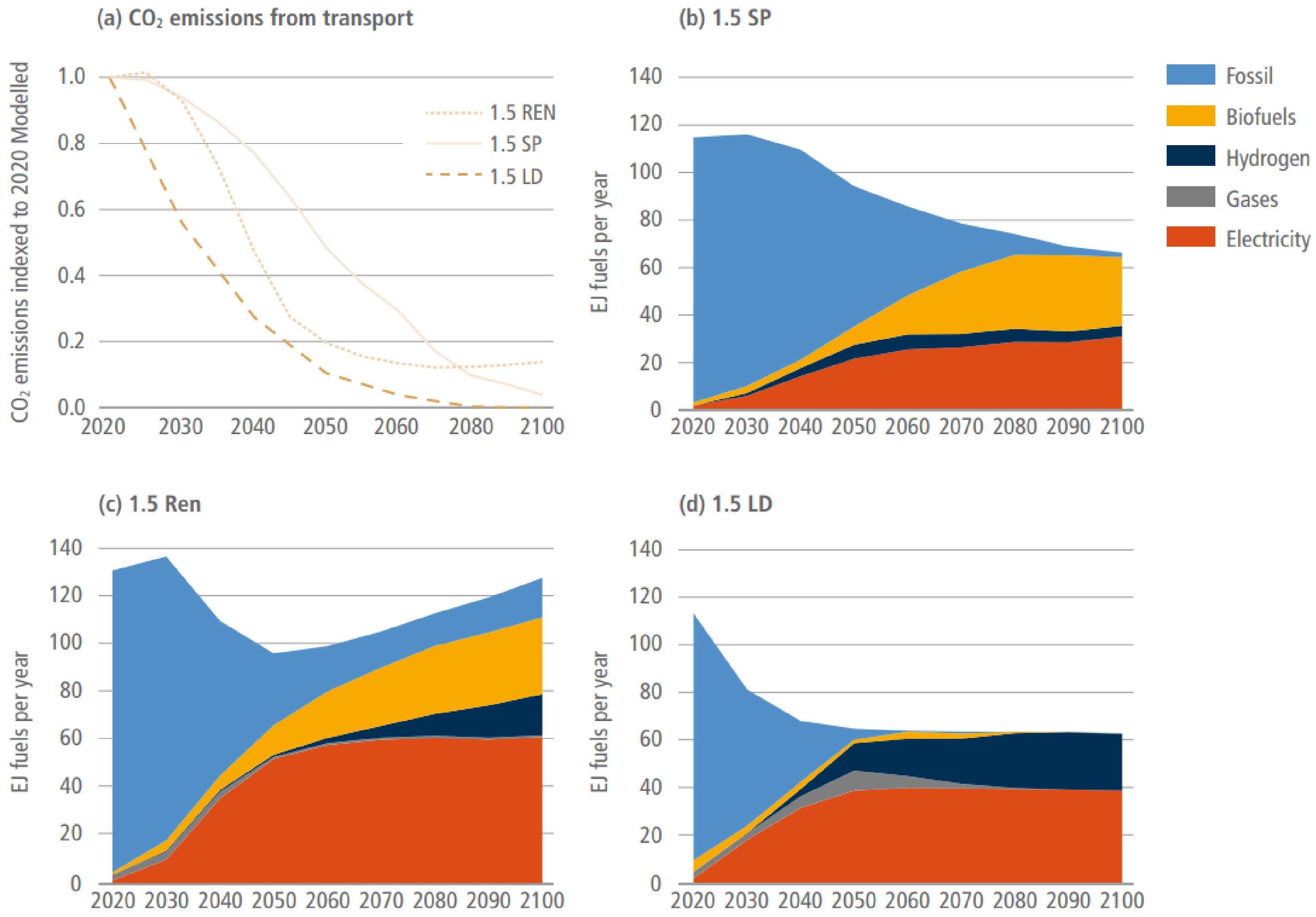
There are very different low-carbon transport systems possible, depending on:

- The choice of fuels
    - Electricity plays a major role in all scenarios
    - The level of biofuels used differs strongly
    - Hydrogen plays a role in all, but the importance varies
- The level of activity
- The level of system and vehicle efficiency

The graphs show three illustrative scenarios as examples how the sector can transform.



Climate change impacts on the transport system

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		From extreme events		From slow onset events	
		Cyclone winds *Surface & river flooding* *Coastal flooding*	*Extreme temperatures*	*Sea level rise*	*Temperature and precipitation patterns*
Infrastructure	*Roads* *Railway lines* *Bridges & tunnels* *Transit stations* *Ports* *Airports*	Infrastructure & vehicle destruction	Damage to used construction material	Permanent inundation Erosion of embankments & foundations	Erosion of embankments
Mobility	*Road* *Rail* *Waterways* *Aviation*	Temporary or permanent disruption of mobility options	Limitation to usage of infrastructure		Temporary or permanent disruption of mobility options
Operations	*Additional demands on operations from changes in climate*	Need for emergency resources for clean-up and repair	Increased need for repair		Need for cooling / heating Need for shelter

Transport mitigation options

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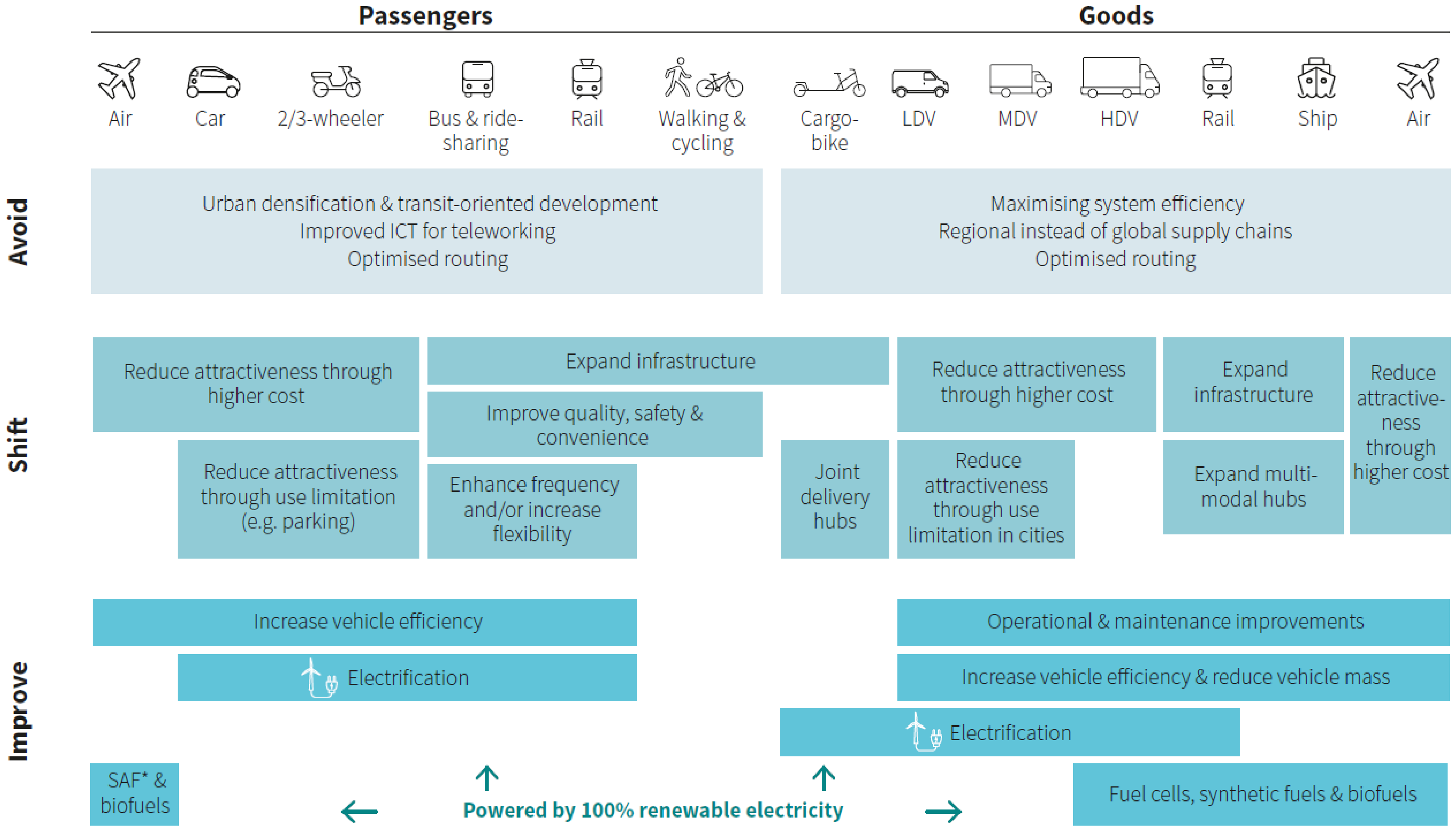
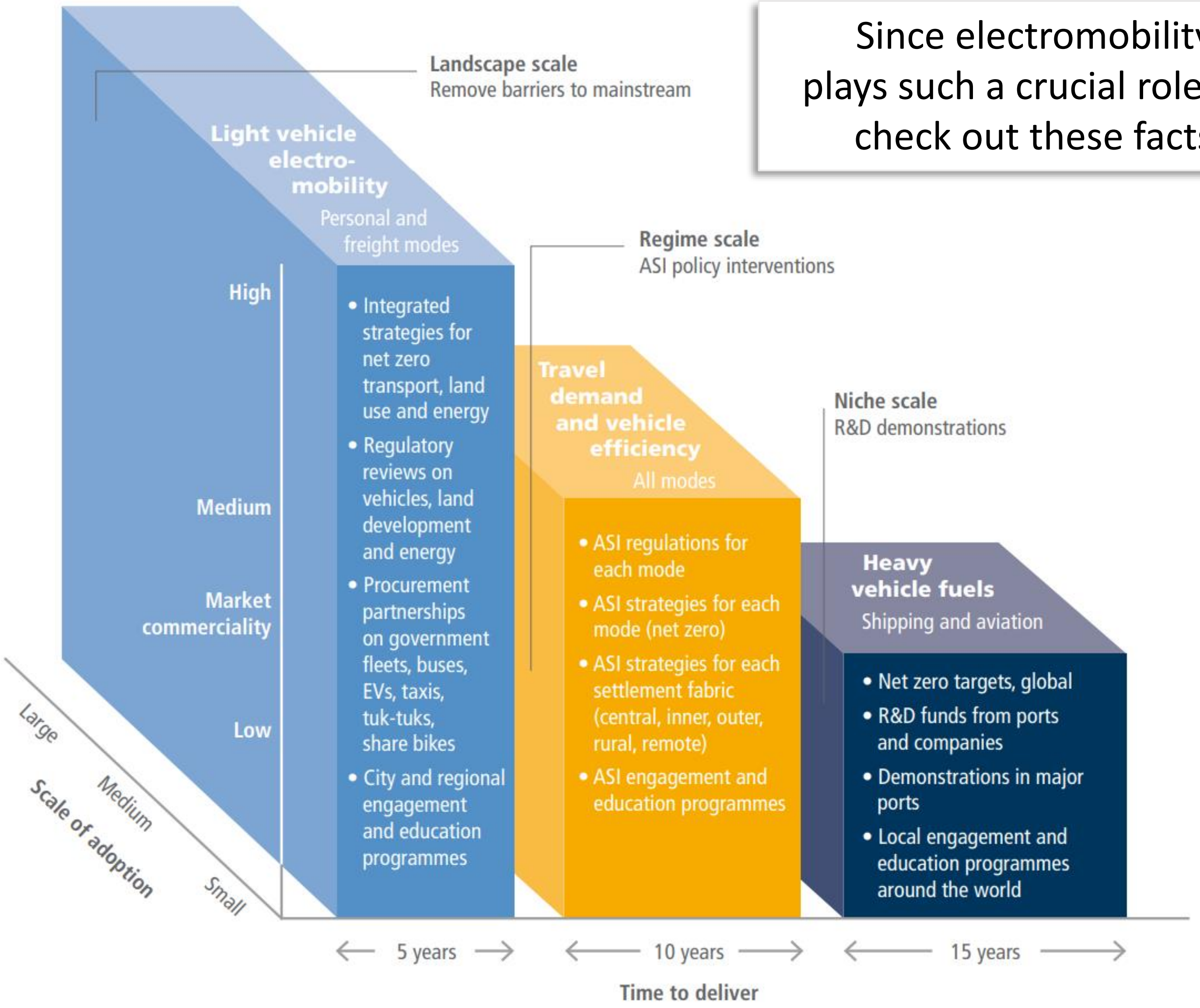
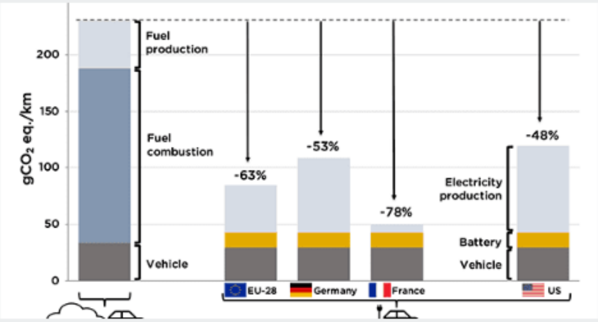


Scale and timeline for adoption



Since electromobility plays such a crucial role, check out these facts



Card stack

[Five things you know about electric vehicles that aren't exactly true]

Benefits and drawbacks of different options

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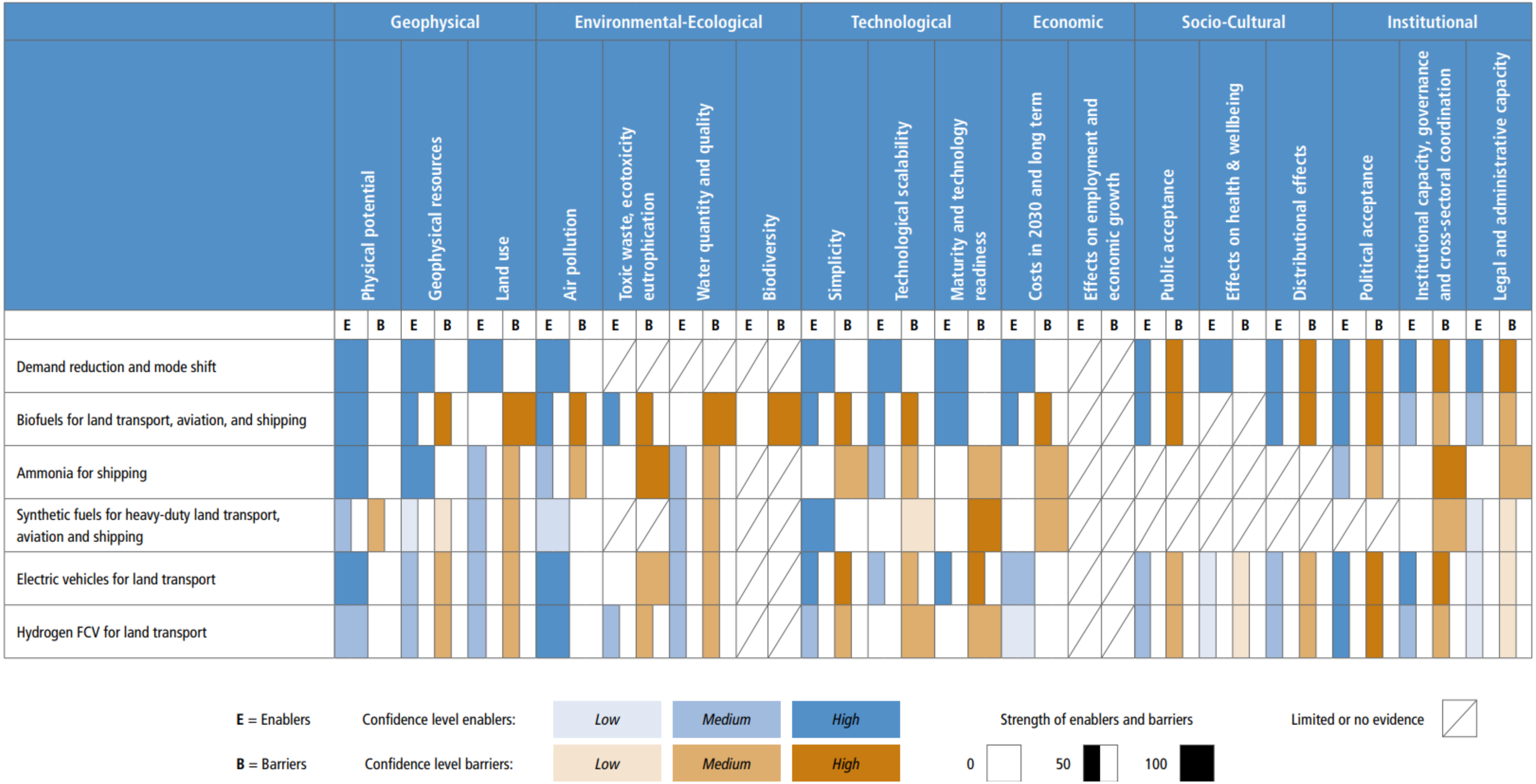

Policy instruments

- Policy instruments to motivate action are well-established.
- Some have been implemented and tested in many parts of the world for years with well-established effectiveness.
- All of these instruments will need to be tailored to the existing policy and regulatory framework of the country.

Foster integrated planning

- National guidelines for low-carbon compatible and equitable land-use planning

Pricing & economic instruments

Vehicle purchase
- Abolish personal vehicle favouring taxation and benefits
- Purchase taxation (e.g. 'bonus/malus')

Cross-cutting
- Financial instruments to de-risk private investment

Vehicle use
- Abolish fossil fuel subsidies
- Carbon tax for road vehicles
- Inclusion of transport in emissions trading systems
- Road charging & tolls
- Congestion pricing
- Parking pricing
- Aviation fuel tax
- Environmentally differentiated port pricing

Information, education & awareness raising
- National awareness raising/marketing campaigns
- Provision of real-time information through online services (for public & shared mobility and logistics)
- Research & development for locally adapted solutions
- Training of operators & drivers

Support mechanisms for optimised logistics
- Regulation to enable asset sharing (information, vehicles, warehousing)
- Incentives or direct investment in urban consolidation centres
- Incentive schemes for intelligent transport systems
- Initiate and support voluntary business association programs to reduce emissions in logistics

National programmes to support a shift to shared mobility options
(public transport, new mobility & paratransit)

Disincentives for private vehicles
- Parking regulation & enforcement
- Restricted access to zones / vehicle restriction schemes
- Speed limitations
- Regulation enabling express lanes for shared mobility

Support to shared options
- Incentives or direct investment in infrastructure
- Public transport reform & incentives for optimised routing & frequency
- Subsidies for ride-share transport options, incl. public transport
- Support for integrated ticketing systems
- Legal frameworks to govern new mobility services

Measures to support low-carbon freight logistics
- Incentives or direct investment in rail, waterway and port infrastructure
- Incentives or direct investment in multi-modal hubs
- Regulatory frameworks for seamless freight operation across modes (contractual, pricing)

National measures to support non-motorised transport
- Incentives or direct investment in infrastructure
- National regulations & standards for design
- Legal frameworks for bike-sharing

Support efficiency of vehicles
- Vehicle efficiency standards
- Import regulation based on efficiency
- Mandatory vehicle labelling
- Vehicle & vessel scrappage and retrofit schemes

Support mechanisms for electric vehicles & charging infrastructure

Vehicles
- Purchase incentives
- Non-financial incentives (e.g. preferential parking)
- Public procurement
- Mandates for manufacturers
- Incentives or direct investment in electrification of rail

Charging
- Incentives or direct investment in charging infrastructure
- Standards for charging infrastructure
- Standards for payment schemes
- Flexible electricity pricing for EV charging
- EV readiness requirements for buildings

Support mechanisms for other low-carbon propulsion systems

As for EVs plus:
- Fuel-blending mandates
- Fuel certification and standardisation based on carbon intensity
- Guidelines or mandates for life-cycle evaluation of fuels
- Low- and zero emission vehicle mandates

Cross-cutting instruments | Instruments to support avoid strategies | Instruments to support shift strategies | Instruments to support improve strategies

Example: Vehicle taxation in Singapore

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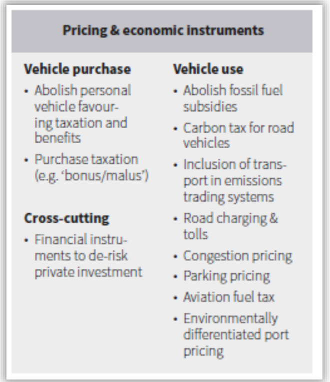
Check out this free simulation tool


Pricing & economic instruments

Vehicle purchase
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Cross-cutting
- Financial instruments to de-risk private investment

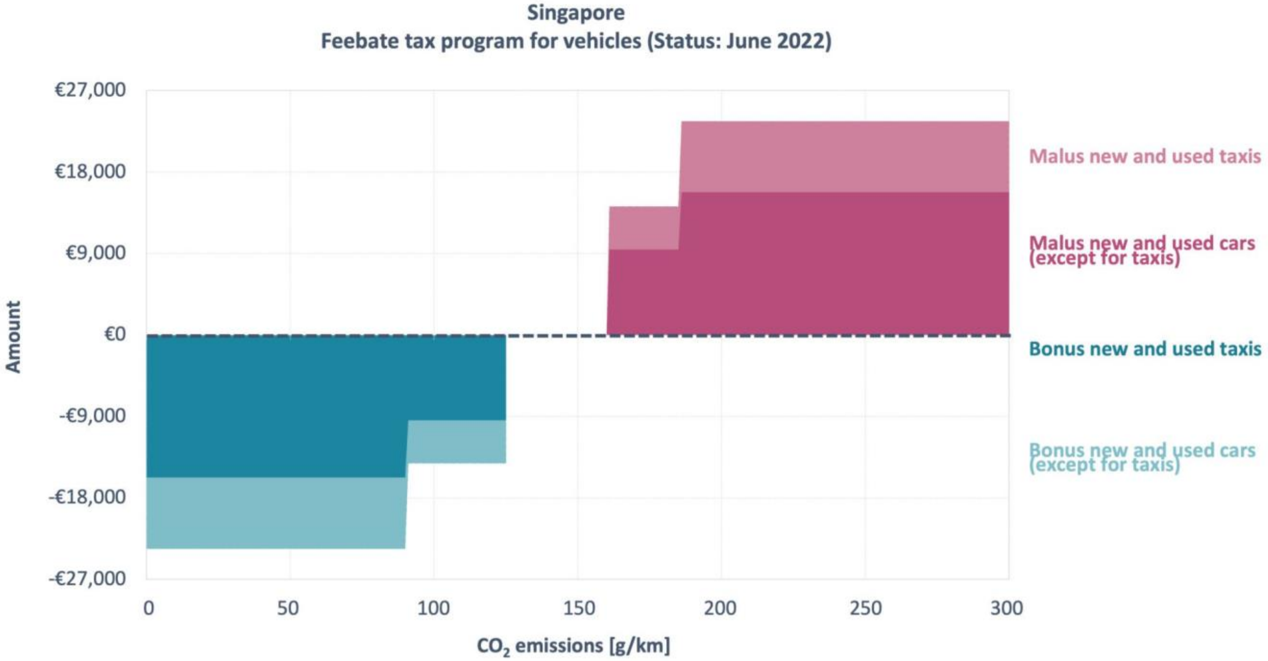
Vehicle use
- Abolish fossil fuel subsidies
- Carbon tax for road vehicles
- Inclusion of transport in emissions trading systems
- Road charging & tolls
- Congestion pricing
- Parking pricing
- Aviation fuel tax
- Environmentally differentiated port pricing

Feebate tax program

- Additional fee that applies to new and newly imported used vehicles registered for the first time in Singapore.
- Rates depend on CO2 emission levels in addition to other pollutants: high emitting models need to pay a fee; low emitting models get a bonus payment.
- Extended until 2025.

Lessons

- Feebates can be designed to be revenue neutral.
- Effective in stimulating demand for lower-emission vehicles, including electric vehicles



Example: Encouraging non-motorised transport in Indonesia

‘Panca Trotoar’ programme, Bandung

- Started in 2014 in the third largest city and capital of the West Java Province.
- Improvement or building of new sidewalks to encourage walking by creating safe and attractive pedestrian environments, with safety and security being a major barrier to walking in the city.
- Goal to increase appeal of sidewalks, including benches for resting, stone balls to block traffic, flowerpots for decoration, garbage cans for cleanliness and street lighting for safety.

Lessons

- The program produced positive impacts on lifestyle, create cleaner air and reduce emissions.
- Combining the initiative with parking policies may encourage more modal shift.
- Activities are easily scalable within a city and to other cities.

National measures to support non-motorised transport

- Incentives or direct investment in infrastructure
- National regulations & standards for design
- Legal frameworks for bike-sharing

Ensuring a just transition of the system is essential

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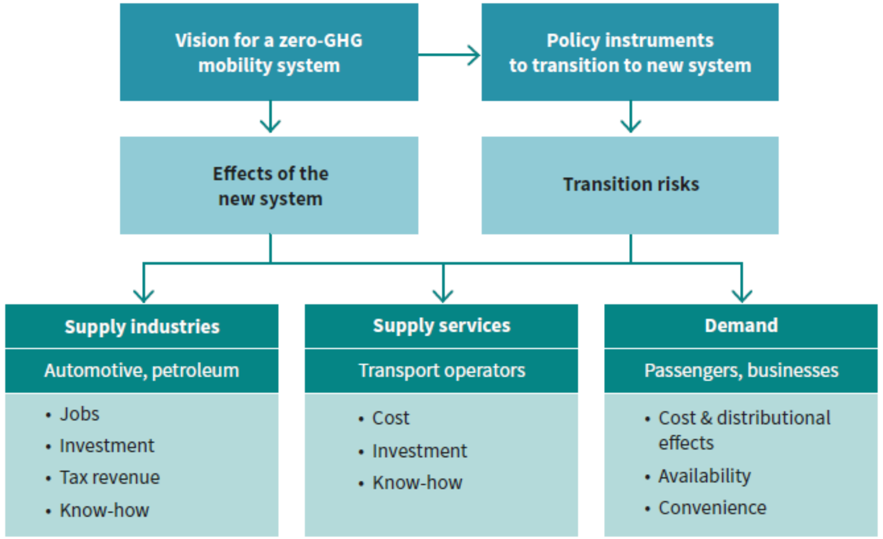
Consequences of the transition to low-carbon transport systems can be especially disruptive if they:

- Affect large shares of the population.
- Are concentrated in specific regions.

To buffer negative effects, there must be a deliberate effort to plan for and invest in a transition to environmentally and socially sustainable jobs, sectors and economies:

- Current systems are far from just and equitable: addressing these challenges will enhance support for the transition.
- The transition will require huge investments: using these to create jobs where they are needed and supporting new opportunities for incumbent industries will turn risks to opportunities.



Key resources for energy supply information

Information

Open Energy Info (OpenEI):

http://en.openei.org/

ITF Transport Outlook:

https://www.itf-oecd.org/itf-transport-outlook-2021

SLOCAT Transport and Climate Change Global Status Report:

https://tcc-gsr.com/

Tracker of Climate Strategies for Transport:

https://changing-transport.org/tracker/

Key expertise

Institute for Transportation & Development Policy (ITDP):

http://www.itdp.org/

International Council on Clean Transportation (ICCT):

http://www.theicct.org/

International Transport Forum:

https://www.itf-oecd.org/

Partnership on Sustainable, Low Carbon Transport:

https://slocat.net/

Topics for discussion

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Climate Change Secretariat

- What are the major drivers of growth in travel and transportation energy use in your country?
- What are the key priorities for the sector in your country? How can mitigation actions help to support these?
- What are the principal barriers to addressing freight emissions and how are they being addressed?
- Which policy instruments have been used so far to ensure high levels of public and non-motorised transport?

MODULE B4

BUILDINGS

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Buildings: Key challenges

- Long lifetimes of infrastructure (over half of current global building stock will still be standing in 2050).
- Dependency on individual behaviour for the implementation of solutions.
- Principal/agent problem for rented property.
- Need to adapt existing stock and new buildings to future climate, adding complexity and possibly cost.

Indirect emissions & space heating drive emission growth

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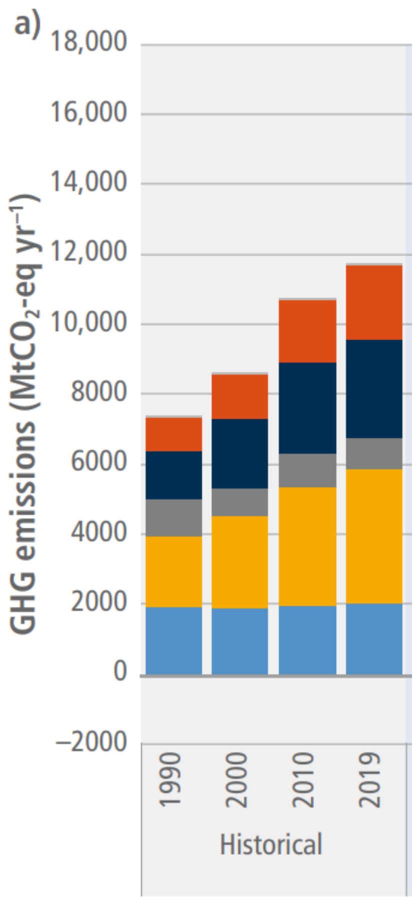
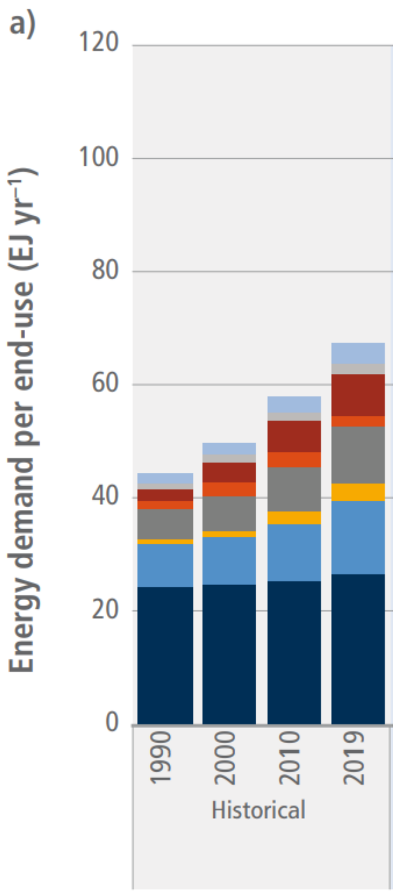


GHG emissions

- Building were responsible for 21% of global emissions in 2019.
- 57% were from indirect emissions from electricity and heat generation off-site and cement & steel production



Energy use

- Space heating remains the dominant energy use, but with low growth.
- Energy demand from connected and small appliances increased by 280% from 1990 to 2019.

Residential direct emissions
Residential indirect emissions
Non-residential direct emissions
Non-residential indirect emissions
Embodied emissions
All buildings non-CO_2 emissions

Space heating
Water heating
Space cooling
Cooking
Lighting
Connected and small appliances
Cleaning appliances
Refrigeration

Buildings: Non-climate drivers

Space demand

Growth in floor area per capita accounted for 52% of growth in emissions from 1990 to 2019.

Appliances

Ownership of connected appliances increased between 94% and 403% across regions from 1990 to 2019.

Urbanisation

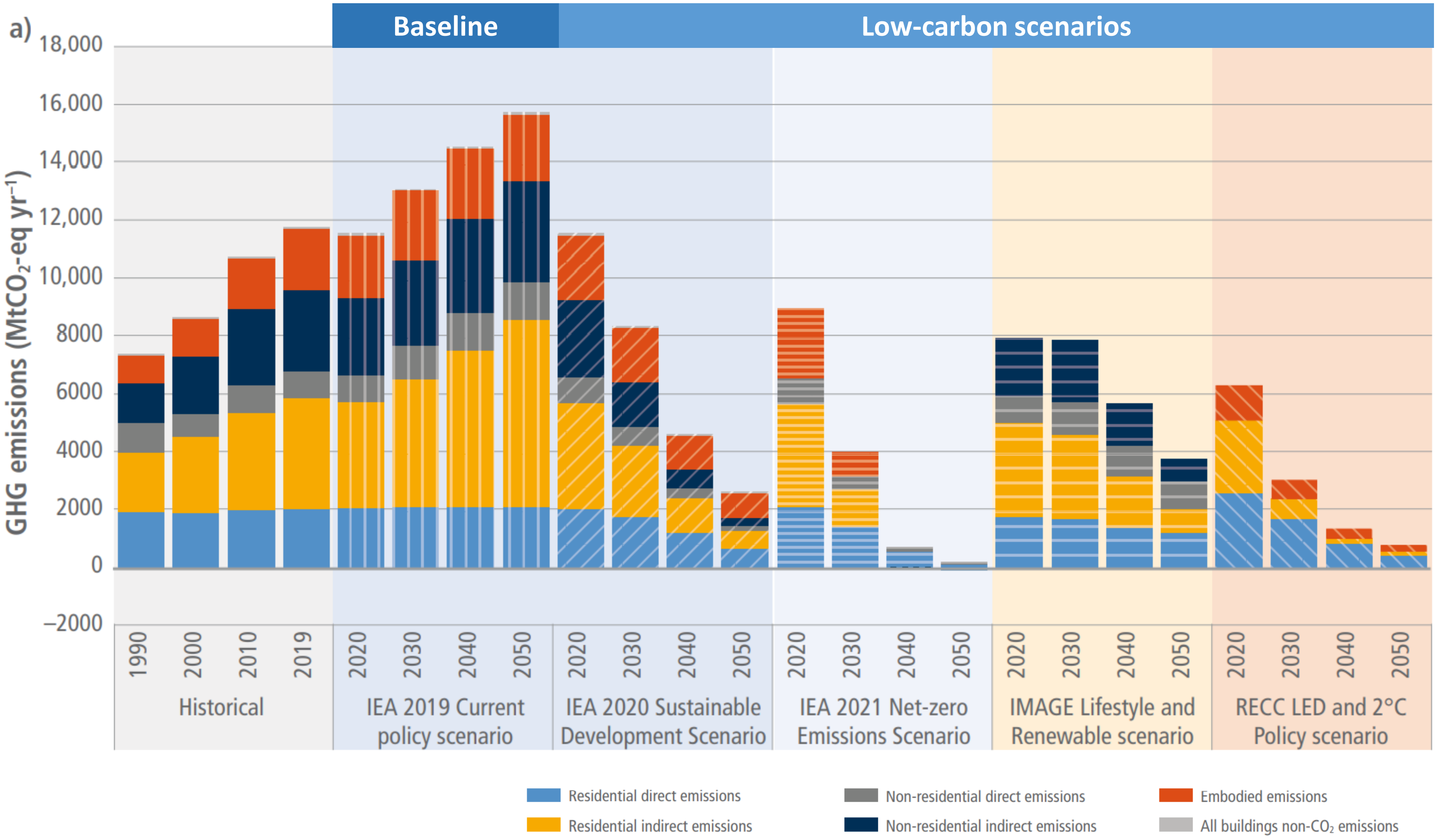
The share of urban population is set to increase from 55% in 2018 to 68% by 2050.

Population

Population growth accounted for 28% of the growth in global emissions from 1990 to 2019.

Projections: Current policies lead to increasing emissions

- Under current policies, emissions are projected to increase by around 33% from 2019 to 2050.
- In the IEA net zero scenario building sector emissions would be only 29 Mt CO_2 by 2050.
- In the NZE indirect emissions are zero by 2050, while indirect emissions remain in the other scenarios.



Growth and composition of emissions vary across regions

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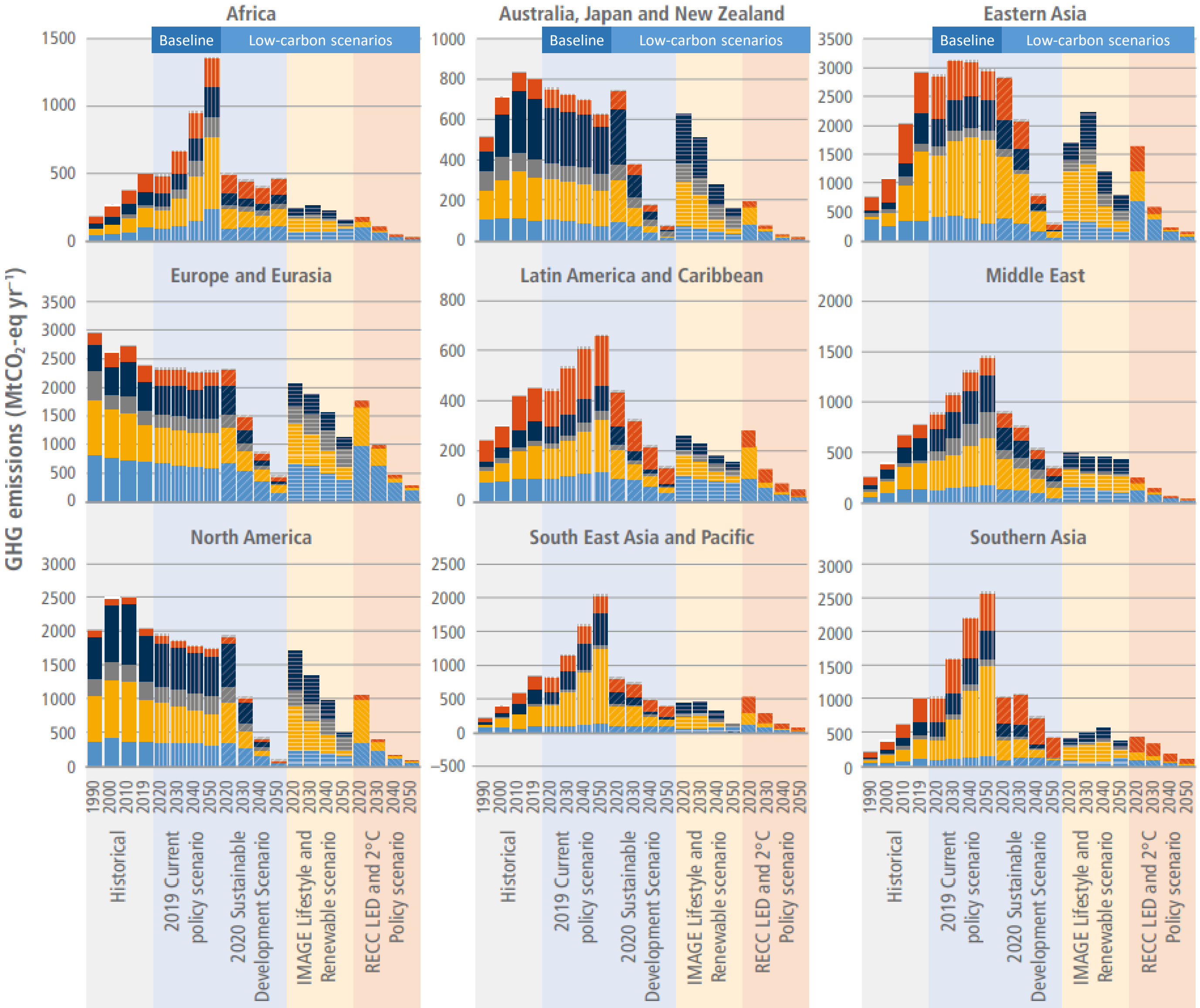
- Under current policies, emissions increase in all developing countries, compared to 2019.

Low-carbon scenarios:

- By 2050, the lowest emissions are projected to occur in developed Asia and Pacific.
- The highest emissions are projected to occur in Europe and Eurasia.



Regional differences in drivers

Non-climate drivers

- Per capita floor area remains lowest in Africa and remains low in most developing countries.
- Higher rates of new construction in most developing countries, owing to population growth and space needs.
- Larger focus on existing stock in developed countries.
- Historic buildings with low performance especially prevalent in Europe.

Climate drivers

- Higher cooling loads in tropical and subtropical countries.
- Heating loads are more pronounced in moderate and arctic climate regions.

Climate change impacts on buildings

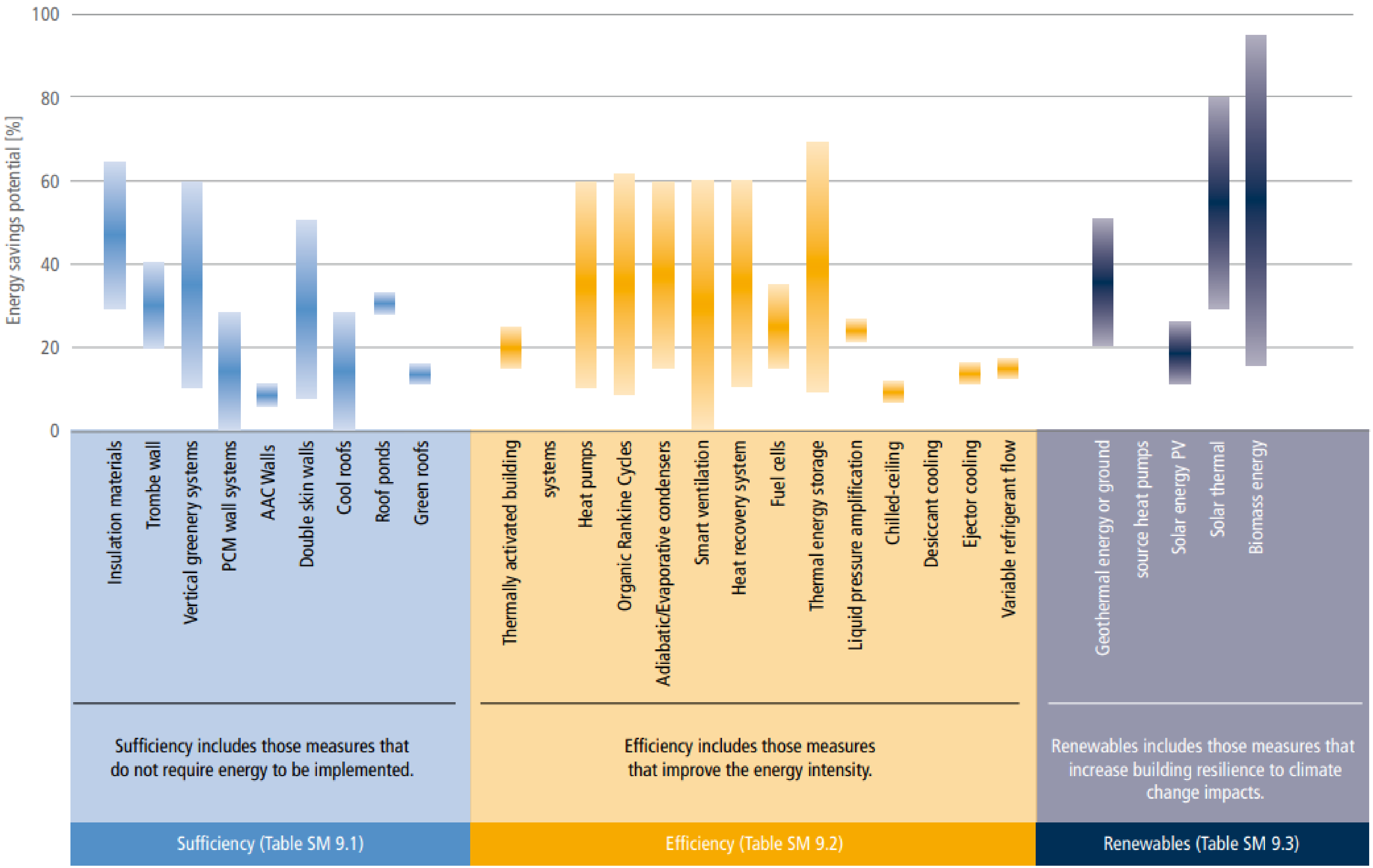
- Performance, durability and safety of buildings and their elements (facades, structure, etc.) through changes in temperature, humidity, wind, and chloride and CO_2 concentrations.
- Temperature variations affect the building envelope, e.g. with cracks and detachment of coatings.
- Higher humidity (caused by wind-driven rain, snow or floods) hastens deterioration of bio-based materials such as wood and bamboo, also deteriorating indoor air quality and users' health.
- Higher frequency and intensity of hurricanes, storm surges, wildfire, sea-level rise and coastal and non-coastal flooding can escalate. economic losses to buildings.
- Higher demand for thermal comfort (esp. cooling) can impact health, sleep quality and work productivity, having disproportionate effects on vulnerable populations and exacerbating energy poverty.

Adaptation measures can increase energy and material consumption

↕

Mitigation measures influence the vulnerability of buildings and required adaptation

Mitigation options: Building envelope



Enhancing the efficiency and economic feasibility of heating through district heating networks provides another alternative to reduce GHG emissions.

Mitigation options: Other options

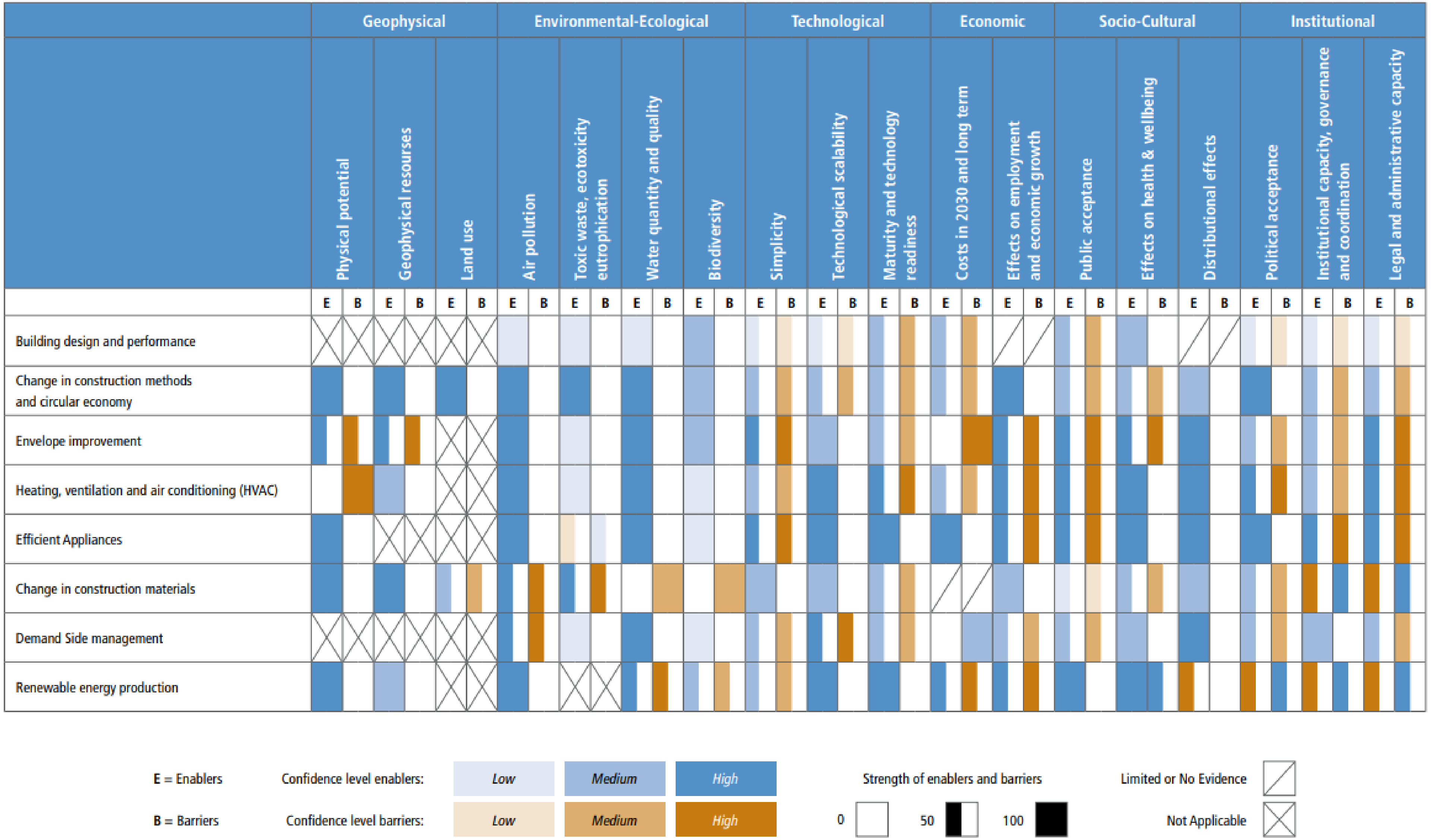
Appliances and lighting

- Energy efficiency of appliances.
- Smart appliances (reduction of peak load).
- Move to more efficient lighting technologies, esp. LEDs.

Non-technical mitigation options

- Passive management:
  - Adaptation of clothing.
  - Allocation of activities per room.
  - …
- Active management:
  - Use of lighting (turning off if not needed).
  - Use of hot water (reduce shower time).
  - Reduce heating times or temperatures (e.g. during the night, in less frequented rooms).
  - Efficiency of cooking (e.g. putting lid on).
  - …

Benefits and drawbacks of different options



Policy instruments

	Sufficiency & efficiency	On-site renewable energy generation
Regulatory	Building energy codes Building labels and performance certificates Energy audits Minimum energy performance standards Appliance energy labelling Information campaigns Public procurement regulations & guidance	Building codes Renewable energy portfolio standards Net metering Electricity market design Public procurement regulations & guidance
Market-based	Carbon allowances Utilities programmes Energy efficiency obligations Energy or carbon taxes	Green certificates (tradable) Energy communities
Financing & business models	Investment grants Commercial & subsidised loans Energy services agreements Energy performance contracting Energy efficiency mortgages	Direct investments Feed-in tariffs

Substantial potential at negative mitigation cost

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26% of total sector baseline emissions in **developed** could be saved at negative cost

20% of total sector baseline emissions in **developing** countries could be saved at negative cost

* including ICT, water heating, and cooking.
** including the change in construction methods; management and operation of buildings; and efficient heating, ventilation, and air-conditioning.
*** typically in new high performance buildings.
**** including thermal efficiency of building envelopes; management and operation of buildings; and efficient heating, ventilation, and air-conditioning.

Nearly zero buildings and low-carbon buildings

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- Different envelope design and technologies are needed, depending on the climate and the building shape and orientation.
- Passive House standard: annual heating and cooling energy demand decrease between 75% and 95% compared to conventional values.
- Documented low-energy buildings are mostly located in Europe and North America, with some in Asia and very few in Australia, Latin America and the Middle East.

Net-zero retrofitting

BCA Academy Building, Singapore

New construction

Infosys, Software Development Block 10, India

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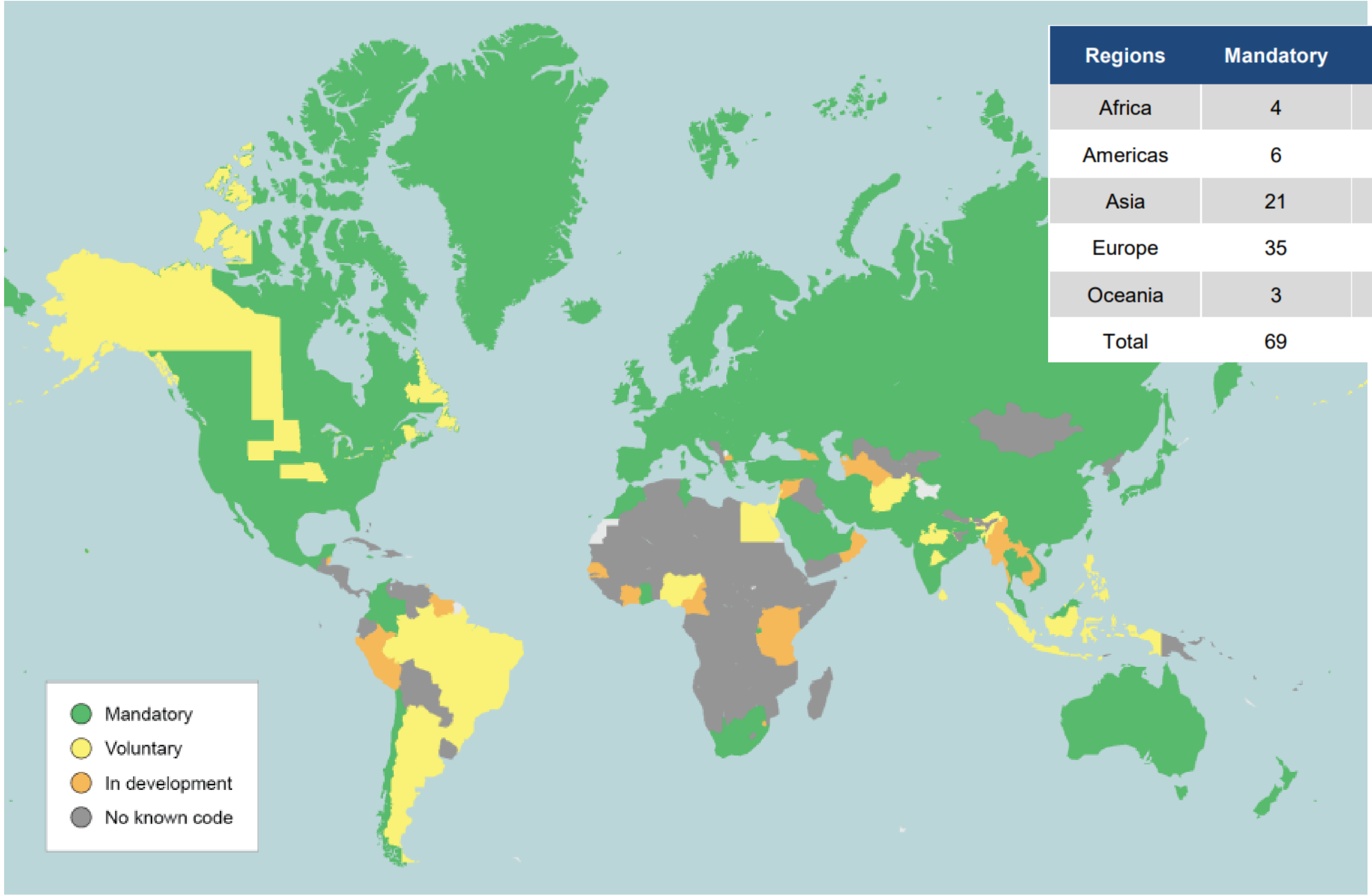
Coverage of energy codes for new buildings, 2021



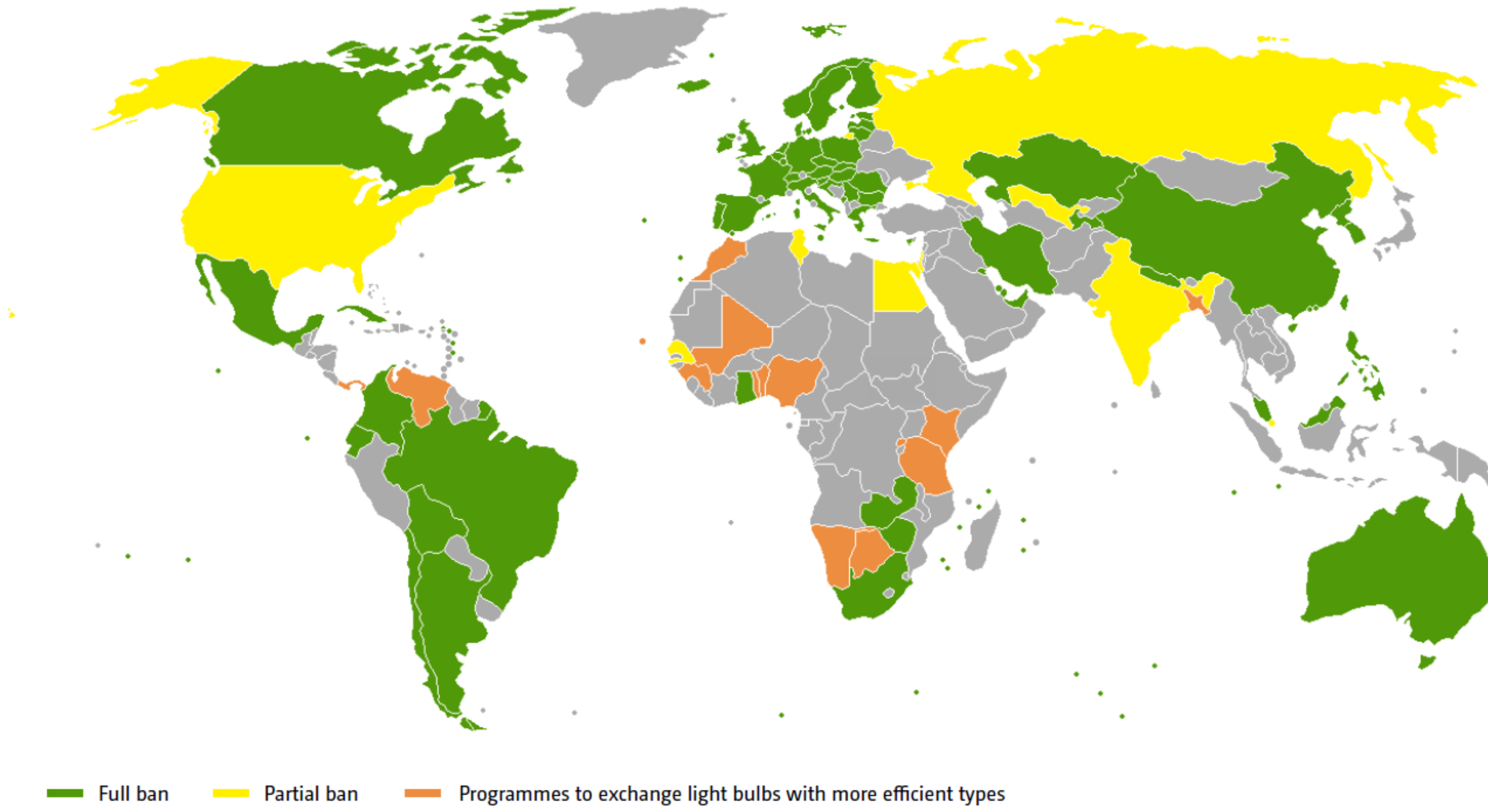
Regions	Mandatory	Voluntary	In development	No known code	Total
Africa	4	3	8	39	54
Americas	6	2	12	15	35
Asia	21	6	6	13	46
Europe	35		1	7	43
Oceania	3		3	10	16
Total	69	11	30	84	194

The number of countries with building codes has increased by 30% since 2015.

Challenges in designing new building codes and enforcing existing ones remain in many countries.

Note: Building codes relating to specific cities are not shown

Coverage of policies to ban inefficient lighting



One effective way to improve the energy performance of a whole class of products is to implement a ban on inefficient ones.

The ban on incandescent light bulbs implemented in many countries is a good example.

Example: India's national Cooling Action Plan

The national Cooling Action Plan, introduced in 2019, sets out multiple targets:

- Reduce cooling demand across all sectors by 20–25%
- Reduce refrigerant demand by 25–30%
- Reduce cooling energy requirements by 25–40% by the financial year 2037/2038
- Targets for space cooling in buildings
- Targets for air-conditioning technology

Additionally, the programme encourages research and development in the cooling sector, as well as training and capacity-building.

Some results to date

- Action points on space cooling have been finalised
- Building codes for large commercial and for residential buildings have been developed
- RAC service technicians have been trained

Examples: Mandatory building renovation

The **French** Law on Energy Transition for Green Growth includes requirements for upgrading the energy performance of a building on the occasion of other works, such as renovating a facade, re-roofing or undertaking a loft conversion.

In **Germany**, retrofitting obligations under the Energy Saving Ordinance must be fulfilled by building owners within a specific time frame. All such obligations, some of which have been in force for over 10 years, are also subject to the precondition of cost-effectiveness. They cover insulation, the replacement of old boilers and the installation of renewable energy systems when replacing a heating system in an existing building.

Denmark has established minimum energy requirements for building components in the case of change of building use, including the conversion of an outbuilding or usable roof space to accommodation.

Contribution of mitigation in buildings to the SDGs

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10 REDUCED INEQUALITIES

2 hours per day saved for women and girls from collecting fuel in Africa

13 CLIMATE ACTION

Up to 90% GHG emissions reduction in developed countries

Up to 80% of GHG emissions reduction in developing countries

3 GOOD HEALTH AND WELL-BEING

24,500 avoided premature deaths and **22,300** disability-adjusted life years (DALYs) of avoided asthma in the EU

1.8 million fewer avoided premature deaths from HAP in developing world in 2030

11 SUSTAINABLE CITIES AND COMMUNITIES

Up to 28% higher selling prices for decarbonised building in developed countries

7 AFFORDABLE AND CLEAN ENERGY

Up to 2.8 billion people in developing countries lifted from energy poverty

5 to 8 million households in Europe lifted from energy poverty

8 DECENT WORK AND ECONOMIC GROWTH

Up to 30 direct and indirect jobs per million USD invested in building retrofit or new energy efficient buildings

2 million direct jobs from transforming fuel-based lighting to solar LED lighting in developing countries

Key resources for energy supply information

Information

Open Energy Info (OpenEI):

http://en.openei.org/

IEA Policies and Measures Databases:
https://www.iea.org/policies

Enerdata Global Energy Trends:
https://www.enerdata.net/publications/reports-presentations/world-energy-trends.html

Key expertise

The Global Alliance for Buildings and Construction (GlobalABC)

https://globalabc.org/

The American Institute of Architects

https://www.aia.org/

Buildings Performance Institute Europe (BPIE)

https://www.bpie.eu/

Topics for discussion

- Building energy codes are a proven and effective instrument. Does your country have such codes in place?
  - If yes: how effective are they? What could be done to enhance ambition and effectiveness?
  - If no: what are the key challenges preventing implementation? What could be ways to overcome these?
- What are the principal barriers to energy efficiency in households and commercial buildings in your country?

MODULE B5

INDUSTRY

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Industry: Key challenges

- Lack of proven technology solutions in some industries.
- Diversity of the sector and related solutions.
- Enabling adoption of new solutions in small- and medium-sized enterprises.
- Industrial sector GHG emissions accounting is complicated by carbon storage in products

Growth of emissions was most rapid from 2000 to 2010

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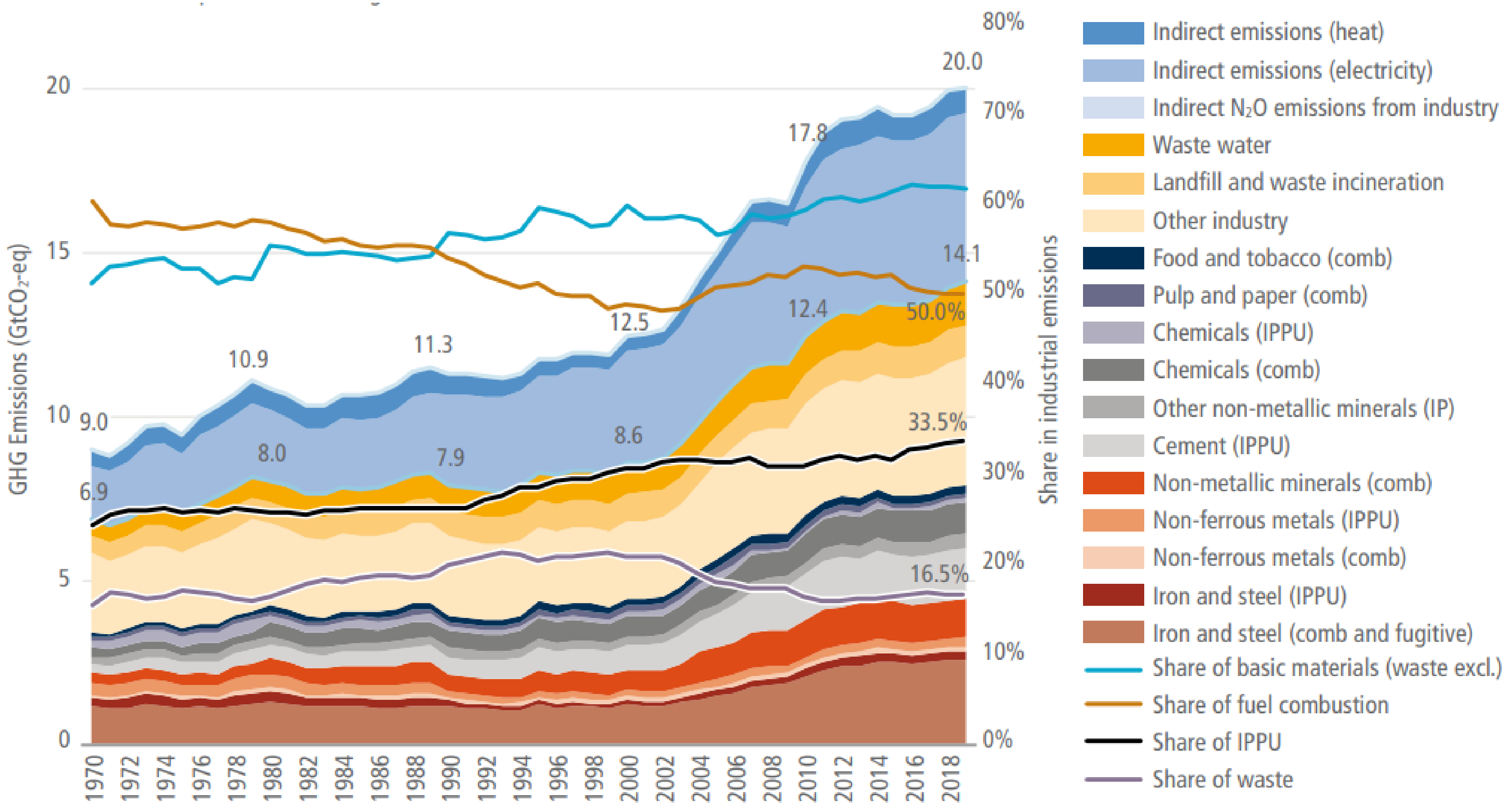

Total emissions increased by 77% from 1990 to 2019

Direct emissions increased by 79%

Waste is included here and represented 3.9% in 2019

Emission sources and gases in industry are divers

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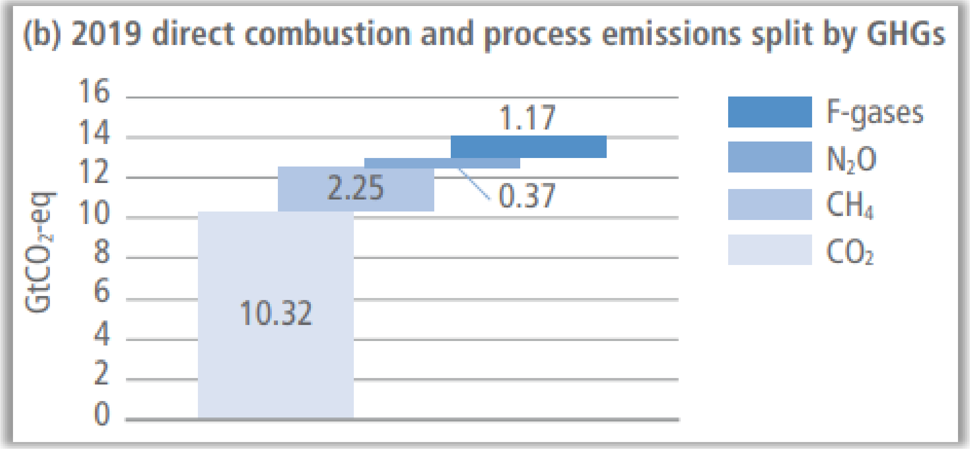
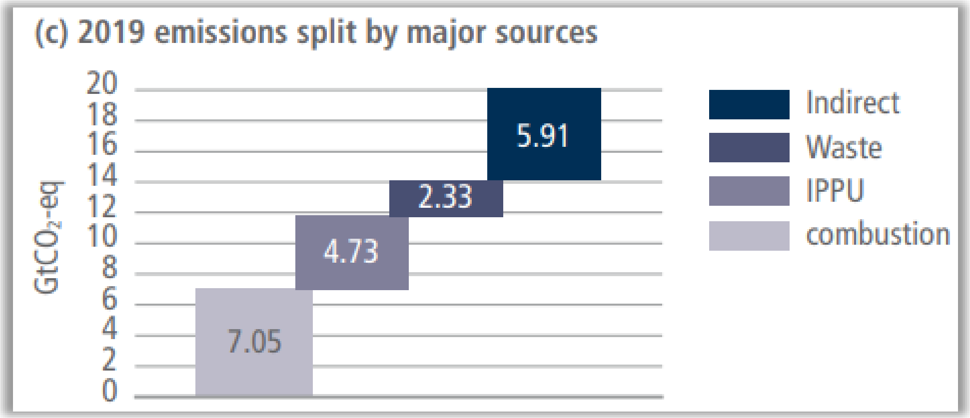
- Direct combustion of fossil fuels.
- Indirect emissions from off-site generated electricity and heat.
- Emissions from industrial waste and wastewater.
- Direct emission of gases (IPPU):
  - CO_2 from industrial processes.
  - Non-CO_2 gases:
    - N_2O from adipic acid, nitric acid, and caprolactam production.
    - F-gases, such as PFCs from aluminium smelting and semiconductor manufacture.
    - SF_6 from insulated electrical switchgear, production of flat screens and semiconductors.
    - CH_4 from various chemical processes.





Asia experienced the largest growth

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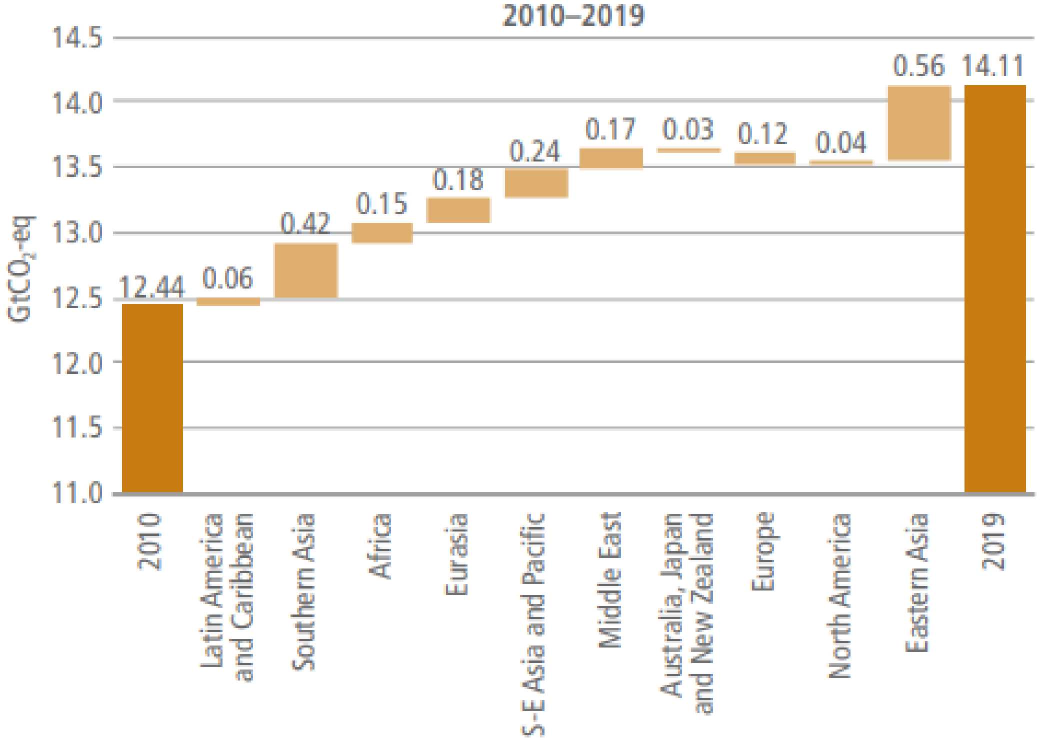
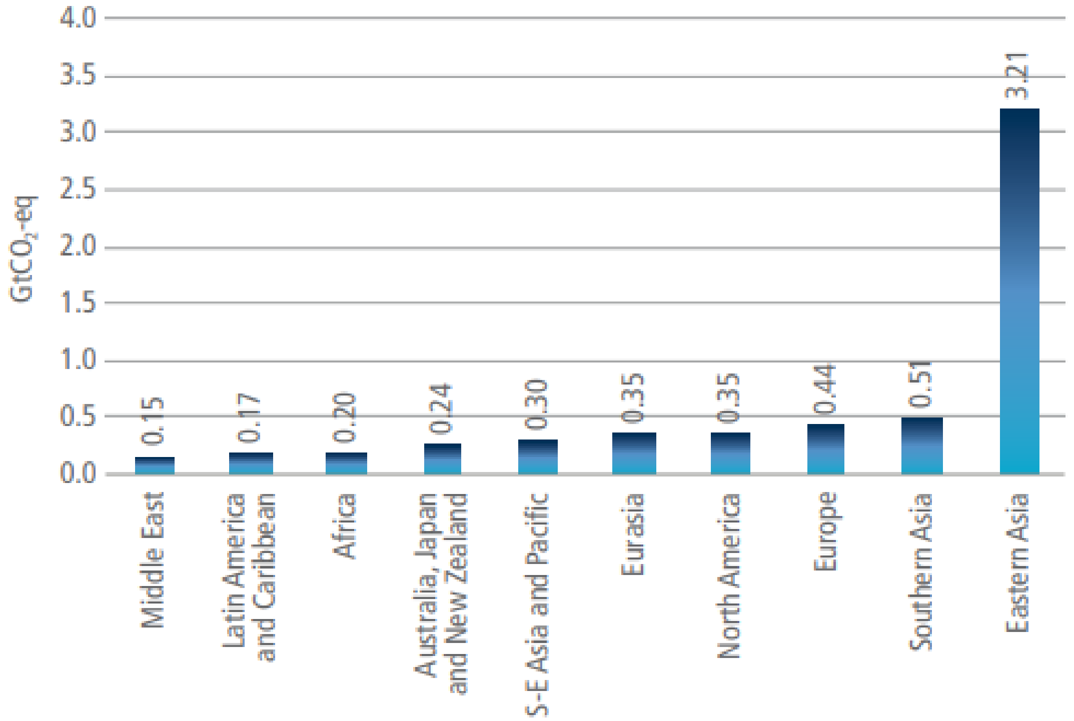
Southern and Eastern Asia were responsible for 58% of growth observed between 2010 and 2019

Eastern Asia had the largest share of global indirect GHG emissions in 2019, at 54%

(b) 2010–2019 increments of industrial GHG emissions in 10 world regions (direct emissons only)



(c) 2019 indirect GHG emissions in 10 world regions



Material demand drives emissions growth in industry

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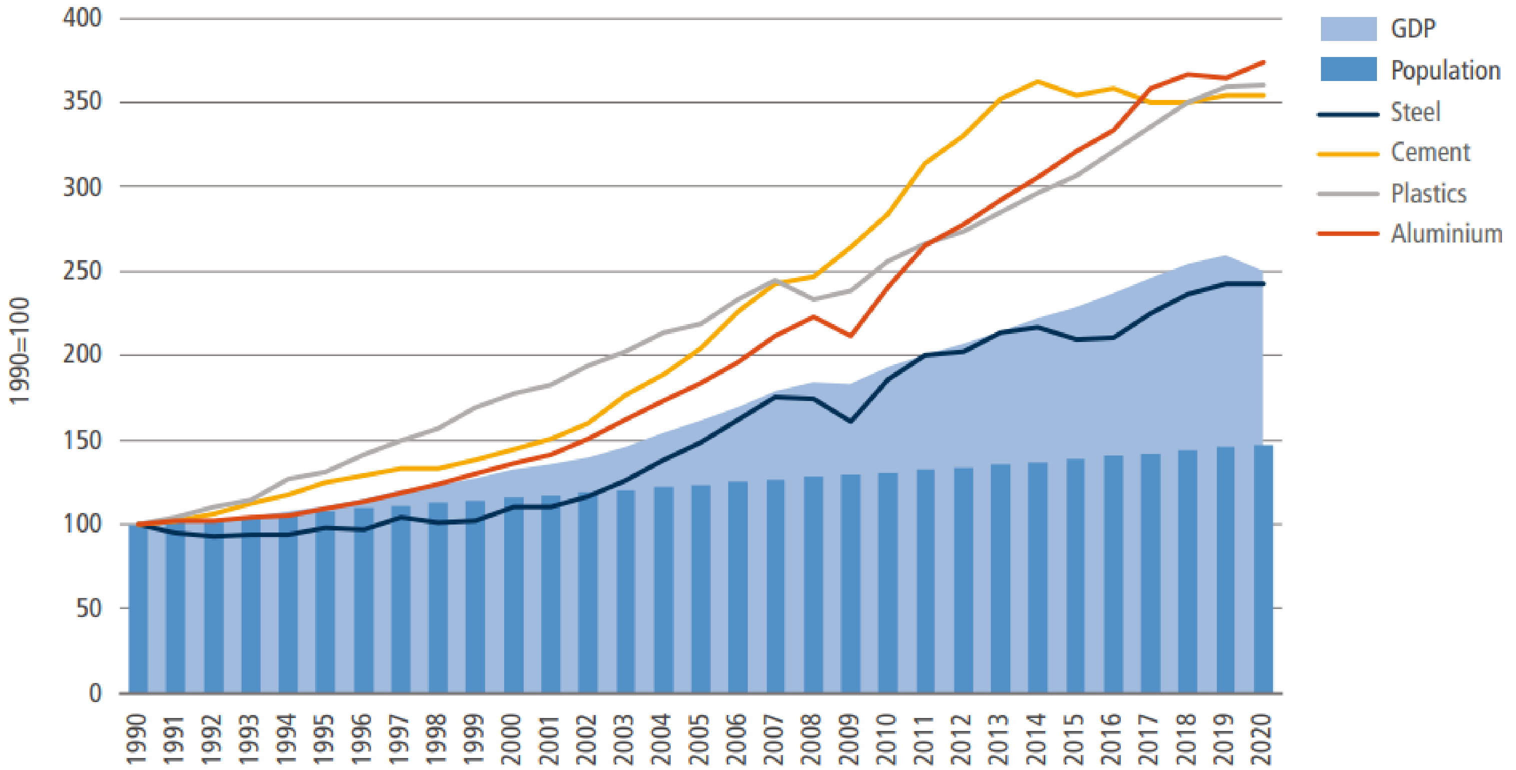
Demand for key energy-intensive materials increased by a factor of

2.5 - 3.5



Demand for materials is driven by GDP and to a lesser extent population growth.

Cement demand peaked in 2014 and remains roughly stable since.

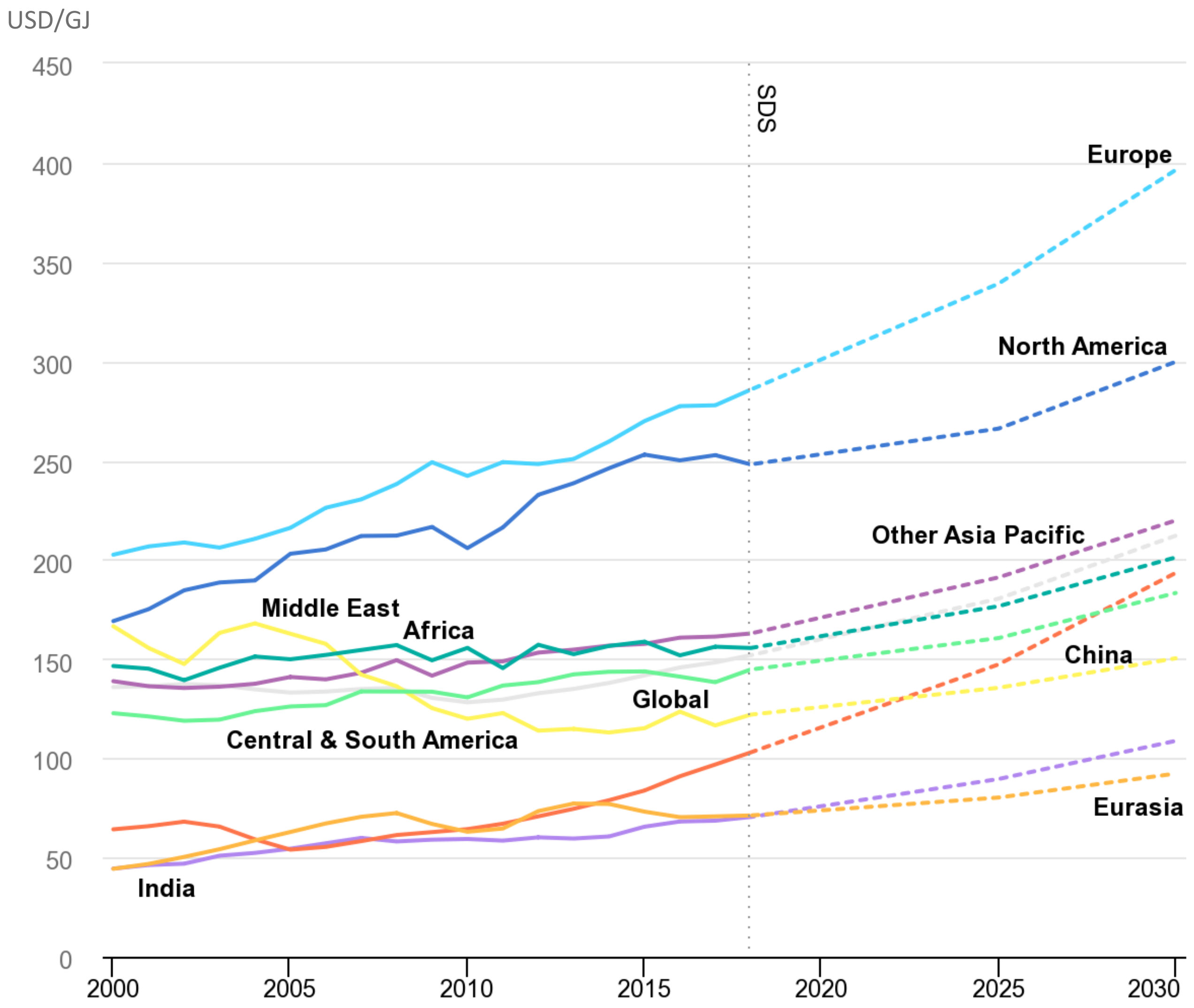
Aluminium has the highest growth at around 370% from 1990 to 2020.

Energy productivity improvements slow down emissions growth, but more is needed

Key contributors to the increase in energy productivity are:

- The deployment of state-of-the-art technologies
- Operational adjustments leading to more efficient equipment use
- A structural shift away from energy-intensive industry

➡ Global industrial productivity needs to increase 2.8% per year to 2030 to get on track with the SDS – an acceleration from the 2.1% annual growth of 2010-18.



Climate change impacts on industry

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- Disrupted supply chains through impacts on mobility or production infrastructure of input products.
- Reduced worker productivity through increased heat stress, especially for outdoor workers.
- Availability of clean freshwater for industrial processes.
- Direct damage to industrial infrastructure from extreme weather events.
- Disruption of ICT infrastructure from extreme events, disrupting production and logistics.

Adaptation measures may affect the demand for basic materials, e.g. for protective infrastructure

Mitigation options in industry: General classification

Mitigation options

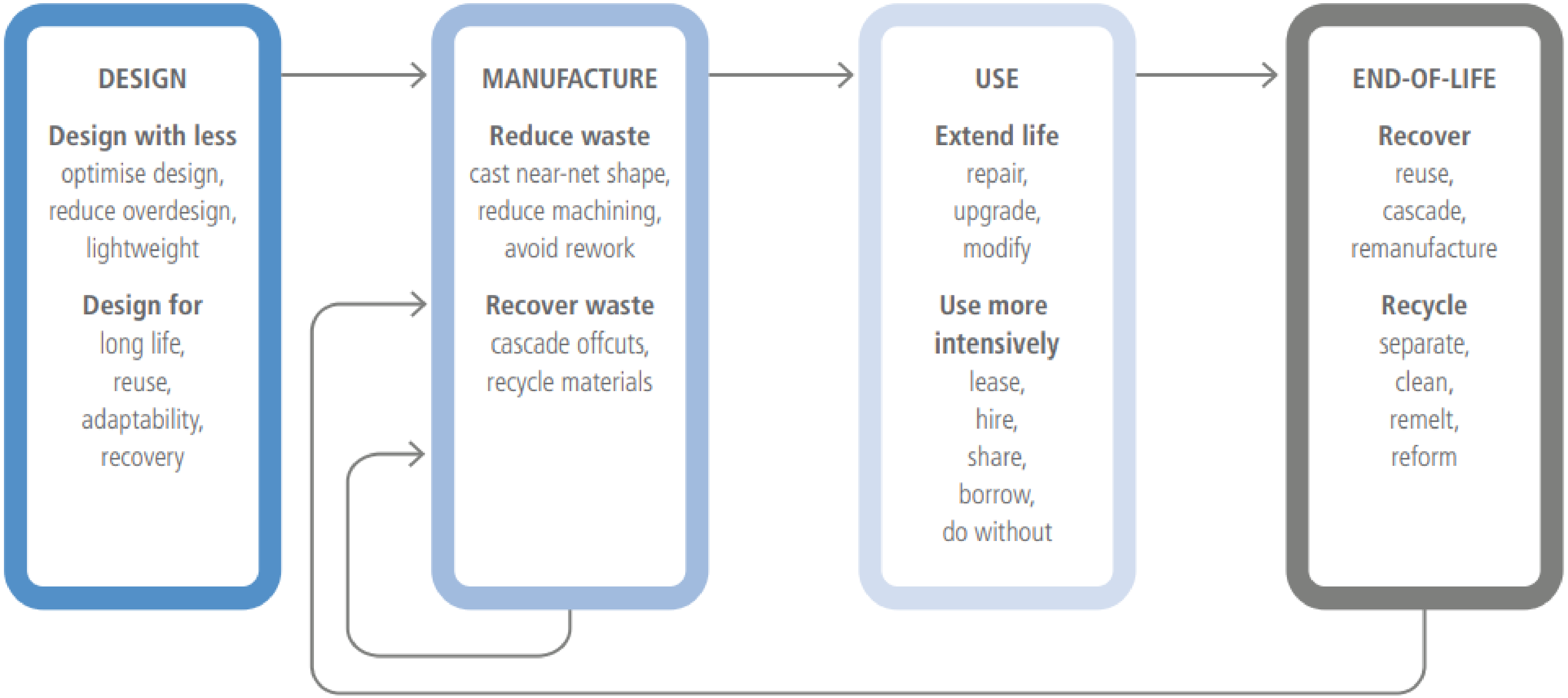
	Short to medium term	Medium to long term
Decarbonising production	– Reduction of indirect emissions via lower-carbon electricity and heat supply	– Provision of emissions-free elctricity and high temperature heat
	– Energy efficiency improvements to best available technologies	– Energy efficiency approaching thermodynamic minimums
	– Fuel switching, biomass and electricity use for high temperature process heat	– Deep low-carbon electrification, green hydrogen use
	– Partial substitution of high-carbon feedstock	– Zero emissions feedstock (green hydrogen, biomass) for basic materials production
	– Small scale and sectorally narrow concentrated CO_2 flow CCUS	– Broad-scale, large-scale concentrated CO_2 flow and possibly post-combustion CCUS
Decarbonising demand	– Material efficiency and substitution	– Ecodesign, material efficiency, demand reduction
	– Increasing recycling rates	– Circular material flows and effective industrial waste management

Base year and contributions from the drivers are only illustrative. Drivers' contribution varies across industries. Indirect emissions reduction is considered as outcome of mitigation activites in the energy sector; see Chapter 6.

Contributions from different drivers to the transition to net-zero emissions vary with time:

- Energy efficiency dominates in the short- and medium-term.
- Contributions from the other drivers steadily grow over time.

Material efficiency strategies



Mitigation options for selected industries

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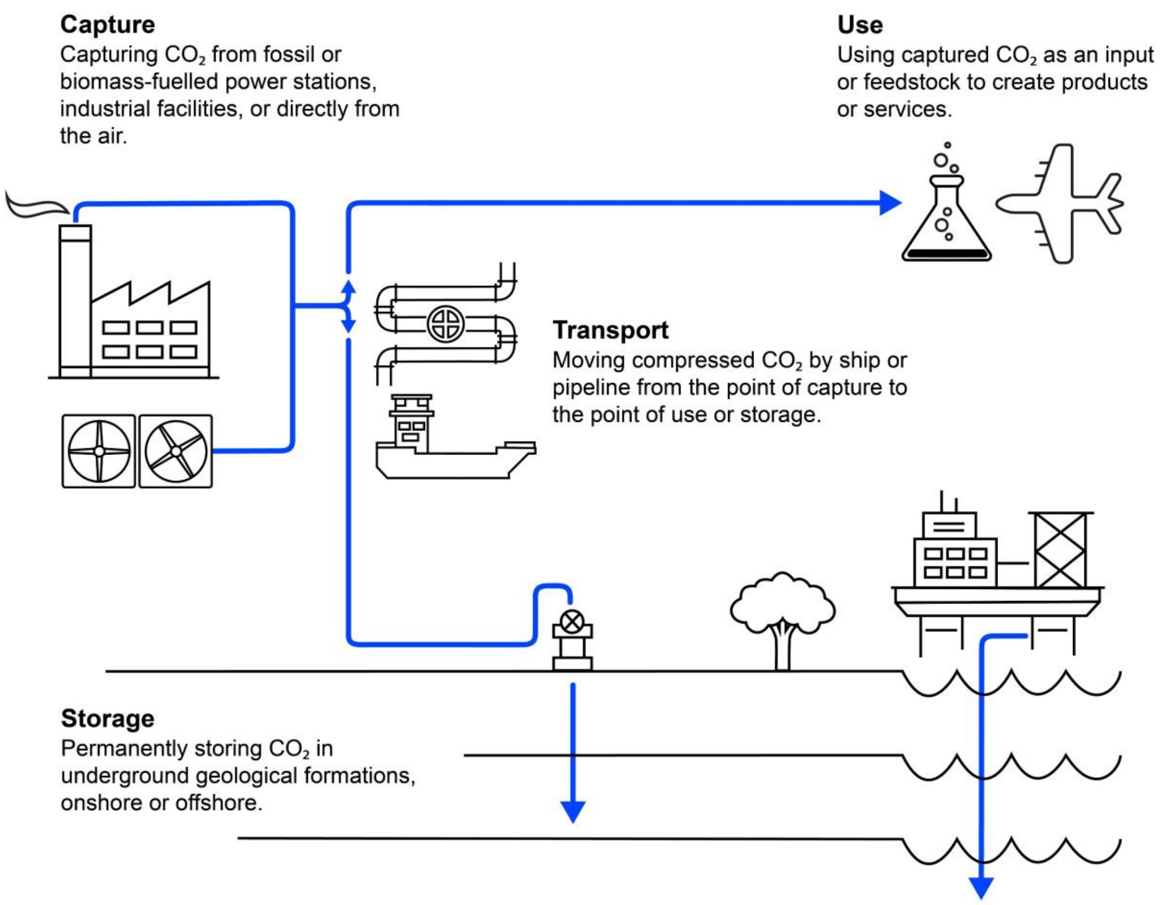
Sector	Energy efficiency	Fuel switching	Feedstock replacement	Material efficiency	Circular economy
Steel	• HIsarna® process • Operational efficiency in the BF-BOF process	• Electric arc furnaces (electricity) • Aqueous electrolysis • Hydrogen co-firing • Bio-based fuels	• Methane based syngas direct reduced iron (DRI) • Hydrogen-based direct reduced iron (H-DRI)	• More targeted steel use in end products • Product sharing • Near net-shape casting	• Increase recycling
Cement & concrete		• Bio-based fuels • Hydrogen • Electricity	• Reduction of clinker content	• Building design optimisation • Stronger concrete • Alternative building materials	
Chemicals	• Heat recovery • Combined power generation from waste products	• Bio-based fuels • Hydrogen • Electricity Especially for heat generation	• Grey hydrogen to green hydrogen • Pyrolysis oil • Biomass feedstocks		• CO_2 capture and use as feedstock • Product design for re-use and recycling • Chemical recycling

The role of CCS and CCU



Net effects on atmospheric emissions depend on:

- The initial source of the carbon (fossil fuel, industrial processes, biogenic, or direct air capture).
- The duration of storage or use.

Potential negative emissions (removals) can be achieved, if:

- The initial carbon source is biogenic.
- CO_2 is directly captured from air.
- Permanence of storage is ensured.

As a general rule it is not possible to capture all the CO_2 emissions from an industrial plant

Policy instruments

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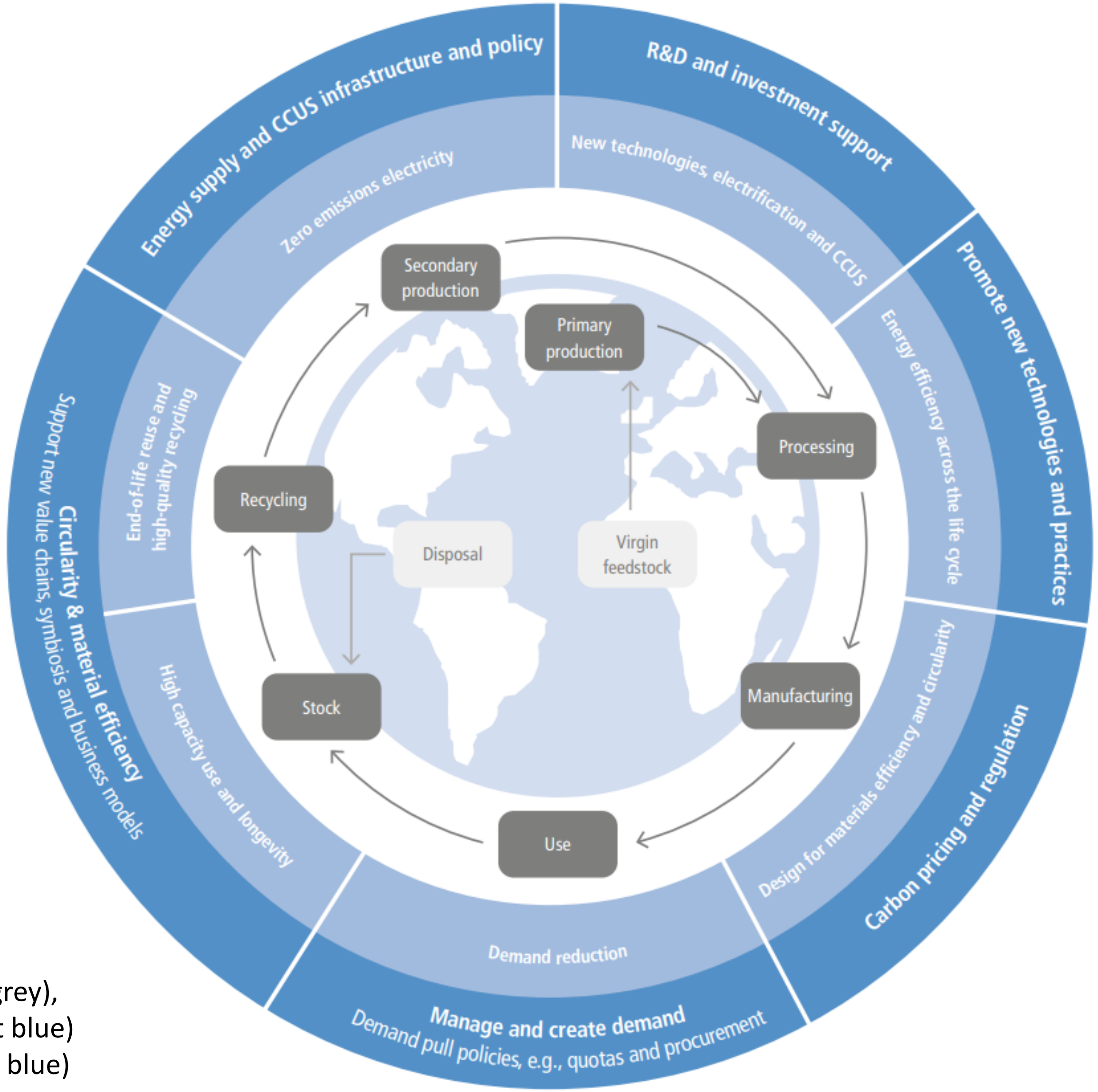
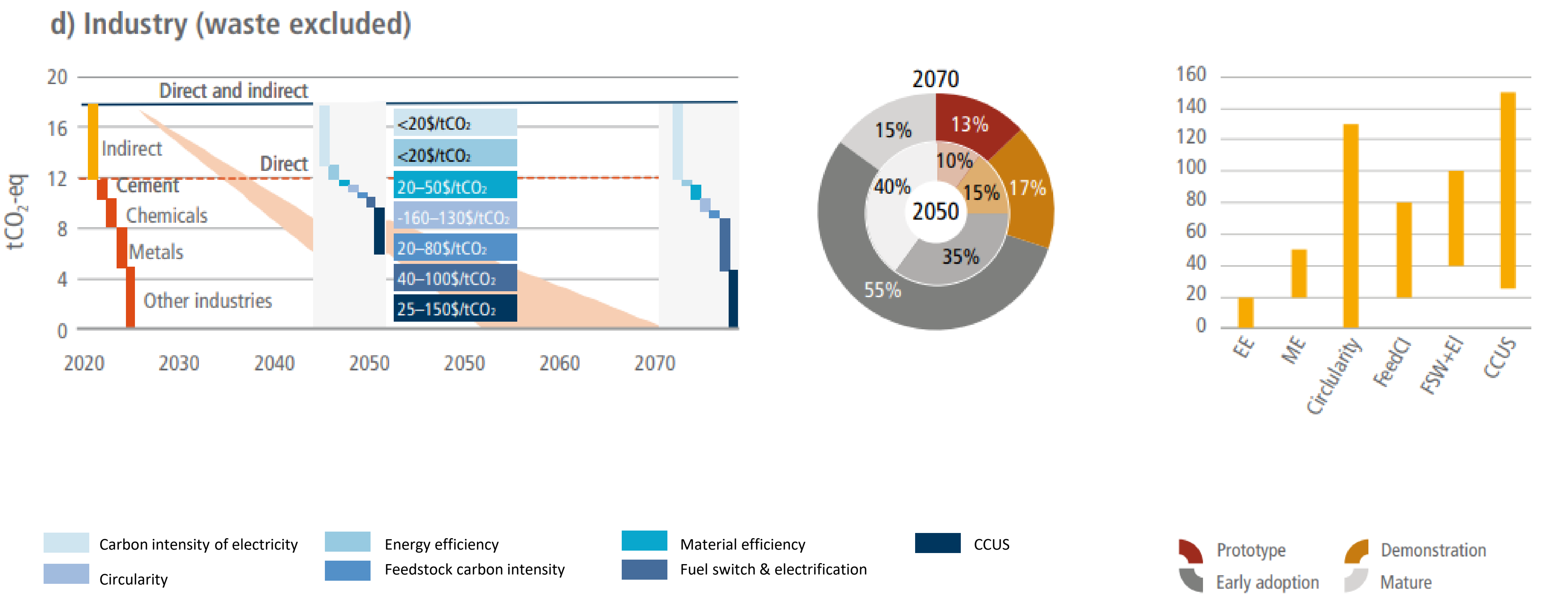
Key policy instruments include:

- GHG pricing coupled with border adjustments or other economic signals for trade exposed industries;
- Robust government support for research, development, deployment;
- Energy, material and emissions standards;
- Recycling policies;
- Sectoral technology roadmaps;
- Market pull policies;
- Support for new infrastructure



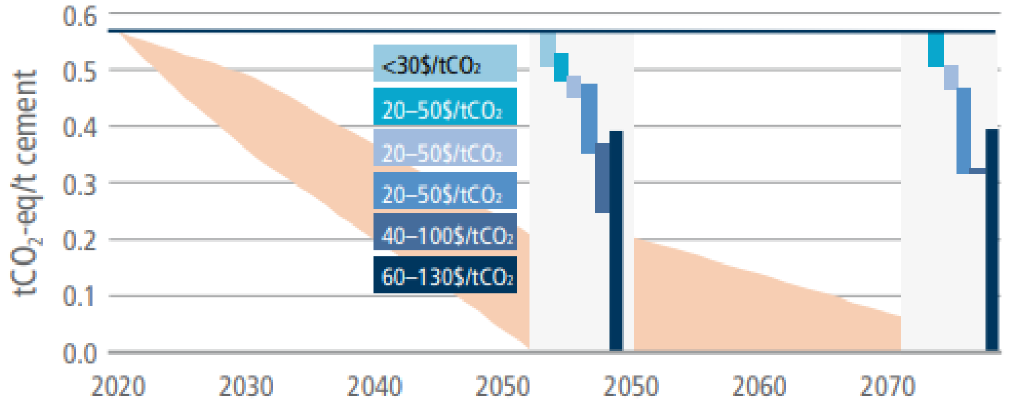
Life cycle of materials (grey), Mitigation options (light blue) Policy approaches (dark blue)

Potentials and cost for industry mitigation

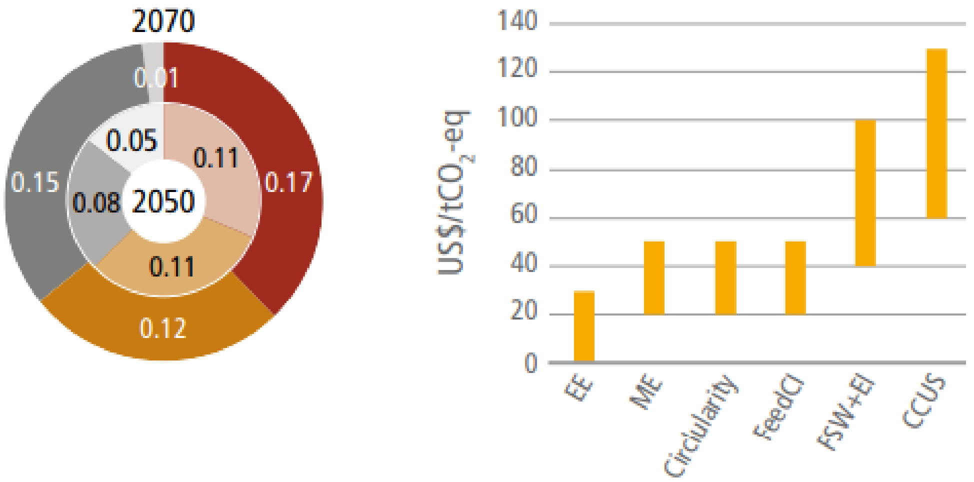


Potentials and cost for selected industries

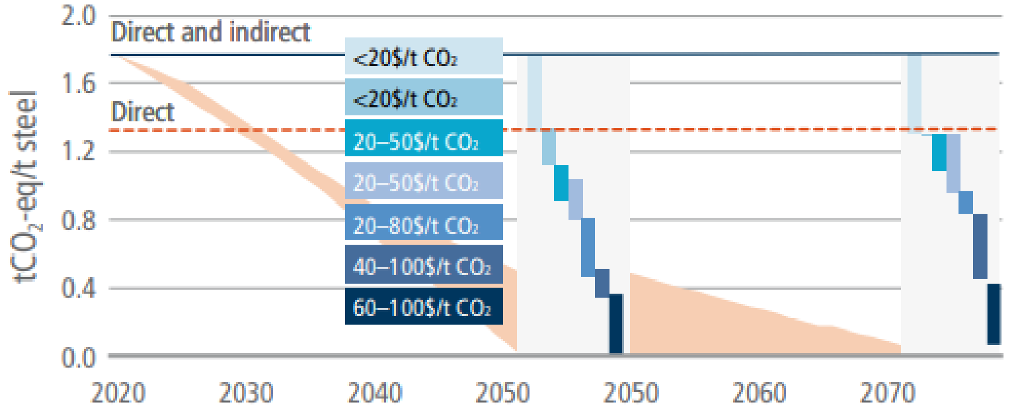
a) Cement



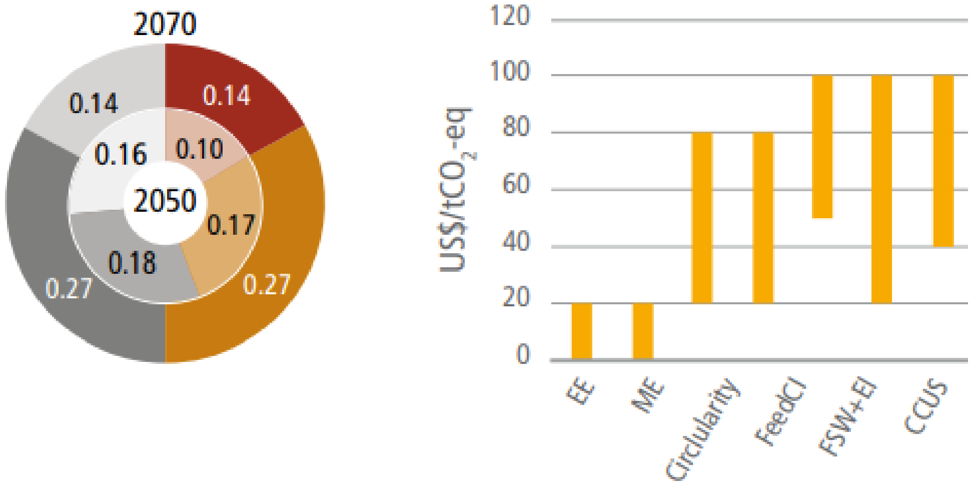
Costs rise: cement – 35–115%; house < 1%



b) Steel



Costs rise: steel – 10–50%; home or car <1%



Example: Initiative for a climate-friendly industry in North Rhine Westphalia

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IN4Climate NRW - Initiative for a climate-friendly industry in North Rhine Westphalia (NRW)

- Launched in September 2019 as a platform for collaboration between representatives from industry, science and politics.
- More than 30 companies representing mainly steel, cement, chemical, aluminium industry, refineries and energy utilities.
- Work is conducted in ‘innovation teams’ and underlying working groups with a self-organized process.

Objectives:

- To identify and set concrete impulses for development and implementation of breakthrough technologies.
- Specify necessary infrastructures (e.g., for hydrogen production, storage and transport).
- Specify appropriate policy settings.

Examples of the potential role of different actors

Actors	Direction: planning and strategising pathways to net zero	Innovation: RD&D for new technologies and other solutions	Market creation: create and shape demand-pull for various solutions	Knowledge and capacity: build institutional capacity across various actors	Coherence: establish international and national policy coherence
International bodies and multilateral collaboration	More attention to industry in NDCs. Monitor progress and identify gaps. Develop international roadmaps.	Include heavy industry decarbonisation in technology cooperation (e.g., Mission Innovation).	International standards, benchmarking systems, and GHG labels. Allow for creation and protection of lead markets.	Support knowledge building and sharing on industrial decarbonisation.	Align other conventions and arenas (e.g., WTO) with climate targets and include heavy industry transitions in negotiations.
Regional and national government and cities	Require net zero strategies in permitting. Set targets and facilitate roadmaps at various levels. Sunset clauses and phase-out agreements for polluting plants.	Experimentation for recycling, materials efficiency, and demand management. Hydrogen, electrification, and other infrastructure.	Public procurement for innovation and lead markets. Green infrastructure investments.	Develop policy expertise for industrial transformation. Support and facilitate material efficiency and circular solutions through design standards, building codes, recycling, and waste policy.	Support vertical policy coherence (i.e., international, national, city level).
Civil society	Monitor and evaluate leaders and laggards. Support transparency.	Engage in responsible innovation programs, experimentation, and social innovation.	Progressive labelling, standards and criteria for low emissions materials and products (e.g., LCA-based), including updating.	Engage in policy processes and build capacity on industrial decarbonisation. Support consumer information and knowledge.	Monitor and support policy coherence and coordination across policy domains (trade, climate, waste, etc.).
Industrial sectors and associations	Adopt net zero emissions targets, roadmaps, and policy strategies for reaching them. Assess whole value chains, scope 3 emissions and new business models.	Share best practice. Coordination and collaboration. Efficient markets for new technology (e.g., licensing).	Work across (new) value chains to establish lead markets for low emissions materials as well as for materials efficiency and circularity.	Education and retraining for designers, engineers, architects, etc. Information sharing and transparency to reduce information asymmetry.	Coordination across policy domains (trade, climate, waste, etc.). Explore sectoral couplings, new value chains and location of heavy industry.

Key resources for energy supply information

Information

Open Energy Info (OpenEI):

http://en.openei.org/

IEA Policies and Measures Databases:
https://www.iea.org/policies

Energy Transitions Commission (2018). Mission possible:

https://www.energy-transitions.org/publications/mission-possible/

Key expertise

Technology Collaboration Programme: Industrial Energy-Related Technologies and Systems:

https://iea-industry.org/

Topics for discussion

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- How might the industrial sector mitigation options interact with trade and competitiveness issues?
- How might your country be affected by a global market for low-carbon technologies?
- What are the barriers preventing industries in your country from increasing energy efficiency?
- What are the technology transfer needs in the industrial sector in your country, and how might these be addressed through mitigation actions?

MODULE B6

AFOLU

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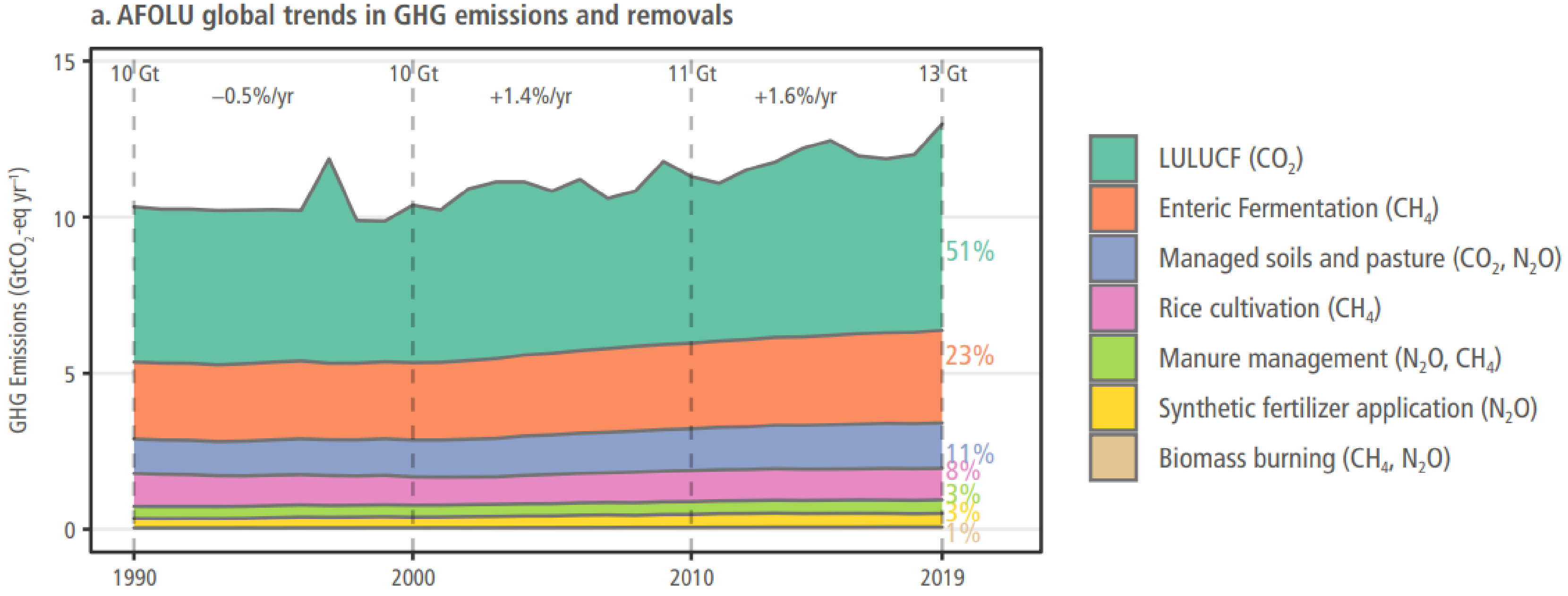
AFOLU: Key challenges

- High uncertainties in estimation of GHG emissions and removals, linked to application of methods and challenges in data collection.
- Balancing sustainable development priorities in complex systems: mitigation, adaptation, food security, biodiversity, etc.
- Multitude of actors and high dependence on behaviour change for mitigation options.
- Climate change impacts, mitigation and adaptation measures have important implications for vulnerable people and communities.

Emission trends

- In 2019, just over half of GHG emissions from the sector were from land use, land use change and forestry (LULUCF).
- In agriculture, the largest share of emissions stems from enteric fermentation.
- CO_2 emissions in the sector are predominantly from LULUCF.
- Agricultural emissions are mostly in the form of CH_4 and N_2O.



At the global level, there is a high uncertainty in estimates of CO_2 emissions from AFOLU, owing to alternative methodological approaches and assumptions.

Interaction between land management and greenhouse gases

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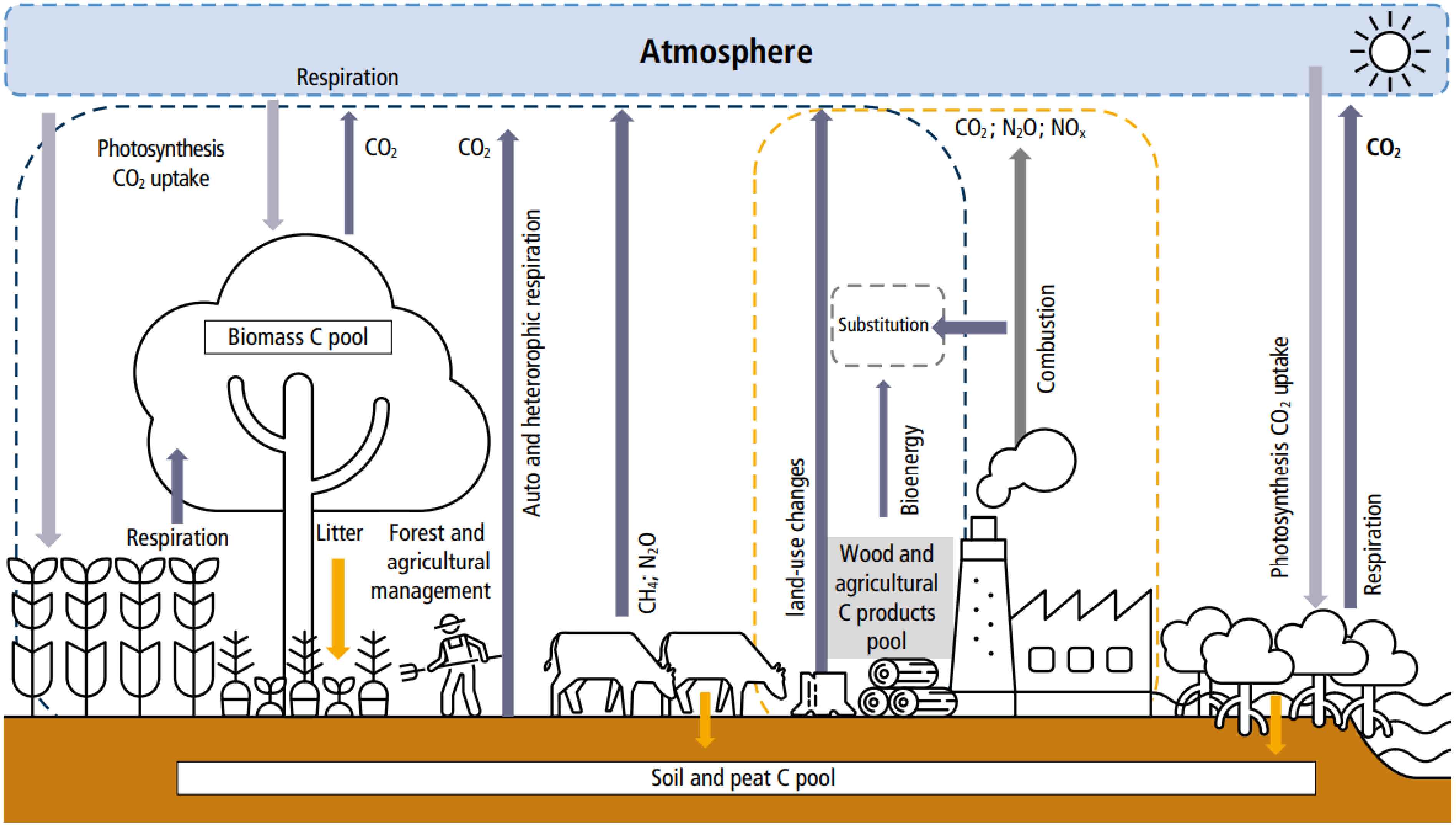
The interplay between land use and GHG fluxes (emissions and removals) is complex.

There are many links to the other sectors.



Drivers for emissions: LULUCF

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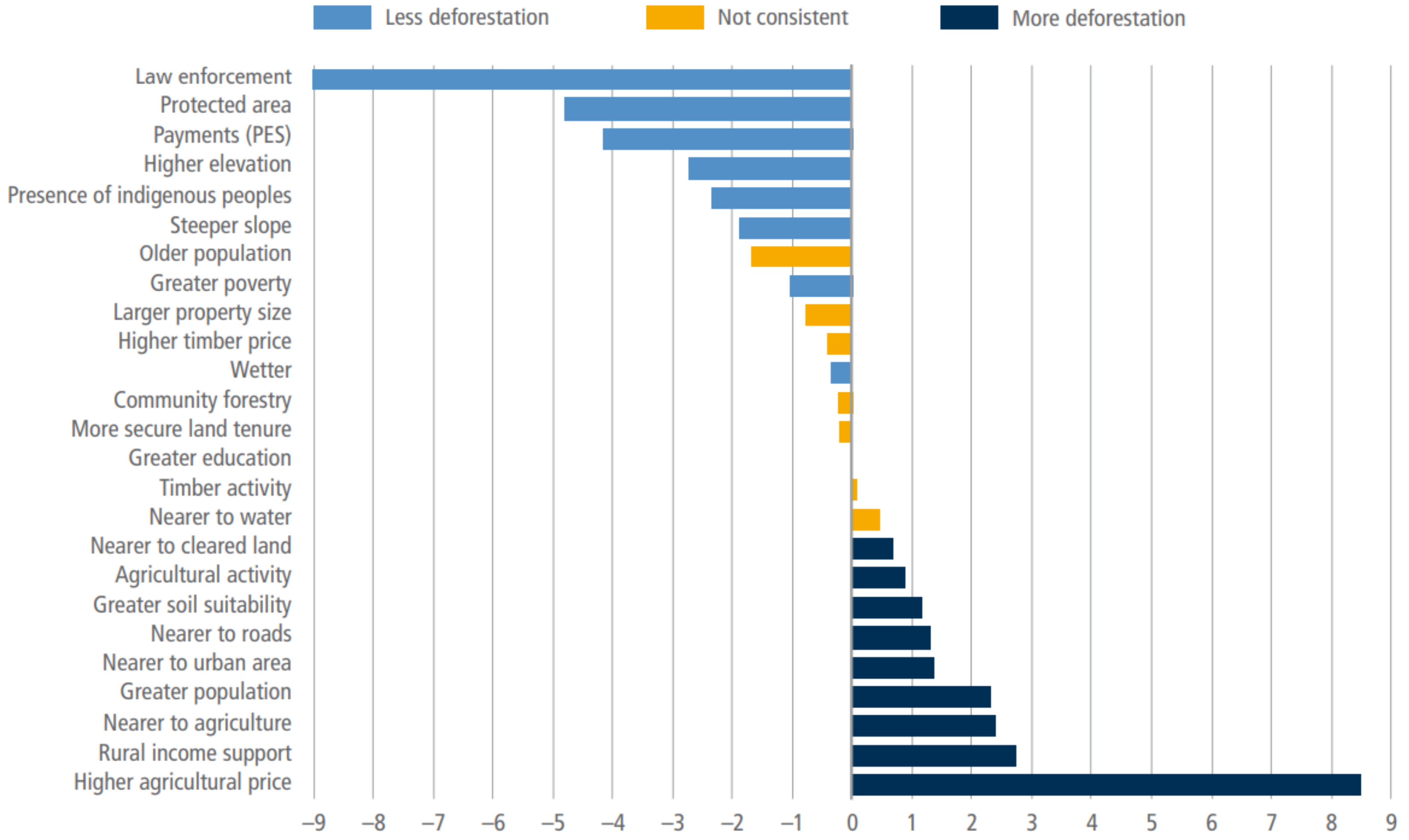
Key drivers are:

- Conversion of natural ecosystems to agriculture.
- Infrastructure development and urbanisation.
- Extractive industry development.
- Fire regime changes.
- Logging and fuelwood harvest.

➡ The global forest area declined by about 178 Mha in the 30 years from 1990 to 2020!



Drivers for emissions: Agriculture

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Direct driver of GHG emissions

Growing demand for animal-sourced food

Expansion of paddy rice cultivation area

Enhanced synthetic fertiliser use

Underlying reasons

Increasing income levels

Population growth

Demand for bioenergy

Indirect drivers for changes in the AFOLU sector

Migration

Migration changes land and resource use patterns. Most migration is from rural to urban areas.

Science & technology

Technological advances can have positive and negative effects on multiple factors, including GHGs.

Global trade

29-30% of emissions from tropical deforestation potentially result from international trade of agricultural commodities.

Institutions & governance

Laws, legal frameworks and social structures influence land management.

Regional differences

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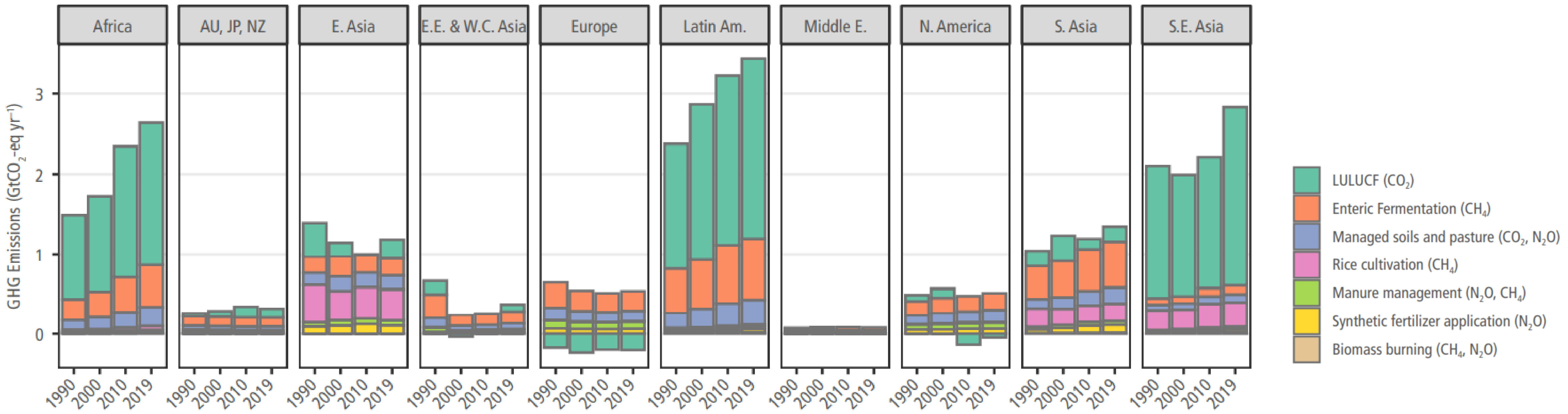
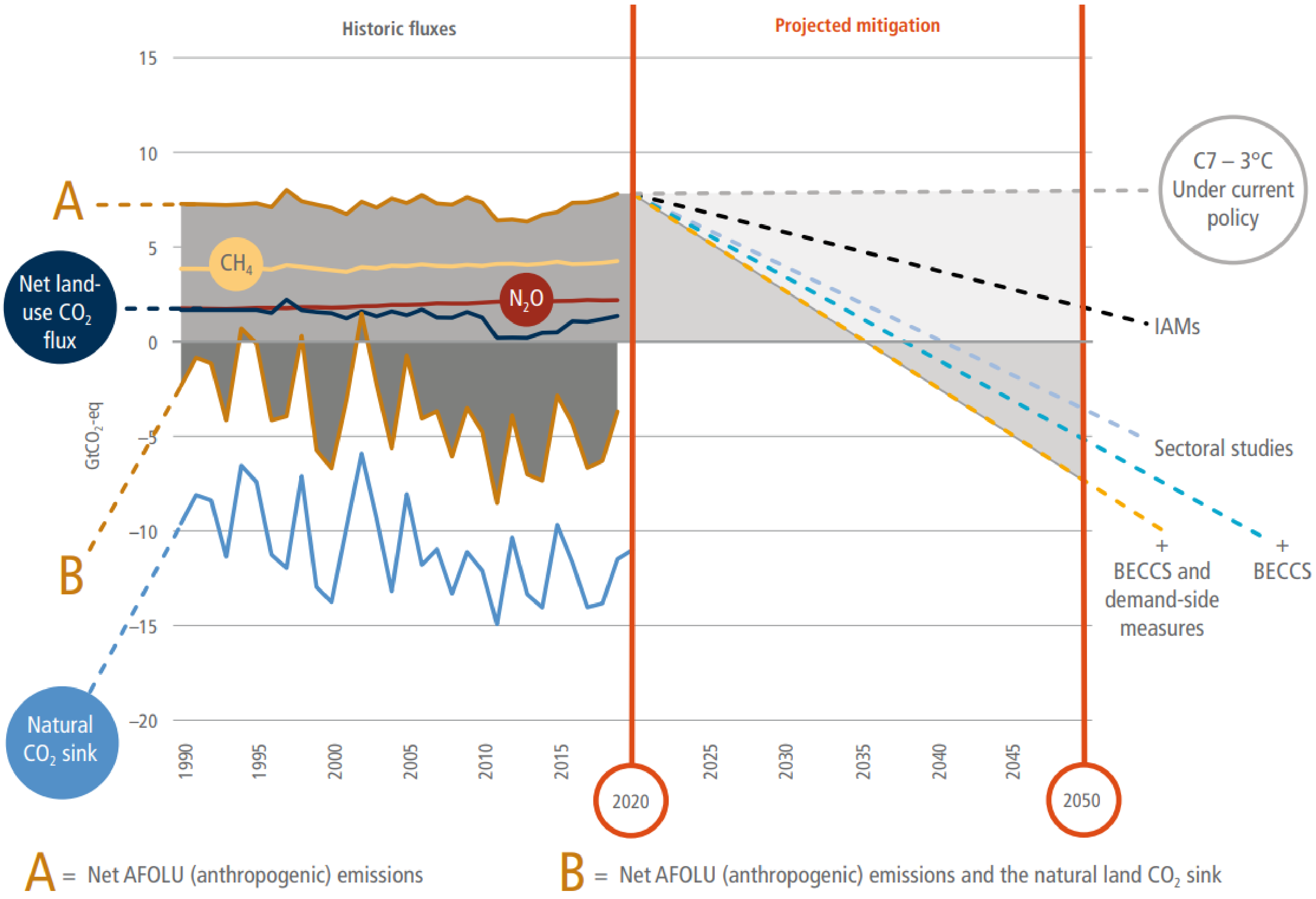
- The composition of GHG emissions in the AFOLU sector varies across regions:
  - Africa, Latin America and South-East Asia having high shares of LULUCF related emissions.
  - East Asia having high shares of emissions from rice cultivation.
  - South Asia having high shares of emissions from enteric fermentation.



Projections

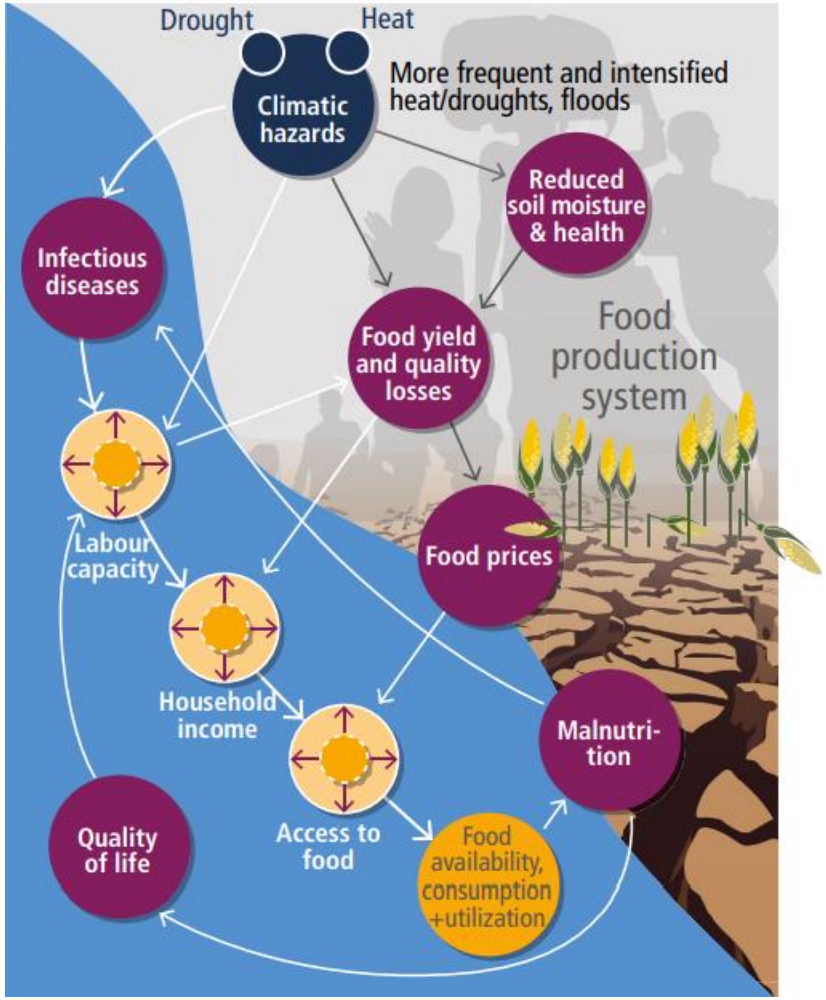
If managed and regulated appropriately, the land sector could become carbon-neutral as early as 2030–2035.

Current policies would likely lead to a moderate growth compared to current levels.



Climate change impacts on the sector

- Regionally different, but mostly negative, impacts on crop yields and quality and marketability of products.
- Heat stress on mortality and productivity of livestock.
- Indirect effects on livestock production from impacts on grassland quality, shifts in species distribution and range changes in livestock diseases.
- Loss of yields from marine fish populations and warming-induced shifts (mainly poleward) of species.
- The possibility of tropical forests reaching ‘tipping points’ in their resilience and experiencing rapid die-off cannot be ruled out.



Mitigation options, potential & co-benefits: Forests

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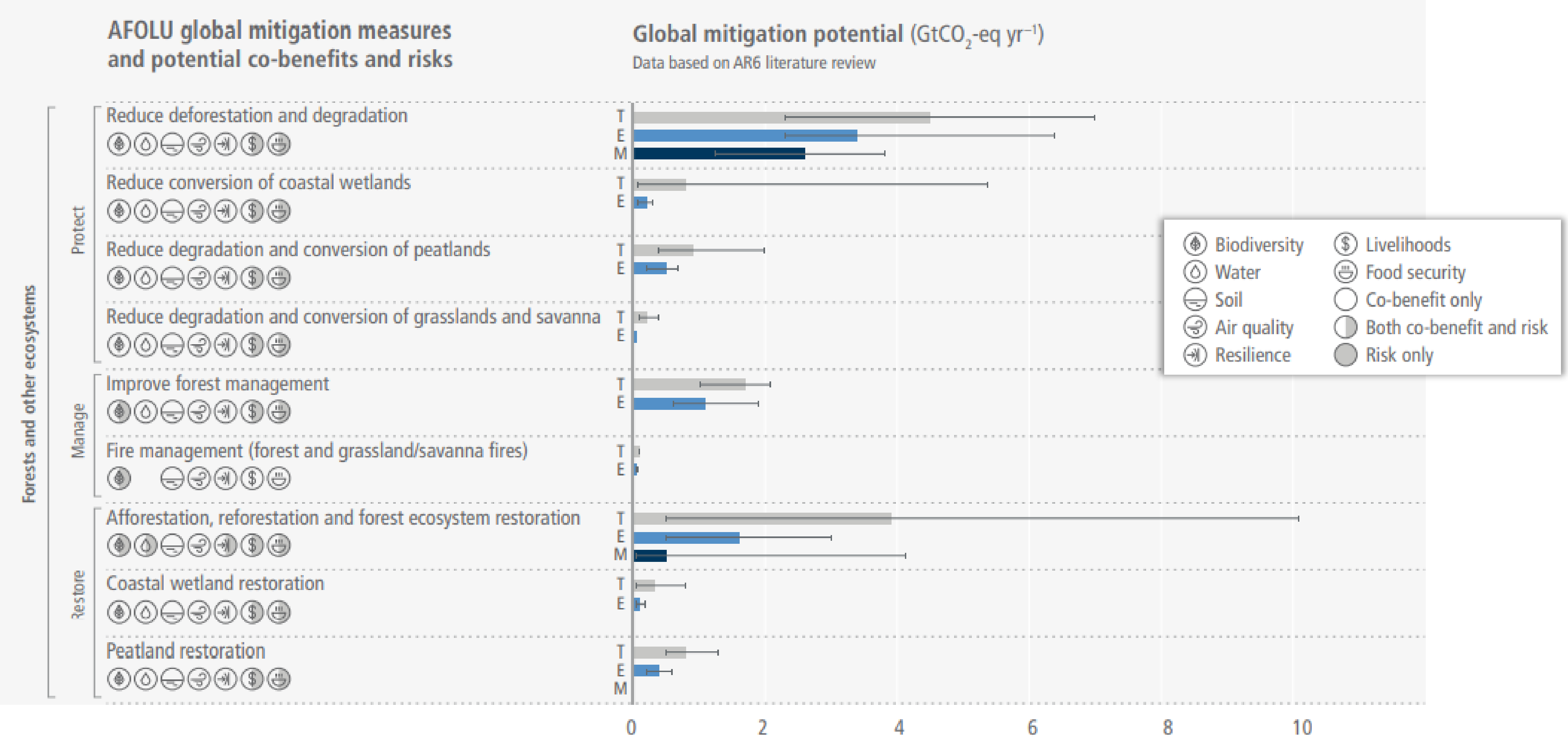
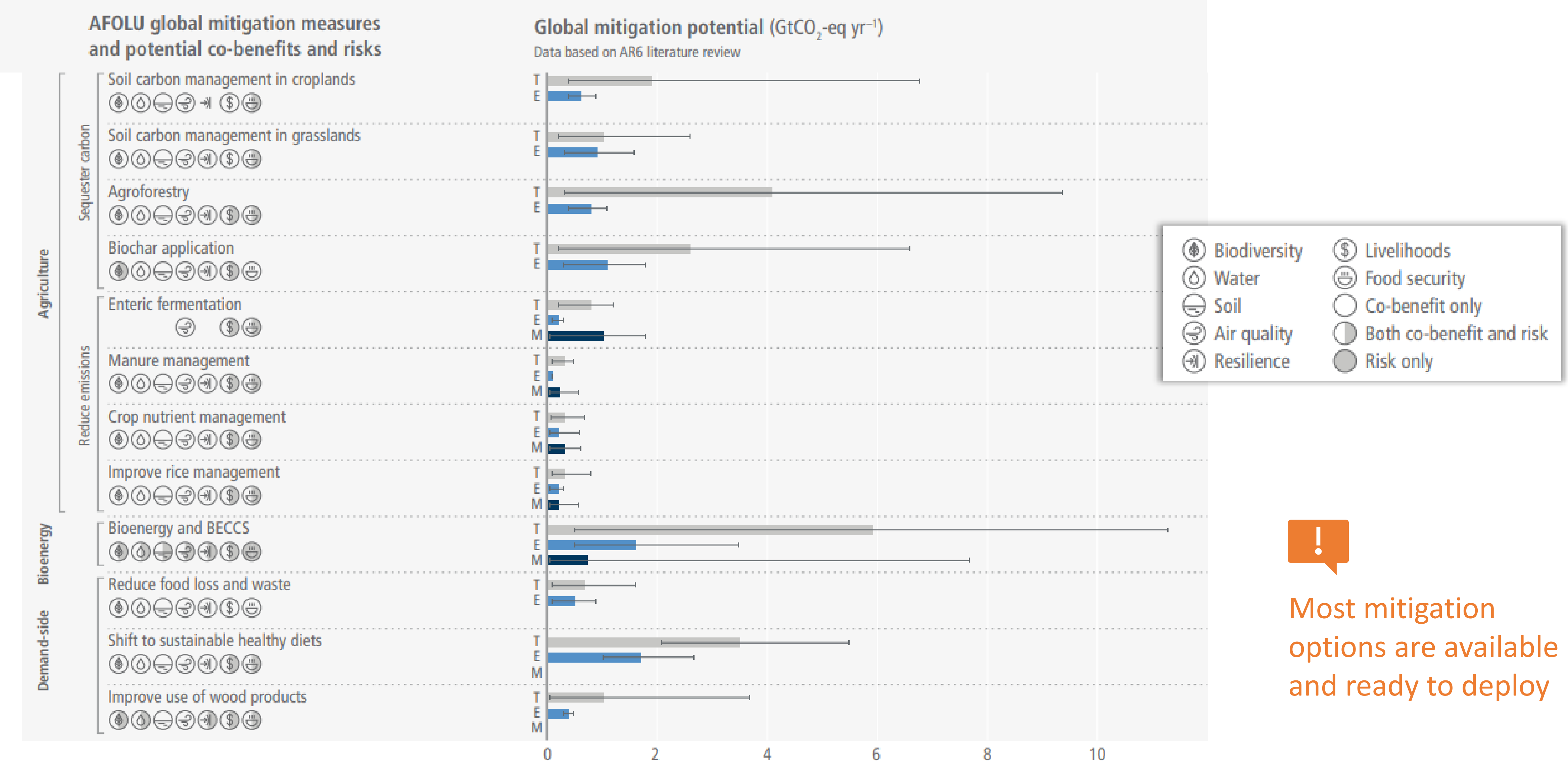


Mitigation options, potential & co-benefits: Agriculture



Most mitigation options are available and ready to deploy

Selected mitigation cost: Forests

Substantial reduction potentials are available at a cost below USD 20

Estimated annual mitigation potential ($GtCO_2e$ per year) by carbon price

Mitigation option	Estimate type	<USD20 tCO_2-eq^{-1}	<USD50 tCO_2-eq^{-1}	<USD100 tCO_2-eq^{-1}	Technical
Forests and other ecosystems total	Sectoral	2.9 (2.2–3.5)	3.1 (1.4–5.1)	7.3 (3.9–13.1)	13 (5–29.5)
	IAM	2.4 (0–10.5)	3.3 (0–9.9)	4.2 (0–12.1)	ND
Forests and other ecosystems – Protect (Reduce deforestation, loss and degradation of peatlands, coastal wetlands, and grasslands)	Sectoral	2.3 (1.7–2.9)	2.4 (1.2–3.6)	4.0 (2.5–7.4)	6.2 (2.8–14.4)
	IAM	ND	ND	ND	ND
Forests and other ecosystems – Restore (Afforestation, reforestation, peatland restoration, coastal wetland restoration)	Sectoral	0.15	0.7 (0.2–1.5)	2.1 (0.8–3.8)	5 (1.1–12.3)
	IAM (A/R)	0.6 (0.2–6.5)	0.6 (0.01–8.3)	0.7 (0.07–6.8)	ND
Forests and other ecosystems – Manage (Improve forest management, fire management)	Sectoral	0.4 (0.3–0.4)	ND	1.2 (0.6–1.9)	1.8 (1.1–2.8)
	IAM	ND	ND	ND	ND

Selected mitigation cost: Agriculture

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Estimated annual mitigation potential ($GtCO_2e$ per year) by carbon price

Mitigation option	Estimate type	<USD20 $tCO_2\text{-eq}^{-1}$	<USD50 $tCO_2\text{-eq}^{-1}$	<USD100 $tCO_2\text{-eq}^{-1}$	Technical
Agriculture total	Sectoral	0.9 (0.5–1.4)	1.6 (1–2.4)	4.1 (1.7–6.7)	11.2 (1.6–28.5)
	IAM	0.9 (0–3.1)	1.3 (0–3.2)	1.8 (0.7–3.3)	ND
Agriculture – Carbon sequestration (Soil carbon management in croplands and grasslands, agroforestry, and biochar)	Sectoral	0.5 (0.4–0.6)	1.2 (0.9–1.6)	3.4 (1.4–5.5)	9.5 (1.1–25.3)
	IAM	ND	ND	ND	ND
Agriculture – Reduce CH_4 and N_2O emissions (Improve enteric fermentation, manure management, nutrient management, and rice cultivation)	Sectoral	0.4 (0.1–0.8)	0.4 (0.1–0.8)	0.6 (0.3–1.3)	1.7 (0.5–3.2)
	IAM	0.9 (0–3.1)	1.3 (0–3.2)	1.8 (0.7–3.3)	ND

Policy instruments

	LULUCF	Agriculture
Regulatory	Legal limits on land conversion Replanting requirements Protected areas Community forest management (CFM)	Legal requirements for implementation of agricultural practices Protected areas (mainly marine) Legal provisions to minimise the potential environmental and social trade-offs from bioenergy production
Market-based	Results based payments Carbon offset schemes Payment for Ecosystem Services (PES)	Carbon offset schemes Agro-environmental Subsidy Programs/PES
Voluntary	Forest certification programs	Supply chain management

AFOLU-specific barriers and options to overcome them

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Barriers	Options to overcome barriers
Governance, actors and policy instruments	
• Potential implications of measures on poverty, inequality, human well-being, marginalisation • Large number of actors, with millions of small-scale farmers and additional stakeholders across the value chain • Cultural values and social acceptance, e.g. regarding diets • Unclear land tenure and land use rights • Accountability of institutions and enforcement of regulation • Conflicting mitigation measures: e.g. forest conservation and bioenergy demand	• Enabling political participation of local stakeholders • Conversion of land to community management • Clarification of property rights
Technology barriers	
• Availability of land and water, due to conflicting priorities • Availability of technologies for MRV of land use	• Integrated planning • Enhance international research
Capacity constraints	
• Lack of institutional capacity to deal with complex interactions of measures in the sector	• Enhance international research
Financial constraints	
• Design and coverage of financing mechanisms • Scale and accessibility of financing • High risk aversion among agricultural operators	• Incentive mechanisms • Direct funding of investments • Creating synergies with funding for non-GHG conservation measures

Examples for adaptation – mitigation synergies

- **Water-related nature-based solutions**, such as wetland restoration or mangrove rehabilitation are prominent examples of the creation of important carbon sinks, while enhancing natural defences against water-related risks.

- **Forest conservation**, afforestation and reforestation measures can all contribute to increasing carbon sequestration from the atmosphere. At the same time these measures can reduce the risk of flooding and associated slope instabilities leading to land or mudslides or torrents.

- **Soil conservation** and reforestation policies have managed to increase carbon sequestration while enhancing soil retention services and improving and sustaining yields.

Example: Forest management in North America

Management of native forests by the Menominee people in North America

- The Menominee Indian Reservation was created by treaty in 1854 and covers 95,000 ha of land in Wisconsin that spans multiple forest types.
- The Menominee people practice sustainable forestry on their reservation.
- Over the past 160 years more than 2.3 billion board feet have been harvested from the area.
- The forest volume standing today is higher than when timber harvesting began more than 160 years ago.

Lessons

- ➲ Community forest owner associations are ways for small forest owners to educate, jointly put wood on the market, employ better forest management, use machinery together, and apply certification jointly.
- ➲ In this manner and with all their diversity of goals, they manage to maintain carbon sinks and stocks, while preserving biodiversity and producing wood.

Example: Climate smart villages

The climate smart village (CSV) approach

- The CSV approach seeks an integrated vision.
- It fosters the understanding of climate change with the implementation of adaptation and mitigation actions.
- Rural communities and local stakeholders are the leaders of this process, scientists facilitate knowledge.

Lessons

- Understanding the local priorities, context, challenges, capacity, and characteristics is the first step and building capacity is key.
- The integration of technologies and services that are suitable for the local conditions resulted in many gains for food security and adaptation and for mitigation where appropriate.
- There is considerable yield advantage when a portfolio of technologies is used, rather than the isolated use of technologies.

Key resources for energy supply information

Information

OECD - Agriculture and climate change:

https://www.oecd.org/greengrowth/sustainable-agriculture/agriculture-and-climate-change.htm

Key expertise

Food and Agriculture Organization of the United Nations (FAO):

https://www.fao.org/home/en/

International Fund for Agricultural Development (IFAD)

https://www.ifad.org/en/

World Food Programme (WFP)

https://www.wfp.org/

Center for International Forestry Research (CIFOR)

https://www.cifor.org/

Climate and Land Use Alliance (CLUA)

http://www.climateandlandusealliance.org/

Topics for discussion

- How much does AFOLU contribute to GHG emissions in your country and how is this changing?
- What is the potential of the mitigation options for reducing GHG emissions in your country?
- What types of agriculture mitigation measures might enhance or decrease food security?

Topics for discussion

- What tools are used in your country to measure or monitor forest carbon stocks? To analyze potential mitigation measures?
- Are maps, land tenure regulations, monitoring teams, etc. available in your country to help assess land use mitigation potential?
- How might REDD crediting or incentives interact with domestic forestry and land-use policies?

MODULE B7

CROSS-CUTTING

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Cross-cutting elements

Cross-sectoral aspects of mitigation:

- Mitigation measures used in more than one sector.
- Implications of mitigation measures for interaction and integration between sectors.
- Competition among sectors for scarce resources.

Energy efficiency

Urban systems

Food systems

Land use

Systemic approach

Water

Facilitating energy efficiency

- **Status**: Almost all countries exhibit declining energy intensity trends.
- **New investments** in power, industry, transport and building infrastructure can be substantially more efficient than existing stock.
- Economic growth is powering a rapid increase in investment in these sectors, especially in developing countries, which can be utilised to minimise energy use and deploy low-GHG processes.
- **Policies**: Most countries have initiatives to promote energy efficiency in these sectors.
- Adoption is driven by quality and productivity increases.
- **Key challenges**: Financing efficiency measures is still challenging in many countries, despite cost-effectiveness of measures.

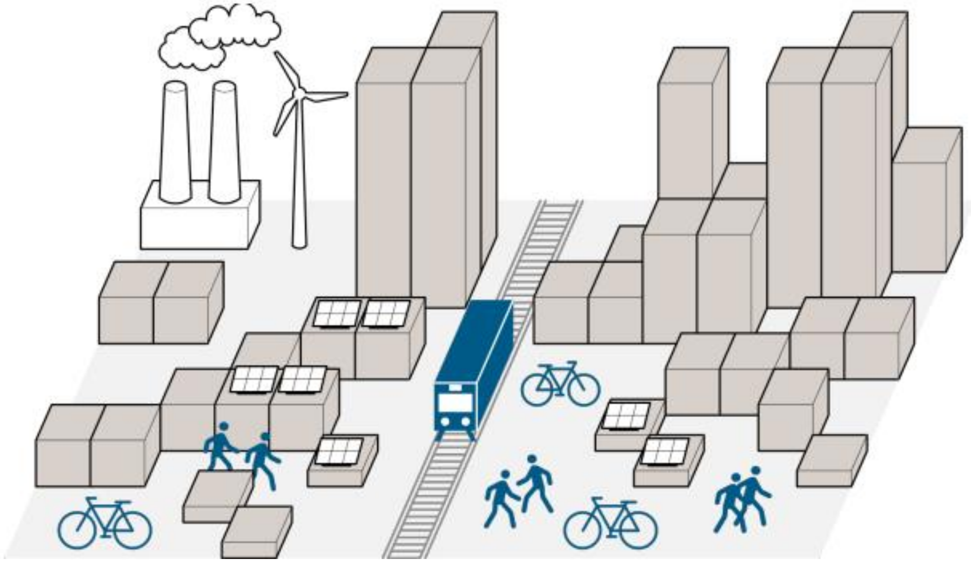
Effects of urbanisation on GHG emissions

Increasing

Higher income and levels of consumptions.

Land use change from expansion.

Energy use and emissions from infrastructure construction and maintenance.



Decreasing

Higher population densities enable sharing of infrastructure and services (higher carbon efficiency per capita).

Economies of scale.

Depends on

Stage of development (new/emerging vs. rapidly growing vs. established cities).
Urban form (compact and walkable vs. dispersed and auto-centric).
Level of integrated spatial planning.
Broader energy system supporting the city.

Integrating mitigation, adaptation and sustainable development in urban areas is possible

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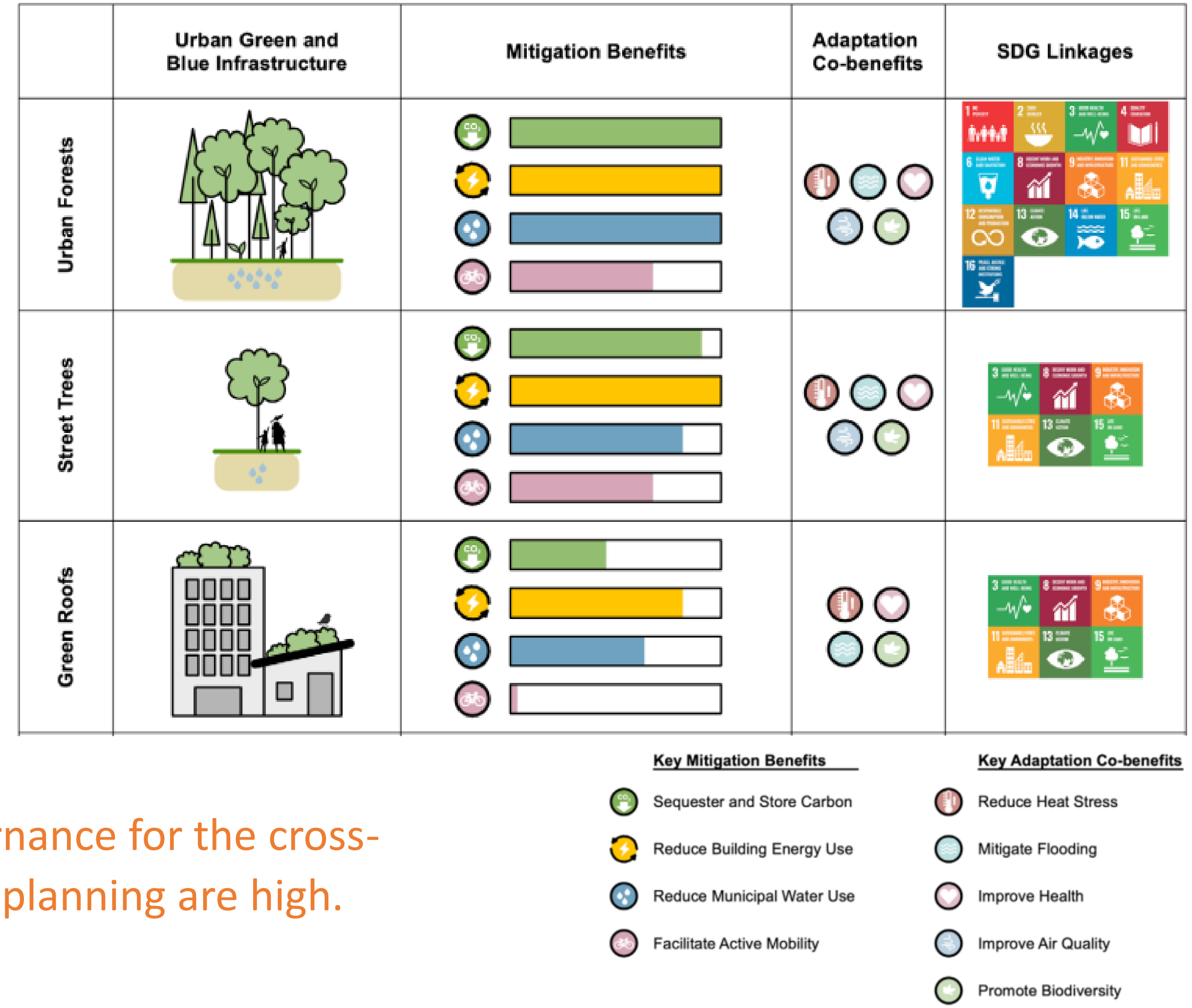
- Many mitigation actions in the urban space have adaptation benefits and contribute to sustainable development.
- Integrated spatial and cross-sectoral planning is key and can provide multiple sustainable development benefits.
- Urban green and blue infrastructure provides multiple benefits.
- Low-carbon energy systems can be supported through local generation and smart grid design.



Requirements on institutional capacity and governance for the cross-sector coordination needed for integrated urban planning are high.

Food systems

Supply

Large differences in food systems:

- Traditional: short supply chains, low integration.
- Modern: complex supply chains across the globe with high vertical and horizontal integration.

High degree of consolidation in modern food systems led to

- High influence of a few actors post-farmgate.
- Loss of indigenous agriculture and food systems.
- Lack of ability to change systems for farmers.

Intricately linked to sustainable development,
esp. health, huger, poverty & responsible consumption and production

Demand

Total production of calories is sufficient for the world population, but unequally distributed:

- Increasing trend to overweight and obesity.
- Continuing hunger and underweight, although projected to decrease.
- Continuing lack of nutrients in the diet.

Opposing trends in consumer choices:

- Increasing demand for animal-based products, refined grains, sugar and sodium with increasing income.
- Trends towards vegetarian and vegan diets.
- Emergence of novel food products, e.g. based on insects, algae, or products from bio-refineries.

Mitigation options across the system working together

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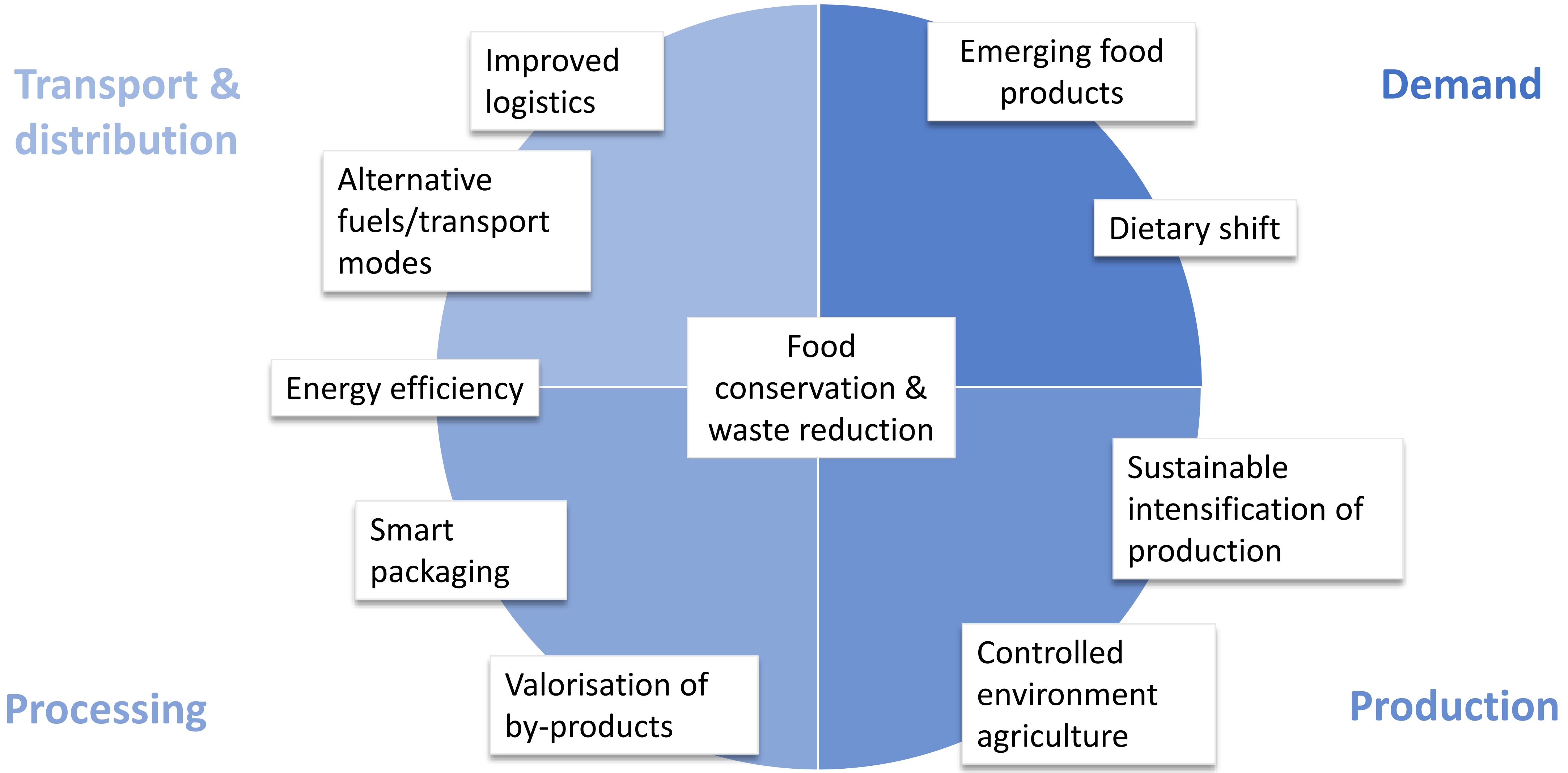
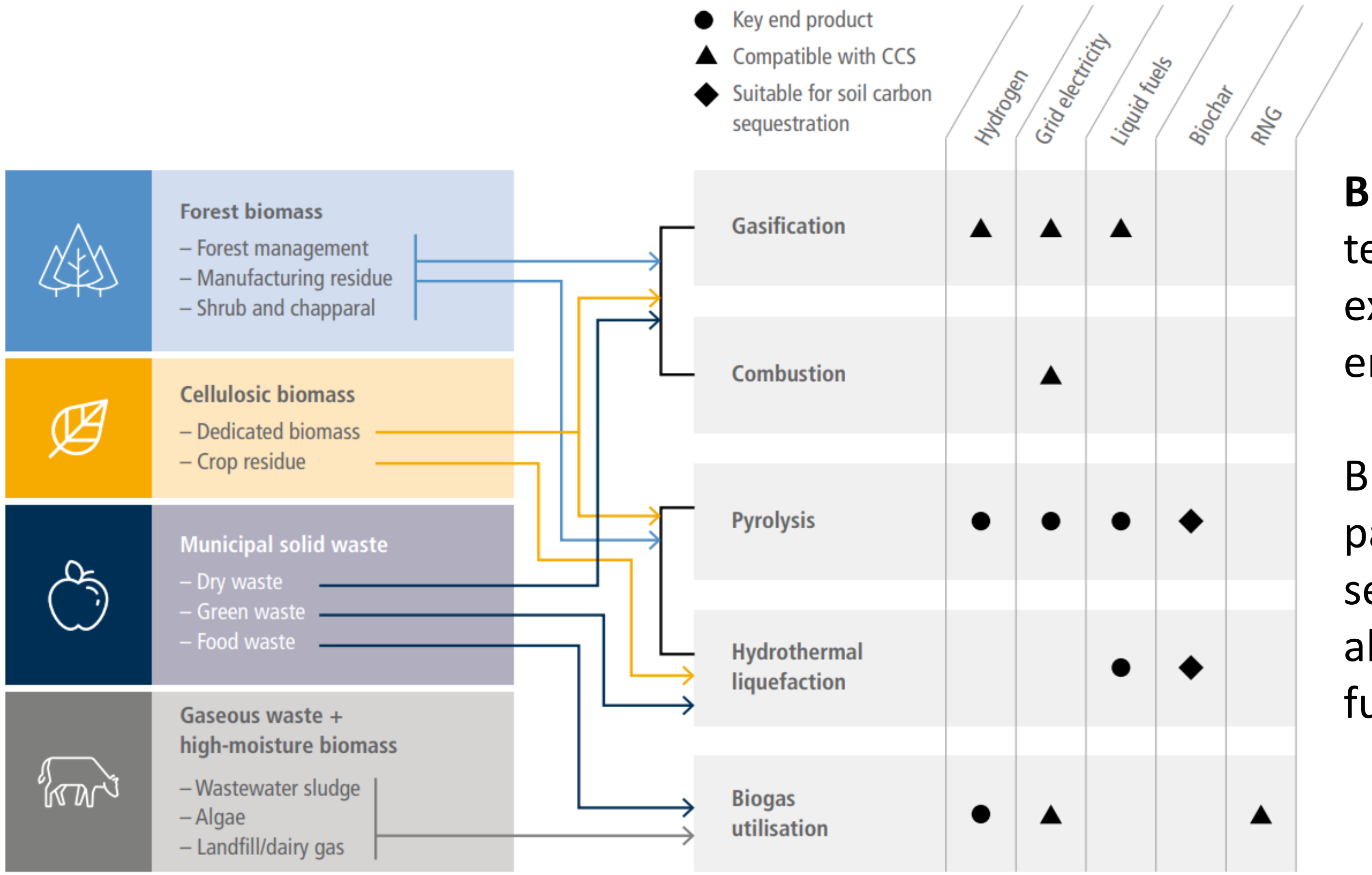


Bioenergy options impacting land use

Potential competition with land for food production and forestry, water use, impacts on ecosystems, and land-use change



Bioenergy is versatile: technology pathways exist to produce multiple energy carriers.

Bioenergy could be particularly valuable for sectors with limited alternatives to fossil fuels.

RNG = Renewable natural gas

CCS = Carbon capture and storage

Selected impacts, risks and co-benefits associated with land occupation by mitigation

Mitigation option	Impacts and risks	Opportunities for co-benefits
Non-bio-based options that may displace food production		
Solar PV	Land use competition; heat island effect (scale dependent)	Use of areas unsuitable for agriculture; integration with buildings; integration with food production is being explored.
Hydropower	Land use competition, displacement of natural ecosystems, CO2 and CH4 emissions	Water storage and regulation of water flows; Pumped storage can store excess energy from other renewable generation sources.
Bio-based options that may displace existing food production		
Afforestation / reforestation	Land use competition, potentially leading to indirect land use change; reduced water availability; loss of biodiversity	Strategic siting to minimise adverse impacts on hydrology, land use, biodiversity
Agroforestry	Competition with adjacent crops and pastures reduces yields	Shelter for stock and crops, diversification, biomass production, increases soil organic matter and soil fertility.
Options that don’t occupy land used for food production		
Management of organic waste	Can contain contaminants (heavy metals, persistent organic pollutants, pathogens)	Processing can enable return of nutrients to farmland

A systemic approach: Policies to enhance Avoid-Shift-Improve

Service	Avoid	Shift	Improve
Mobility	Integrate transport & land use planning; Smart logistics; Tele-working; Compact cities; Fewer long-haul flights; Local holidays	Modal shifts: from car to cycling, walking, or public transit; from air travel to high-speed rail	Lightweight vehicles; Hydrogen vehicles; Electric vehicles; Eco-driving
Shelter	Smaller decent dwellings; Shared common space; Multigenerational housing	Less material-intensive dwelling designs; Shift from single-family to multi-family dwellings	Use wood as material; Use low-carbon production processes for building materials
Thermal comfort	Change temperature set-points; Change dressing code; Change working times	Architectural design (shading, natural ventilation, etc.)	Solar thermal devices; Improved insulation; Heat pumps; District heating
Goods	Reduce consumption quantities; Long lasting fabric, appliances; Sharing economy	Materials efficient product design	Use of low carbon materials; New manufacturing processes and equipment use
Lighting	Occupancy sensors; Lighting controls	Architectural designs with maximal daylighting	LED lamps

Complex effects of actions on water availability need to be considered

Many countries are already facing challenges related to the availability of water for:

Households

Agriculture

Industry

Power generation

Co-benefits
Effects of mitigation actions that improve the existing situation

Adverse side-effects
Effects of adaptation and mitigation actions that deteriorate the existing situation or create new challenges

Impact of the changing climate on local water resources

All three elements need to be considered when designing mitigation and adaptation measures

Water: Examples for adaptation – mitigation linkages

Hydropower

Main objective: mitigation through replacement of fossil fuel power generation

Synergies: reduction of water-related risk: e.g. use of stored water for irrigation

Trade-offs: subject to water availability; GHG emissions from construction; harmful impacts on environment incl. biodiversity

Desalination plants

Main objective: adaptation to enhance availability of water

Trade-offs: increase in energy demand can increase GHG emissions; environmental effects from brine discharge

Solution: generation of energy from renewable sources; treatment and reuse of brine

Topics for discussion

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- What are some key challenges associated with cross-sectoral mitigation approaches (technologies and policies) in your country:
  - In assessment?
  - In implementation?
- How can an assessment team ensure analytical consistency across many different sectors?

THANK YOU FOR YOUR ATTENTION.

https://unfccc.int/CGE

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