PBL Netherlands Environmental Assessment Agency

CLIMATE CHANGE MEASURES AND SUSTAINABLE DEVELOPMENT GOALS

Mapping synergies and trade-offs to guide multi-level decision-making

Note

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Urgent action is needed to achieve both the Paris Agreement's goals and the other Sustainable Development Goals (SDGs). Many measures aimed at reducing greenhouse gas emissions also have an impact on other SDGs. Insight into these impacts is essential, as this may affect the types of measures to focus on and provides the information necessary to maximise the co-benefits and manage the risks of climate change mitigation measures on other SDGs. This report provides such insight for the most promising short- to medium-term climate change mitigation measures for selected world regions. The main findings are:

- There are significantly more synergies than trade-offs between climate change measures and other SDGs in all world regions. However, the magnitude of these synergies and trade-offs varies according to regional and socio-economic context. In North America, Europe, and Central and South America, the measures demonstrate only a few trade-offs that are largely related to technology choices that could exacerbate inequality and impact biodiversity. In Sub-Saharan Africa, South Asia, and Southeast Asia, most of the measures could hinder efforts to reduce poverty, end hunger and improve well-being, if not complemented by policies to protect the poor from increasing food and energy prices. Mitigation measures in the Middle East and North Africa can help diversify the oil-dependent economies in this region and accelerate the reform process to foster inclusive growth and reduce inequality. However, the resulting decline in oil demand could exacerbate inequality.
- Of the 20 mitigation measures analysed, increasing the share of renewable energy in power generation shows the most synergies with other SDGs in all world regions. However, the choice of technology is relevant here. Most trade-offs were found for large hydropower dams, which could lead to displacement of local communities, and loss of natural forests and biodiversity.
- Reducing coal-fired power generation is an important climate change mitigation measure with large benefits for air quality and human health. However, it would negatively impact employment in coal-mining industries, and could, at least in the short run, lead to increasing electricity prices.
- Measures in industry also show considerable synergies, especially with SDGs related to decent work for all, fostering innovation, sustainable cities and communities, and responsible consumption and production. However, important trade-offs are related to increased energy and water demand of applying carbon capture and storage (CCS) and the additional costs associated with CCS. There is also a concern about leakage of stored carbon in water bodies.
- All selected measures to reduce emissions from buildings, consisting of measures to improve energy efficiency and stop installations of oil boilers, show strong synergies with many other SDGs. The main barrier to improve residential and commercial building efficiency is the high upfront investment requirement, which can be addressed by facilitating access to finance and stimulating innovation.
- In the transport sector, the additional costs of improving fuel efficiencies or promoting electric or other zero-emission vehicles can lead to trade-offs with poverty-related SDGs. Fiscal incentives, improved consumer information, road toll rebates, low-emission zones, and support schemes for deploying charging infrastructure can alleviate these.
- The mitigation measures to reduce CO_2 emissions from land use and non-CO_2 emissions from agriculture, livestock, and waste are critical in meeting required global emission reductions. Reducing deforestation and increasing reforestation have

strong synergies with biodiversity and environmental SDGs. However, in low-income regions, these measures have potential trade-offs with poverty alleviation and food security. To limit these impacts, the forestation measures could be complemented with policies that would strengthen the rights, capabilities and local decision-making on land and resources, credit programmes for small-scale farmers, and transfer payments to poor rural dwellers for ecosystem services.

- Although all the mitigation measures analysed in this report are tested in some regions, transferring these measures to other regions requires understanding of the local context and, in some cases, complementary policies to protect the vulnerable parts of society.

1 Context and aim

The Paris Agreement and Sustainable Development Goals (SDGs) have brought nations together under the common objective of preventing dangerous climate change and promoting sustainable development. The Paris Agreement focuses on mitigation of and adaptation to climate change, whereas the SDGs aim to end poverty, promote prosperity and people's well-being, while protecting the environment [1]. The links between climate change and sustainable development are strong; SDG 13 specifically aims at combating climate change and its impacts [1], and Article 7 of the Paris Agreement calls for 'enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development' [2]. Indeed, climate change and other environmental issues are highly interconnected. They often not only reinforce each other (see Box 1.1), but the available solutions also make them closely intertwined [3, 4]. Some mitigation measures are even specific SDG targets; for instance, while increasing the share of renewables in power generation is an important measure to reduce greenhouse gas emissions, it is also a specific target under SDG 7.2. Different measures to mitigate climate change face different potential trade-offs and synergies with other environmental challenges and sustainable development. Understanding these synergies and trade-offs is essential for the successful implementation of both the Paris Agreement and SDGs.

Climate change mitigation requires coordinating or harmonising efforts at sectoral, regional and national levels. Understanding the synergies and trade-offs between climate change mitigation measures and other development programmes provides valuable insight for successful decision-making, allocation of resources, and coordination at various levels of implementation. This is needed to maximise the co-benefits of the measures across multiple targets, while also managing the risks of possible trade-offs. It also facilitates coherence of measures at various levels of decision-making and offers decision-makers a systemic view of the impact of these measures in relation to the SDGs.

Box 1.1: The impact of climate change on SDGs

Climate change will increasingly threaten the social, economic and natural systems, thereby hindering progress towards achieving sustainable development. A warming climate is expected to impact the availability of necessities, such as fresh water, food and energy. Rising sea levels and temperatures, changing rainfall patterns, increased droughts, ocean acidification, and more frequent and intense natural hazards demonstrate how climate change deepens existing development challenges. Current warming already has large impacts on ecosystems, human health and agriculture [5], making achieving the SDGs more challenging.

The vulnerability of systems to climate change impacts varies between regions, between sectors and even within sectors. The vulnerability to adverse impacts of climatic change is largely determined by access to resources, information, and technology and by the stability and effectiveness of their institutions [6]. The ability of a system to anticipate, absorb, accommodate, or recover from the impact of climate change shows the resilience of the system. To a great extent, increasing resilience can be achieved by reducing vulnerabilities and increasing adaptive capacity.

There is a large body of literature that offers important insights into the interactions between different SDGs. However, literature that focuses more specifically on the synergies and trade-offs between climate mitigation measures and other SDGs is more limited. The IPCC Special Report on Global Warming of 1.5 °C [5] summarises the findings of studies that are available on this topic. However, some of the mitigation measures assessed by the IPCC are rather aggregated and little attention is given to regional differences. The aim of this report is to identify potential trade-offs and synergies for the most promising climate change mitigation measures for selected world regions.

Such an understanding has become even more urgent after the COVID-19 crisis and in view of the intended investment strategies to stimulate recovery [7]. These investment schemes provide an opportunity to align economic goals with climate and sustainable development goals (see Box 1.2 on COVID-19 and climate change). The concept of 'building back better' is trying to reflect this [8]. This refers to harmonising recovery measures with climate change mitigation, reducing the vulnerability to future disasters, and building community resilience [9]. In practice, building back better is not easy. It requires an integrated perspective, coordination, and good knowledge. This can also be seen in existing post-disaster reconstruction programmes, such as in Sri Lanka, which often have similar ambitions [10]. In this context, the SDGs could provide a framework for building back better, and climate change mitigation measures that positively impact other SDGs will also help to reduce the general vulnerability of countries and regions.

Box 1.2: COVID-19 and climate change

The COVID-19 pandemic, in addition to the immediate human suffering and the loss of livelihoods for millions, has demonstrated the vulnerabilities of our societies and economic systems [11]. The impacts of the pandemic on the global economy and overall sustainable development and attainment of the 2030 Agenda are becoming increasingly visible [12–15]. Short-term efforts focus on dealing with the immediate impacts, but long-term recovery packages also focus on rebuilding more resilient and inclusive societies [16]. COVID-19 is similar to climate change in several ways: they are both global problems, responses entail both mitigation and adaptation, and delayed action has far-reaching consequences and increases mitigation and adaptation costs and limits policy options. However, unlike COVID-19, climate change has a longer time-scale, and, though less visible in the short term, the impacts will be more severe [17].

Clearly, a transition to a low-carbon economy also involves risks. Such a transition requires changes in policy, legal, technology, and market structures that may generate winners and losers [18]. As a result of deliberate policy choices, changing preferences and ongoing technological change, some parts of the economy grow, and other parts decline. Certain technology choices and economic activities are likely to impact some regions more than others. The level of these risks depends on the nature, timing and focus of the changes. In general, the more delayed and abrupt the transition will be, the harder the consequences of sudden adjustment from economic agents will be; hence, the higher the level of risk [19]. The risks include the impact of increased pricing of greenhouse gas (GHG) emissions, unsuccessful investment in new technologies, uncertainty in market signals, and increased cost of raw materials [18]. Moreover, climate change mitigation measures affect many other SDGs, such as energy security, air quality, human health, land management, food security, water scarcity, and biodiversity [20]. Many climate change mitigation measures have synergies with other SDGs, but some involve potential trade-offs.

The report is further organised as follows. Chapter 2 explains how promising mitigation measures were selected and Chapter 3 discusses potential synergies and trade-offs of these measures with SDG targets on a general, global level. Chapter 4 provides more regional detail, discussing the synergies and trade-offs of the promising mitigation measures with the highest potential to reduce emissions in each world region. Chapter 5 provides a synthesis of results.

2 Identifying promising climate change mitigation measures

Limiting global warming to well below 2 °C or even 1.5 °C requires climate change mitigation actions to be taken at global, national, regional and local levels [21], leading to profound alterations in all economic sectors. Long-term model-based scenarios can explore the kind of actions needed to achieve these climate goals. These models have a detailed representation of the systemic nature of the challenge and simulate the cost of mitigation under technology, environmental and policy constraints. Most of these scenarios explore cost-optimal mitigation measures over time, across regions and across greenhouse gases to meet the Paris agreement goals [22]. Cost-optimal pathways, however, do not always lead to the preferred measures by all stakeholders as other considerations also play an important role (e.g. equity considerations, social and political feasibility, market imperfections).

Mitigation measures are regarded promising if they are not only attractive based on costs but also on other important considerations. Earlier studies [23–26] have identified promising climate mitigation measures by looking at measures that were successfully implemented in one or more countries and had a noticeable impact on greenhouse gas emissions. These measures can relatively easily be implemented in the short to medium term (i.e. one to three decades) and have proven to be effective. Table 2.1 at the end of this chapter provides a list of these measures, in the literature referred to as 'good practice policies'. Together, they represent a set of promising measures for climate change mitigation. It is important to note that these measures have a strong technological focus: changes in behaviour are not included in this assessment, even though they can significantly contribute to sustainable development and reducing greenhouse gas emissions [27]. Moreover, implementation of these measures is not yet sufficient to achieve the goals of the Paris Agreement — more measures, especially in the longer term, are required for this. The measures are discussed in more detail below.

2.1 Power generation

Power and heat generation accounted for about 36% of global fossil-fuel-related CO_2 emissions in 2019 [28]. Although power generation, and especially from carbon-intensive energy sources, has decreased due to COVID-19 restrictions, it is expected that it will bounce back, especially in emerging economies, without policy interventions [29]. Power generation provides large potential for climate change mitigation in all regions.

Halting the installation of unabated coal-fired power plants (i.e. coal-fired plants without carbon capture and storage) has proven to be an effective mitigation measure. Once built, coal plants are usually in operation for several decades, generating emissions that are detrimental to the climate and human health [30]. Coal use in the power sector is already declining in more than half of the G20 countries, primarily driven by declining renewable energy prices, the discovery of abundant natural gas, and as a consequence of regulations designed to reduce emissions and protect public health [21]. Some regions, particularly South Asia, Southeast Asia, and Sub-Saharan Africa, still rely heavily on coal for power generation. While lower electricity demand has led to a large decrease in global coal use for power generation in 2020, many coal-fired power plants are planned and under development in various regions. Expectations are that coal-fired power generation will rebound in 2021 [31, 32].

Next to halting the installation of coal-fired power plants, increasing the share of renewable power generation (solar, wind and hydro) is at the heart of the transition to a low-carbon energy system. In 2019, the share of renewables in global power generation was close to 27%, of which 60% hydropower. Renewable energy sources have been the most resilient to the COVID-19 lockdown measures [33]. Given the sustained cost decline of renewable energy technologies, especially solar PV and wind, all regions are already planning to substantially increase the share of renewable energy in power generation. However, there is potential for faster deployment of renewable energy technologies [34].

2.2 Industry

The industrial sector is responsible for about 25% of global fossil-fuel-related CO_2 emissions (including process emissions) in 2019 [28]. The growth in energy consumption has been driven by increasing production in energy-intensive industries, especially in South and Southeast Asia. After a decline in energy demand in the industry sector in 2020 due to the COVID-19 pandemic, demand is likely to continue to increase again over the coming decades [35], especially in fast-growing developing economies, such as South Asia [36].

Promising mitigation measures in the near and medium term for the industry include improving energy efficiency and installing carbon capture and storage (CCS).

Energy intensity in the industrial sector has steadily improved for decades, but the potential for further improvement is still large. Already existing technologies can economically deliver a 30% reduction in global industrial energy consumption, increasing to 60% with anticipated future technological innovations [35]. Energy efficiency in the industry can be achieved by employing a wide variety of measures, including maintaining, refurbishing and retuning equipment, retrofitting, replacing and retiring obsolete equipment, process lines and facilities, using heat management to decrease heat loss and waste energy, improving process control, streamlining processes, reusing and recycling products and materials, and increasing process productivity [37]. The decision to invest in these measures is usually affected by volatile energy prices. Without targeted policies, investments in energy efficiency in the industrial sector could be sidelined by the crisis following the pandemic.

Emissions in some industrial sectors can be difficult to abate due to process emissions and the need for high-temperature heating, such as in the cement, steel and chemical sectors. With increasing urbanisation, the demand for cement, steel and chemicals will remain strong. In these industries, CCS can play an important role in mitigating emissions.

2.3 Buildings

Buildings are responsible for 30% of global final energy consumption, and about 9% of fossil-fuel-related CO_2 emissions in 2019 (not accounting for indirect emissions from power generation) [28, 34]. Reducing greenhouse gas emissions from buildings is an important component of global climate change mitigation strategies.

Amid the growing demand for heating and cooling, amongst other factors, energy use of buildings has been increasing in recent years, leading to an all-time high in CO_2 emissions from buildings in 2019 [38]. There has been a continuous improvement in energy intensity, but the increase in floor area has offset this. There is a large untapped potential for improving energy efficiency in appliances and buildings, especially in developing and emerging economies. In developed countries, renovations of existing buildings can play a major role in reducing energy demand. Comprehensive retrofits, such as by upgrading windows, applying internal and external wall insulation and roof insulation, draught-proofing, replacing heating and cooling equipment, upgrading control systems, improving lighting, and reducing hot water usage, may all considerably reduce a building's energy requirement.

Space and water heating, in most regions, is responsible for the largest share of final energy use of buildings, and most of this energy is still being fossil-fuel generated. This provides a large potential for reducing emissions in buildings by discontinuing the use of oil-based boilers in old and new buildings. Existing technologies, such as heat pumps, electric boilers, solar heating systems and district heating are obvious substitutes.

2.4 Transport

The transportation sector is responsible for almost 20% of global fossil-fuel-related CO_2 emissions, with road transport accounting for about 80% of these emissions. Emissions from transport, and especially aviation, show a strongly increasing trend, driven by population and income growth. IEA projects that, under the Sustainable Development Scenario, passenger kilometres per capita will double, car ownership will rise by 60%, and passenger and freight aviation will more than triple between 2019 and 2070 [39]. This makes emission reduction in the transport sector a colossal task that calls for structural shifts and a broad mix of technologies and measures.

The potential for mitigation in the transport sector is large in several regions, especially in OECD countries. Fuel efficiency measures have the potential to considerably reduce emissions from passenger cars. In recent years, the fuel efficiency of passenger cars has shown an improvement, but this is more than offset by the increase in the global car fleet. Studies demonstrate that by employing already existing technologies, it is possible to improve the average fuel efficiency by 50% by 2050 relative to 2010 [6]. Another strategy for climate change mitigation is to increase the share of non-fossil fuels in new vehicle sales. Electric vehicles are significantly more efficient than internal combustion vehicles and have zero exhaust emissions: even with a carbon intensity of 650 gCO_2/kWh of the power grid (implying a coal share as high as 75%), electric cars emit up to 25% less carbon than diesel cars [40]. Cars on biofuels also emit less air pollutants than gasoline cars.

Aviation accounts for around 2.5% of global CO_2 emissions, and it is among the fastest-growing emitters. Air travel demand has declined dramatically due to the COVID-19 pandemic, resulting in significant revenue loss in the aviation industry. Though it is expected that the demand will bounce back to its pre-pandemic level within two to three years [41], the sector is unlikely to invest strongly in technological improvements. Still, in the next couple of years, aircraft retirement and airline consolidation are likely to demonstrate a considerable improvement in overall fleet efficiency [39]. Improving efficiency and reducing the carbon intensity of fuel used in aviation is an important measure to reduce greenhouse gas emissions in the medium to long term. Increasing aviation efficiency can be achieved through improving operational efficiency (such as advanced communications, navigation and surveillance and air traffic management) and aircraft efficiency (replacing older, less efficient aircrafts with more efficient ones that use more efficient propulsion systems (engines), advanced lightweight materials, and improved aerodynamics).

2.5 Land use

Land plays an important role in the global cycles of greenhouse gases. Annual emissions from land-use and land-cover changes are estimated at about 3 $GtCO_2$ between 2006 and 2015 (with a wide uncertainty range), which is about 10% of total global CO_2 emissions [42]. Land-use-related measures play a considerable role in climate change mitigation as they can remove CO_2 from the atmosphere. The potential for mitigation is considerable in Central and South America, Southeast Asia and Sub-Saharan Africa.

Reducing emissions from land-use change will be vital for global efforts to combat climate change. Changes in land use, mainly those associated with deforestation due to the expansion of agricultural land, are a massive source of carbon emissions and contribute substantially to global warming. Afforestation, reforestation, and halting deforestation are therefore very effective measures to decrease CO_2 concentrations in the atmosphere — either by decreasing emissions (halting deforestation) or by improving carbon uptake (afforestation and reforestation).

2.6 Non-CO_2

Non-CO_2 greenhouse gas emissions included in this study are methane (CH_4) and nitrous oxide (N_2O). Due to the diversity of their sources, non-CO_2 emissions constitute a significant share in total greenhouse gas emissions of the regions and offer considerable potential for climate change mitigation.

Methane is the largest contributor to climate change after CO_2. Manure storage and enteric fermentation are major sources of CH_4 emissions in some regions. These emissions are projected to increase with increases in livestock populations, especially in developing countries. Changing current manure management practices could significantly reduce livestock methane emissions. Anaerobic digestion of livestock manure is identified as one of the most promising instruments. Some measures help reduce CH_4 emission from enteric fermentation, notably reducing the herd size — by dietary changes or selective breeding [43].

Coal mines are amongst the largest sources of anthropogenic CH_4 emissions, estimated to account for 11% of global anthropogenic CH_4 emissions [44]. Without abatement measures in the coal mining industry, coal production is projected to remain a major source of CH_4 emissions. The technology to recover and use methane from coal mines is readily available. Another large source of CH_4 emissions is from venting and flaring of oil and natural gas. In various regions, measures to reduce venting and flaring can strongly reduce CH_4 emissions using existing technologies.

Waste from landfills is another important source of CH_4 emissions. Increased recycling and energy recovery of biodegradable solid waste are some of the cost-effective ways of reducing CH_4 emissions from waste [45]. New technologies for better conversion of waste to biomethane can effectively reduce CH_4 emissions in the sector [46].

Nitrous oxide is a powerful contributor to global warming, and human-driven N_2O emissions have been growing unabated for several decades. A reliable supply of nitrogen is central to the productivity of crop and animal production systems. However, the growing demand for nitrogen fertilisers in agriculture has led to a sharp growth in nitrogen pollution levels and related greenhouse gas emissions. A seven-fold increase in nitrogen fertiliser use in the past has only resulted in the doubling of food production [47]. Several countries have demonstrated that nitrogen use can be reduced without sacrificing crop yields [48].

Another source of N_2O is nitric and adipic acid production. These products are commonly used as feedstock in manufacturing, particularly for fertiliser and synthetic fibres. N_2O emissions in the industry can be abated by catalytic destruction, thermal decomposition, using the N_2O for nitric acid production, or recycling the N_2O as feedstock for adipic acid production [49]. Abatement technologies are already available at low cost and neither directly impact other emissions nor production levels [50].

Table 2.1 Promising climate change mitigation measures based on successful implementation

Source	Measure
Power generation	No new installations of unabated coal power plants Increase in the share of renewables in total power generation per year
Industry	Improve energy efficiency Apply carbon capture and storage
Buildings	Improve energy efficiency of appliances Improve energy intensity of new residential and commercial buildings Improve efficiency of existing buildings by increasing the share of existing buildings being renovated No new installations of oil boiler capacity in new and existing residential and commercial buildings
Transport	Improve average fuel efficiency of new passenger cars Increase the share of non-fossil in new vehicle sales Improve energy efficiency of aviation
Land use	Increase natural forest afforestation and reforestation Halt natural forest deforestation
Non-CO_2	Treat manure from livestock with anaerobic digesters (reduces CH_4 emissions) Selective breeding to reduce CH_4 emissions from enteric fermentation Increase nitrogen use efficiency (reduces N_2O emissions from fertiliser) Coal mine CH_4 emissions recovery Reduce venting and flaring of CH_4 Reduce N_2O emissions from adipic/acid production Reduce CH_4 emissions from waste

3 Synergies and trade-offs

This chapter discusses the most important synergies and trade-offs between the promising climate change mitigation measures identified in the previous chapter and SDGs. The synergies and trade-offs analysis takes [5] and [51] as starting point, followed by additional literature study, especially for regional relevance (Chapter 4 specifically focuses on regional synergies and trade-offs). Some choices have to be made in discussing synergies and trade-offs, as there is an almost endless number of them. Therefore, only the most direct synergies and trade-offs are discussed. An example of a direct synergy in developing countries is between increasing power generation from renewable energy sources and access to modern and sustainable energy in developing countries. An indirect synergy would be a reduction in deforestation and forest degradation due to lower use of biomass as a consequence of increased access to electricity.

The SDGs are underpinned by no less than 169 targets. An assessment of the interlinkages with all targets would be infeasible. Therefore, we discuss here the most often mentioned synergies and trade-offs between the promising mitigation measures and SDGs in general. Only for the SDGs 8 (decent work for all *and* inclusive and sustainable economic growth), 15 (sustainably manage forests/combat desertification *and* halt biodiversity loss), and 17 (revitalise global partnerships *and* strengthen means of implementation) separate goals are defined, as different synergies and trade-offs were identified for these goals. Table 3.1 at the end of this chapter provides a summary of the synergies and trade-offs.

3.1 Power generation

The selected promising measures to mitigate greenhouse gas emissions in power generation are (i) no new installations of unabated coal power plants and (ii) increasing the share of renewables in total power generation.

Coal-fired power plants are an important cause of air pollution, leading to increased respiratory and cardiovascular diseases, abnormal neurological development in children, and cancer [52, 53]. Hence, halting the construction of unabated coal-fired power plants has clear synergies with reducing air pollution (**SDG 11**) and human health impacts (**SDG 3**). The health benefits are significant especially in dense urban centres of rapidly developing countries [54]. The coal sector withdraws, consumes and pollutes large volumes of freshwater at every stage of the process, hence, the resulting decline in coal use has a positive impact on water availability (**SDG 6**). Coal has been the leading source of cheap and accessible energy and has been fundamental in supporting the development of base-load electricity in several developing countries. Hence, limiting the use of it could impact universal access to electricity (**SDG 7**).

The decline in coal-related activities could lead to the loss of jobs in the mining sector, with impact on poverty alleviation in some regions (**SDG 1**). Coal reserves are available in almost every country globally, and coal mining plays a significant role in several economies by providing employment and resources through export. Therefore, reducing coal use will undoubtedly impact employment in countries with substantial coal mining, such as South Africa and India, if not complemented by other policies (**SDG 8,10**).

Expanding the share of renewables for power generation has several synergies with SDGs, and most directly with the **SDG 7** target of increasing renewables. Switching from fossil-based energy sources to solar, wind or hydro leads to improved human health (**SDG 3**) by improving air quality (**SDG 11**). It can also lead to improved access to clean water and to lower water scarcity (**SDG 6)**, as i) solar- and wind-based renewable energy systems need less water than thermal power plants, and ii) the extraction and transport of fossil fuels often lead to spills and leaks contaminating water resources [51]. In developing regions, such as Sub-Saharan Africa and South Asia, renewables contribute to achieving universal access to clean and modern energy (**SDG 7**), since electricity can be generated off the grid in low-density settlements at much lower costs than on-grid solutions. In general, renewables create more jobs and decent and safer jobs than fossil fuel technologies [51, 55] (**SDG 8**). Renewables also enhance the demand for local services and goods if the technology is produced locally, contributing to local economic growth (**SDG 8**). Expanding renewable energy use also reduces natural resource depletion (**SDG 12**). Ocean-based renewable energy infrastructure could enable marine protection (**SDG 14**). Accelerating the deployment of renewable energy technologies requires not only continuous technology improvement, but also innovations to integrate those technologies into the energy system (**SDG 9**), and public private partnerships and collaborative networks across the globe to share knowledge and experience (**SDG 17**).

The trade-offs of renewable energy systems are very technology-specific. Energy prices in some regions may increase as a result of less mature technologies or when more advanced renewable technologies are preferred. This affects affordability for the poor (**SDG 1,7,10**). The construction of hydropower dams reduces river network connectivity and alter the natural flow reducing water and ecosystem quality (**SDG 6**). Utility scale solar and wind farms require large areas of land, competing with other land services such as protecting biodiversity (**SDG 15**) and agriculture (**SDG 2**). Construction of large dams is sometimes associated with displacement of communities and impacts on natural ecosystems and their services (**SDG 15**)[56]. There are also concerns about toxic elements released during decommissioning and disposal of PV cells [57] (**SDG 6**, **15**), the noise from wind turbines that could affect human health (**SDG 3**), ocean-based renewable energy systems competition with other marine activities (**SDG 14**), and the wind turbine impact on bats and birds (**SDG 15**)[58].

3.2 Industry

The selected promising measures in industry include improving energy efficiency and applying CCS.

In addition to directly addressing **SDG 7** (increasing energy access), **enhanced energy efficiency in the industry sector** offers an opportunity to reconcile economic competitiveness with climate change mitigation. Large-scale energy efficiency can positively impact the economy by large energy expenditure savings, enhancing competitiveness and economic development (**SDG 8**). It also increases productivity by lowering maintenance costs and increasing production yields per unit of input [59] and enables the creation of jobs in the energy service delivery sector (**SDG 8**) [32]. Other benefits include providing better health (**SDG 3**), new business opportunities (**SDG 1,8,10**), enhancing energy security (**SDG 7**), better environmental compliance, better work conditions (**SDG 8,11**), enabling innovative and sustainable energy infrastructure (**SDG 9**), better air quality (**SDG 11**) especially in the dense urban centres of rapidly developing countries [60], and reduced water use and waste (**SDG 6,12**) [61]. The diffusion of efficient appliances has synergies with international partnership (**SDG 17**) because innovations and deployment of new technologies require transnational capacity building and knowledge sharing [62].

Another important measure to reduce CO_2 emission, especially in carbon-intensive industries, is the use of **CCS**. CCS can be fitted to new or existing refineries and iron, cement, ammonia, and chemical pulp industries. The supply chain of the CCS industry can become a significant source of employment and protect jobs in related industries (**SDG 8**). CCS could develop quality, reliable, sustainable and resilient infrastructure (**SDG 9**), would overall lead to less air pollutants (**SDG 11**), and promotes sustainable production (**SDG 12**). CCS plants are capital-intensive and require strong international collaboration for research, development and operation (**SDG 17**).

There is, however, a concern over CO_2 leakage from transportation and storage infrastructure that impacts human health and well-being and marine and coastal ecosystems (**SDG 3, 14**). In some sub-sectors, CCS is likely to raise production costs considerably, thereby potentially increasing poverty (**SDG 1**). Industrial CCS application is expected to increase water use for cooling and processing (negatively impacting **SDG 6**). CCS operations require additional energy, leading to increased prices (**SDG 7**). However, industrial CCS could improve energy efficiency if the processes are optimised [63], and some studies argue that there are several low-cost applications of CCS [64].

3.3 Buildings

The selected promising measures to reduce greenhouse gas emissions from buildings include i) improving the energy efficiency of appliances, ii) improving the energy intensity of new residential and commercial buildings, iii) no installation of new oil boiler capacity in new and existing residential and commercial buildings, and iv) improving the efficiency of existing buildings by increasing the share of existing buildings being renovated.

Improving the energy efficiency of appliances and buildings (measures i, ii, and iv) provides multiple benefits. Improving building efficiency can slow down the growth of energy demand, especially in developing countries, freeing up capital and capacity for expanding energy access (**SDG 7**). Improving energy efficiency leads to lower energy expenditure that increases disposable income (**SDG 1**). Efficient buildings improve health and quality of life by reducing local emissions and fossil fuel use (**SDG 3, 11**), lower energy bills increasing disposable income (**SDGs 1, 10**), and improving energy security. Efficiency improvements of cookstoves lead to empowerment of women in developing countries who spend several hours per day collecting fuelwood and cooking meals (**SDG 5**). Measures to reduce energy consumption in buildings also enhance competitiveness (**SDG 8**), stimulate innovation (**SDG 9**), and enable sustainable resource use (**SDG 12**) [65]. Although energy efficiency measures create decent work opportunities (**SDG 8**), the net employment effect remains uncertain due to macroeconomic feedback [62]. International cooperation can enhance energy efficiency improvements through the sharing of best practices and policies, promoting global partnership (**SDG 17**).

Switching away from oil boilers provides significant energy efficiency improvements (**SDG 7**). Oil is an expensive fuel in most regions, hence, replacing it could provide noticeable economic benefits that facilitates achieving **SDG 1** [66]. Replacing oil boilers reduces local air pollution (**SDG 11**) and prevents soil and ground water pollution (**SDGs 6, 12, 15**) from oil leakage resulting from structural failure, corrosion, and loose fittings in the system. It also creates additional jobs in the building and heating industries (**SDG 8**) and stimulates innovation to low-carbon heating technologies (**SDG 9**).

The largest potential trade-off with the above measures is related to the relatively high upfront investment costs of some of the measures. Depending on how the measures are implemented, this may lead to a higher risk of poverty (**SDGs 1, 10**) and harm the progress towards universal energy access (**SDG 7**), even though they will lead to lower energy bills.

3.4 Transport

The identified promising measures to reduce greenhouse gas emissions in the transport sector include i) improving average fuel efficiency of new passenger cars, ii) increasing the share of non-fossil in new vehicle sales, and iii) improving energy efficiency of aviation.

In addition to mitigating climate change, **improving fuel efficiency of passenger cars** directly contributes to better access to energy services (**SDG 7**). Efficiency improvements of cars also contribute to improving local air quality (**SDG 11**) and reducing particulate emissions, reducing human health impacts (**SDG 3**). It also reduces water consumption and waste for transport fuel production (**SDG 6**), reduces oil import and consumption (**SDG 12**), and aids the transition to low-carbon transport. The resulting decline in oil extraction and oil spills leads to improved water and soil quality and a reduction in the overall environmental impact of the transport sector (**SDGs 14, 15**). Measures for improving fuel efficiency could create incentives for innovation in vehicle technology (**SDG 9**). Global collaboration provides the opportunity to share and learn from countries' experiences and learnings (**SDG 17**).

However, since these improvements require long-term and large investments by vehicle manufacturers, it could negatively affect some manufacturers in the industry that naturally seek a shorter payback on any investment (**SDG 8**). In the long run, the resulting decline in oil demand could have significant impact on the economy of oil exporting countries that have high share of fossil-fuel-related sectors in the economy, especially in Africa and the Middle East (**SDGs 8, 10**) [67].

The wider **adoption of non-fossil fuel vehicles**, for instance electric vehicles or vehicles on biofuels, reduces air pollution (**SDG 11**) and related health impacts (**SDG 3**), increases the share of renewables in the global energy mix (**SDG 7**), enables infrastructure development (**SDG 9**), and creates a more resilient and sustainable future for urban dwellers (**SDG 11**). Lower use of fossil fuels leads to improved water and soil quality due to a decrease in oil mining activities and oil spills (**SDG 6**) and reduces in the overall environmental impact of the transport sector (**SDGs 12, 14, 15**). Electric cars also have much lower noise pollution than conventional vehicles. Wider adoption of non-fossil fuel vehicles calls for strong international partnerships between vehicle manufacturers, between dealerships/trading companies and policymakers, and manufacturers and oil companies (**SDG 17**).

Increasing efficiency could lead to additional jobs in energy efficiency (**SDG 8**), increases disposable income by reducing fuel expenditure (**SDG 10**), and improves resource efficiency amid lower energy use (**SDG 12**).

A wider adoption of alternative fuels also has some trade-offs. Generating biofuels from food crops or from crops grown on land that could be used for food creates a potential conflict with food security (**SDG 2**). Without proper management of their charging patterns, rapid increase of electric vehicles could result in large variations in power demand [68] and overload local power systems (impacting **SDG 7**) [69]. A transition to a predominantly electric car fleet requires reskilling of the existing work force and restructuring of the automotive industry (**SDG 8**).

Increasing **aviation energy efficiency** directly contributes to achieving **SDGs 7** and **12** through the more efficient use of resources. Due to the labour-intensive nature of many energy efficiency projects, it is an opportunity for creating jobs (**SDG 8**). It also enhances innovation into sustainability of the industry (**SDG 9**), reduces air pollution (**SDG 11**), and improves resource efficiency (**SDG 12**). Aviation fuel efficiency gains could provide considerable cost savings for the industry, as well. Innovation in road transport and aviation calls for strong international collaboration on knowledge and experience sharing (**SDG 17**).

3.5 Land use

Important measures for CO_2 emission reduction in the land use sector include increasing afforestation and reforestation, and halting deforestation.

Deforestation, mainly driven by commercial logging, large-scale and small-scale agriculture, cattle ranching, and logging for fuelwood, pose major challenges to sustainable development, has affected the lives and livelihoods of millions of people [70], and is the main driver of loss of species and biodiversity. Therefore, **afforestation and reforestation** directly contribute to **SDG 15** (i.e. halting biodiversity loss). Forests are also fundamental for food security and improved livelihoods. Forest products supply part of the household income for local households in developing countries, contributing to achieving **SDG 1** as well as **SDG 10** (i.e. reducing relative poverty). Forests provide wild fruits, vegetables and bush meat for nourishment (**SDG 2**), and reduce harmful air pollutants in urban areas (**SDGs 3, 11**). Forestry is labour-intensive with relatively low capital investment needs; hence, targeted investments could generate new jobs (**SDG 8**). However, afforestation could result in competition for land with food production, negatively affecting **SDGs 1** and **2,** especially in Sub-Saharan Africa and South Asia. It could also negatively affect local water supply by increased evapotranspiration (**SDG 6**).

Similar synergies and trade-offs can be identified for **halting deforestation**, which has a clear direct synergy with **SDG 15**. Halting deforestation also reduces soil erosion and regulates local weather, contributing to sustainable food production systems (**SDG 2**), improves local air quality (**SDG 11**) and stimulates responsible consumption of natural resources (**SDG 12**) [71]. Deforestation can lead to reductions in water quality and quantity; halting deforestation, thus, improves access to clean water and sanitation (**SDG 6**). It can also help foster local economic development through collaborations between forest management, local communities and the private sector (**SDGs 1, 10**). Both afforestation and deforestation require international partnerships for financial and technological capacity building in developing countries (**SDG 17**).

Drivers of deforestation are mainly rooted in wider social and economic issues. Measures to halt deforestation could lead to reduced employment opportunities for those dependent on selling firewood (impacting **SDGs 1, 8**). In regions such as Sub-Saharan Africa, deforestation is driven by smallholder agriculture to meet the rapid growing demand for food that cannot simply be met by improving yield [72]. Hence, measures to halt deforestation could collide with the goal to end hunger (**SDG 2**). Expanding road networks is one driver of deforestation, hence, promoting afforestation and halting deforestation could impact market access and connectivity (**SDG 9**).

3.6 Non-CO_2

Non-CO_2 greenhouse gas emissions, mainly CH_4, N_2O, and fluorinated gases, account for about a quarter of global anthropogenic greenhouse gas emissions. A diverse set of promising measures was identified to reduce non-CO_2 greenhouse gas emissions. For CH_4, these consist of i) treating manure from livestock with anaerobic digesters, ii) selective breeding to reduce CH_4 emissions from enteric fermentation, iii) coal mine CH_4 emissions recovery, iv) reducing venting and flaring, v) reduce CH_4 emissions from waste. For N_2O, reducing emissions from adipic/acid production in the industry sector and increasing nitrogen use efficiency in agriculture were identified as promising measures.

Anaerobic digestion of manure is a proven technology for reducing CH_4 emissions. Livestock manure can be converted into biogas, providing access to modern and sustainable energy for millions of people (**SDG 7**)[73]. It also produces bio-slurry that is used as organic fertiliser, promoting sustainable agriculture (**SDGs 2, 15**), reduces odour nuisance and has positive public health impact (**SDG 3**), and limits soil and water nutrient pollution (**SDG 6**). Proper management of manure contributes to reduction in waste and land and water pollution (**SDG 12**). Using anaerobic digesters creates additional economic activities (**SDG 8**). International public-private partnership involving research institutions, agro-industry companies, non-profit organisation and governments could foster innovation in proper manure management to reduce methane emissions (**SDG 17**). The most important trade-offs associated with large-scale implementation of anaerobic digesters relate to the fact that livestock manure is the major fertiliser in many low-income countries. Reducing its availability might affect the targets to end hunger and to decrease relative poverty (**SDGs 1, 2**) [74].

Selective breeding reduces CH_4 emissions from enteric fermentation, while increasing productivity with limited resources. It therefore contributes to achieving **SDGs 1** and **10** by increasing farm incomes. It also provides opportunities to increases the contribution of the livestock sector to national economic growth, enabling global economic convergence (**SDG 8**). Finally, selective breeding increases the supply of animal-sourced foods through better feeding and breeding (**SDG 2**), reduces water demand from livestock systems as well as associated livestock waste water flows (**SDG 6**), improves productivity and feed-use efficiency (**SDG 12**), and reduces and reverses land degradation for livestock expansion (**SDG 15**) [75].

Excess nitrogen use leads to adverse environmental and health impacts. Reducing nitrogen use by **improving efficiency in nitrogen application** therefore benefits several other SDGs. It reduces the cost of production, improving food affordability (**SDG 2**) and increasing incomes for farmers (**SDGs 1, 10**). It also reduces groundwater contamination, eutrophication of freshwater and estuarine ecosystems (**SDGs 6, 14**). It saves the use of fossil fuels needed to produce fertilisers (**SDG 12**) and reduces soil and water pollution resulting from nitrates, ammonia, and other nitrogen substances released in the environment (**SDG 15**) [76]. However, reduced cost of production could increase the demand for food (also due to more waste) and feed, leading to increased livestock production, partly offsetting the environmental benefits of nitrogen use efficiency (**SDG 15**) [77].

Coal mine CH_4 emission recovery provides numerous benefits: it enhances coal mine safety (**SDG 8**), enables conservation of local energy (**SDG 12**), and increases the revenue of the mine. The recovered CH_4, depending on the quality, can be used for power, district heating, boiler fuels, or purified and fed to natural gas distribution systems generation (**SDG 7**).

Reducing non-CO_2 emissions from gas and oil production, by **reducing venting and flaring**, contributes to the **SDG 7** target to provide universal energy services for all. It also contributes to improving well-being (**SDG 3**) by reducing air pollution (**SDG 11**), and creates additional economic activities (**SDG 8**) [78]. Halting venting and flaring also promotes responsible consumption and production of natural resources (**SDG 12**) and reduces the impact on land and ecosystem around the flaring site (**SDG 15**). Capturing and using the associated natural gas during oil production enhances government revenue (**SDG 17**).

Reducing CH_4 emissions from waste can reduce air pollution (**SDGs 3, 11**), improve safety by reducing explosion and fire hazards (**SDG 11**), and improve water quality by reducing pollution (**SDGs 6, 14**) [79]. CH_4 from landfills can be recovered and used for power generation or as a direct source of energy, providing an additional source of renewable energy (**SDG 7**). Collecting and treating landfill gas generates revenue and creates jobs in the local community and beyond (**SDGs 8, 17**). However, these measures require high capital costs to build and install landfill CH_4 recovery systems, and, if successful, CH_4 gas recovery could overshadow measures that aim to reduce waste in general (**SDG 12**).

With projected growth in demand for fertiliser and synthetic fibres, **reducing N_2O emissions from adipic/acid production in the industry sector** offers a large potential for climate change mitigation. Nitrogen oxide causes air pollution that adversely affects human health and the environment. It forms acid rain when dissolved in water and damage vegetation and terrestrial and aquatic ecosystems. Reducing it, therefore, has synergies with goals for clean water and sanitation (**SDG 6**), life under water (**SDG 14**), and life on land (**SDG 15**).

Table 3.1 summarises the synergies and trade-offs discussed in this chapter. The mitigation measures are listed in the rows and relevant SDG targets in the columns. Cells with an orange colour ( ) indicate that the risks for trade-offs between the mitigation measure and the SDG outweigh the potential for synergies. A yellow shading ( ) means that both synergies and trade-offs are possible, depending on the chosen technology or the regional context. The lighter green shading ( ) indicates that the potential for synergies outweigh the risks of trade-offs and the darker green shading ( ) indicates that the potential for synergies strongly outweigh the risks for trade-offs. Cells without a colour indicate that there are no clear synergies or trade-offs.

Table 3.1 Synergies and trade-offs between climate change mitigation measures and SDGs

SDG target / Mitigation measure	No poverty	Zero hunger	Good health and well-being	Gender equality	Clean water and sanitation	Affordable and clean energy	Decent work for all	Inclusive sustainable economic growth	Fostering innovation	Reduced inequalities	Sustainable cities and communities	Responsible consumption & production	Life below water	Sustainably manage forests	Halt biodiversity loss	Revitalize global partnership	Strengthen means of implementation
	1	2	3	5	6	7	8		9	10	11	12	14	15		17	
Electricity generation																	
No new installations of unabated coal power plants	O		DG		LG	Y	Y	O		O	DG						
Increase renewables in electricity generation	Y	O	LG		DG	DG	DG	LG	DG	Y	DG	DG	Y	Y	Y	LG	LG
Industry																	
Improve energy efficiency in industry	LG		LG		LG	LG	LG	LG	DG	LG	DG	DG				LG	LG
Apply carbon captured and storage in industry	O		O		O	O	DG	Y	DG		LG	DG	O			LG	
Buildings																	
Improve energy efficiency of appliances	LG		LG	LG		DG	LG	Y	DG	LG	LG	DG				LG	
Improve energy intensity of new buildings	LG		LG			DG	LG	Y	LG	LG	DG	DG				LG	
Increasing renovations of existing buildings	LG		LG			DG	LG	Y	LG	LG	DG	DG				LG	LG
No new installations of oil boilers in buildings	Y				LG	DG	LG		LG	Y	DG	DG		LG	LG		
Transport																	
Improve fuel efficiency of new passenger cars			LG		LG	LG	Y	O	LG	Y	DG	DG	LG		LG	LG	LG
Increase non-fossil new vehicle sales		O	LG		LG	Y	Y	Y	DG		DG	DG	LG		LG	LG	LG
Improve energy efficiency of aviation						LG	Y	LG	DG		LG	DG				LG	LG
Land use																	
Increase afforestation and reforestation	Y	O	LG		O		LG	Y		LG	LG				DG		DG
Halt natural forest deforestation	O	LG	LG		LG		O			Y	LG	LG		DG	DG		DG
Non-CO2																	
Treat manure with anaerobic digesters (CH_4)	Y	Y	LG		LG	DG		LG				LG			LG	LG	LG
Selective breeding to reduce CH_4 emissions	LG	Y			LG		LG	LG				LG		LG	LG		
Increase nitrogen use efficiency (N_2O)	LG	DG			LG					DG		DG	DG		DG		
Coal mine CH_4 emissions recovery						DG	LG					DG					
Reduce venting and flaring of CH_4			LG			DG	Y	DG			LG	DG			DG		LG
Reduce CH_4 emissions from waste			LG		LG	DG	LG				DG	Y	LG				LG
Reduce N_2O emissions adipic/acid production					LG								DG		DG		

O: Risks for trade-offs outweigh potential of synergies
Y: Synergies and trade-offs strongly dependent on context
LG: Potential of synergies outweigh risks for trade-offs
DG: Potential of synergies strongly outweigh risks for trade-offs

4 Regional assessment

The synergies and trade-offs between the promising climate change mitigation measures and SDGs are further discussed here in the context of the world regions North America, South and Central America, Europe, Middle East and North Africa, South Asia, Southeast Asia, and Sub-Saharan Africa. These regions were selected, based on a discussion with the Dutch Ministry of Foreign Affairs.

To allow a deeper discussion of the synergies and trade-offs, we discuss for each region only the mitigation measures for the three sectors with the highest mitigation potential. The synergies and trade-offs can differ between world regions either because the relative importance of mitigation measures differ or because of region-specific synergies and trade-offs for similar mitigation measures.

We have used scenario analysis (Table 4.1) to identify the promising measures with largest mitigation potential. More concretely, the IMAGE integrated assessment model [80] was used to assess the mitigation potential of the measures listed in Table 2.1.

As reference, the **current policies** scenario was used. This scenario is based on middle-of-the-road socio-economic projections and includes implementation of climate, energy and land-use policies that are ratified as of 1 July 2019.

The second scenario, called **good practice policies**, assumes implementation of the good practice policies listed in Table 2.1 on top of the policies under the current policies scenario. These measures are universally implemented, but with regional differentiation based on input from country experts (Annex 1 provides more detail on the regional implementation of the measures). This scenario is used for low- and middle-income regions, as for these regions this scenario leads already to significant emission reductions compared with the current policies scenario (but not yet sufficient for achieving the Paris climate objectives).

For the highest income regions Europe and North America, we look at a third, more ambitious, scenario (**bridge**) because of two reasons. First, the emission reductions in the good practice scenario are more modest for regions with higher incomes. Second, and more importantly, more ambitious emission reductions for richer countries are in line with the UNFCCC principle of common but differentiated responsibilities and respective capabilities (CBDR-RC). This principle reflects equity and responsibility according to different national circumstances. The Bridge scenario goes beyond the good practice policy scenario by imposing an additional carbon price from 2030 onwards in order to reduce emissions further in line with the 2 °C target.

To identify the promising measures with the highest mitigation potential, we look for each region at the difference in sectoral emissions between the current policies scenario and either the good practice policies scenario (for all regions but North America and Europe) or the bridge scenario. For the measures in the three sectors with the largest absolute reductions, the synergies and trade-offs are discussed. The good practice policies and bridge scenarios also include economy-wide measures (universal carbon tax and reducing F-gases), but the synergies and trade-offs of these measures are not assessed. If there are specific promising mitigation measures for a specific region identified in literature that are not included in Table 2.1, these are discussed here, as well. It is important to keep in mind that reductions shown in this chapter are not yet sufficient to achieve the Paris climate agreement objectives, as we focus only on the most promising measures in middle- and low-income regions (the aim is not to show which measures are required to achieve the Paris climate objectives, but to show the synergies and trade-offs of the most promising measures).

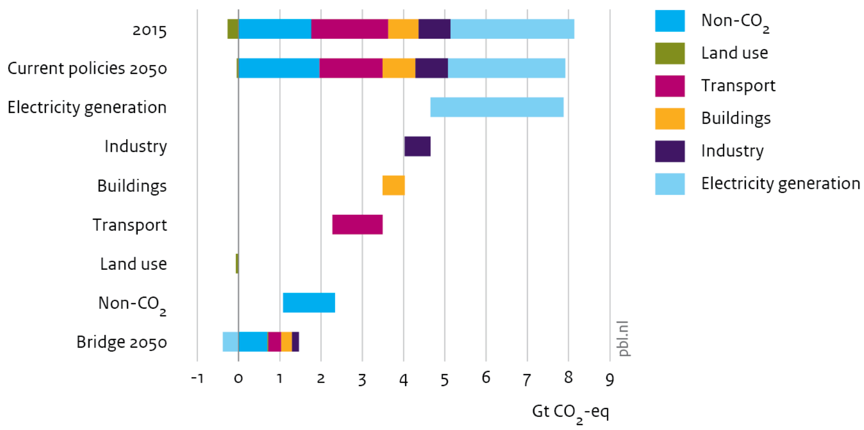
Table 4.1 Scenario descriptions

Scenario	Description
Current policies	A reference scenario including current climate policies adopted as off July 1, 2019.
Good practice policies	Based on the current policies scenario with global implementation of good practice policies until 2050. The extent to which policies are implemented differs between high and low-income countries (see Annex 1).
Bridge	This scenario is similar to the good practice policies scenario until 2030 and then follows a cost-optimal pathway to meeting the 2 °C target by 2100. This is simulated by implementing a global carbon price to all gases and sectors.

4.1 North America

There is a large difference in emissions between the Current policies scenario and the Bridge scenario in 2050 in North America (Figure 4.1). The largest emission reductions are directly related to power generation, followed by the transport sector and non-CO_2 greenhouse gases. We therefore focus on synergies and trade-offs related to these sectors.

Figure 4.1 Contribution of sectors to emission reduction, North America



4.1.1 Power generation

Halting the installation of unabated coal power plants and increasing the share of renewable energy in power generation account for the largest reduction in projected emissions in the Bridge scenario relative to the Current policies scenario.

The use of coal is already declining in the region as a consequence of the decline in renewable energy prices, discovery of abundant natural gas, as well as regulations designed to reduce emissions and protect public health [21]. Halting the use of unabated coal completely has several benefits for other SDGs. It has important health benefits (**SDG 3**), as coal-fired power plants are a major contributor to air pollution (**SDG 11**). Decline in the use of coal could save large amounts of fresh water for coal mining and processing (**SDG 6**). With the declining renewable energy prices, shifting away from coal could also be economically attractive as it provides more employment opportunities and avoids the risk of stranded assets (**SDG 8**).

North America has considerable wind, solar, geothermal and hydropower resources. Renewable energy already plays an important role in power generation in the region: hydropower accounts for 63% of total power generation in Canada, the United States has a considerable potential for hydropower and solar energy, and Mexico relies heavily on hydropower and has great potential for solar, wind and geothermal energy. Expanding renewable energy sources in power generation directly increases the share of renewable energy, improves energy efficiency and also improves access to clean fuels in parts of Mexico (**SDG 7**). Renewable energy systems have several synergies with other SDGs, as well: they lead to improved water quality, air quality and soil quality by reducing emissions and leakage (**SDGs 6, 11**). In general, they create more jobs than fossil fuel technologies and stimulate the creation of decent and safer jobs (**SDG 8**), while contributing to economic growth and employment through the sourcing of local goods and services (**SDG 17**) and stimulation of innovation (**SDG 9**). In general, renewable energy systems lead to less natural resource depletion (**SDG 12**) and ocean-based renewable energy systems enable marine resource protection (**SDG 14**).

A potential trade-off of increasing renewable energy is that energy prices may increase as a result of more expensive (or less matured) technologies. Higher energy prices in North America are not only related to more advanced technology choices, but also to more stringent emissions controls and higher feedstock costs (**SDG 10**) [81]. However, in some parts of North America, some renewable sources, such as onshore wind, are now reaching price parity with or becoming cheaper than fossil fuels. Utility scale renewable energy systems, such as solar farms and concentrated solar power, require large areas of land and may limit land availability and access to local communities (**SDG 15**) [55]. Visual impacts have been amongst the leading concerns to installing onshore wind farms in North America. There are also concerns about competition of marine-based renewable systems with other marine activities (**SDG 14**), and biodiversity-related impacts of wind power facilities involving birds, bats, and natural habitats (**SDG 15**).

4.1.2 Transport

The continuous growth in the number of passenger cars in North America will contribute to increased CO_2 emissions from transport, if not complemented by increases in fuel efficiency and low-carbon fuel technologies. Given the large stock of old vehicles in North America, improving the fuel efficiency of new vehicles combined with accelerated retirement of older, less fuel-efficient vehicles are effective ways of reducing emissions in the short and medium term. Electric vehicles, with virtually zero exhaust emissions, could provide large emission reductions from transport.

Energy efficiency improvements and fuel-switching in the transport sector contributes to achieving SDG7 targets by improving overall energy efficiency and increasing the share of renewable energy, as fossil fuel use is reduced. Both measures also improve energy security, as the fuel mix of transport gets more diverse, and stimulate innovation in vehicle technology (**SDG 9**). Electric vehicles also lead to less air and noise pollution, improve local air quality (**SDG 11**), improve health and well-being (**SDG 3**), reduce water consumption (**SDG 6**) and improve water and soil quality due to a decrease in oil mining activities and oil spills, and a reduction in the overall environmental impact of the transport sector (**SDGs 14, 15**). Increasing efficiency could lead to additional jobs in energy efficiency (**SDG 8**), increases disposable income by reducing fuel expenditure (**SDG 10**), and improves resource efficiency amid lower energy use (**SDG 12**). However, reducing emissions from passenger cars could prove to be a challenge because it requires large upfront investments by vehicle manufacturers (**SDG 8**) [82].

The aviation sector in North America is expected to recover faster from the COVID-19 crisis than in several other major aviation markets, mainly driven by the large domestic market [83]. If not accompanied by further efficiency improvements, aviation greenhouse gas emissions, the second biggest source of transport greenhouse gas emissions after road transport, will continue to grow. Improved fuel efficiency in aviation contributes to overall energy efficiency (**SDG 7**), creates more safe and decent jobs (**SDG 8**), enhances innovation by increases the financial resilience of the industry (**SDG 9**), improves resource efficiency (**SDG 12**), and reduces air pollution (**SDG 11**).

4.1.3 Non-CO_2 emissions

Abating non-CO_2 greenhouse gas emissions, especially CH_4 emissions from coal mining and oil and natural gas production and CH_4 and N_2O emissions from agriculture and land use, also has the potential to strongly contribute to reducing emissions in North America.

Agriculture emits significant amounts of non-CO_2 greenhouse gases from crop and livestock activities in North America. N_2O emissions can be reduced by reducing the use of organic and non-organic fertilisers, while CH_4 emissions can be reduced by either reducing ruminant livestock or reduction in emission per unit of production. The latter could be achieved by improving production practices or improving feed quality and digestibility [84]. Reducing the use of fertilisers reduces the cost of production (**SDG 10**), saves the use of fossil fuels needed to produce fertilisers (**SDG 12**), and reduces the pollution resulting from nitrates, ammonia, and other nitrogen substances released in the environment (**SDGs 14, 15**) [76]. Managing nitrate leaching on farms improves water quality (**SDG 6**). Selective breeding could increase productivity (**SDG 12**) resulting in substantial increases in farm profitability (**SDGs 8, 10**). Reduction in livestock reduces water demand (**SDG 6**) and decrease deforestation for additional pasture lands and frees up land that could be restored for biodiversity (**SDG 15**).

The energy sector is one of the largest contributors to non-CO_2 greenhouse gas emissions in the region. Large quantities of CH_4 are released during coal mining and oil and natural gas production, processing, transmission and distribution. Without abatement measures in the coal mining industry, coal production is projected to remain a major source of greenhouse gas emissions. Recovery and use of coal mine methane leads to improved worker safety (**SDG 8**) and could be a potential supply of a local clean energy source (**SDGs 7, 12**).

Gas production in North America is expected to increase amid expanded use of enhanced oil recovery, and unconventional production such as from exploitation of vast shale gas reserves amid advances in production technology. This increase in production and consumption of gas contributes to future increases in non-CO_2 greenhouse gas emissions. There are already cost-effective technologies that are readily available to tackle CH_4 emissions from the oil and gas sector [76]. Reducing venting and flaring helps meeting energy demands (**SDG 7**), create additional economic activities (**SDG 8**), improve health and well-being by reducing air pollution (**SDG 11**), enables responsible consumption (**SDG 12**), and reduces the negative effects on the flora and fauna around the flaring site (**SDG 15**)[78].

The United States is one of the major producers of adipic acid, which is mainly used in the production of nylon. Nitrous oxide emissions from the production of adipic and nitric acid have decreased in the region with the widespread installation of abatement technologies. However, there is still large potential to reduce emissions that would result in co-benefits to clean water and sanitation (**SDG 6**), life under water (**SDG 14**), and life on land (**SDG 15**).

Table 4.2 Synergies and trade-offs between climate change mitigation measures and SDGs, North America

Mitigation measure \ SDG target	Good health and well-being (3)	Clean water and sanitation (6)	Affordable and clean energy (7)	Decent work for all (8)	Inclusive sustainable economic growth (8)	Fostering innovation (9)	Reduced inequalities (10)	Sustainable cities and communities (11)	Responsible consumption & production (12)	Life below water (14)	Sustainably manage forests (15)	Halt biodiversity loss (15)	Revitalize global partnership (17)	Strengthen means of implementation (17)
Electricity generation														
No new installations of unabated coal power plants	DG	LG		LG				DG						
Increase renewables in electricity generation		DG	DG	DG	LG	DG	Y		DG	Y	O	O	LG	LG
Transport														
Improve fuel efficiency of new passenger cars	LG	LG		LG	Y	LG	LG	DG	DG	LG		LG	LG	LG
Increase non-fossil new vehicle sales	LG	LG		LG	LG	DG		DG	DG	LG		LG	LG	LG
Improve energy efficiency of aviation			LG	LG	LG	DG		LG	DG				LG	LG
Non-CO2														
Selective breeding to reduce CH_4 emissions		LG			LG		DG		LG		LG	LG		
Increase nitrogen use efficiency (N_2O)		LG					DG		DG	DG		DG		
Coal mine CH_4 emissions recovery			DG	LG					DG					LG
Reduce venting and flaring of CH_4			DG	LG				DG	DG			DG		LG
Reduce N_2O emissions adipic/acid production		LG								DG		DG		

- O (orange): Risks for trade-offs outweigh potential of synergies
- Y (yellow): Synergies and trade-offs strongly dependent on context
- LG (light green): Potential of synergies outweigh risks for trade-offs
- DG (dark green): Potential of synergies strongly outweigh risks for trade-offs

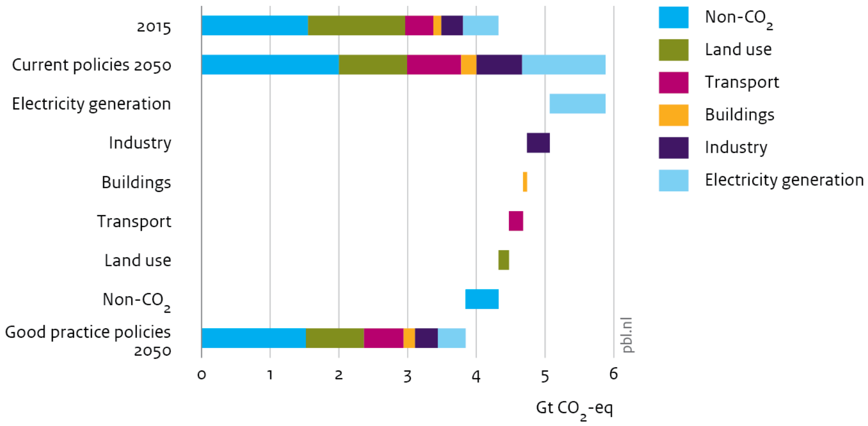
4.2 Central and South America

The promising mitigation measures with the largest emission reductions in Central and South America are increasing the share of renewable energy in power generation, non-CO_2 emission reduction, and, to a lesser extent, improved energy efficiency and reduced emissions from industry (Figure 4.2).

4.2.1 Power generation

Central and South America's power generation is dominated by hydropower. Its dependence on hydropower raises concerns about the impact of climate change on energy security. The region is rich in non-hydropower renewable energy resources, too. Rapid cost reductions, maturing technologies and renewable energy policy reforms offer opportunities not only to combat climate change by further reducing fossil fuel use, but also to diversify the energy supply of the region — thus, reducing the dependence on large hydropower. There are also complementarities between hydropower and other renewable energy technologies. Hydropower plants with reservoirs are flexible assets and they are cost-effective ways to counteract short-term variations in the production of variable renewable energy technologies. On the other hand, during dry seasons, non-hydropower renewable technologies can balance the production of electricity when hydropower generation is lower [85].

Figure 4.2 Contribution of sectors to emission reduction, South and Central America



Bioenergy for power and onshore wind capacities has shown considerable growth in absolute terms since 2000 [85]. Geothermal and solar energy are also important in meeting the growing energy demand and providing energy access to currently underserved communities through clean, modern, and sustainable energy.

Renewable energy systems enhance water security (**SDG 6**), enable the achievement of **SDG 7**, lead to improved human health (**SDG 3**) by increasing local air quality (**SDG 11**), stimulate economic growth by creating local jobs (**SDG 8**), reduce poverty (**SDGs 1, 10**), and reduce natural resource depletion (**SDG 12**). Successful deployment of renewable energy technologies calls for innovations in all parts of the value chain (**SDG 9**). Governance and infrastructure challenges present major concerns in developing renewable energy projects in the region, increasing the associated risk and costs. If not supported by pro-poor policies, the expansion of renewable energy could increase the price of electricity, making access difficult to the poor (**SDG 7**). Utility scale application of solar and wind technologies could conflict with food production and biodiversity goals (**SDGs 2, 15**).

4.2.2 Industry

Industry is another important sector for climate change mitigation in Central and South America. Energy-intensive industries, related to natural resource exploitation, play a significant role in economic development of the region [85]. There are many opportunities to improve the efficiency of industrial equipment and operations, for instance by adopting demand-side management solutions, introducing highly efficient motors, and developing material recycling. Efficiency improvements enable expanding energy access with existing capacity (**SDG 7**). Improved energy efficiency in industry enhances economic competitiveness and sustainable economic development (**SDGs 1, 8, 9, 10**), advances health and well-being (**SDG 3**) by improving local air quality (**SDG 11**), and reduces water use and waste (**SDGs 6, 12**).

CCS also plays an important role in reducing industrial CO_2 emissions, especially for activities that are most challenging to abate. It provides one of the most mature and cost-effective options for reducing emissions in hard-to-abate industries such as cement, iron and steel, and the chemical sub-sectors. Deployment of CCS in industry creates and retains jobs (**SDG 8**), provides clean growth opportunities and helps ensure a just and sustainable transition for communities (**SDG 9**), improves local air quality (**SDG 11**), and supports sustainable production (**SDG 12**) [85]. Leakage of CO_2 from CCS plants could impact human health and well-being (**SDG 3**) and marine and coastal environments (**SDG 14**). CCS could increase production costs, impacting poverty alleviation and competitiveness (**SDGs 1, 8**), increase water use (**SDG 6**), and increase energy consumption of industries (**SDG 7**).

4.2.3 Non-CO_2 emissions

South America is one of the largest contributors to global agricultural non-CO_2 greenhouse gas emissions. There is a considerable potential to reduce CH_4 and N_2O from agriculture and livestock production in the region. These reductions can be achieved by reducing ruminant livestock numbers (e.g. as a result of lifestyle change) or emissions per unit of production (e.g. as the result of changes in production practices or improving feed quality and digestibility) [84].

Reduction in fertiliser application could reduce N_2O emissions without compromising production. It reduces the cost of production, hence, improves affordability of food (**SDG 2**). Reduced fertiliser use improves human health (**SDG 3**), increases productivity and margins on agriculture products (**SDGs 1, 10**), improves resource efficiency (**SDG 12**), and minimises leaching of nitrates, improving soil and water quality (**SDGs 14, 15**) and availability of clean water (**SDG 6**). It also reduces the risk of eutrophication.

Reducing the number of ruminant livestock also reduces the land required for and emissions from production of feed crops for livestock (**SDG 15**). The measure also reduces water use in livestock systems (**SDG 6**) and improves productivity (**SDG 12**). Though agriculture and livestock present great opportunities for emission reduction, reducing livestock numbers could negatively affect food prices and the livelihoods of smallholders (**SDG 1,2**).

Table 4.3 Synergies and trade-offs between climate change mitigation measures and SDGs, Central and South America

SDG target / Mitigation measure	No poverty	Zero hunger	Good health and well-being	Clean water and sanitation	Affordable and clean energy	Decent work for all	Inclusive sustainable economic growth	Fostering innovation	Reduced inequalities	Sustainable cities and communities	Responsible consumption & production	Life below water	Sustainably manage forests	Halt biodiversity loss	Revitalize global partnership	Strengthen means of implementation
	1	2	3	6	7	8		9	10	11	12	14	15		17	
Electricity generation																
Increase renewables in electricity generation	light green	orange	light green	dark green	dark green	dark green	light green	dark green	light green	dark green	dark green	yellow	orange	orange	light green	light green
Industry																
Improve energy efficiency in industry	light green		light green	light green	light green	light green	light green	dark green	light green	dark green	dark green				light green	light green
Apply carbon captured and storage in industry	orange		orange	orange	orange	dark green	orange	dark green		light green	dark green	orange			light green	
Non-CO2																
Increase nitrogen use efficiency (N_2O)	light green	dark green		light green					dark green		dark green	dark green		light green		
Selective breeding to reduce CH_4 emissions	orange	orange		light green							light green		light green	light green		
Reduce venting and flaring of CH_4			light green		dark green	light green	dark green			light green	dark green			dark green		light green

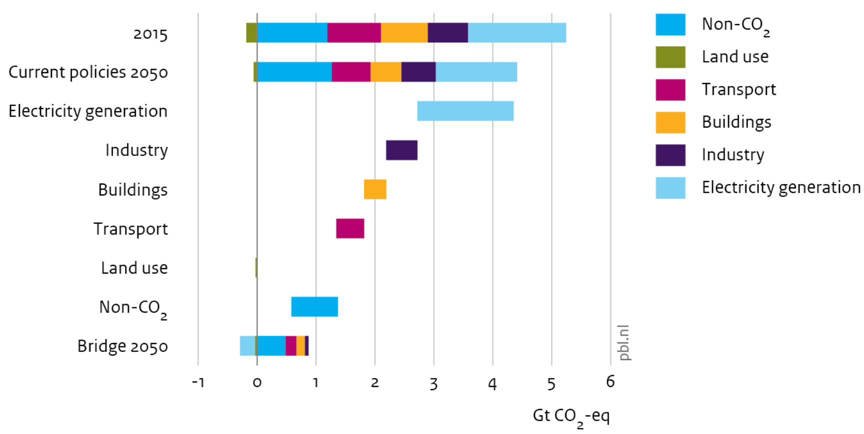
(orange) Risks for trade-offs outweigh potential of synergies
(yellow) Synergies and trade-offs strongly dependent on context
(light green) Potential of synergies outweigh risks for trade-offs
(dark green) Potential of synergies strongly outweigh risks for trade-offs

Several countries in Central and South America are net exporters of oil and gas. Venting and flaring, which releases substantial volumes of CH_4 along with black carbon and N_2O, is a common practice in oil production. Employing a variety of flaring reduction technologies provides an opportunity to reduce non-CO_2 emissions from fossil fuel production. Reducing venting and flaring helps meeting energy demands (**SDG 7**), contributes to better health (**SDG 3**), creates additional economic activities (**SDG 8**), and improves well-being by reduce air pollution (**SDG 11**) [78]. In addition, the measure improves resources efficiency (**SDG 12**) and reduces impact on biodiversity (**SDG 15**).

4.3 Europe

Of the identified promising measures, halting coal and increasing low-carbon sources in power generation, increasing energy efficiency and applying CCS in industry, and reduction in non-CO_2 emissions from oil and natural gas, coal mining, agriculture and waste leads to the largest emission reductions in Europe (Figure 4.3).

Figure 4.3 Contribution of sectors to emission reduction, Europe



4.3.1 Power generation

Power generation accounted for about a third of energy-related CO_2 emissions in Europe in 2019 [29] and shows the largest potential to reduce emissions. Increasing energy efficiency and the share of renewables and fuel switching were essential drivers of emission reductions in the European power sector in the past decades. Energy demand is projected to stay relatively constant in the coming decades, with the share of electricity steadily increasing [29]. Electrification is an important strategy to reduce emissions from end-use sectors in Europe. Low-carbon power generation will therefore play a central role in the transition. Switching from coal to renewables (mainly wind and solar), smart grids, and energy efficiency will all contribute to the additional emission reduction under the Bridge scenario, relative to the Current policies scenario. Coal is one of the most affected fuels by the COVID-19 pandemic in Europe [29], leading to lower utilisation and early retirements of coal-fired power plants. Flexible natural-gas-powered plants could support further expansion of variable renewables in the energy system. The European COVID-19 recovery package is in line with the net-zero greenhouse gas objective of the region [29].

Halting the installation of unabated coal-powered plants reduces air pollution (**SDG 11**), hence, reduces human health impacts (**SDG 3**), particularly in urban settlements. It also has a positive impact on fresh water availability (**SDG 6**). If ill-prepared, the resulting decline in the use of call might affect parts of Europe where large number of people are employed in coal mines (**SDGs 8, 10**).

An increased share of renewables in the energy system reduces natural resource depletion (**SDG 12**), improves energy security (**SDG 7**), and leads to improved air and water quality (**SDGs 6, 11**) contributing to improved health and well-being (**SDG 3**). Renewable energy brings socio-economic benefits by creating numerous decent and safe jobs, as well as increasing demand for local goods and services (**SDG 8**). Successful adoption of renewable energy technologies requires innovations in technology, business models and systems operation (**SDG 9**). A switch to a renewables-based power grid could result in a slight increase in electricity prices in Europe due to the higher costs of some renewable technologies, particularly off-shore wind that could impact low-income households (**SDG 10**) [29]. Issues related to impacts of wind energy turbines on biodiversity (**SDG 15**) and human health (**SDG 3**) and competition between ocean-based renewable systems and other marine activities (**SDG 14**) need to be addressed.

4.3.2 Industry

In 2018, the industry sector accounted for 25% of total final energy consumption in Europe. Energy-intensive industries are an indispensable part of the European economy and clean industrial transformation is a crucial component of the EU green deal. Although energy efficiency in industry has increased considerably over the last couple of decades, improvements have been lower in most energy-intensive industries [86]. The decline in final energy consumption was driven by a shift towards less-energy-intensive manufacturing industries, ongoing structural changes towards tertiarisation of EU economy, and technological and energy efficiency improvements under stricter policies and regulations.

European industrial CO_2 emissions primarily stem from mineral, metal, petroleum refining, chemical, food, and paper industries. In line with energy efficiency improvements, emissions from European industries have also been steadily declining over the years. In EU-28 for instance, emissions from energy-intensive industries have declined by almost 30% between 1990 and 2018 [87]. The sector still has untapped potential for further CO_2 emission reduction. The bridge scenario shows a 90% emission reduction in Europe in 2050 relative to the Current policies scenario. Enhanced energy efficiency in industry reduces water use (**SDG 6**), creates jobs in sectors directly relevant to energy efficiency and the wider economy (**SDG 8**), reduces energy expenditure enhancing competitiveness and growth (**SDGs 9, 10**), reduces air pollution (**SDGs 3, 11**), and promotes resource efficiency (**SDG 12**).

Together with energy efficiency, CCS plays a role in achieving this level of emission reduction. Without CCS, reducing emissions from some energy-intensive industries, such as steel and cement, will not be feasible. CCS technology is already at an advanced stage, but not yet ready for large-scale industrial application. High upfront capital costs and higher operational costs create a barrier to uptake of CCS; hence, government policy is a necessary part of market creation. Deployment of CCS in industry creates and retains jobs (**SDG 8**), provides resilient and clean growth opportunities (**SDGs 8, 9**), helps ensure a just and sustainable transition (**SDG 9**), improves local air quality (**SDG 11**), and enables sustainable production (**SDG 12**) [85].

Issues that need to be addressed, while implementing CCS in industries includes concerns over CO_2 leakage that could affect human health (**SDG 3**) and coastal systems (**SDG 14**), increased water and energy use by CCS plants (**SDG 6,7**), and increased cost of production that affects competitiveness (**SDG 8**).

4.3.3 Non-CO_2 emissions

Agriculture and fossil fuel production are accountable for the majority of non-CO_2 greenhouse gas emissions in Europe. CH_4 leaks from fossil fuel production sites, transmission systems, ships, and distribution systems. In the agricultural sector, it originates from enteric fermentation, manure management, and rice cultivation (the last mainly in Italy). Sources of CH_4 also include uncontrolled emission of landfill gas from landfill sites, the treatment of sewage sludge and leaks from biogas plants due to poor design or maintenance [46].

The majority of non-CO_2 emissions from agricultural are attributable to livestock production, including manure decomposition and enteric fermentation, and fertiliser use (both organic and synthetic). Enteric fermentation is by far the largest single source of CH_4 emission in Europe. Change in feed and a decrease in the number of livestock have contributed to the reduction in CH_4 emissions from agriculture, over the past decades. N_2O emissions from agriculture soil (converted from inorganic fertilisers, animal waste, sewage sludge applications, biological N-fixation and crop residues) also contributes significantly to total greenhouse gas emissions in Europe. Measures such as optimisation of fertiliser application rates, improved feed conversion efficiency by optimising livestock diets, better control of manure management systems could help reduce non-CO_2 greenhouse gas emissions from the agriculture sector [88]. Measures that lead to reduced emissions could benefit farmers and animals by contributing to food security (**SDG 2**) [89], reduced water use (**SDG 6**), reduced costs (**SDGs 8, 10**), reduced waste and land and water pollution (**SDGs 12, 14**), improved animal welfare, and protecting biodiversity (**SDG 15**).

Coal mining, natural gas production and solid fuel transformation account for a considerable share of non-CO_2 greenhouse gas emissions in Europe. Coal demand is falling sharply, and several economies within the region have pledged to phase out coal in the coming decades. This would lead to a dramatic decline in non-CO_2 emissions from coal mining and burning. Strategies to reduce non-CO_2 emissions from gas and oil production, such as measures to eliminate venting and flaring, leakage detection and repair, mandatory monitoring, reporting and verification, and adoption of CH_4 performance standards, could help reduce CH_4 emission from the petroleum industry [90]. These measures to reduce greenhouse gas emissions reduce negative health impacts (**SDG 3**), enhance coal mine safety, create additional economic activities (**SDG 8**), improve air and water quality (**SDGs 11, 14**), promote responsible production and consumption (**SDG 12**), and protect land and ecosystems (**SDG 15**).

Increased recycling and energy recovery of biodegradable solid waste instead of landfill are effective measures to reduce CH_4 emissions from waste [45]. New technologies for better conversion of waste to biomethane can be effective in further reducing CH_4 emissions in the sector [46]. Reducing CH_4 emissions from waste can improve safety (**SDG 3**), provide local air and water quality benefits (**SDGs 6, 11, 14**), and create additional economic activities in collecting, treating and utilising landfill gas (**SDG 8**). However, the success implementation of the measure should not deter efforts aimed at reducing waste (**SDG 12**).

Table 4.4 Synergies and trade-offs between climate change mitigation measures and SDGs, Europe

SDG target / Mitigation measure	Zero hunger (2)	Good health and well-being (3)	Clean water and sanitation (6)	Affordable and clean energy (7)	Decent work for all (8)	Inclusive sustainable economic growth (8)	Fostering innovation (9)	Reduced inequalities (10)	Sustainable cities and communities (11)	Responsible consumption & production (12)	Life below water (14)	Sustainably manage forests (15)	Halt biodiversity loss (15)	Revitalize global partnership (17)	Strengthen means of implementation (17)
Electricity generation															
No new installations of unabated coal power plants		dark green	light green			orange		yellow	dark green						
Increase renewables in electricity generation		light green	dark green	dark green	dark green	light green	dark green	orange	dark green	dark green	yellow		orange	light green	light green
Industry															
Improve energy efficiency in industry		light green	light green		light green	light green	dark green	light green	dark green	dark green				light green	light green
Apply carbon captured and storage in industry		orange	orange	orange	dark green	yellow	dark green		light green	dark green	orange			light green	
Non-CO2															
Treat manure with anaerobic digesters (CH_4)		light green	light green			light green				dark green			light green	light green	light green
Increase nitrogen use efficiency (N_2O)			light green					dark green		dark green	dark green		dark green		
Selective breeding to reduce CH_4 emissions	light green		light green		light green	light green				light green		light green	light green		
Coal mine CH_4 emissions recovery				light green	light green					dark green			light green		light green
Reduce venting and flaring of CH_4		light green			light green	light green			light green	dark green	light green		dark green		light green
Reduce CH_4 emissions from waste		dark green	light green		light green		light green		dark green	yellow	light green		light green		light green

orange: Risks for trade-offs outweigh potential of synergies
yellow: Synergies and trade-offs strongly dependent on context
light green: Potential of synergies outweigh risks for trade-offs
dark green: Potential of synergies strongly outweigh risks for trade-offs

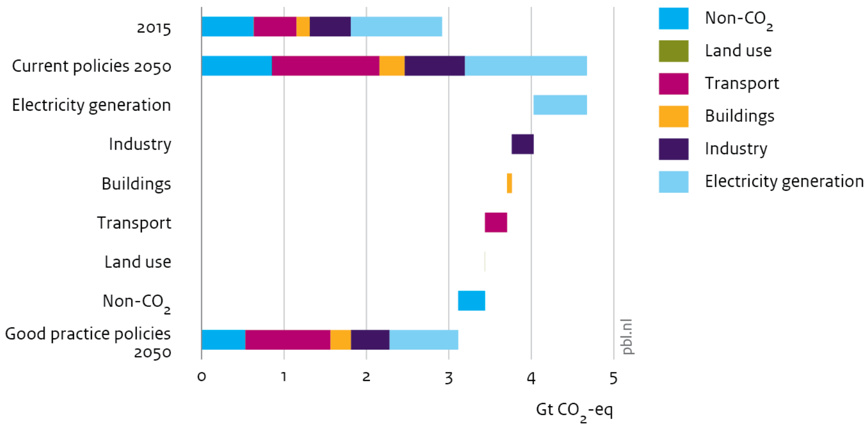
4.4 Middle East and North Africa

The Middle East and North Africa is home to half of the world's known oil and gas reserves [91]. Oil and gas form the backbone of the region's economies and trade. As shown in Figure 4.4, power generation, followed by transport and non-CO_2 greenhouse gases, account for the largest emissions reductions in the region.

4.4.1 Power generation

Countries in the Middle East and North Africa (MENA) are characterised by the availability of large supplies in conventional oil and gas resources and heavy dependence on fossil fuels for energy supply and domestic consumption. These countries' economies are also strongly dependent on crude oil production and exports. Although the energy mix is slowly changing, most of the increasing demand for energy is still being met by fossil fuels. Renewable energy, dominated by hydropower, accounts for a small share of the energy mix [92].

Figure 4.4 Contribution of sectors to emission reduction, Middle East and North Africa



However, renewable energy is gaining ground in the region [93], driven by the radical decline in renewable energy prices. The large potential for solar and wind energy could offer competitive alternatives to fossil fuels in power generation. Several countries in the region have set up ambitious targets for the development and deployment of renewable energy [94]. This will free up some fossil fuel resources for net energy exporters, while providing large savings for net energy importing countries. Increasing shares of renewables in the energy system increases electricity access in countries, such as Libya and Yemen (**SDG 7**) enabling additional economic activities for poverty alleviation (**SDG 1**). As explained in Chapter 3, renewable energy systems require less water (**SDG 6**), stimulate economic growth and diversification, job creation, improved balance of trade (**SDGs 8, 10**), reduces local air pollution (**SDG 11**) hence improves health and well-being (**SDG 3**), and reduces natural resource depletion (**SDG 12**) [95]. Realising the wider adoption of renewable energy technologies could create local industries that can be actively involved in the research and development (**SDGs 8, 9**).

4.4.2 Transport

The transport sector is another major contributor to CO_2 emissions in the region, accounting for over a quarter of the projected emissions under the Current policies scenario in 2050, and good practice measures could significantly reduce these. Road transport plays a dominant role in transportation, which is driven by the prevalence of fossil fuel subsidies [96]. The COVID-19 pandemic has resulted in a significant fall in oil prices, leading to an economic downturn that made subsidies a considerable burden to governments. It also provides an opportunity to restructure fossil fuel subsidies and stimulate efficient and sustainable modes of transport.

Given the young nature of the region's population, further growth in the number of passenger cars is expected. Hence, rapid improvements in vehicle fuel efficiency are crucial for emission reduction from the transport sector. Similarly, falling battery costs and clean air initiatives spur the adoption of electric vehicles in the region. This has created economic opportunities for companies offering infrastructure for electric vehicles. The transition towards alternative fuels for passenger cars aligns well with the transition in the energy sector. Efficiency improvements and fuel-switching contribute to reducing local air pollution (**SDG 11**) improving human health (**SDG 3**), and responsible consumption of natural resources (**SDG 12**). It also reduces water consumption and waste (**SDG 6**) and leads to improved water and soil quality (**SDG 14,15**). Similarly, the transition to non-fossil-fuel vehicles improves air quality (**SDG 11**), improves health and well-being (**SDG 3**), and stimulates resilient and sustainable infrastructure development (**SDG 9**). However, the resulting decline in oil demand could delaying economic reform programmes in the region exacerbating inequality (**SDGs 8, 10**). Rapid growth in electric vehicles could overload local power systems impacting access in countries with low generation capacity (**SDG 7**).

Energy efficiency in aviation improves overall energy efficiency in the region (**SDG 7**), reduces air pollution and contribute to sustainable use of resources (**SDG 12**). Improving aviation energy efficiency calls for innovations in all aspects of the industry (**SDG 9**). However, if not properly managed, the resulting decline in oil demand could impact on the economy of oil exporting countries (**SDGs 8, 10**).

4.4.3 Non-CO_2 emissions

The oil and gas industry in the Middle East and North Africa is associated with high levels of CH_4 emissions. Gas venting and flaring is common practice in several oil rich countries, releasing large amounts of CH_4. Leakage from gas pipelines is another source of CH_4. Some flaring activities happen not far from human settlements, with proven negative impact on health and well-being [97]. The flared gas could offer a low-carbon alternative for reliable power generation, especially in Yemen, Libya and Djibouti where access is limited (**SDG 7**), as well as serving as a backup for renewable generation. As mentioned in Chapter 2, there are proven technologies that can help abate flaring, venting and leaking. This not only offers an opportunity to build back greener after COVID-19, but is also commercially attractive.

By reducing or halting gas venting and flaring, governments can improve health and safety (**SDG 3**), add value by driving up revenue (**SDGs 8, 10**), reduce air pollution (**SDG 11**), promote responsible consumption and production of natural resources (**SDG 12**), and reduce the impact on land and ecosystem around the flaring site (**SDG 15**). If not properly monitored, restrictions in flaring could lead to an increase in venting. Halting venting and flaring requires investments and the cost of collecting and moving the gas can initially be higher than the value of the gas itself.

Table 4.5 Synergies and trade-offs between climate change mitigation measures and SDGs, Middle East and North Africa

SDG target / Mitigation measure	No poverty	Zero hunger	Good health and well-being	Clean water and sanitation	Affordable and clean energy	Decent work for all	Inclusive sustainable economic growth	Fostering innovation	Reduced inequalities	Sustainable cities and communities	Responsible consumption & production	Life below water	Halt biodiversity loss	Revitalize global partnership	Strengthen means of implementation
	1	2	3	6	7	8		9	10	11	12	14	15	17	
Electricity generation															
Increase renewables in electricity generation	Potential of synergies outweigh risks for trade-offs		Potential of synergies outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs			Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs
Transport															
Improve fuel efficiency of new passenger cars			Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Risks for trade-offs outweigh potential of synergies	Risks for trade-offs outweigh potential of synergies	Potential of synergies outweigh risks for trade-offs	Risks for trade-offs outweigh potential of synergies	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	
Increase non-fossil new vehicle sales			Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Risks for trade-offs outweigh potential of synergies	Risks for trade-offs outweigh potential of synergies	Risks for trade-offs outweigh potential of synergies	Potential of synergies outweigh risks for trade-offs	Risks for trade-offs outweigh potential of synergies	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs
Improve energy efficiency of aviation					Potential of synergies outweigh risks for trade-offs	Risks for trade-offs outweigh potential of synergies	Risks for trade-offs outweigh potential of synergies	Potential of synergies outweigh risks for trade-offs	Risks for trade-offs outweigh potential of synergies	Potential of synergies outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs
Non-CO2															
Reduce venting and flaring of CH_4			Potential of synergies outweigh risks for trade-offs		Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs		Potential of synergies outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs	Potential of synergies outweigh risks for trade-offs	Potential of synergies strongly outweigh risks for trade-offs		Potential of synergies outweigh risks for trade-offs

- Risks for trade-offs outweigh potential of synergies
- Synergies and trade-offs strongly dependent on context
- Potential of synergies outweigh risks for trade-offs
- Potential of synergies strongly outweigh risks for trade-offs

4.5 South Asia

Power generation, industry, and non-CO_2 accounted for 80% of total greenhouse gas emissions in 2015 in South Asia. The trend is projected to continue under current policies (Figure 4.5). These sectors offer large potential for greenhouse gas savings with good practice policies.

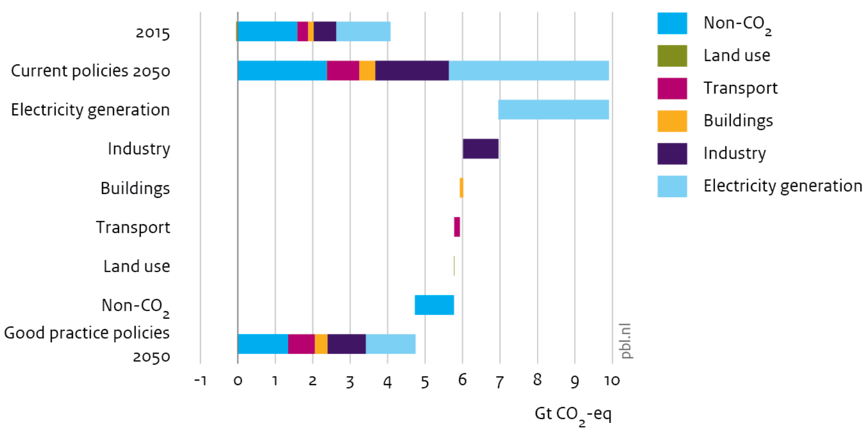
4.5.1 Power generation

Several countries in South Asia are characterised by severe lack of access to electricity and heavy reliance on solid fuels for cooking and heating. Rapid population growth and economic development has fuelled a growing thirst for energy in the region. The increase in energy consumption is driving energy-related emissions, with India, Pakistan and Bangladesh heavily depending on coal, oil and natural gas for their energy needs, and renewable energy constituting a very small percentage of total energy consumption.

Amid an economic slowdown, higher hydropower output and growing power generation from wind and solar, power generation from coal-fired plants in India showed a decline in 2019 for the first time in over four decades [31]. In 2020, the region saw a further drop in coal demand, driven by a drop in electricity demand resulting from measures to halt the spread of COVID-19. However, India, Pakistan and Bangladesh have large expansions of coal-fired power plants planned (though Bangladesh has pledged to downsize planned expansions [31]). Halting the installation of unabated coal-fired power plants reduces air pollution (**SDG 11**), health impacts (**SDG 3**), and the risk of stranded assets [98]. The measure could reduce the competition for scarce fresh water resource (**SDG 6**). However, halting new installations of coal power plants may negatively impact energy access (**SDG 7**). The decline of economic activities in coal mining and coal export could have a negative implication for employment in some parts of the region (**SDGs 8, 10**). The associated loss of income could exacerbate poverty in the region (**SDG 1**).

A resilient energy sector is critical to sustainable economic growth. Although coal and oil can be expected to continue to play a role in the near future, there are some efforts in the region to diversify energy supply, reduce fossil fuel dependence, and improve energy security in meeting the growing energy demand [99]. The potential for renewable energy is huge in South Asia: Bhutan and Nepal have large hydropower resources, India has massive solar and wind power potential, and Afghanistan and Sri Lanka have large wind energy potential [99]. Utilisation of this potential is a major component of the region's development strategy and is crucial for climate change mitigation.

Figure 4.5 Contribution of sectors to emission reduction, South Asia



Due to the uneven distribution of fossil energy resources and underdeveloped infrastructure, the region is heavily dependent on fuel import, making the energy system vulnerable to price volatilities and supply instability. Moreover, South Asian cities are known hotspots for air pollution, caused mainly by heavy use of polluting sources of energy [100]. The development of renewable energy technologies fosters innovation and promotes economic growth (**SDGs 8, 9**) while enhancing access to secure, clean, and affordable energy (**SDG 7**) and reducing air pollution (**SDG 11**), hence improving human health and well-being (**SDG 3**). It improves access to clean water and reduces water scarcity (**SDG 6**), and reduces natural resource depletion (**SDG 12**). Expanding electricity access generated by renewable energy also helps to reduce the use of biomass for cooking, contributing to improving health and reducing local deforestation and forest degradation.

However, utilising the renewable energy potential of the region, especially hydropower, requires an extensive infrastructure development that requires significant levels of investment. This could lead higher electricity prices (**SDG 1**). Large hydropower development could also lead to displacement of local communities, and loss of natural forests and biodiversity (**SDG 15**). There are also issues, such as noise pollution and hazard to birds and bats from wind turbines and toxic waste from solar panels if not disposed properly (**SDG 3, 15**). Utility-scale solar or wind farms require large areas of land that can interfere with the existing land uses (**SDG 2**).

4.5.2 Industry

The manufacturing industry is amongst the largest contributors to greenhouse gas emissions in South Asia. In India, by far the biggest economy in the region, the manufacturing sector is dominated by energy-intensive industries such as cement, iron and steel, fertilisers, and pharmaceuticals. The sector's energy mix is dominated by fossil fuels [101]. The manufacturing industry has been the leading sector for strong growth in coal demand in the past decades.

India and other South Asian countries have implemented energy efficiency and emission standards for industry. However, there is still considerable potential for improving energy efficiency and reducing emissions in the sector, as shown in Figure 4.5. With a considerable growth projected in industrial output in India, the use of coal is projected to increase significantly without mitigation measures, leading to a strong increase in greenhouse gas emissions [101]. Energy efficiency improvements in furnaces, industrial motors, boilers, gasifiers, and kilns can contribute significantly to reducing industrial emissions [102]. Increased recycling of metals, paper and glass can also reduce energy demand.

Improvements in industrial energy efficiency contributes to achieving **SDG 7** and could strongly reduce energy expenditures, increasing the competitiveness of the sector (**SDGs 8, 10**). Energy efficiency measures also ensure better health and well-being (**SDG 3**), provide new business opportunities (**SDGs 1, 8, 9**), better environmental compliance, better work conditions (**SDG 8**), health benefits through better local air quality (**SDG 11**), and reduced water use and waste (**SDGs 6, 12**) [61]. However, large initial investments are needed for retrofits.

CCS will also play a key role in mitigating industrial emissions in South Asia. If widely implemented, CCS can reduce emissions from the rapidly growing industrial sector in the region. The co-benefits of CCS include job protection in heavy industry (**SDG 8**), development of resilient infrastructure (**SDG 9**), local air quality improvement (**SDG 11**), and sustainable production (**SDG 12**). However, the high capital cost of the CCS plant together with increase in energy consumption could affect competitiveness of the industry impacting poverty alleviation (**SDG 1**) and energy access (**SDG 7**) goals. There is also a concern about CO_2 leaking that could impact health (**SDG 3**) and marine ecosystems (**SDG 14**).

4.5.3 Non-CO_2

Most of non-CO_2 greenhouse gas emissions in South Asia are attributed to agriculture, mining and waste. Agriculture CH_4 emissions in South Asia primarily come from rice cultivation and livestock production [103]. In the current policies scenario, emissions from agriculture are expected to increase to satisfy the food demand for the growing population. This brings the challenge to enhance yield while minimising emissions from agriculture. Alternate wetting and drying techniques could reduce CH_4 emissions from rice cultivation considerably, while improving yields (**SDG 2**). The technique also saves significant amounts of water relative to conventional methods [104].

India has the largest total livestock population in the world, with associated CH_4 emissions from both enteric fermentation and manure management [105]. The livestock sector is a promising area to reduce CH_4 emissions in South Asia through improving livestock diet, selective breeding, and treating manure with anaerobic digesters. These measures produce bio-slurry for organic fertiliser (**SDG 2**), reduce foul smell (**SDG 3**), reduce soil and water pollution (**SDG 6**), create additional economic activities and improve productivity (**SDG 8**), reduce waste (**SDG 12**), and reduce land degradation (**SDG 15**). Manure converted to biogas can provide sustainable energy for the community (**SDG 7**). However, limiting availability of manure, which is used as fertiliser in small holder agriculture, could affect the targets to end hunger and to decrease relative poverty (**SDGs 1, 2**)

Fertiliser use efficiency in South Asia is very low and the intensity is expected to increase, increasing N_2O emissions from agriculture. Improving fertiliser use efficiency can reduce N_2O emissions while improving yield, reducing the cost of production considerably, thereby providing higher profits to farmers (**SDGs 1, 10**) and improving affordability (**SDG 2**) [104]. It also enables efficient use of resources (**SDG 12**) and reduces ground water and soil contamination (**SDGs 14, 15**) enhancing clean water availability (**SDG 6**).

Coal mines (active and abandoned) are also responsible for non-CO_2 greenhouse gas emissions in South Asia. Assuming an economic recovery, it is expected that electricity demand and industrial output will increase in 2021. As a result, the region's coal demand could rebound fast, increasing CH_4 emissions from coal mining. There are readily available cost-effective CH_4 emission reduction measures that can yield environmental and economic benefits. The recovered CH_4, depending on the quality, can be used for power generation, district heating, boiler fuels, or purified and fed to natural gas distribution systems. Besides reducing greenhouse gas emissions, coal mine CH_4 emission recovery provides numerous benefits: it enables conservation of local cleaner energy (**SDGs 7, 12**), enhances coal mine safety, and increases the revenue of the mine (**SDG 8**).

South Asia, as one of the largest producers of municipal solid waste amid high population density, has a large potential to reduce non-CO_2 greenhouse gas emission from waste. Most of the waste in the region ends up in open dumps and landfills that continue to emit CH_4 for years, even after the landfill is closed [106]. As observed in the past decade in India, the rapid growth in urban population and changes in economic status in the region are expected to change the amount and composition of solid waste and thereby also on associated CH_4 emissions [106]. As already mentioned in chapter 2, increased recycling and energy recovery of solid waste instead of landfill helps reduce non-CO_2 greenhouse gas emissions. If landfills are properly designed, CH_4 can be recovered and used for power generation or as direct source of energy (**SDG 7**). These measures provide additional sources of renewable energy, improve air quality (**SDGs 3, 11**), reduce water and soil pollution (**SDG 14**), hence, improve availability of clean water (**SDG 6**) [79]. However, these measures incur high capital costs to build and install landfill CH_4 recovery systems and, if successful, could derail efforts to reduce waste (**SDG 12**).

Table 4.6 Synergies and trade-offs between climate change mitigation measures and SDGs, South Asia

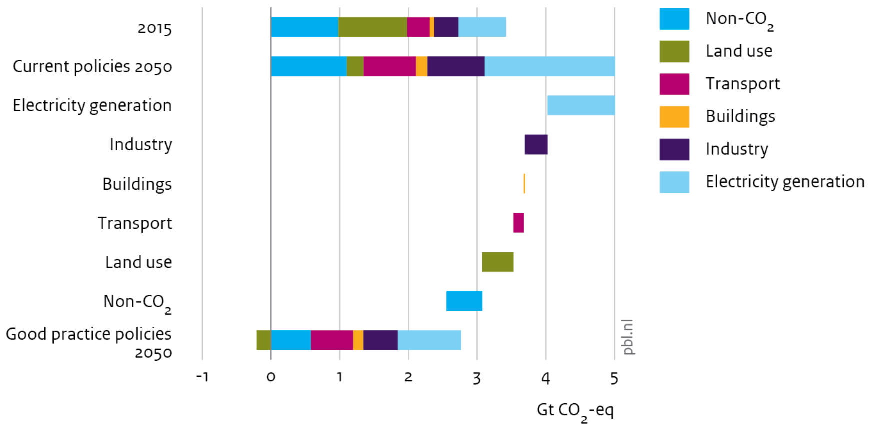
SDG target / Mitigation measure	No poverty (1)	Zero hunger (2)	Good health and well-being (3)	Clean water and sanitation (6)	Affordable and clean energy (7)	Decent work for all (8)	Inclusive sustainable economic growth (8)	Fostering innovation (9)	Reduced inequalities (10)	Sustainable cities and communities (11)	Responsible consumption & production (12)	Life below water (14)	Sustainably manage forests (15)	Halt biodiversity loss (15)	Revitalize global partnership (17)	Strengthen means of implementation (17)
Electricity generation																
No new installations of unabated coal power plants	Orange		Dark green	Light green	Orange	Yellow	Orange		Yellow	Dark green						
Increase renewables in electricity generation	Yellow	Orange	Light green	Dark green	Dark green	Dark green	Dark green	Dark green	Yellow	Dark green	Dark green	Yellow	Yellow	Yellow	Light green	Light green
Industry																
Improve energy efficiency in industry	Light green		Light green	Light green	Light green	Light green	Light green	Dark green	Light green	Dark green	Dark green				Light green	Light green
Apply carbon captured and storage in industry	Orange		Orange	Orange	Orange	Dark green	Yellow	Dark green		Light green	Dark green	Orange			Light green	
Non-CO2																
Treat manure with anaerobic digesters (CH_4)	Yellow	Yellow	Light green	Light green	Dark green		Light green				Light green			Light green	Light green	Light green
Selective breeding to reduce CH_4 emissions	Light green	Light green		Light green		Light green	Light green				Light green		Light green	Light green		
Increase nitrogen use efficiency (N_2O)	Light green	Dark green		Light green					Dark green		Dark green	Dark green		Dark green		
Coal mine CH_4 emissions recovery					Dark green	Light green					Dark green					Light green
Reduce CH_4 emissions from waste			Light green	Light green	Dark green	Light green		Light green		Dark green	Yellow	Light green		Light green		Light green

Orange: Risks for trade-offs outweigh potential of synergies
Yellow: Synergies and trade-offs strongly dependent on context
Light green: Potential of synergies outweigh risks for trade-offs
Dark green: Potential of synergies strongly outweigh risks for trade-offs

4.6 Southeast Asia

Southeast Asia recorded the fastest growth in greenhouse gas emissions in the world in the period between 1990 and 2010. This growth in emissions was driven by growing reliance on fossil fuels, deforestation and land degradation. At the same time, countries in the region are amongst the most vulnerable to the impacts of climate change, calling for immediate action to curb the trend. The largest potential to reduce greenhouse gas emission with good practice policies in Southeast Asia lies in power generation, land use and non-CO_2. Figure 4.6 shows that total greenhouse gas emissions in the region in 2050 could be reduced by almost half with good practice measures relative to the current policies scenario, with 80% of the reductions coming from these three sectors.

Figure 4.6 Contribution of sectors to emission reduction, South East Asia



4.6.1 Power generation

The largest share of energy-related emissions in the region comes from power generation [107]. Power generation in Southeast Asia has been growing over the past few decades driven by rapid economic growth, urbanisation, expanded access to electricity and growing population [108]. Currently, around three quarters of electricity is generated by fossil fuels. The energy mix is dominated by coal in Indonesia, the Philippines and Malaysia, and oil and gas in Vietnam, Thailand and Singapore [109]. Solid biomass, hydropower, solar PV and wind provide the rest of the energy mix. Southeast Asia's electricity demand is expected to increase significantly over the coming decades and in the current policies scenario, most of the increase is supplied by coal, natural gas and large hydro. Geothermal, bioenergy, wind and solar PV accounts for the remainder [110].

The expansion of coal-fired power plants in the region stands in stark contrast with climate change mitigation strategies. Halting further construction of unabated coal-fired plants has several co-benefits to human health and the environment. It reduces air pollution in cities (**SDG 11**) providing enormous benefits to human health and well-being (**SDG 3**). Given the rapid decline in the cost of renewables and increasing awareness of the importance of climate change policies, moving away from investing in unabated coal-fired power plants reduces the risk of stranded assets (**SDG 8**). However, given the rising demand for energy and affordability challenges of the region, the measure could exacerbate poverty (**SDG 1**).

The growing demand for electricity calls for action to address energy security and environmental concerns of the region. Several countries in the region aim to stimulate faster deployment of renewables to address these challenges. Significant investments in renewable energy infrastructure were made before the pandemic and governments in the region have laid out a five-year plan to increase renewable energy capacity under the second phase of ASEAN Plan of Action for Energy Cooperation (APAEC) 2021–2025 [111].

Southeast Asia has significant solar potential, and Indonesia, Myanmar and several lower Mekong countries have considerable hydropower potential. There is modest wind potential in Indonesia, the Philippines, Thailand and Vietnam, and significant geothermal potential in Indonesia and the Philippines [110]. As discussed in the previous sections, expanding renewables has several synergies with other SDGs, especially with access to secure, clean, and affordable energy (**SDG 7**), economic growth (**SDG 8**), and reduction in air pollution (**SDG 11**). The trade-offs include increasing electricity prices unproportionally affecting the poor (**SDG 1**), competition with other land services (**SDGs 2, 15**), noise pollution (**SDG 3**), and impacts on birds and bats (**SDG 15**).

4.6.2 Land use

Southeast Asian forests are shrinking faster than in any other region. Net forest conversion represents one of the main sources of CO_2 emissions in Southeast Asia, emphasising the importance of natural forest protection for climate change mitigation in the region. Large-scale deforestation in the region is driven by agricultural expansion, mainly for oil palm cultivation, especially in Indonesia and Malaysia. Though their contribution is much less than that of palm oil, other cash crops such as rubber, sugarcane and coffee are also accountable for forest loss in the region. Logging is a significant factor contributing to deforestation in Thailand and Myanmar.

Indonesia has the highest forest-related CO_2 emissions in the region, resulting from deforestation, peatland degradation, and forest fires [112]. The smoke from forest fires is damaging to human health and the economy. Deforestation has a devastating impact on local communities and biodiversity. Reducing deforestation and increasing afforestation and reforestation slows the decline of terrestrial carbon stock [84]. These measures enhance the provision of food (**SDG 2**) and clean water (**SDG 6**) and protect ecosystems (**SDG 15**). Forest products contribute to household income, enabling poverty alleviation (**SDG 1**). Reforestation would also create additional jobs (**SDGs 8, 10**), as it is much more labour-intensive than the current exploitation of forests [113]. However, these measures could result in an increase in agricultural prices (**SDGs 1, 2**) and escalate the competition for water resources (**SDG 6**) [84]. Promoting afforestation and halting deforestation could limit infrastructure development, impacting connectivity (**SDG 9**).

4.6.3 Non-CO_2

Rice production is a significant source of non-CO_2 greenhouse gas emissions in Southeast Asia. Rice plays a significant role in societies in Southeast Asia; it is the staple food, it provides livelihoods for the majority of farmers, and it is a leading consumer of land and water resources. Indonesia, Vietnam and Thailand are among the top 10 rice producers in the world and most of the countries are rice exporters. Rice is cultivated in flooded fields under anaerobic soil conditions, releasing CH_4. The rapid increase in rice productivity was also supported by fertiliser application that results in N_2O emissions. Therefore, actions to reduce non-CO_2 greenhouse gas emissions from rice cultivation in the region have great potential to mitigate climate change impacts. These actions include proper application of nitrogen fertiliser, combined with water-saving technologies and good nutrient management [114]. By improving fertiliser appliance efficiency, rice yield can be improved (**SDG 2**), increasing the profit margin for farmers (**SDGs 1, 10**), and improve resource efficiency (**SDG 12**). It also reduces water and soil pollution (**SDGs 14, 15**) enhancing availability of clean water (**SDG 6**).

Table 4.7 Synergies and trade-offs between climate change mitigation measures and SDGs, Southeast Asia

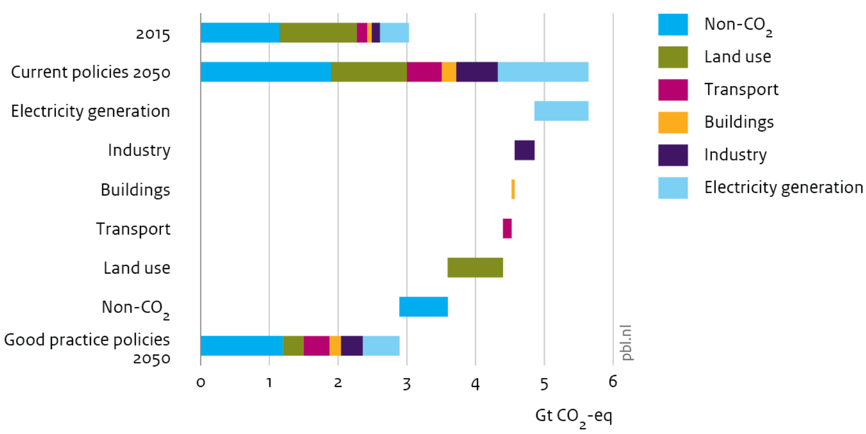
SDG target / Mitigation measure	No poverty	Zero hunger	Good health and well-being	Clean water and sanitation	Affordable and clean energy	Decent work for all	Inclusive sustainable economic growth	Fostering innovation	Reduced inequalities	Sustainable cities and communities	Responsible consumption & production	Life below water	Sustainably manage forests	Halt biodiversity loss	Revitalize global partnership	Strengthen means of implementation
	1	2	3	6	7	8		9	10	11	12	14	15		17	
Electricity generation																
No new installations of unabated coal power plants	orange		dark green			light green	light green	light green	light green	dark green						
Increase renewables in electricity generation	light green	light green	light green	dark green	dark green	dark green	light green	light green	light green	dark green	dark green	dark green	orange	orange	light green	light green
Land use																
Increase afforestation and reforestation	yellow	yellow		orange		light green	light green		light green	light green				dark green		dark green
Halt natural forest deforestation	orange	yellow		light green		orange			orange	light green			dark green	dark green		dark green
Non-CO2																
Increase nitrogen use efficiency (N_2O)	light green	dark green		light green					dark green		dark green	dark green		dark green		

(orange) Risks for trade-offs outweigh potential of synergies
(yellow) Synergies and trade-offs strongly dependent on context
(light green) Potential of synergies outweigh risks for trade-offs
(dark green) Potential of synergies strongly outweigh risks for trade-offs

4.7 Sub-Saharan Africa

Sub-Saharan Africa has the lowest access rate to modern energy and the energy system is dominated by solid biomass. Farmers in the region rely heavily on rain-fed agriculture and the agricultural sector is characterised by poor farming practices. To foster social and economic development and meet the growing food demand, increasing energy access and agricultural productivity are shaping development agendas in the region. As shown in Figure

Figure 4.7 Contribution of sectors to emission reduction, Sub-Saharan Africa



4.7, power generation, agriculture and non-CO_2 emissions show the largest potential for climate change mitigation with good practice measures in Sub-Saharan Africa.

4.7.1 Power generation

Coal plays a significant role in the power mix in Sub-Saharan Africa. South Africa alone accounts for 85% of the installed coal-fired capacity and 93% of coal production. Coal-fired power plants are responsible for over three quarters of Sub-Saharan Africa's emissions from the power sector. Halting the construction of unabated coal power plants bring several co-benefits, especially reducing air pollution (**SDG 11**) and improving health and well-being (**SDG 3**). However, limiting the use of coal could impact universal electricity access targets (**SDG 7**), as it can be used for increasing relatively cheap baseload power. It could also affect economic activities and employment in coal-producing countries, notably South Africa, impacting poverty alleviation (**SDG 1**) and economic growth (**SDGs 8, 10**).

Expanding electricity access through solar, wind and geothermal energy in Sub-Saharan Africa has significant synergies with most SDGs. Decentralised renewable-based electricity systems are an integral part of providing universal access to electricity in remote, isolated and low population density settlements in Sub-Saharan Africa (**SDG 7**) [115]. As mentioned previously, renewable energy systems create more jobs than fossil-fuel energy systems, contributing to economic growth and employment (**SDGs 8, 10**). They also lead to an expansion of sustainable, reliable, and resilient infrastructure and related industries (**SDG 9**), reduces air pollution (**SDG 11**), and promotes sustainable consumption/production and resource efficiency (**SDG 12**). Renewable energy technologies create more jobs per dollar invested and use primarily indigenous resources [116, 117]. Li, Kalnay [118] show that large-scale deployment of wind and solar farms in the Sahara leads to more rain and vegetation (**SDG 15**).

Renewable energy systems have the potential to also provide vast benefits for human health through reduced household and ambient air pollution [119], and enhance water security (**SDG 6**) [120]. A recent report by the UN [121] highlighted the role of energy in fighting COVID-19. Energy services are key in preventing disease and fighting pandemics — from powering health care facilities (**SDG 3**) and supplying clean water for essential hygiene (**SDG 6**), to enabling communications and IT services that connect people while maintaining social distancing (**SDG 9**).

There are, however, also some direct trade-offs associated with these measures. Technologies such as solar PV or wind turbines will create new resource and supply chain dilemmas, though these trade-offs are lower than those associated with fossil fuel extraction [51]. Studies also show that energy prices could increase due to the use of more expensive and immature technologies [122] with unfavourable impacts on poverty reduction and energy access (**SDGs 1, 7, 10**). Other impacts of solar and wind farms include competition for land with agriculture (**SDG 2**) and other land services (**SDG 15**), noise pollution (**SDG 3**), and impact on birds and bats (**SDG 15**).

4.7.2 Land use

Increasing afforestation and reforestation, as well as halting natural forest deforestation, are important measures for climate change mitigation in Sub-Saharan Africa. These measures play a pivotal role in poverty eradication (**SDG 1**) by improving ecosystem services and improving air quality (**SDG 11**) and health and well-being (**SDG 3**). Forestry generates several jobs and increase the demand for forest products (**SDG 8**,**10**). The measures also directly improve life on land by reducing soil erosion, water conservation, and improved soil organic matter and biodiversity (**SDG 15**). At the same time, afforestation could result in a decline in local water supply driven by evapotranspiration and create competition for land for food production (**SDG 6**). Measures to halt deforestation could impact livelihoods that depend on wood for their energy needs or on small-scale agriculture (**SDGs 1, 2**).

4.7.3 Non-CO_2 emissions

Livestock manure is used as traditional fertiliser in large parts of Sub-Saharan Africa, particularly for smallholder farmers. But proper manure management is lacking, resulting in nutrient losses and CH_4 emissions. Treating manure with anaerobic digesters offer several benefits. The biogas produced in the process can provide access to clean energy where access to electricity and clean cooking energy is a challenge (**SDG 7**), with additional health (**SDG 3**), economic, and productivity (**SDG 8**) benefits. The bio-slurry is rich in nutrients and can be applied directly to crops and vegetables to improve yield (**SDG 2**). As poorly discharged manure can lead to contamination and eutrophication of surface and ground water, proper manure management enhances the availability of clean water (**SDG 6**) and reduces waste and pollution (**SDG 12**). On the other hand, limiting the availability of manure for smallholder farmers might impact their productivity, which makes it harder to achieve targets to reduce poverty (**SDG 1**) and hunger (**SDG 2**).

Livestock breeds in Sub-Saharan Africa are numerous and diverse and have been providing livelihood as well as food and nutrition. By selectively breeding, farmers reduce the impact on the climate while increasing productivity of their livestock. The measure increases household income (**SDG 1**), improves the supply of animal sourced food (**SDG 2**), and improves the contribution of livestock to economic activity (**SDG 8**). By reducing the size of the cattle, selective breeding reduces water demand and waste water flows (**SDG 6**), improves productivity (**SDG 12**), and reduces land degradation for livestock expansion (**SDG 15**).

Increasing the production of food requires more land and other inputs, such as minerals, water and energy. Yet, the natural resource base necessary to contribute to food needs is deteriorating, ecosystems are under stress and biological diversity is declining. Increasing nitrogen use efficiency is an important measure for climate change mitigation as it reduces N_2O emissions. Current greenhouse gas emissions from fertiliser use in Sub-Saharan Africa are low, but a substantial increase in nutrient inputs is projected due to future food needs in the region. This provides the opportunity to meet future food security needs (**SDG 2**) while a more efficient use of fertilisers will reduce water contamination (**SDGs 6, 14**) [123]. Considering that developing countries are highly dependent on agriculture, this is key for increasing the resilience of agricultural systems and dependent communities to climate change and other threatening factors [124]. Efficient use of fertilisers also reduces production cost increasing profit margin of farmers (**SDGs 1, 10**), enables resource efficiency (**SDG 12**), and reduces impact on the ecosystem (**SDG 15**).

Other promising non-CO_2 emission reduction measures include coal mine CH_4 emissions recovery and reducing CH_4 from venting and flaring. Reduction in CH_4 emissions from Southern Africa's coal mines and reducing venting and flaring in oil-producing countries in West Africa also contributes to regional emission reductions. These measures contribute to increasing access to modern energy (**SDG 7**), improve mine safety (**SDG 8**), reduce air pollution (**SDG 11**), promotes efficient use of resources (**SDG 12**), and reduce the impact on land and ecosystem (**SDG 15**).

Table 4.8 Synergies and trade-offs between climate change mitigation measures and SDGs, Sub-Saharan Africa

SDG target / Mitigation measure	No poverty	Zero hunger	Good health and well-being	Clean water and sanitation	Affordable and clean energy	Decent work for all	Inclusive sustainable economic growth	Fostering innovation	Reduced inequalities	Sustainable cities and communities	Responsible consumption & production	Life below water	Sustainably manage forests	Halt biodiversity loss	Revitalize global partnership	Strengthen means of implementation
	1	2	3	6	7	8		9	10	11	12	14	15		17	
Electricity generation																
No new installations of unabated coal power plants	Orange		Dark green		Yellow	Yellow	Orange		Yellow	Dark green						
Increase renewables in electricity generation	Yellow	Yellow	Light green	Dark green	Light green	Light green	Light green	Light green	Light green	Dark green	Dark green		Light green	Yellow	Light green	Light green
Land use																
Increase afforestation and reforestation	Yellow	Yellow	Light green	Orange		Light green	Light green		Light green	Light green				Dark green		Dark green
Halt natural forest deforestation	Orange	Yellow	Light green	Light green		Orange			Orange	Light green			Dark green	Dark green		Dark green
Non-CO2																
Treat manure with anaerobic digesters (CH_4)	Yellow	Yellow	Light green	Light green	Dark green		Light green				Light green			Light green	Light green	Light green
Selective breeding to reduce CH_4 emissions	Dark green	Light green		Light green		Light green	Light green				Light green		Light green	Light green		
Increase nitrogen use efficiency (N_2O)	Light green	Dark green		Light green					Dark green		Dark green	Dark green		Dark green		
Coal mine CH_4 emissions recovery					Dark green	Light green					Dark green					Light green
Reduce venting and flaring of CH_4			Light green		Dark green	Light green	Light green		Light green	Light green	Dark green	Light green		Light green		Light green

- Orange: Risks for trade-offs outweigh potential of synergies
- Yellow: Synergies and trade-offs strongly dependent on context
- Light green: Potential of synergies outweigh risks for trade-offs
- Dark green: Potential of synergies strongly outweigh risks for trade-offs

5 Synthesis

Many climate change mitigation measures have strong interlinkages with other Sustainable Development Goals (SDGs). Urgent action is needed to keep the Paris Agreement's goals within reach and achieve the SDGs set for 2030. Insight into the synergies and trade-offs of climate mitigation measures and other SDGs is essential to identify the policy interventions that achieve the objectives of both Agenda 2030 and the Paris Agreement, while limiting trade-offs and enhancing synergies. The identified synergies and trade-offs can be used to facilitate coherence of mitigation measures at various levels of decision-making, while offering a systemic view of the impact of these measures in relation to the SDGs. The aim of this report is to identify potential trade-offs and synergies for the most promising short- to medium-term climate change mitigation measures, for selected world regions. Where this report focuses on climate change mitigation measures, a similar study for adaptation measures could provide valuable insight for decision makers, as well.

A set of 20 promising mitigation measures was identified for power generation, transport, buildings, industry, land use, and non-CO_2 emissions. These measures were selected because they have been successfully implemented in one or more countries and have a noticeable impact on greenhouse gas emissions within one to three decades. The most important synergies and trade-offs of these measures with other SDGs for selected world regions have been identified based on an extensive literature review, using the Special IPCC report on 1.5 °C and literature published since then.

The main conclusion is that there are more synergies than trade-offs between mitigation measures and other SDGs (Table 5.1). This is consistent with findings of other studies. Of the 20 measures analysed, increasing the share of renewable energy in power generation shows the most synergies with other SDGs in all regions. All selected measures in the buildings sector show many strong synergies with other SDGs. Some trade-offs were identified for measures in industry and transport, but also, here, the number of synergies is higher. For land-use and non-CO_2-related measures, it strongly depends on the type of measures taken. Below, the most important trade-offs are discussed, as these mainly require policy intervention.

The selected mitigation measures for power generation are increasing the share of renewables and reducing coal-fired power generation. Reducing coal-fired power generation is an important climate change mitigation measure. However, it would negatively impact employment in coal-mining industries, that is partly expected to be compensated by increasing jobs in other sectors, and could, at least in the short run, lead to increasing electricity prices. To identify trade-offs for the measure to expand renewable energy, the choice of technology is relevant. Most trade-offs were found for large hydropower dams, which could lead to displacement of local communities, and loss of natural forests and biodiversity.

Measures in industry also show considerable synergies, but also important trade-offs related to high investment requirements of efficiency improvement measures and increased energy and water demand of applying carbon capture and storage (CCS). R&D subsidies, market-based incentives and environmental regulation could stimulate the wider deployment of CCS in industries, while further process optimisation improves the energy efficiency of CCS plants.

All selected measures to reduce emissions from buildings (consisting of measures to improve energy efficiency and stop installations of oil boilers) show strong synergies with many other SDGs. The main barrier to improve residential and commercial building efficiency is the high upfront investment requirement, which can be addressed by facilitating access to finance.

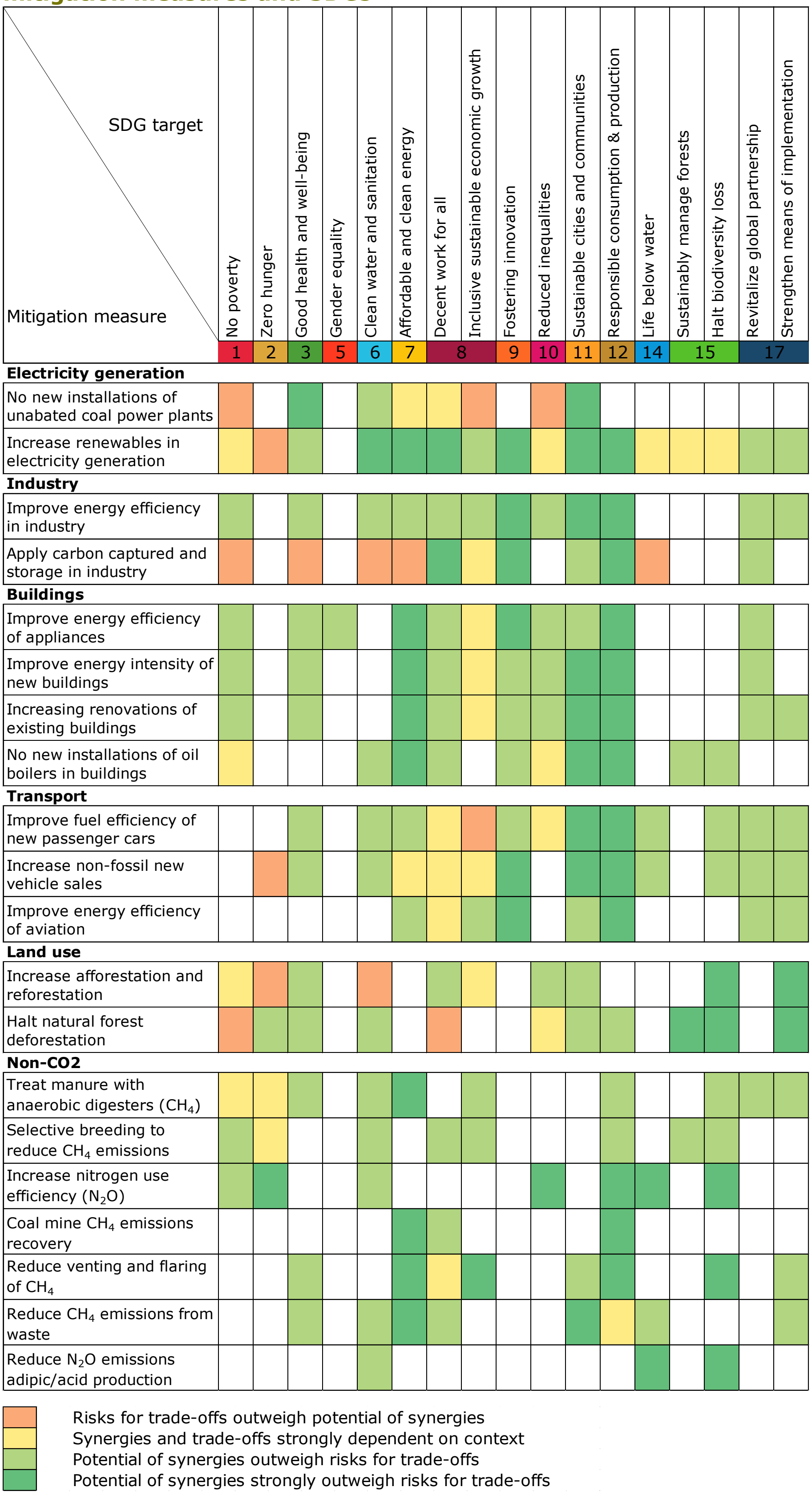
In the transport sector, the additional costs of improving fuel efficiencies or promoting electric or other zero-emission vehicles can lead to trade-offs with some SDGs. Fiscal incentives, improved consumer information, road toll rebates, low-emission zones, and support schemes for deploying charging infrastructure can alleviate these.

The mitigation measures to reduce CO_2 emissions from land use and non-CO_2 emissions from agriculture, livestock, and waste are critical in meeting required global emission reductions. Reducing deforestation and increasing reforestation have strong synergies with biodiversity and environmental SDGs. However, in low-income regions, these measures have trade-offs with poverty alleviation and food security. To limit these impacts, the forestation measures could be complemented with pro-poor policies that would strengthen the rights, capabilities and local decision-making on land and resources, credit programmes for small-scale farmers, and transfer payments to poor rural dwellers for ecosystem services.

There are significantly more synergies than trade-offs in all selected world regions. However, the magnitude of these synergies and trade-offs varies according to regional and socio-economic context. In North America, Europe, and Central and South America, the measures demonstrate very few trade-offs that are largely related to technology choices that could exacerbate inequality and impact biodiversity. In Sub-Saharan Africa, South Asia, and Southeast Asia, most of the measures could hinder efforts to reduce poverty, end hunger and improve well-being, if not complemented by policies to protect the poor from increasing food and energy prices. Mitigation measures in the Middle East and North Africa can help diversify the oil-dependent economies in this region and accelerate the reform process to foster inclusive growth and reduce inequality. However, the resulting decline in oil demand could delay economic reform programmes in the region, exacerbating inequality.

It is important to remember that, while these measures are tested in some regions, transferring these best practices requires understanding of the local context and, in some cases, complementary policies to protect the vulnerable part of society. Besides, the study addressed the direct effects only, whereas several studies show that the indirect impacts of climate change mitigation measures could be far-reaching, as well.

Table 5.1 Summary table of synergies and trade-offs between climate change mitigation measures and SDGs



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Annex 1. Regional implementation of the mitigation measures

Sector	Measure	Level of implementation		
Land use	Increase natural forest afforestation and reforestation: % increase in forest area per year, for 2015-2030	China, Latin America: 2%	South & South East Asia, Sub-Saharan Africa, Australia: 1%	Europe, Turkey, 23% of Russia, United States: 0.5%
	Halt natural forest deforestation	0 ha/year by 2030		
Electricity generation	No new installations of unabated coal power plants	High-income countries: by 2025	Other countries: by 2030	
	Increase of the share of renewables in total electricity generation per year (starting in 2020, until 2050 and up to 50%, maximum)	1.4 percentage points increase per year		
Buildings	Improve energy efficiency of appliances compared to 2015	High-income countries: 17% by 2030	Other countries: 7% by 2025/2030	
	Improve energy intensity of new residential and commercial buildings	EU: 35 & 40 kWh/m^2 by 2025	Other high-income countries: 22 & 30 kWh/m^2 by 2025	Other countries: 22 & 30 kWh/m^2 by 2035
	No new installations of oil boilers in new and existing buildings	EU: by 2020	Other high-income countries: By 2030	Other countries: by 2040
	Improve efficiency of existing buildings — Share of existing buildings being renovated	High-income countries: 11% by 2030	Other countries: 6% by 2030	
Industry	Apply CCS - Carbon captured and stored as share of industry's total CO_2 emissions	High-income countries: 1.5% by 2030	Other countries: 1.5% by 2040	
	Improve energy efficiency, relative to 2015	High-income countries: 11% by 2030	Other countries: 6% by 2030	
Transport	Improve energy efficiency of aviation, starting in 2018	0.78% per year by 2030		
	Improve average fuel efficiency of new passenger cars	High-income countries: 38 km/l by 2030	Other countries: 27 km/l by 2030	
	Increase the share of non-fossil in new vehicle sales	High-income countries: 50% by 2030	China: 25% by 2025	Other countries: 25% by 2030
Non-CO_2	Reduce CH_4 emissions, relative to 2015 levels	High-income countries: 55% by 2030	Other countries: 28% by 2030	
	Coal mine CH_4 emissions recovery	30% by 2030		
	Reduce venting and flaring of CH_4 — emission reduction relative to 2015 levels	36% by 2030		
	Treat manure from livestock with anaerobic digesters — CH_4 emission reduction relative to 2015 levels	High-income countries: 33% by 2030	Other countries: 15% by 2030	
	Increase nitrogen use efficiency — Reduction of N_2O emissions from fertiliser, relative to 2015 levels	High-income countries: 10% by 2030	Other countries: 5% by 2030	
	Selective breeding to reduce CH_4 emissions from enteric fermentation — reduction relative to 2015 levels	High-income countries: 10% by 2030	Other countries: 0% by 2030	
	Reduce N_2O emissions from adipic/ acid production — reduction relative to 2015 levels	99% by 2030		
Economy-wide	Carbon pricing (USD/tCO_2 by 2030)	OECD, EU: 40	Russia, Eastern Europe, China, Korea, Latin America: 25	Other countries: 10
	Reduce F-gas emissions, induced by policies, relative to 2015	High-income countries: 60% by 2030	Other countries: 38% by 2030	

Annex 2. Regional groupings

World regions	Regions/countries included
North America	Canada
	Mexico
	United States
Central and South America	Brazil
	Rest of Central America
	Rest of South America
Europe	Central Europe
	Western Europe
Middle East and North Africa	Middle East
	North Africa
South Asia	India
	Rest of South Asia
Southeast Asia	Indonesia
	Southeast Asia
Sub-Saharan Africa	Eastern Africa
	Rest of Southern Africa
	South Africa
	Western and Central Africa