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Linking Climate and Development Policies –
Leveraging International Networks and Knowledge Sharing

Deliverable [2.1]
Report on current climate-relevant policies in major economies

Climate mitigation policies in the context of sustainable development

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Abstract: A good understanding of implemented climate policies and targets in major economies is necessary to assess expected future emissions and required mitigation action that ensures a temperature increase well below 2°C. To address this necessity, we produced an inventory of key policies in G20 countries that could influence their future greenhouse gas (GHG) emissions. This was achieved through an ex-ante assessment of current climate-related policies of G20 countries with respect to their impacts on GHG emissions reduction. The study firstly entailed developing and making available a database of all climate-related policies in the aforementioned countries to support this study. Additionally, it provides needed information on the trade-offs and synergies, identified in the literature, between individual climate-related policies and sustainable development areas. The resulting assessment is strongly related to the overall goals and objectives of the CD-LINKS

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project to explore low-carbon transition pathways and their interactions with other sustainable development objectives, both nationally and globally.

Keywords: climate, development, policy, G20

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Executive Summary

Objective and method

The main objective of this study was to produce an inventory of key policies in G20 countries that could influence their future greenhouse gas (GHG) emissions, by providing an ex-ante assessment of current climate-related policies of G20 countries with respect to their impacts on GHG emissions reduction. To reach this goal, the research firstly entailed developing a database of all climate-related policies in the aforementioned countries. A secondary objective of this study was to identify the impacts of specific climate mitigation action measures on sustainable development goals (SDGs) from existing literature, and to categorise them by climate mitigation instrument, sector and policy area.

The latter objective is strongly related to the overall goals and objectives of the CD-LINKS project to explore low-carbon transition pathways and their interactions with other sustainable development objectives, both nationally and globally. This deliverable provides needed information on the trade-offs and synergies between individual climate-related policies (both those directed specifically at climate mitigation and those targeting other development issues, such as air pollution) and sustainable development areas.

A good overview of all climate-relevant policies in a country is required to identify the policies with the highest impact on GHG emissions reduction. Therefore, the first step in this study was to produce an inventory of climate-relevant policies and measures. This inventory builds on the database developed by NewClimate Institute (www.climatepolicydatabase.org), currently comprising more than 3000 climate-relevant policies and measures worldwide, with a focus on 30 major economies identified as the highest GHG emitters.

Policy inventory

Figure 1 shows the percentage of G20 countries that have policies in specific sectors, areas and policy types defined in the good practice policy menu of the Climate Policy Database. We found that each section of the good practice policy menu is covered by at least one country. However, the policy areas covered by most countries are energy efficiency (more than 80% in each relevant sector), renewables in the electricity and transport sectors (100% and at least 69%, respectively), and forestry (88%). All G20 countries have support policies for electricity production from renewable sources, and minimum energy/emissions performance standards or support for energy efficient light duty vehicles or passenger cars. Similarly, all G20 countries have GHG emissions reduction targets, although these targets include those presented in the intended nationally determined contributions to the Paris Agreement (INDCs). More than 80% of the countries have climate change strategies, but only 63% have coordinating bodies for climate change to support the implementation of these strategies.

Changing activity, industrial non-energy, and renewables in the residential sector (other than solar PV), are the policy areas with smallest coverage across G20 members. Furthermore, overarching policies, such as offsetting mechanisms, fossil fuel subsidies removals and energy and other taxes, are covered by less than 70% of the countries in all sectors. Moving to low-carbon pathways would require climate mitigation action in all relevant sectors, addressing all existing GHG emissions sources. By not having policies in certain areas, countries might miss opportunities to reduce emissions and the associated potential co-benefits. Examples of co-benefits from increasing deployment of renewables in the residential sector are increased asset value of building units, new job opportunities, improved energy security, and reduced urban heat island effect.

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Low coverage ---------- High coverage

0% 100%

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (81%)				
	GHG reduction target (100%)				
	Coordinating body for climate strategy (63%)				
	Support for low-emission RD&D (63%)				
		National energy efficiency target (69%)	Renewable energy target (44%)		
Electricity and heat		Support for highly efficiency power plants (including codes and standards and fiscal/financial incentives) (94%)	Renewable energy target for electricity sector (88%)	CCS support scheme, including fiscal/financial incentives and infrastructure investment (38%)	
		Reduction obligation schemes (13%)	Support scheme for renewables (including green certificates, fiscal/financial incentives, obligation schemes, net metering or direct investment) (100%)		
			Grid infrastructure development (69%)		
			Sustainability standards for biomass use (6%)		
	Overarching carbon pricing scheme or emissions limit (44%)				
	Energy and other taxes (25%)				
	No fossil fuel subsidies (63%)				
Industry	Strategy for material efficiency (including product standards and other requirements) (38%)	Support for energy efficiency in industrial production (including voluntary approaches, fiscal/financial incentives, obligation schemes or white certificates) (69%)	Support schemes for renewables (including fiscal/financial incentives, green certificates, obligation schemes) (44%)	CCS support scheme (including fiscal/financial incentives and infrastructure investment) (44%)	Landfill methane reduction (31%)
		Energy reporting and audits (81%)	Sustainability standards for biomass use (6%)		Incentives to reduce CH4 from oil and gas production (38%)
		Minimum energy performance and equipment standards (81%)			Incentives to reduce N2O from industrial processes (25%)
					Incentives to reduce fluorinated gases (38%)
	Overarching carbon pricing scheme or emissions limit (38%)				
	Energy and other taxes (31%)				
	No fossil fuel subsidies (6%)				
Buildings	Urban planning strategies (including infrastructure investments) (25%)	Building codes and standards and fiscal/financial incentives for low-emissions choices in heating, cooling, hot water, and cooking (88%)	Support scheme for heating and cooling (19%)		
		Minimum energy performance and equipment standards for appliances (94%)	Support scheme for hot water and cooking (13%)		
			Sustainability standards for biomass use (6%)		
	Energy and other taxes (19%)				
	No fossil fuel subsidies (19%)				
Transport	Urban planning and infrastructure investment to minimize transport needs (56%)	Minimum energy/emissions performance standards or support for energy efficient for light duty vehicles (100%)	Biofuel target (31%)	Support for modal share switch (38%)	
		Minimum energy/emissions performance standards or support for energy efficient for heavy duty vehicles (94%)	Support schemes for biofuels (including fiscal/financial incentives and obligation schemes) (69%)	E-mobility programme (31%)	
			Sustainability standards for biomass use (13%)		
	Tax on fuel and/or emissions (63%)				
	No fossil fuel subsidies (38%)				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (50%)				
	Incentives to reduce CO2 emissions from agriculture (25%)				
	Incentives to reduce CH4 emissions from agriculture (44%)				
	Incentives to reduce N2O emissions from agriculture (38%)				
	Incentives to reduce deforestation and support for afforestation/reforestation (88%)				

Figure 1. Coverage of the good practice policy menu by the G20 countries.

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High impact policies

For each country, a short-list of policies with expected high impact on GHG emissions reduction was compiled and reviewed by national experts. These are presented in a special page of the Climate Policy Database, dedicated to this analysis, which can be accessed at the following link: http://climatepolicydatabase.org/index.php?title=CDlinks_policy_inventory. The most important policies are also listed in Section 4 of this report, under country profiles.

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Abbreviations

CD-LINKS	Linking Climate and Development Policies Leveraging International Networks and Knowledge Sharing, Horizon2020 project
BAU	Business-as-usual
CAFE	Corporate Average Fuel Economy Standards
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
LULUCF	Land use, Land-use Change, and Forestry
PBL	The Netherlands Environmental Assessment Agency
PPP	Purchasing Power Parity
SDG	Sustainable Development Goal
TPES	Total Primary Energy Supply
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
WUR	Wageningen University and Research

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1. Introduction

1.1. Problem definition

Year 2015 brought two important international agreements: Agenda 2030 on the Sustainable Development Goals (SDGs) and the United Nations Framework Convention on Climate Change (UNFCCC)'s Paris Agreement on limiting climate change well below 2°C. These two agreements are strongly interlinked, not only because the Paris agreement aims for climate action to be in accordance with sustainable development objectives, but also because SDG 13 directly addresses climate change actions. Furthermore, numerous direct and indirect impacts of climate actions on other SDGs (see Figure 2) exist[1–4].

Figure 2. Sustainable Development Goals (Agenda 2030)

A weak understanding of multiple policy implications and lack of integration across all sectors and development areas addressed in the Millennium Development Goals, which proceeded the SDGs and ended in 2015, prejudiced the achievement of these goals, as progress on certain issues was made at the expense of development areas improvements[5,6]. Learning from this experience, countries recognise in Agenda 2030[7] the interlinkages between different development areas and emphasise the need for coherent action. Policy coherence for sustainable development has now become a major target in this agenda, under Goal 17: "Enhance policy coherence for sustainable development" (17.14), and an explicit approach to implement and ensure global macroeconomic stability (17.13). Countries should "commit to pursuing policy coherence and an enabling environment for sustainable development at all levels and by all actors"[7].

Given the strong link between climate and development, SDG goals can be incorporated in low-carbon transition pathways[3]. From this perspective, low-carbon transition for climate change mitigation is one of Agenda 2030's most complex targets, affecting almost all other SDGs[1]. Furthermore, climate change was identified as one of the SDGs with the greatest need for substantial effort to be met[8]. Being equipped with the right system analysis tools to identify and quantify synergies and trade-offs that

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emerge from climate and development action, is key for the necessary policy coherence. However, no clear methodology to ensure coherence in practice exists.

Climate-development interactions have already been studied for decades[9]. Furthermore, the importance of mainstreaming climate change into the development agenda was repeatedly addressed in the literature[10,11]. Consequently, various scientific studies have looked into the general climate mitigation co-benefits and side-effect on a variety of development areas[2–4,12]. Other studies focused on the nexus between climate mitigation and specific development areas, such as climate and air pollution[13–15], climate and energy security[15,16] and climate and energy poverty[17–19]. These latter studies consider the two-way interactions between the climate policies and development.

Many countries currently have climate mitigation strategies in place and numerous measures have already been implemented[20]. Assessing these measures and strategies both in terms of their GHG emissions reduction effect and in terms of their impact on other SDGs is key in understanding where and what kind of action is needed to increase the likelihood of meeting SDG13 and all other linked SDGs. Furthermore, understanding where countries currently stand in terms of their climate action measures and effectiveness can help formulate country-appropriate mitigation strategies and take other development areas into account.

1.2. Report objective

The main objective of this study was to provide an ex-ante assessment of current climate-related policies of G20 countries with respect to their impacts on GHG emissions reduction, and hence, to produce an inventory of high GHG emissions reduction impact policies in each country. To reach this goal, the research firstly entailed developing a database of all climate-related policies in the aforementioned countries. A secondary objective of this study was to identify the impacts of specific climate mitigation action measures on SDGs from existing literature, and to categorise them by climate mitigation instrument, sector and policy area.

This objective of this study is strongly related to the overall goals and objectives of the CD-LINKS project to explore low-carbon transition pathways and their interactions with other sustainable development objectives, both nationally and globally. This deliverable provides needed information on the trade-offs and synergies between individual climate-related policies (both those directed specifically at climate mitigation and those targeting other development issues, such as air pollution) and sustainable development areas.

In this study, we have assessed the G20 countries, of which the European Union (EU) is assessed as one region, and the EU members of G20 (Italy, Germany, United Kingdom and France) were not separately considered.

1.3. Report structure

In the next section, the climate and development policies inventory will be presented. This section first presents the database comprising all identified climate and relevant development policies. Second, the methodology to produce a shortlist of the most important policies in terms of GHG emissions reduction is introduced. The literature findings and the methodology to evaluate co-benefits and side effects of current climate action are discussed in section 3. This section identifies interactions between climate mitigation and development, necessary for any assessment of the broader impacts of low-carbon transition pathways. Furthermore, a number of sustainable development indicators addressing different development areas are presented. Finally, section 4 presents the results of the analysis both

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overall, across all G20 members, and at a country level. Country profiles provide details on good practice policies coverage, the inventory of most important policies in terms of GHG emissions, and an overview of country performance against high-level development indicators.

2. Inventory of climate and development policies

2.1. The policy inventory

A good overview of all climate-relevant policies in a country is required to identify the policies with the highest impact on GHG emissions reduction. Therefore, the first step in this study was to produce an inventory of climate-relevant policies and measures. This inventory builds on the database developed by NewClimate Institute (www.climatepolicydatabase.org), currently comprising more than 3000 climate-relevant policies and measures worldwide, with a focus on 30 major economies identified as the highest GHG emitters.

The database provides a record for each covering information on policy objective, policy instrument, policy type, policy sector, year of implementation, policy description and others. The initial version of the database and the supporting website were thoroughly described by Höhne et al. (2015)[20]. However, details on the database in its updated form are provided in Annex 1.

As part of the CD-LINKS project, Wageningen University and Research (WUR) and PBL Netherlands Environmental Assessment Agency, with input from CD-LINKS country teams and national experts, updated this database for the G20 member states. Furthermore, while the database initially only contained climate mitigation policies, the updated inventory has started to also cover policies and measures that have impact on GHG emissions and adaptation to climate change from the following sustainable development areas: adaptation, energy security, energy access, air pollution, food security, land use, economic development, and water. The updated inventory for G20 countries currently consists of 1925 policies from all economic sectors (electricity and heat, industry, transport, buildings, and agriculture and forestry), and the climate-relevant policy objectives defined above as sustainable development areas. This policies inventory will continue to be updated, reaching a new milestone in Month 30 of the CD-LINKS project (February 2018). This second phase of the inventory update will focus on sustainable development policies in G20 countries.

2.2. Good practice policy menu

Previous research[21–25] has started identifying the most effective policies in terms of GHG emissions reduction. For example, Höhne et al. (2015)[20] compiled a good practice policy menu, consisting of high impact climate mitigation policies across sectors (electricity and heat, industry, buildings, transport, agriculture and forestry) and policy areas (changing activities, energy efficiency, renewables, nuclear or CCS or fuel switch, and non-energy). Policies in the good practice policy menu are generally considered to have a higher impact on GHG emissions reductions than other established measures. Hence, the good practice policy menu was used in this study as a starting point for identifying the policies with the highest impact on GHG emissions reductions. To stay well below 2°C, all countries should ideally show strong action in all sectors and policy areas of the good practice policy menu in which GHG emissions exist.

The results of the G20 countries coverage of the good practice policy menu are provided in section 4 of this report. All countries considered in this study have already been evaluated by Höhne et al.

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(2015)[20]. However, here we present results of the updated database, following CD-LINKS inventory work. Furthermore, effects of the climate-related policy measures on other sustainable development areas are presented, based on the good practice policy menu results of each country.

2.3. High impact climate policies

Although all policies in the good practice policy menu are important, some of these are expected to have a higher impact than others, on a country-specific basis. In this study, we identified the most important policies in reducing GHG emissions for each of the G20 countries. These were identified to assess their impact and to transmit the results to the global modelling teams of the CD-LINKS project, that use these as a basis for regional long-term scenarios.

These high-impact policies were selected based on expert opinion and literature research. The experts involved in this selection process were the authors of this report, experts from CD-LINKS country teams, focusing on the team base country, as well as other country-experts that are not affiliated to the CD-LINKS project partner institutes (see 'Acknowledgements' for further details). Where possible, we tried to identify at least one important policy from each sector. First, a list of important climate and energy policies was collected for each country, based on literature (e.g. Kuramochi et al., 2016[26], INDC submissions) and the Climate Policy Database. Second, these policies were classified as either implemented or planned, based on existing supporting policies and likelihood of implementation. Planned policies are defined here as aspirational targets from strategic documents or policies in the pipeline to be adopted. These policies mostly represent targets beyond 2020, or targets that are not backed by effective policy instruments. Planned policies give guidance on how the INDCs might be implemented, if current policies are insufficient. Third, list of implemented policies was sent to country experts for review, with the aim to identify a top 10 (actual number differed per country) of policies with the largest impact on greenhouse gas emissions. In case no country experts could review the list, literature was used (e.g. biennial update reports and other UNFCCC documents in which countries quantify GHG emissions using 'existing measures' scenarios).

Selected high GHG reduction impact policies are presented in a special page of the Climate Policy Database, dedicate to this analysis, and can be accessed at the following link: http://climatepolicydatabase.org/index.php?title=CDlinks_policy_inventory. The most important policies are also listed in section 4 of this report, under country profiles.

3. Co-benefits and side-effects of current climate action

3.1. Climate mitigation links to other SDGs

In this section, the impacts of climate mitigation policies on other SDGs targets are identified for each relevant SDG. This stock-taking exercise of the interlinkages between SDGs and climate change mitigation was based on literature review, using the assessment in Table 6.7 of the Working Group III contribution to the Intergovernmental Panel on Climate Change Assessment Report 5 (IPCC AR, WGIII) as a starting point[4].

The assessment in this section considers only direct impacts of climate mitigation policies and measures and not indirect effects of these actions or of global warming itself (examples of excluded indirect impacts are provided at the end of this section). Below, specific SDG targets are referred to through

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numbers in brackets, giving the SDG number followed by the target number (e.g. (1.3) is target 3 of SDG 1).

SDG1 – Poverty eradication

Climate mitigation policies can have a negative impact on poverty eradication through increases in energy, food and other product prices via carbon and energy taxes[10] (1.2). However, renewable energy prices have dropped substantially, so energy poverty could also decrease as a result of mitigation through new technologies use. Furthermore, investments in energy efficiency could lead to affordable energy access for the poor[18,27]. A side-effect of mitigation could be land use change to grow biofuels or build hydropower installations, with repercussions for food security and farmers' income[12] (1.4). However, only 4% of arable land would be needed for bioenergy according to IEA (2006)[28] projections. Furthermore, emerging bioenergy could become an opportunity for farmers[12].

SDG1 targets impacted by climate mitigation policies (Agenda 2030):

1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions; and

1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including micro finance.

SDG2 – Hunger and food security

Policies supporting biofuel use and forest protection can lead to competition between mitigation and food security targets by reducing the amount of land available for agriculture[29,30] (2.1) and through land use and ownership change (2.3). However, climate policies addressing the use of biofuels, biomass, and low-emissions agriculture can have a positive impact via the introduction of new technologies and knowledge for improved and sustainable production[30]. Furthermore, as discussed under SDG1, bioenergy would only require a small percentage of land while providing benefits such as diversification of income sources and access to new markets[12] (2.3, 2.4, 2.a).

SDG2 targets impacted by climate mitigation policies (Agenda 2030):

2.1 By 2030, end hunger and ensure access by all people, in pat1icular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round;

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment;

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality; and

2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant

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and livestock gene banks to enhance agricultural productive capacity in developing countries, in particular least developed countries.

SDG3 – Health

Climate policies generally have a positive impact on health through co-reduction of emissions of harmful air, water and soil pollutants[11,14,31,32](3.9, 3.4). This pollutant reduction occurs with energy efficiency improvements, reduction in agricultural burning practices and improved cooking stoves[32]. Two climate mitigation measures that could have a negative impact on air, water and soil quality are biofuel production and consumption and the implementation of CCS. Burning biofuels is in itself a source of air pollutants[4]. The collection, transport and processing of traditional cooking fuels are particularly harmful to women's health as they predominantly manage the gathering, transportation, processing and combustion of the biomass chain[33,34]. CCS poses a risk of CO_2 leakage, and other storage and transport related risks[4]. Road traffic accidents can be significantly reduced via urban planning, modal share switch and infrastructure investments to decrease traffic-related GHG emissions[31] (3.6). Lower levels of traffic congestion, modal switches and the conservation and development of green spaces in urban areas are likely to have a positive influence on mental and physical health of citizens[35] (3.4). However, an increased use of silent electric vehicles can have a negative impact on road safety[4] (3.6).

Of particular concern among the public, decision makers and their support staff (e.g. technical experts and scientists) are the health effects from exposures due to ionizing radiation. However, observations are repeatedly unable to reveal clear evidence of radiation-induced health effects when an individual has been exposed to low doses, with low doses being defined at levels well above those expected to be received by any individual from the examined energy sources[36,37]. Furthermore, coal leads to even higher radiation exposure than coal [38]. In terms of rare catastrophic events, there have been two emergencies at nuclear power plants (Chernobyl in 1986 and Fukushima in 2011) that resulted in substantial releases of radioactive material. The Chernobyl accident resulted in the deaths of 28 power plant employees and fireman from acute radiation syndrome and also in excess thyroid cancers among the public (6000 as of 2006) with a small number of fatalities (15 as of 2005). Nonetheless, it is important to note that an emergency this severe is not considered possible for the current nuclear power plants, as many changes have been made to the reactor design to improve in safety[39]. For the Fukushima Daiichi accident the doses to the public are generally low or very low and no discernible increased incidence of radiation-related health effects are expected[40].

An additional concern for health are the hazardous chemicals (e.g. cadmium) used in the manufacturing of solar panels. The hazardous chemicals required for solar panel manufacturing combined with an absence of many PV companies addressing appropriate recycling, highlights the need for appropriate polices to manage potential health and environmental impacts of solar PVs [41].

SDG3 targets impacted by climate mitigation policies (Agenda 2030):

3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being;

3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents; and

3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

SDG6 – Water and sanitation

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Climate mitigation policies may increase water efficiency through the elimination of water intensive power plants (e.g. coal-fired power plants), although measures such as bioenergy[42], concentrated solar power (CSP), and geothermal energy and hydropower may have a negative impact[4] (6.4). Additionally, hydropower could provide some benefits such as flood control, water availability and irrigation[4]. Measures to increase energy efficiency and adoption of sustainable agricultural practices could lower water use levels[43] (6.4). The protection and restoration of forest areas and peat lands for climate mitigation purposes could also lead to the protection or improvement of watersheds[30] (6.6). Reduction of water pollutants via sustainable industrial and agricultural practices (e.g. reduced nutrient use) have a positive impact on the protection of fresh water bodies, avoiding issues such as eutrophication and acidification[30] (6.3). Climate mitigation measures that address methane emissions from waste would lower the water contamination potential of these sources (6.3).

SDG6 targets impacted by climate mitigation policies (Agenda 2030):

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally;

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity; and

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

SDG7 - Energy

The climate and energy SDGs are strongly interlinked. Firstly, tackling GHG emissions implies increasing the share of low-carbon energy technologies, such as renewables (7.2). Secondly, increasing energy efficiency substantially in all sectors could lead to increased energy security and decreased energy poverty[11,18] (7.1, 7.3). Renewable and modern energy sources, although currently generally more expensive than conventional sources, are more easily introduced in remote areas, enabling broader electricity access[44] (7.1, 7.b). Finally, the increase in diversity of (clean) energy sources, related infrastructure investments and a decrease in fuel price volatility could improve energy security[11](7.1).

SDG7 targets impacted by climate mitigation policies (Agenda 2030):

7.1 By 2030, ensure universal access to affordable, reliable and modern energy services;

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix;

7.3 By 2030, double the global rate of improvement in energy efficiency; and

7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support.

SDG8 – Economic growth

Low-carbon transition implies an increased efficiency in energy productivity, achieved through technological diversification, upgrading and innovation[11] (8.2). Ensuring continuous economic growth, diversification and efficiency improvements requires avoiding lock-in of human and physical capital in

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the fossil fuel industries, which are based on finite resources[4] (8.1, 8.2). Climate mitigation measures help countries decouple their economies from fossil fuels and related environmental degradation (8.4). SDG8 aims to create decent jobs and to encourage creativity and innovation, aspects that are strongly encouraged and needed in climate change measures of clean technology research, development and diffusion[4] (8.3). Furthermore, climate mitigation action has a high potential for creating safe and secure working environments[32] (8.8). Switching to low-carbon energy technologies, such as renewables, can provide decent new jobs[11,45] (8.5, 8.6), to improve working environments where industrial infrastructure is renewed and upgraded[4], and reduces fossil fuel production work-related risks such as coal mining accidents, although nuclear and hydroenergy have a potential to increase work-related accidents[32](8.8).

For ionizing radiation, the largest collective effective dose to workers per unit of electricity generated is from coal mining. Furthermore, for the mining of rare metals for construction materials, the largest occupational collective effective dose[1] was from solar photovoltaic (PV) technology[38]. Similarly to section SDG 3 Health, at the individual level except for some rare and unusual cases, most of the exposures to ionizing radiation of workers in the life cycle of electricity-generating technologies would all be below the levels at which health effects would be observed[36,37]. Concerning work safety, installing rooftop PVs leads to a significant number of fatalities resulting from falls[46], and working on rooftops having one of the highest civilian occupation fatality rates in the USA[47]. Furthermore, in a survey, solar PV producers were not able to provide documentation to verify that their supply chains do not contain conflict minerals based on the due diligence guidelines set by the Organisation for Economic Co-operation and Development (OECD), another potential risk of an increase in solar panels[48,49].

SDG8 targets impacted by climate mitigation policies (Agenda 2030):

8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries;

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors;

8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services;

8.4 Improve progressively. through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead;

8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value;

8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training; and

8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment.

[1] Normalized to energy generated in 2010.

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SDG9 – Infrastructure and industrialization

An important element in low-carbon transitions is investment in new, reliable and sustainable infrastructure and industries, involving both an upgrade of old inefficient industries and adoption of new technologies (9.1, 9.2, 9.4). Furthermore, research and development of clean, energy efficient, and low-emissions technologies and their supported diffusion to countries of lower capabilities[11] are high on the climate mitigation agenda as well as that of SDG9 (9.5).

SDG9 targets impacted by climate mitigation policies (Agenda 2030):

9.1 Develop quality, reliable. sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being. with a focus on affordable and equitable access for all;

9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries;

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities; and

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including. by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.

SDG11 – Cities

Buildings energy efficiency improvements have varied impacts on affordable energy and housing in the short- and long-term. In the short term, this requires high upfront investments and may lead to an increase in housing costs[4]. However, the increased energy efficiency would lead to affordable energy for more households, as a later long-term benefit. The net effect would likely be an increase in adequate, safe and affordable housing and basic services[18,27] (11.1). Another important sector in cities is transport. Climate change mitigation action addresses this sector in two ways: one the one hand, it aims to improve planning, infrastructure, public transport, and modal switch to lower traffic (congestion) related GHG emission[31,35], and on the other hand it tackles vehicles emissions intensity through regulations and support for low-carbon technologies (11.2). Urban planning for low-carbon cities could improve sustainability of urban and human settlements, and increase productivity as travelling time is reduced[4] (11.3). Additionally, policies to combat GHG emissions would also lead to improved air quality in cities, and hence, improved health of citizens[11,32,35] (11.6).

SDG11 targets impacted by climate mitigation policies (Agenda 2030):

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums;

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons;

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11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries; and

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

SDG12 – Sustainable consumption and production

An important climate mitigation measure is the improvement of energy and material efficiency leading to sustainable management and efficient use of natural resources (12.2, 12.5, 12.6). Nonetheless, one drawback of renewable energy is the increased use of rare metals for the production of photovoltaic solar panels and wind turbines. Furthermore, action to reduce GHG emissions often leads to reduction of other pollutants as well (12.4). Climate mitigation action does not only address the producers, but also the consumers via climate change awareness campaigns, education programs, and requirements of performance and comparison labels for products (12.8). Implementation measure 12.c is directly addressed by GHG emissions reductions measures that focus on eliminating fossil-fuel subsidies and discourage wasteful consumption via energy and carbon taxes.

SDG12 targets impacted by climate mitigation policies (Agenda 2030):

12.2 By 2030, achieve the sustainable management and efficient use of natural resources;

12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil to minimize their adverse impacts on human health and the environment;

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse;

12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle;

12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature; and

12.c Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities.

SDG14 - Oceans

GHG emissions reduction measures benefit oceans in two ways. Firstly, improved agricultural practices reduce the discharge of nutrients that cause eutrophication (14.1). Secondly, GHG emissions lead to ocean acidification. Tackling these emissions thus also reduces the negative impact on oceans (14.3).

SDG14 targets impacted by climate mitigation policies (Agenda 2030):

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution; and

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14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.

SDG15 - Ecosystems

Next to oceans, ecosystems represent the most important carbon sink. For this reason, ecosystems conservation, restoration and sustainable use are high on the climate mitigation agenda. Climate mitigation measures may strongly benefit ecosystems such as forests, wetlands[11,30], and others (15.1, 15.2, 15.4, 15.5). In addition to existing natural areas, urban planning for sustainable cities could imply the development of green roofs and recreational areas, increasing urban biodiversity[4]. Biodiversity is also supported by the adoption of sustainable agricultural practices (e.g. lower use of pesticides and nutrients)[30]. Not only biodiversity benefits from sustainable agricultural practices, but also soil quality is improved, and desertification is slowed down[30] (15.3). Generally, reduction in air, soil and water pollution (as discussed under previous SDGs) greatly benefits ecosystems. In spite of all the benefits, side effects of climate mitigation action can also occur. For instance, large scale monocultures of biofuel crops would negatively affect biodiversity[4]. Furthermore, renewable energy resources such as hydropower can especially impact the natural habitat[4]. CO_2 leakage from CCS would also lead to negative impacts on surrounding ecosystems[4]. Nonetheless, these potential negative impacts from climate mitigation measures may be minor compared to impacts of fossil fuel upstream activities and downstream distribution and consumption.

SDG15 targets impacted by climate mitigation policies (Agenda 2030):

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements;

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally;

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world;

15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, to enhance their capacity to provide benefits that are essential for sustainable development; and

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.

Indirect impacts of climate mitigation policies and measures were excluded to avoid double counting of SDG linkages. Impacts of global warming are already well-described in the literature[50]. The purpose of this research was not to prove the necessity of the low-carbon transition, but rather to help identify sustainable development pathways that maximize synergies and minimize trade-offs between SDG13 and all other SDGs.

Examples of indirect links that were not included in the analysis are provided below for a better understanding of the climate-development linkages selection in this study:

- Climate mitigation has an indirect positive impact on SDG1 (poverty eradication) through its co-benefit to energy access (SDG7). However, in this study we only consider the direct impact on energy access target in SDG7;

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- Improved cooking stoves are more likely to benefit women's and children's health, indirectly leading to increased gender equality SDG5 (gender equality). However, we only mention the impact on SDG3 (health), where the link is more direct;
- SDG10 (inequalities) can benefit from reduced inequalities through broader energy access, but this is directly linked to SDG7 on energy. Furthermore, environmental impacts are expected to hit the poorer and more vulnerable countries and communities harder, increasing inequalities. Nonetheless, these latter impacts are a direct result of global warming itself, and not of specific mitigation policies; and
- Maintaining the increase in global temperature at a low level can help to prevent the spread of diseases such as malaria and to prevent overheating-related premature deaths, two targets of SDG3 (health). However, these health-related issues are caused by global warming, and not by climate mitigation action per se.

3.2. Co-benefits and the good practice policy menu

To more easily visualize the development impacts of climate mitigation policies in given countries, by sector, policy area, and policy instrument, the identified co-benefits and adverse side-effects of climate mitigation action were distributed across the good practice policy menu (introduced in section 2.2.). The result of this exercise is presented by sectors in Table 1 to Table 5.

From the identified climate mitigation policies impacts on SDGs targets, six major development areas emerge: health (including air pollution impacts and work and traffic related safety), energy (security and access), economic development (including technological spillovers, competitiveness, job opportunities and price volatility), food security (land use and enabling technologies and practices), water impacts (water use and water pollution), nature conservation (biodiversity and ecosystems conservation. For simplicity, mitigation co-benefits and adverse side-effects on SDGs are presented in the good practice policy menu based on these development areas rather than the individual SDGs.

Given the substantial work undertaken in the IPCC AR5, WGIII, the table of mitigation co-benefits and adverse side-effects presented in the AR5 (see Annex 2) was used as a starting point for translating the impacts into the good practice policy menu format. On a sectoral basis, the IPCC table was adapted as follows:

- *Electricity and heat sector*: As the energy efficiency area was missing in the IPCC table, the impacts related to industrial technological energy efficiency improvements were adopted. Renewable energy impacts in this sector were directly translated from the IPCC table. Fossil and bioenergy CCS were adopted as impacts in the nuclear or CCS or fuel switch sector.
- *Industry:* Material efficiency of goods and recycling and product demand reduction impacts were adapted as impacts of the changing activity policy area. Technological energy efficiency improvements via new processes were placed under industrial energy efficiency. Impacts of fossil and bioenergy CCS from the electricity sector were also included under the industry sector. Non-CO2 GHG emissions reduction impacts were linked to non-energy policies. Similarly, methane leakage prevention, capture and treatment impacts that appeared under the electricity and heat sector in the IPCC table were adopted under industrial non-energy area.
- *Buildings*: Behavioural changes reducing energy demand impacts were placed under changing activity. Furthermore, all impacts under human settlements and infrastructure sector were also

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placed under changing activity policy area. Retrofit of existing buildings, exemplary new buildings and efficient equipment impacts were adopted under energy efficiency. Incorporation of renewable energy impacts were distributed under the renewables policy area.

- *Transport*: Impacts of journey distance reduction and avoidance, and those of compact urban form and improved transport infrastructure were placed under changing activity policy area. Reduction of energy intensity impacts were translated as energy efficiency impacts. Reduction of fuel carbon intensity impacts were split into biofuels, placed under renewables, and electricity, attributed to a separate section in the nuclear and CCS and fuel switch policy area, eco-mobility. Also under nuclear or CCS or fuel switch, the modal shift impacts were included under the section 'modal share shift'.
- *Agriculture and Forestry*: This sector was separated into agriculture and forestry. Although the impacts are broadly similar across the two, various differences also exist.

Although the IPCC co-benefits and adverse side-effects table was used as a starting point, additional impacts on development, identified in Section 3.1. were included where relevant. In some cases, it was necessary to define impacts of individual cells (e.g. modal share shift and electro-mobility in the transport sector), while in other cases the impacts corresponded to the entire sector-policy area section as a whole. Mitigation policies from overarching cells would indirectly provide all benefits and side-effects from all other individual cells under all policy areas of the given sector. However, here we focus only on the very direct impacts. In general, these overarching policies take the form of energy and GHG emissions taxes, offsetting schemes or removal of fossil fuel subsidies, mainly impacting on energy and product prices, hence, affecting poverty. However, they do not have a high direct impact on any of the other development fields.

The overarching sector, 'General', was excluded from this analysis due to the fact that it mainly leads to indirect impacts as a result of climate emissions reduction targets and strategies and the existence of a coordinating body for climate change. Similarly, national energy efficiency targets and renewable energy targets do not directly impact on development, but they facilitate the implementation of other policy instruments in this area. Cross-sectoral research and development could lead to technological spillover as a benefit, but it depends very much on the type of research.

In the tables below, the direction of the arrows (upwards or downwards) indicate whether there is an increase or decrease in the presented development aspect. The colours of the arrows indicate if the impact is a co-benefit (green) or an adverse side-effect (red). A question mark indicates that the overall effect of the impact is unclear (whether positive or negative). This visualisation approach was also adopted from the IPCC AR5.

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3.2.1. Electricity and heat sector

Table 1: Development co-benefits and side-effects in the electricity and heat sector

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
Electricity and heat		Economic development ↑Technological spillover ↑Competitiveness and productivity ↑Potential unemployment (closure of inefficient power plants) ↑Energy price increase and then decrease ↑New business opportunities	Economic development ↑Local employment impact ↑Extra measures to match demand (for PV, wind and some CSP) ↑Threat of displacement (for large hydro) ↑New market/income opportunities ↑Technological spillover	Economic development ↑Preservation vs. lock-in of human and ↑physical capital in the fossil industry ↑Long-term monitoring of CO2 storage	
		Energy (security and access) ↑Energy security increase (lower need for imports and longer lasting resources)	Energy (security and access) ↑Energy security (resource sufficiency, diversity in the near / medium term) ↑Contribution to (off-grid) energy access	Energy (security and access)	
		Health ↓Air pollution decrease (human health and ecosystems improvement) ↓Mining accidents decrease	Health ↓Air pollution (except bioenergy) ↓Coal mining accidents	Health ↑Risk of CO2 leakage ↑Upstream supply-chain activities ↑Safety concerns for CCS and nuclear (storage, transport, occupational safety)	
		Food security	Food security ↓Land available for agriculture (due to cultivation of biofuels) ↑ Agricultural technologies spillover (biofuels)	Food security	
		Water use ↑Water availability ↓Water pollution	Water use ↑Irrigation, flood control, navigation, water availability (use of reservoirs and regulated rivers) ↓Water use (for wind and PV) ↑Water use (bioenergy, CSP, geothermal, and hydro) ↓Reduced water pollution	Water use ↑Water use	
		Nature conservation ↓Impact on ecosystems and natural resource ↓Fossil fuel extraction	Nature conservation ↑Habitat impact (for some hydro and wind) ↓Fossil fuel extraction ↑Use of critical metals for PV and wind turbines	Nature conservation ↑Ecosystem impact via upstream supply-chain activities	
	Economic development ↑Energy prices (CO2 and energy taxes) ↑Technological spillover ↑National tax revenue ↑Competitiveness and productivity				

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3.2.2. Industry sector

Table 2: Developmnet co-benefits and side-effects in the industry sector

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
Industry	Economic development ↓National sales tax revenue, medium term ↑Employment in waste recycling market ↑Competitiveness in manufacturing ↑New infrastructure for industrial clusters ↑New business opportunities ↓Local conflicts (resource extraction)	Economic development ↑Employment impact ↑Competitiveness and productivity ↑Technological spillovers ↑New business opportunities	Economic development ↑Local employment impact ↑Extra measures to match demand (for PV, wind and some CSP) ↑Threat of displacement (for large hydro) ↑New market/income opportunities	Economic development ↑Preservation vs. lock-in of human and ↑physical capital in the fossil industry ↑Long-term monitoring of CO2 storage	Economic development ↑Competitiveness and productivity
	Energy (security and access)	Energy (security and access) ↑Energy security (via lower energy intensity)	Energy (security and access) ↑Energy security (resource sufficiency, diversity in the near / medium term) ↑Contribution to energy access	Energy (security and access)	Energy (security and access)
	Health ↓Health impacts and safety concerns ↑ Wellbeing via diverse lifestyle choices	Health ↓Health impact via reduced local pollution ↑Safety, working conditions and job satisfaction	Health ↓Air pollution (except bioenergy) ↓Coal mining accidents	Health ↑Risk of CO2 leakage ↑Upstream supply-chain activities ↑Safety concerns for CCS and nuclear (storage, transport, occupational safety)	Health ↓Air pollution ↑Coal mines and PFC industry safety and better work conditions
	Food security	Food security	Food security ↓Land available for agriculture (due to cultivation of biofuels) ↑ Agricultural technologies spillover (biofuels)	Food security	Food security
	Water use ↓Water pollution	Water use ↑Water availability and quality ↓Water pollution*	Water use ↑Irrigation, flood control, navigation, water availability (for multipurpose use of reservoirs and regulated rivers) ↓Water use (for wind and PV) ↑Water use (bioenergy, CSP, geothermal, and hydro) ↓Water pollution	Water use ↑Water use	Water use ↓Reduced water pollution ↑Water conservation
	Nature conservation ↓Air and water pollution and waste material ↓ Post-consumption waste ↓Use natural resources	Nature conservation ↓Fossil fuel extraction ↓Local pollution and waste	Nature conservation ↑Habitat impact (for some hydro) ↓Coal mining ↑Landscape and wildlife impact (for wind) ↑Use of critical metals for PV and wind turbines	Nature conservation ↑Ecosystem impact via upstream supply-chain activities	Nature conservation ↓ Ecosystem impact via reduced pollution
	Economic development ↑Energy prices (CO2 and energy taxes) ↑Technological spillover ↑National tax revenue ↑Competitiveness and productivity				

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3.2.3. Building sector

Table 3: Development co-benefits and side-effects in the buildings sector

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
Building	Economic development ↑Lower need for energy subsidies	Economic development ↑Employment impact ↑Productivity (for commercial buildings) ↑Lower need for energy subsidies ↑Asset values of buildings ↑Disaster resilience ↓Fuel poverty (for retrofits and efficient equipment) ↑Productive time for women and children (cookstoves)	Economic development ↑Employment impact ↑Lower need for energy subsidies ↑Asset values of buildings ↑Energy cost ↑Productive time for women/children (cookstoves) ↓Fuel poverty		
	Energy (security and access) ↑Energy security	Energy (security and access) ↑Energy security ↑Energy access	Energy (security and access) ↑Energy security ↑Energy access (in remote areas)		
	Health ↓Outdoor air pollution ↑Improved indoor environmental conditions	Health ↓Outdoor air pollution ↓Indoor air pollution (for efficient cookstoves) ↑Improved indoor environmental conditions ↓Urban heat island effect ↑Thermal comfort (for retrofits and exemplary new buildings) ↓Insufficient ventilation	Health ↓Air pollution ↓Reduced Urban Heat Island (UHI) effect		
	Water use	Water use ↓Water consumption and sewage production ↓Water pollution	Water use ↓Water pollution		
	Nature conservation ↓Ecosystem impact (less outdoor air pollution)	Nature conservation ↓Ecosystem impact (less outdoor air pollution)	Nature conservation ↓Ecosystem impact (less outdoor air pollution) ↑Urban biodiversity (for green roofs)		
	Economic development ↑Energy prices (CO2 and energy taxes) ↑National tax revenue ↑Technological spillover				

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3.2.4. Transport sector

Table 4: Development co-benefits and side-effects in the transport sector

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch		Non-energy
Transport	Economic development ↑Productivity (reduced urban congestion and travel times, affordable and accessible transport) ? Employment opportunities in the public transport sector vs car manufacturing jobs ↑Equitable mobility access to jobs	Economic development ↑ Increased vehicle price ↑Technological spillovers	Economic development ↑Technological spillovers	Modal share shift	Economic development ↑Productivity (reduced urban congestion and travel times, affordable and accessible transport) ? Employment opportunities in the public transport sector vs car manufacturing jobs Energy (security and access) ↑Energy security (reduced oil dependence and exposure to oil price volatility) Health ↓Health impact for non-motorized modes via Increased physical activity ↑Potentially higher exposure to air pollution ↓Noise (modal shift and travel reduction) ↑Road safety (via modal shift and / or infrastructure for pedestrians and cyclists) ↓Traffic-related stress Nature conservation ↓Ecosystem impact via reduced urban air pollution	
	Energy (security and access) ↑Energy security (reduced oil dependence and exposure to oil price volatility)	Energy (security and access) ↑ Energy security (reduced oil dependence and exposure to oil price volatility) ↓ Energy poverty	Energy (security and access) ↑Energy security (diversification, reduced oil dependence and exposure to oil price volatility)			
	Health ↑Potentially higher exposure to air pollution ↑Equitable mobility access to jobs ↑Road safety (via infrastructure)	Health ↓ Urban air pollution	Health ? Air pollution (bioenergy vs fossil fuels) ↓Oil industry accidents			
	Food security	Food security	Food security ↓Land available for agriculture (due to cultivation of biofuels) ↑ Agricultural technologies spillover (biofuels)	Eco-mobility	Economic development ↑Technological spillovers (e. g., battery technologies for consumer electronics) ↓Infrastructure investments Energy (security and access) ↑Energy security (diversification) Health ↓Air pollution ↓Health impact via reduced noise (electrification and fuel cell LDVs) ↓Road safety (silent electric LDVs at low speed) Nature conservation ↓Electricity use: reducing most pollutants ↑Material use (unsustainable resource mining)	
	Water use	Water use ↓Reduced water pollution	Water use ↑Water use from biofuel cultivation			
	Nature conservation ↓Ecosystem impact via reduced urban air pollution ↑Ecosystem impacts via new/shorter shipping routes	Nature conservation ↓ Ecosystem and biodiversity impact via reduced urban air pollution	Nature conservation ↑Large-scale monocultures ↑Land use competition			
	Economic development ↑Energy prices (CO2 and fuel taxes) ↑National tax revenue ↑Technological spillover					

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3.2.5. Agriculture and forestry sector

Table 5: Development co-benefits and side-effects in the agriculture and forestry sector

		Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
Agriculture and Forestry	Agriculture	Economic development ↑Entrepreneurship development and employment increase ↓Less labor-intensive ↑Diversification of income sources and access to markets ↑Income concentration (technologies) ↑Additional income to (sustainable) landscape management (technologies) ↑Technology innovation and transfer (technologies) ↑Innovative financing mechanisms for sustainable resource management crops ↑↓Tenure and use rights at the local level (for indigenous people and local communities) especially when implementing activities in natural forests ↑↓Access to participative mechanisms for land management decisions ↑Enforcement of existing policies for sustainable resource management				
		Energy (security and access) ↑Energy security (resource sufficiency) (technologies)				
		Health ↑Human health e. g., through less pesticides, reduced burning practices and practices like agroforestry and silvo-pastoral systems ↓Air pollution via decrease of burning practices				
		Food security ↑Food-crops production through integrated systems and sustainable agriculture intensification ↓Food production (locally) due to large-scale monocultures of non-food ↑Large-scale monocultures ↑Land use competition ↑Soil quality ↑Agricultural productivity increase				
		Water use ↑Increased water availability ↓Decreased eutrophication and acidification (nutrient use and burning practices)				
		Nature conservation ↑Provision of ecosystem services via ecosystem conservation and sustainable management as well as sustainable agriculture ↓Erosion ↑Ecosystem resilience ↑Albedo and evaporation ↑Animal welfare e. g., through less pesticides, reduced burning practices and practices like agroforestry and silvo-pastoral systems ↑Increased biodiversity				

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	Forestry	Economic development ↑Entrepreneurship development and employment increase ↓Less labor-intensive ↑Diversification of income sources and access to markets ↑Income concentration (technologies) ↑Additional income to (sustainable) landscape management (technologies) ↑Technology innovation and transfer (technologies) ↑↓Tenure and use rights at the local level (for indigenous people and local communities) especially when implementing activities in natural forests ↑↓Access to participative mechanisms for land management decisions ↑Enforcement of existing policies for sustainable resource management
		Energy (security and access) ↑Energy security (resource sufficiency) (technologies)
		Health ↑Human health e. g., through less pesticides, reduced burning practices and practices like agroforestry and silvo-pastoral systems ↓Air pollution via decrease of burning practices
		Food security ↑Land grabbing
		Water use ↑Increased water availability ↓Decreased acidification (burning practices)
		Nature conservation ↑Cultural habitats and recreational areas via (sustainable) forest management and conservation ↑Provision of ecosystem services via ecosystem conservation and sustainable management as well as sustainable agriculture ↓Erosion ↑Ecosystem resilience ↑Albedo and evaporation ↑Animal welfare through reduced burning practices and practices like agroforestry and silvo-pastoral systems ↑Increased biodiversity

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3.3. Current country-specific development status

In the previous chapter we explored the impacts of climate mitigation policies on various areas of sustainable development. However, the relevance and magnitude of these impacts depend, in part, on the current country-specific development conditions. Therefore, to understand the importance and potential effect of specific climate mitigation policies in the G20 countries, we consider a set of development indicators that correspond to the assessed sustainable development areas: economic development, energy, air pollution, food security, and water use. Nature conservation was excluded due to the higher difficulty in assessing current ecosystems degradation levels. Furthermore, the levels of annual GHG emissions of each country is also presented.

3.3.1. GHG emissions

The G20 member states include the highest GHG emitters worldwide, this aspect being one of the main reasons for selecting this group as the study main focus. As shown in Figure 3[2], China was the highest GHG emitter among the G20 countries (and worldwide) in 2014, with an annual level of emissions of more than 12 $GtCO_2eq$. This emissions level is almost double that of the next highest emitter, the United States (just above 6 $GtCO_2eq$), and triple that of the third highest emitter, the European Union (below 4 $GtCO_2eq$). The following three largest emitters, India, Indonesia and the Russian Federation, have similar GHG emissions levels, around half those of the United States. In terms of GHG emissions per capita (Figure 4[3]), countries with low overall emissions, such as Saudi Arabia, Republic of Korea and South Africa, move to the top of the list, with some of the highest per capita emissions.

When comparing GHG emissions intensity (GHG emissions per unit of GDP), the order of countries

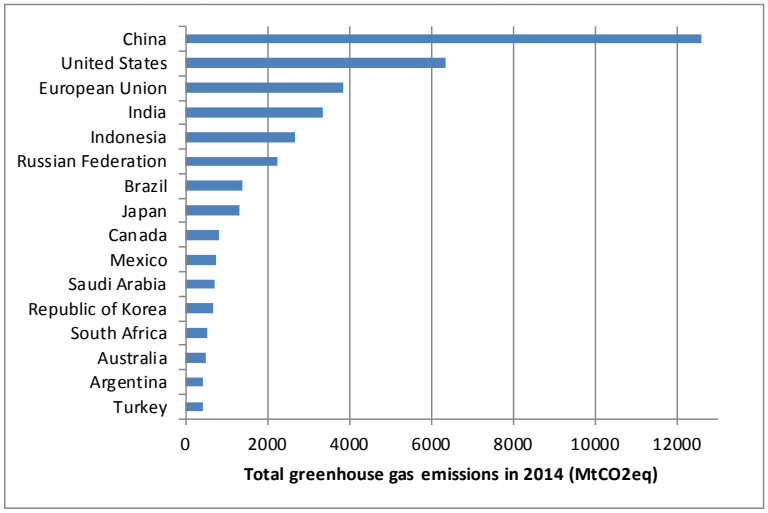

Figure 3: Total GHG emissions from G20 countries in 2014, including LULUCF

changes substantially. From this perspective (see Figure 5[4]), South Africa becomes top of the list, with emissions intensities of almost 11 $ktCO_2eq/US\$mil$ (current). The following two countries with high emissions intensity are Saudi Arabia and Turkey. On the other hand, the economies with lowest emissions intensities are the European Union, China and Brazil. Differences in GHG emissions intensity

[2] PRIMAP GHG emissions data (http://pmd.gfz-potsdam.de/pik/showshort.php?id=escidoc:1504004)
[3] World Bank Data for population (https://data.worldbank.org/indicator/SP.POP.TOTL) and PRIMAP for GHG emissions (see above)
[4] World Bank Data on GDP (http://data.worldbank.org/indicator/NY.GDP.MKTP.CD/) and PRIMAP for GHG emissions (see above)

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across these countries can be both a result of economic structure (share of emissions intensive industries versus services) or of inefficiencies in the sectors responsible for GHG emissions. Please, note that the GHG emissions here include forest sinks.

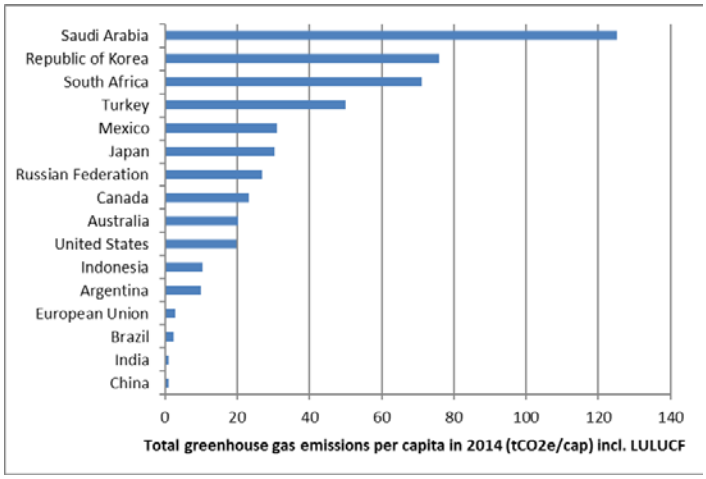

Figure 4: Total GHG emissions per capita in the G20 countries in 2014

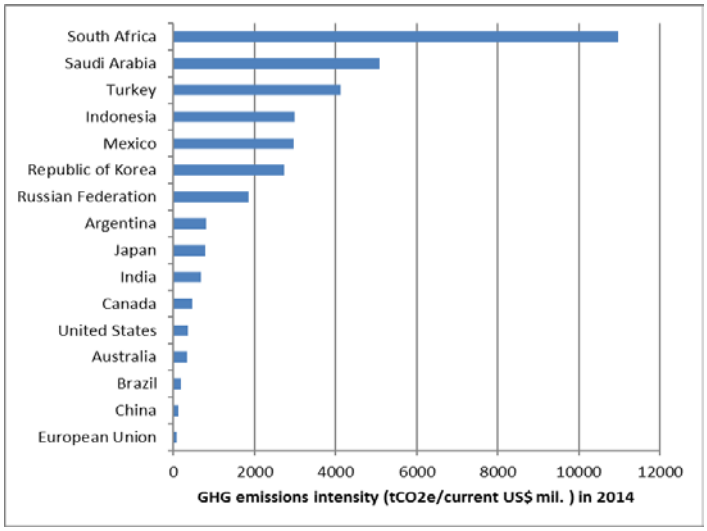

Figure 5: GHG emissions intensity in G20 countries in 2014

3.3.2. Economic development

Economic development is an area of sustainable development that is impacted by all climate mitigation policies in the good-practice policy menu. One main indicator of a country's level of economic development is GDP per capita. Within the G20 countries, Australia and the United States are positioned at the top of the list, with similar GDP per capita values of more than 55 thousand current US$ per capita in 2015 (see Figure 6[5]), followed by Canada, with almost 45 thousand current US$ per capita. Japan and the European Union also have similar values of this indicator, just above 40 thousand

[5] World Bank Data (http://data.worldbank.org/indicator/NY.GDP.PCAP.CD)

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current US$ per capita. The least economically developed countries, from the narrow perspective of GDP per capita, are India and Indonesia, both below 5 thousand current US$ per capita. These least developed countries could benefit the most from climate mitigation policies that maximize synergies with economic development.

GDP per capita is a rather general indicator, describing the overall status of the economy. However, a more specific aspect that often appears in the identified economic impacts of climate mitigation is availability of jobs. Figure 7[6] shows South Africa as the G20 country with the highest unemployment rate, 25% of total labour force in 2014. If climate mitigation policies that provide new job opportunities are implemented, the increased employment co-benefits could be beneficial in countries with high unemployment rate. On the other hand, countries with the lowest unemployment rate are Japan, India, and Republic of Korea, with values slightly below 4% of the labour force.

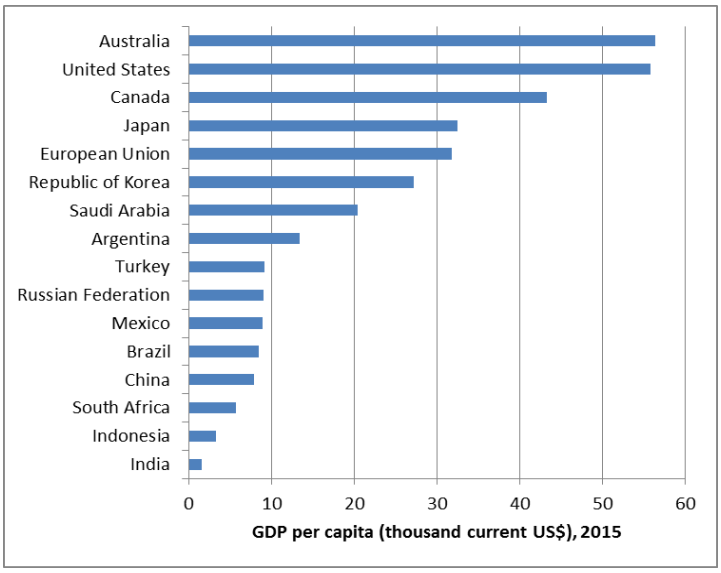

Figure 6: GDP per capita in G20 countries, 2015

[6] World Bank Data (http://data.worldbank.org/indicator/SL.UEM.TOTL.ZS)

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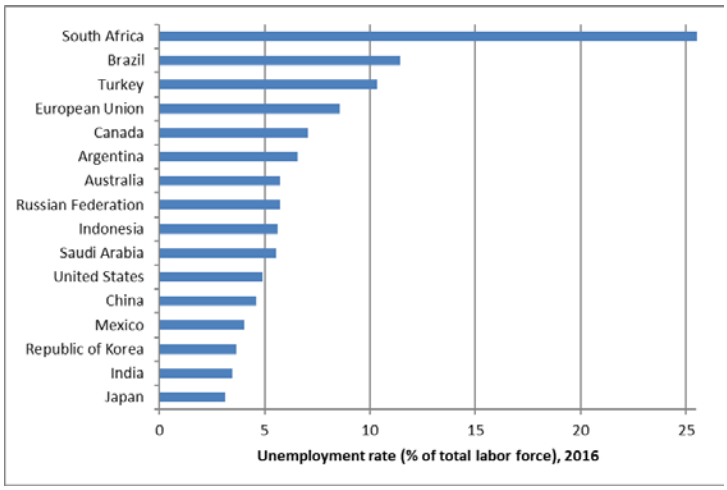

Figure 7: Unemployment rate in G20 countries, 2016

3.3.3. Energy

Burning fossil fuels to produce energy is the main source of GHG emissions from human activities. Therefore, decarbonizing national energy systems is key to climate change mitigation. To achieve deep decarbonization of the energy system, countries need to switch to low-carbon energy sources. Figure 8[7] shows that the energy systems in the G20 member states in 2014 were mostly relying on fossil fuels, with shares as high as 100%, as is the case of Saudi Arabia. Brazil is the country with the highest non-fossil fuels energy consumption share, and the only country consuming more than 40% of its energy from renewable sources. These values suggest that there is potential for energy systems decarbonization in all G20 countries.

In addition to phasing out fossil fuel use, countries can reduce emissions by improving energy efficiency, and hence, lowering their energy intensity. Figure 9[8] shows that South Africa, Russian Federation, Canada and China are the most energy intensive economies, using more than 7 MJ per US$2011 PPP GDP. On the other hand, Turkey, Indonesia and the European Union are the least energy intensive, with primary energy use below 4 MJ per US$2011 PPP GDP. Energy intensity differences across countries could be a result of economic structure (higher share of energy intensive industries versus services), but it could also indicate energy inefficiency across energy intensive sectors. Countries of high energy intensity could focus on increasing their energy productivity through, for instance, energy efficiency improvements across all energy intensive sectors.

[7] World Bank Data (http://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS)
[8] World Bank Data (http://data.worldbank.org/indicator/EG.EGY.PRIM.PP.KD)

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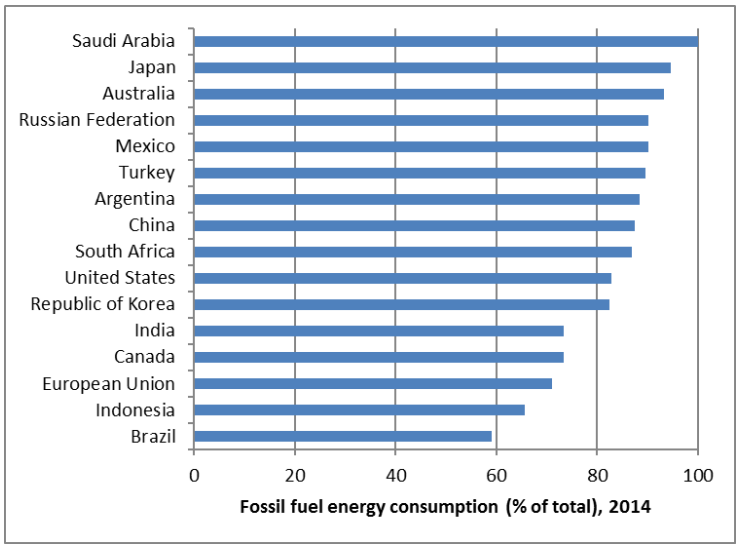

Figure 8: Share of fossil fuels in total energy consumption in G20 countries, 2014

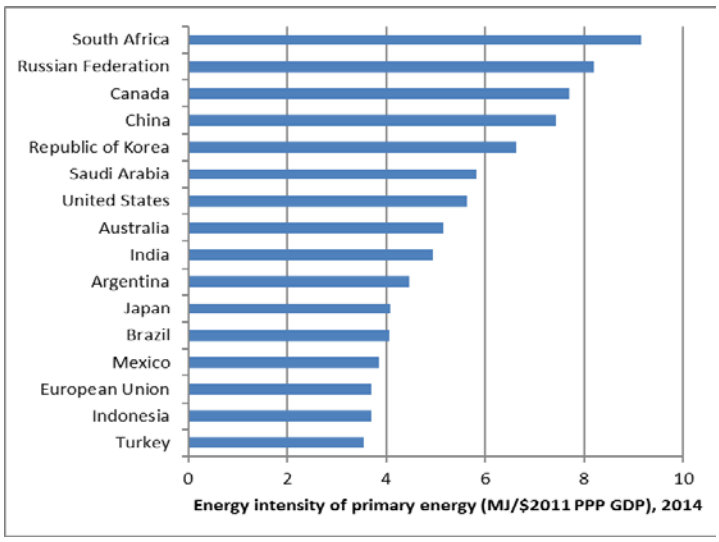

Figure 9: Energy intensity of primary energy in G20 member states, 2014

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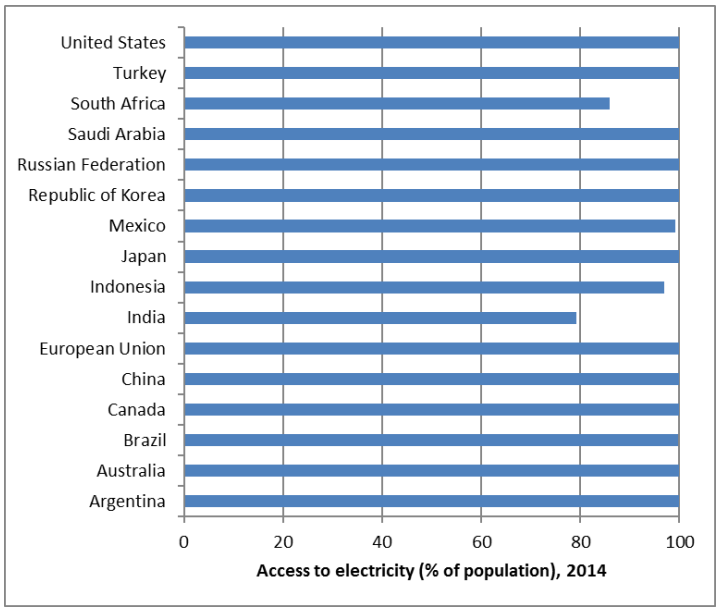

Figure 10: Rate of electricity access in G20 countries, 2014

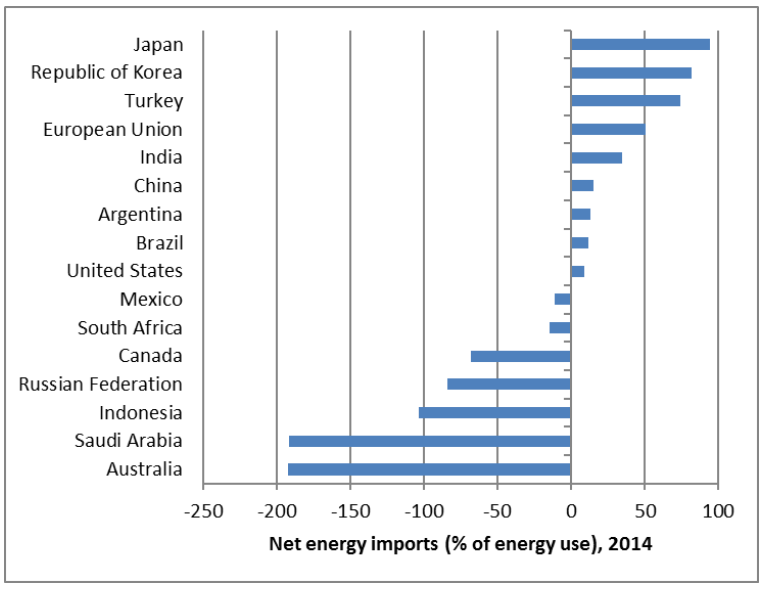

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Figure 11: Net energy imports in G20 countries, 2014

SDG7, concerning energy, focuses on energy access and energy security. In the previous section we have shown that climate mitigation and energy goals are strongly interlinked. Some of the main benefits that many climate mitigation measures offer are energy security and energy access. Because the G20 member states represent some of the major economies globally, most of them currently have 100% electricity access of population (see Figure 10[9]). However, among these member states there are some that still have to develop the necessary infrastructure to supply the remaining citizens without access to electricity. These countries could aim to reach those citizens with clean energy, and take advantage of the benefits renewable energy offers in remote areas.

Energy security is another important development aspect that benefits from climate mitigation action in the energy system. Energy security can be increased both through energy efficiency improvement and through the diversification of resources and switch to renewable sources. In 2014, approximately half of the G20 member states had positive net imports of energy (see Figure 11[10]). Saudi Arabia and Australia have the highest net exports of energy, almost twice the entire country energy consumption. Indonesia is also a net exporter, selling more than 100% of their own energy consumption, respectively. These countries have high energy security levels, as they do not depend on others to satisfy their energy needs. However, high dependency on fossil fuel exports as a source of income is a high economic risk if the world moves toward low-carbon alternatives. On the other hand, countries such as Japan, Republic of Korea and Turkey depend on other countries for 50% to more than 90% of their energy consumption. This is a vulnerable position in terms of energy security. Therefore, these countries would benefit most from energy efficiency improvements and tapping into available local renewable sources.

3.3.4. Air pollution

In the previous chapter, we showed that climate mitigation action provides numerous co-benefits for health. One of these benefits is the reduction of air pollution, and hence, a decrease in premature deaths caused by poor air quality. To assess current air quality in the G20 member states, we selected PM2.5 mean annual exposure as an indicator. WHO (2005) maximum mean annual exposure levels of PM2.5 are 10 µg/m^3. However, the PM2.5 mean annual exposure levels exceed this recommended level in all but two of the G20 countries (see Figure 12[11]). China, India and Saudi Arabia have the poorest air quality, exceeding the recommended limits by more than 5 times. While fossil fuel combustion and biomass burning are the main sources of air pollution in China and India, sand particles and dust are likely to contribute substantially to the poor air quality in Saudi Arabia. The only three G20 members with mean annual exposures below the recommended limit are Australia, Canada and the United States. Hence, air pollution reduction is an important climate mitigation action co-benefit in almost all G20 member states.

[9] World Bank Data (http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS)
[10] World Bank Data (http://data.worldbank.org/indicator/EG.IMP.CONS.ZS)
[11] World Bank Data (http://data.worldbank.org/indicator/EN.ATM.PM25.MC.M3)

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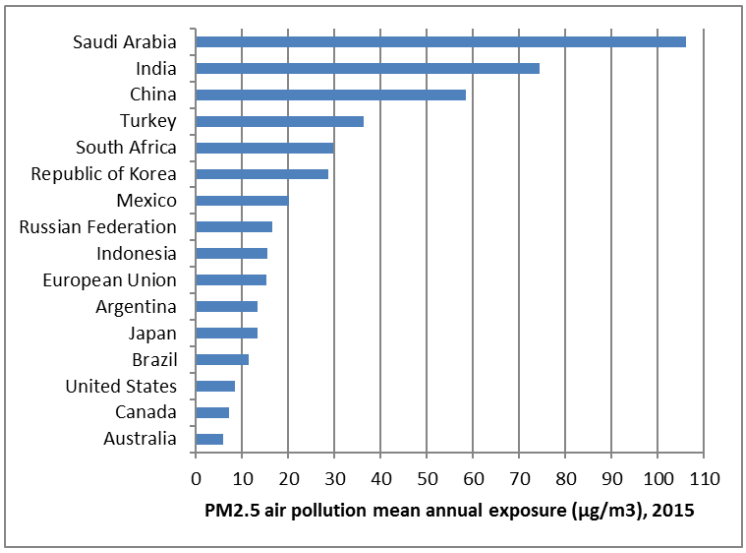

Figure 12: Mean annual exposure to PM2.5 in G20 countries, 2015

3.3.5. Food security

Climate mitigation action can impact food security positively or negatively. Therefore, understanding a country's food production potential and limitations is key to selecting GHG emissions reduction policies that are coherent with food security targets. One side-effect of climate mitigation could be land competition between agriculture and biofuel production. Therefore, we first assess cereal import dependency ratio in G20 countries to see what percentage of cereals countries produce for themselves (see Figure 13[12]). Countries with the highest dependency on cereal imports between 2009 and 2011 were Saudi Arabia, importing on average almost 90% of its cereal consumption, Japan, with almost 80%, and Republic of Korea, dependent for 74% of its cereal consumption. Hence, it is likely that producing biofuels in this countries would decrease food security even more. On the other hand, almost half of G20 member states are net exporters. Amongst these, the largest exporters are Argentina, exporting almost 170% of its food production and Australia, exporting 145%. These countries could profit from emissions reductions measures such as biofuel production and forest conservation and restoration, without a negative effect on food security, if exports are decreased, and not domestic cereal consumption.

[12] FAOSTAT Food Security (http://faostat.fao.org/beta/en/#data/FS)

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Food security is not only an issue of agricultural production potential. It is also influenced by a country's economic development and the ability to feed people. Figure 14[13] shows average food deficit levels between 2014 and 2016 for a selection of G20 countries where such data was available. Currently, India has the highest food deficit, around 110 kcal per person per day, followed by China, with a value of approximately 74 kcal per person per day.

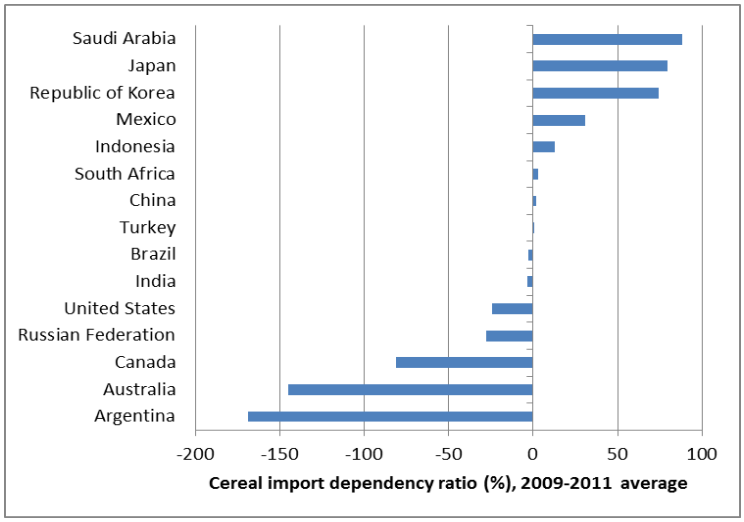

Figure 13: Cereal import dependency ratio in G20 countries as average over the period 2009-2011

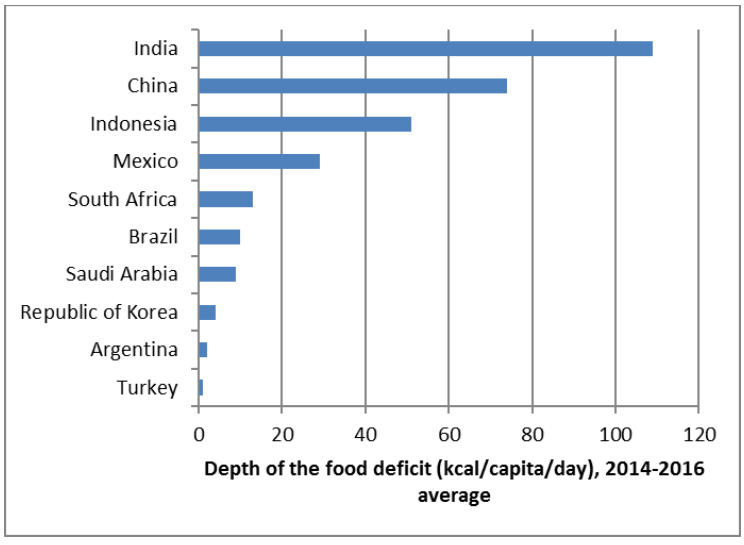

Figure 14: Depth of food deficit in some of the G20 countries over the period 2014-2016

[13] FAOSTAT Food Security (http://faostat.fao.org/beta/en/#data/FS)

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3.3.6. Water use

Climate mitigation action has the potential to improve water quality and to increase or decrease water use. In general, G20 countries withdraw less than the available annually renewable fresh water (see Figure 15[14]). However, Saudi Arabia is an exception, consuming 9.5 times more water than available.

Regarding water use, three sectors stand out as the main consumers: industry, agriculture, and municipal use. In most G20 countries, agriculture has the highest water consumption, except for Canada, Russian Federation and United States, where industry has a higher share of water usage (see Figure 16[15]). India, Saudi Arabia and Indonesia have the highest agricultural water use share, above 80%. Canada is the largest consumer of water in the industry sector (80%), while South Korea and South Africa are countries with the highest share of municipal waste water (almost 30%).

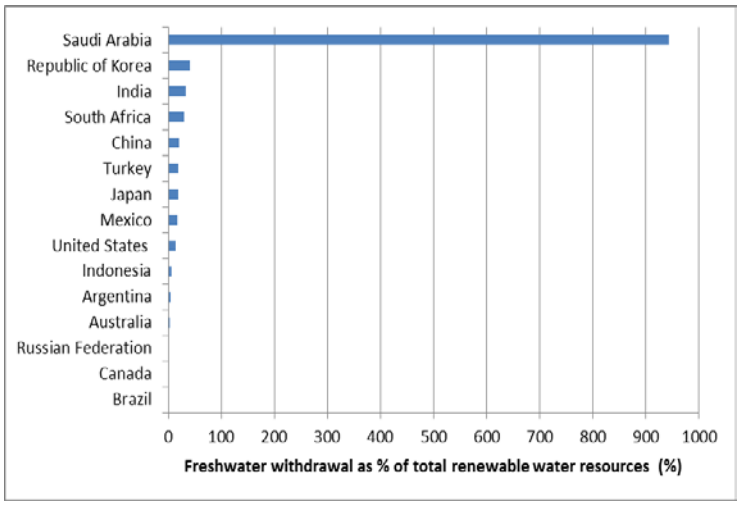

Figure 15: Share of renewable water resources withdrawn by G20 countries various in recent years

[14] AQUASTAT Water data (http://www.fao.org/nr/water/aquastat/data/query/results.html)
[15] AQUASTAT Water data (http://www.fao.org/nr/water/aquastat/data/query/results.html)

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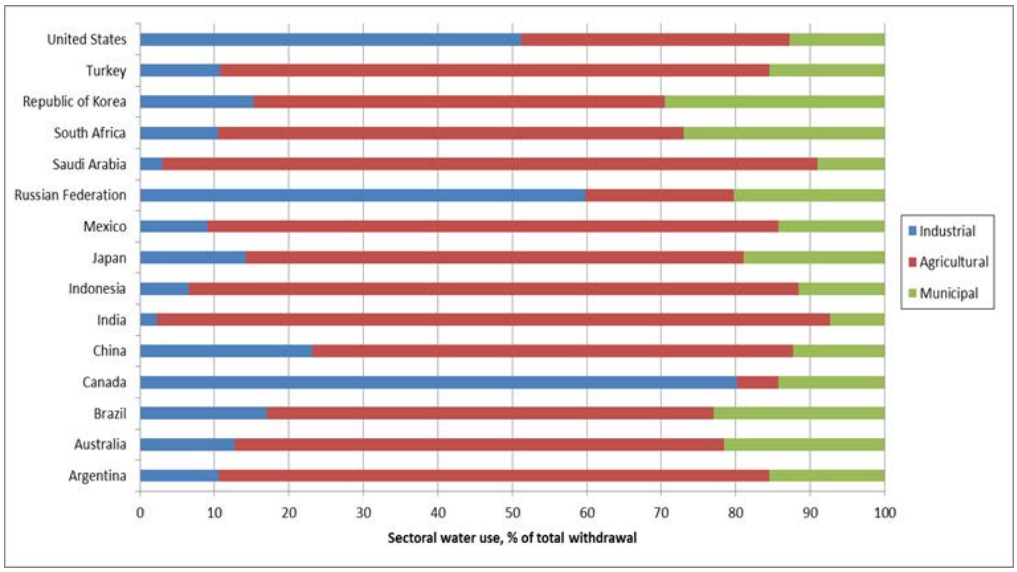

Figure 16: Share of water use across sectors in G20 countries (various recent years)

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4. Results

4.1. Overview of G20 countries (general assessment of indicators)

Low coverage ---------- High coverage

0% 100%

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (81%)				
	GHG reduction target (100%)				
	Coordinating body for climate strategy (63%)				
	Support for low-emission RD&D (63%)				
		National energy efficiency target (69%)	Renewable energy target (44%)		
Electricity and heat		Support for highly efficiency power plants (including codes and standards and fiscal/financial incentives) (94%)	Renewable energy target for electricity sector (88%)	CCS support scheme, including fiscal/financial incentives and infrastructure investment (38%)	
		Reduction obligation schemes (13%)	Support scheme for renewables (including green certificates, fiscal/financial incentives, obligation schemes, net metering or direct investment) (100%)		
			Grid infrastructure development (69%)		
			Sustainability standards for biomass use (6%)		
	Overarching carbon pricing scheme or emissions limit (44%)				
	Energy and other taxes (25%)				
	No fossil fuel subsidies (63%)				
Industry	Strategy for material efficiency (including product standards and other requirements) (38%)	Support for energy efficiency in industrial production (including voluntary approaches, fiscal/financial incentives, obligation schemes or white certificates) (69%)	Support schemes for renewables (including fiscal/financial incentives, green certificates, obligation schemes) (44%)	CCS support scheme (including fiscal/financial incentives and infrastructure investment) (44%)	Landfill methane reduction (31%)
		Energy reporting and audits (81%)	Sustainability standards for biomass use (6%)		Incentives to reduce CH4 from oil and gas production (38%)
		Minimum energy performance and equipment standards (81%)			Incentives to reduce N2O from industrial processes (25%)
					Incentives to reduce fluorinated gases (38%)
	Overarching carbon pricing scheme or emissions limit (38%)				
	Energy and other taxes (31%)				
	No fossil fuel subsidies (6%)				
Buildings	Urban planning strategies (including infrastructure investments) (25%)	Building codes and standards and fiscal/financial incentives for low-emissions choices in heating, cooling, hot water, and cooking (88%)	Support scheme for heating and cooling (19%)		
		Minimum energy performance and equipment standards for appliances (94%)	Support scheme for hot water and cooking (13%)		
			Sustainability standards for biomass use (6%)		
	Energy and other taxes (19%)				
	No fossil fuel subsidies (19%)				
Transport	Urban planning and infrastructure investment to minimize transport needs (56%)	Minimum energy/emissions performance standards or support for energy efficient for light duty vehicles (100%)	Biofuel target (31%)	Support for modal share switch (38%)	
		Minimum energy/emissions performance standards or support for energy efficient for heavy duty vehicles (94%)	Support schemes for biofuels (including fiscal/financial incentives and obligation schemes) (69%)	E-mobility programme (31%)	
			Sustainability standards for biomass use (13%)		
	Tax on fuel and/or emissions (63%)				
	No fossil fuel subsidies (38%)				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (50%)				
	Incentives to reduce CO2 emissions from agriculture (25%)				
	Incentives to reduce CH4 emissions from agriculture (44%)				
	Incentives to reduce N2O emissions from agriculture (38%)				
	Incentives to reduce deforestation and support for afforestation/reforestation (88%)				

Figure 17: Overall good-practice policy menu coverage in the G20 countries

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Figure 17 shows the percentage of G20 countries that have policies in specific sectors, areas and policy types defined in the good practice policy menu. We found that each section of the good practice policy menu is covered by at least one country. However, the policy areas covered by most countries are energy efficiency (more than 80% in each relevant sector), renewables in the electricity and transport sectors (100% and at least 69%, respectively), and forestry (88%). All G20 countries have support policies for electricity production from renewable sources, and minimum energy/emissions performance standards or support for energy efficient light duty vehicles or passenger cars. Similarly, all G20 countries have GHG emissions reduction targets, although this targets include those presented in the INDCs. More than 80% of the countries have climate change strategies, but only 63% have coordinating bodies for climate change to support the implementation of these strategies.

Changing activity, industrial non-energy and renewables in the residential sector (non-solar PV), are the policy areas with least coverage across G20 members. Furthermore, overarching policies, such as offsetting mechanism, fossil fuel subsidies removals and energy and other taxes are covered by less than 70% of the countries in all sectors. Moving to low-carbon pathways require climate mitigation action in all relevant sectors, addressing all existing GHG emissions sources. Hence, ideally, climate mitigation policies should exist across the entire good practice policy menu in every country, in sectors that lead to GHG emissions. By not having policies in certain areas, countries do not only fail to reduce emissions, but they also miss the potential co-benefits emerging from decarbonisation of these areas. Examples mitigation co-benefits from renewables in the residential sector are increased asset value of building units, new job opportunities, improved energy security, and reduced urban heat island effect.

4.2. Country profiles

This section presents country-specific results of our analysis, in the form of country profiles. The country profiles will include:

- Good practice policy menu coverage by implemented climate policies in the country;
- Sectoral emissions[16];
- List of selected high-GHG emissions reduction impact policies; and
- Country performance on high-level development indicators (introduced in section 3.3).

Analysis of countries coverage of the good practice policy menu was based on the Climate Policy Database in its latest updated version as a result of data collection by CD-LINKS project. The colours of the good practice policy menu indicate if implemented policies exist (green) in the specific category of the menu, if they are missing (red), or if this information is unknown (grey).

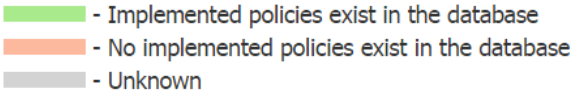

Figure 18. Good practice policy menu legend

Countries performance with respect to high-level development indicators is presented in comparison to the indicator levels of other G20 members. Hence, the minimum and maximum values are set by the countries with the lowest and highest value of a given indicator. In the country profiles, a country value is graphically represented in a bar chart, with respect to the minimum, maximum, and average value among the G20 members.

[16] Data on sectoral emissions was extracted from The Shift Project (http://www.tsp-data-portal.org/Breakdown-of-GHG-Emissions-by-Sector#tspQvChart)

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4.2.1. Argentina

Compared to other G20 members, Argentina had the second lowest GHG emissions levels in 2014, but a median GHG emissions intensity level, (see Figure 3 and Figure 5). Argentina's largest GHG emitting sectors are agriculture (27%), forestry (23%) and electricity and heat (16%) (see Figure 20). However, the coverage of good practice policies (Figure 19) shows currently a stronger focus on transport and electricity and heat sectors. To achieve additional emissions reductions, a first step could be to implement (more) policies in the main emitting sectors, and additionally, to cover more policies and sectors from the policy menu (e.g. policies in industry).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (1)				
	GHG reduction target (1)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D				
		National energy efficiency target (1)	Renewable energy target		
Electricity and heat		Highly efficiency power plants	Renewable energy target (1)	CCS support scheme	
		Reduction obligation schemes	Support scheme for renewables (4)		
			Grid infrastructure development		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency	Support for renewables	CCS support scheme	Landfill methane
		Energy reporting and audits	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives	Support for heating and cooling		
		MEPS for appliances (1)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment (1)	MEPS or support for energy efficient light duty vehicles (1)	Biofuel target (1)	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (1)	Support for biofuels (2)	E-mobility	
			Sustainability standards for biomass (1)		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (2)				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (2)				

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Figure 19: Good-practice policy menu coverage in Argentina

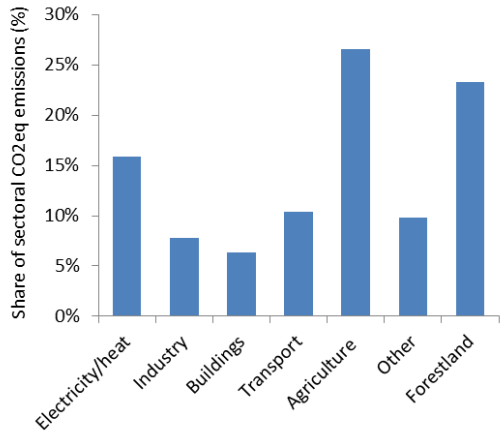

Figure 20: Sectoral GHG emissions as share of total country emissions, Argentina 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Argentina:

Electricity and heat

- *PROBIOMASA - Project for the Promotion of Energy from Biomass - implemented*: Aims to increase biomass energy capacity by 400 MW, split equally between electricity and heat.
- *Law 27191 on Renewable Energy - implemented:* Sets renewable energy share in electricity production of up to 20% by 2025. This is supported by a cap and trade mechanism, feed-in tariff and tax exemptions.

Forestry

- *Law No. 25.080 / 99 Investment in Forestry - implemented:* This law established credits and tax reliefs that cover 20% to 80% of the plantation costs.
- *Law 26.331 for the Environmental Protection of Native Forests - implemented*: A requirement for sustainable management of forests is set and non-compliance is subject to high fines. It covers 4.7million ha of forest between 2007 and 2030.

Transport

- *Law 26.093 Regimen of Regulation and Promotion of the Production and Sustainable Use of Biofuels - implemented*: Sets blending requirements of 12% biofuel in ethanol and diesel from 2016 onwards and implements tax exemptions for biofuels as support mechanism.

Buildings

- *Law 26.473 Prohibiting commercialisation of incandescent light bulbs - implemented*: Commercialisation of incandescent light bulbs has been banned since 2010.

Cross-sectoral

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets an unconditional target of 15% GHG emissions reduction (incl. LULUCF) by 2030 compared to BAU, and a conditional target (subject to external financing and support) of 30% GHG emissions reductions by 2030 compared to BAU.
- *National Program for Rational and Efficient Use of Energy (PRONUREE) - implemented:* The policy sets electricity savings targets of 6% (1500 MW) in 2016 compared to 2007.

Development related co-benefits and side-effects

Argentina is a country of median economic development amongst the G20 member states (Figure 6), although below average (Figure 21), and has a below average unemployment level, just above 6% (Figure 7). By not having a broader coverage of the good practice policy menu, Argentina misses numerous economic development co-benefits, including industry job opportunities. The share of fossil fuel consumption is rather high in Argentina, almost 90% (Figure 8), and Argentina is a net energy importer, although at a low level (Figure 11). Therefore, while part of the mitigation efforts go towards renewables, increasing energy security and lowering the use of fossil fuels, more could be done by supporting renewables in industry and buildings as well. Energy efficiency is addressed only in buildings and transport, two sectors of low emissions. However, Argentina has a very low level of energy use per GDP amongst the G20 members (Figure 9). This could be due to the economic structure of the country, which may rely on higher shares of low-energy use sectors.

Concerning health, Argentina is one of the G20 countries with lower annual PM2.5 exposure, yet, with a value above the recommended limit (Figure 12). As the highest cereal exporter amongst G20 countries, exporting more than 1.5 times its own consumption (Figure 13), Argentina could have biofuel production without impacting on food security, if cereal exports are lowered instead of domestic consumption. Biofuels are already supported through a number of policies in Argentina. Nonetheless, the country still has a small food calories deficit per person per day (Figure 14).

Given the share of emissions in the agriculture sector (27%), it is no surprise that Argentina's largest water use resides in this sector (Figure 16). Policies in the agricultural sector would help reduce both GHG emissions and water consumption, while providing co-benefits in other development areas.

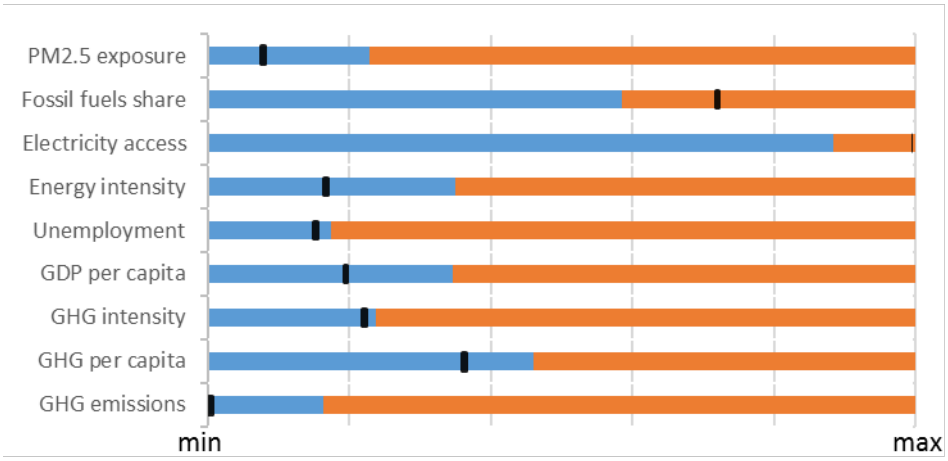

Figure 21: Development indicators in Argentina compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.2. Australia

Australia had neither very high emissions levels compared to other G20 countries, nor high GHG emissions intensity in 2014 (Figure 3 and Figure 5). The country's emissions per capita in 2014 are well above the G20 members average, yet within the lower half (Figure 4). While policies exist in all economic sectors in Australia, these focus mainly on energy efficiency, not covering policy areas such as changing activity, renewables (except for electricity and heat), and alternative fuels (Figure 22). As the electricity and heat sector covers 42% of total emissions (Figure 23), mitigation action could strongly focus on this sector, for instance, through energy efficiency improvement and a switch to renewables.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy				
	GHG reduction target (2)				
	Coordinating body for climate strategy				
	Support for low-emission RD&D (3)				
		National energy efficiency target (1)	Renewable energy target		
Electricity and heat		Highly efficiency power plants (1)	Renewable energy target (1)	CCS support scheme (1)	
		Reduction obligation schemes	Support scheme for renewables (3)		
			Grid infrastructure development		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit (1)				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency (3)	Support for renewables	CCS support scheme (1)	Landfill methane
		Energy reporting and audits (1)	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment (1)			N2O from industry
					Fluorinated gases (1)
	Overarching carbon pricing scheme or emissions limit (2)				
	Energy and other taxes (1)				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (2)	Support for heating and cooling		
		MEPS for appliances (3)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes (1)				
	No fossil fuel subsidies				
Transport	Urban planning and investment	MEPS or support for energy efficient light duty vehicles (1)	Biofuel target	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (1)	Support for biofuels	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions (1)				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products				
	Incentives to reduce CO2 emissions from agriculture (2)				
	Incentives to reduce CH4 emissions from agriculture (2)				
	Incentives to reduce N2O emissions from agriculture (2)				
	Incentives to reduce deforestation (3)				

Figure 22: Good-practice policy menu in Australia

While the Energy Productivity Plan plays an important role in reducing GHG emissions, an overarching climate change strategy and a coordinating body for climate action are missing.

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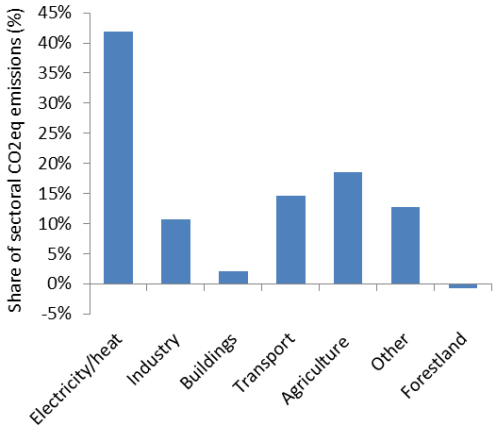

Figure 23: Sectoral GHG emissions as share of total country emissions, Australia 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Australia:

Electricity and heat

- *Renewable Energy Amendment Act 2015 - implemented*: Sets a target of 33000 GWh renewable electricity production in large scale energy production in 2020.
- *Renewable Energy (Electricity) Act 2000 and associated legislation - implemented*: Sets renewable electricity production shares for large- and small-scale producers. Renewable shares can be traded, but non-compliance is subject to a fine of $65/MWh.

Transport

- *Fuel Tax Reform - implemented:* A tax of approximately $0.4/litre applies for diesel and gasoline, and $0.013/litre for biodiesel.

Forestry

- *20 million trees - implemented*: This program aims to plant 20 million trees across Australia from 2010 to 2020.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a GHG emissions reduction target (incl. LULUCF) of 26%-28% by 2030 compared to 2005.
- *Emissions Reduction Fund - implemented:* Registered projects receive certificates for emissions reduction that are bought by the program through an auction system. This program absorbed the Carbon Farming Initiatives program that focused on GHG emissions reduction from agriculture.
- *Energy Productivity Plan - planned:* Aims to increase energy productivity (GDP ($M)/PJ) by 40% by 2030 compared to 2015.
- *CCS Flagships Programme - implemented*: Through this program, the government finances a couple of CCS pilot projects.

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- *Greenhouse and Energy Minimum Standards Act (2012) - implemented:* Sets energy and emissions standards for equipment and appliances.
- *HFC emissions reduction - planned*: Australia set a target of 55% HFC emissions reductions relative to 2010 by 2030

Development related co-benefits and side-effects

In 2015, Australia had the second highest GDP per capita amongst the G20 countries (Figure 6). While economic development per se might not be a priority in terms of climate mitigation co-benefits, new job opportunities could help reduce the 6% unemployment levels (Figure 7).

Australia is a country with one of the highest shares of fossil fuels (more than 90%) in energy consumption amongst G20 countries (Figure 8). Furthermore, it had a just below average level of energy intensity in 2014 (Figure 24). The country could focus on energy efficiency improvements and a switch to alternative fuels, increasing energy diversification at the same time. However, Australia profits economically from fossil fuel production, as it currently almost twice the total amount of energy it uses (Figure 11). Hence, economic interests might hinder plans to reduce fossil fuel production for climate mitigation purposes.

Climate mitigation co-benefits are also low in the health and food security development areas. Amongst G20 countries, Australia has the lowest mean annual exposure to PM2.5, well below the recommended limit (Figure 12). Furthermore, Australia is the second largest exporter of cereals, exporting almost 1.5 times the total amount it needs for domestic consumption (Figure 13). The high production of cereals is visible in the high share of water use in the agriculture sector, more than 65% (Figure 16). However, Australia withdraws less than 4% of its annual renewable freshwater every year (Figure 15).

Although direct co-benefits of climate mitigation policies may not be relevant in the case of Australia, climate non-action adverse side-effects should be a motivation for curving GHG emissions. Australia will be one of the countries strongly hit by the increase in temperature, through desertification, sea level rise, and a substantial or total loss of coral reefs.

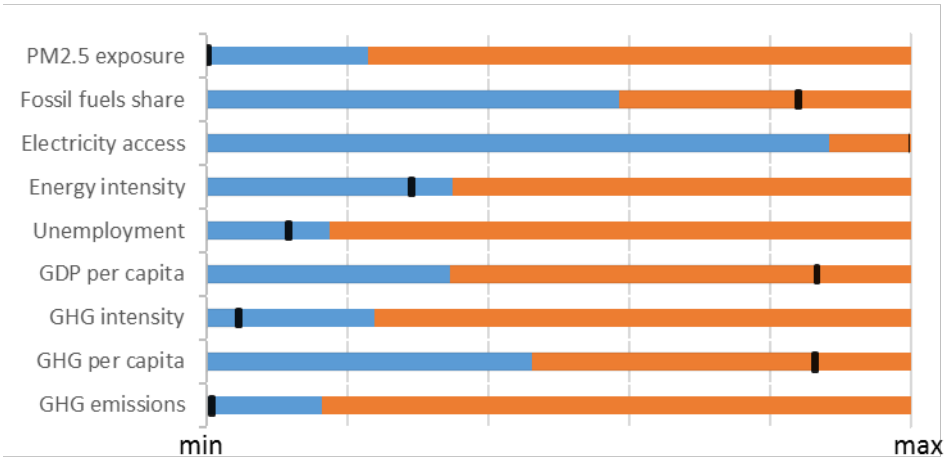

Figure 24: Development indicators in Australia compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represent the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.3. Brazil

Brazil is a low GHG emitter compared to other G20 countries, although amongst the upper half (Figure 3), and is the third lowest emitter per capita (Figure 4). Brazil also has one of the lowest GHG emissions intensity level (Figure 5, Figure 27). Climate mitigation action in Brazil covers all economic sectors (Figure 25), but not all policy areas, missing changing activity and CCS and fuel switch measures. Covering all sectors and policy areas could contribute to further decarbonisation. Brazil has stronger climate action in the forestry sector, which accounts for 34% of total national emissions (Figure 26).

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	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (2)				
	GHG reduction target (2)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D (4)				
		National energy efficiency target (1)	Renewable energy target (2)		
Electricity and heat		Highly efficiency power plants	Renewable energy target (2)	CCS support scheme	
		Reduction obligation schemes	Support scheme for renewables (7)		
			Grid infrastructure development		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes (1)				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency (1)	Support for renewables	CCS support scheme (1)	Landfill methane (1)
		Energy reporting and audits	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment (1)			N2O from industry (1)
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes (1)				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (1)	Support for heating and cooling		
		MEPS for appliances (2)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment	MEPS or support for energy efficient light duty vehicles (3)	Biofuel target (1)	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (1)	Support for biofuels (3)	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions (1)				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products				
	Incentives to reduce CO2 emissions from agriculture (2)				
	Incentives to reduce CH4 emissions from agriculture (1)				
	Incentives to reduce N2O emissions from agriculture (1)				
	Incentives to reduce deforestation (13)				

Figure 25: Good-practice policy menu coverage in Brazil

Although the agriculture sector is almost comparable in terms of emissions to the forestry sector, covering a share of 29% total GHG emissions, less policies are directed towards this area. However, a lower number of policies does not necessarily imply less stringent action. Economy-wide targets for energy efficiency, renewables shares in primary energy and GHG emissions reductions are guiding climate action in Brazil. Furthermore, Brazil has a climate change strategy and coordinating body that support climate action design and implementation.

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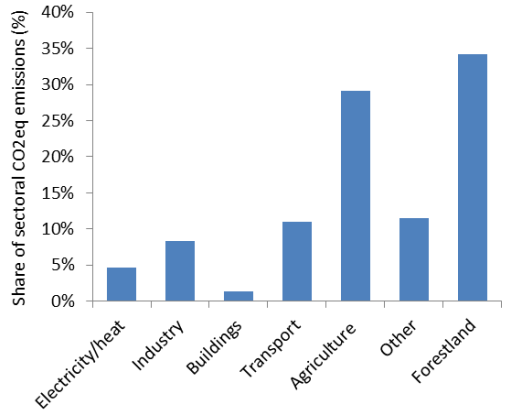

Figure 26: Sectoral GHG emissions as share of total country emissions, Brazil 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Brazil:

Electricity and heat

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets targets of 23% share of renewables in electricity production (excl. hydro) by 2030, and 10% energy efficiency improvement in the electricity sector by 2030 compared to 2015.
- *Plan for Energy Expansion of Brazil - implemented*: Sets a target of 16% renewable electricity production (excluding hydropower) by 2024, and targets for installed capacity by 2024: 117 GW hydro, 8 GW small hydro, 18 GW bioenergy, 7 GW solar, 24 GW wind.
- *Brazil Renewable Energy Auctions - implemented*: Auctions for existing and newly build renewable electricity plants. These replaced the feed-in tariff scheme that run up to 2007.

Industry

- *Climate change mitigation and adaptation sector plan for the consolidation of a low carbon economy in the manufacturing industry - planned*: Sets a target of 5% emissions reductions below business-as-usual scenario (BAU) by 2020 in the industry sector.

Transport

- *Inovar-Auto - implemented:* Sets 30% tax on sold cars that do not meet energy efficiency requirements and provides tax reliefs to cars of higher efficiency than required by the CAFE standards.
- *National Biodiesel Programme (PNPB) - implemented:* Targets biodiesel shares in diesel of 7% in 2015 and 10% in 2019.
- *Ethanol Blending Mandate - implemented: The blending requirements for ethanol are 27% from 2015 onwards*

Forestry and agriculture

- *Intended Nationally Determined Contribution (INDC) - planned:* Aims to restore and reforest 12 million ha forestland and to restore 15 million ha of degraded pasturelands by 2030.

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- *Forest Code (Law 12651) - implemented:* Aims to reforest 12 million hectares by 2030, with support from deforestation prevention and control plans PPCDAm and PPCerrados (see below).
- *Action Plan for Deforestation Prevention and Control of Deforestation and Burning in the Cerrados (PPCerrados) - planned:* Targets a 40% decrease in annual deforestation rate by 2020 as compared to the average between 1995 and 2005 in the Cerrados area.
- *Action Plan for Deforestation Prevention and Control in the Legal Amazon (PPCDAm) - implemented:* Aims for a 80% decrease in annual deforestation rate by 2020 as compared to the average between 1995 and 2005 in the Amazon forest.
- *Low-Carbon Agriculture Plan (ABC Plan) - implemented:* Aims to decrease GHG emissions in the agriculture sector by 133-166 $MtCO_2e$ by 2020, compared to BAU.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets GHG emissions reduction target (incl. LULUCF) of 37% by 2025 and 43% by 2030 compared to 2005. Additionally, renewable targets of 45% share in TPES incl. hydro and 28-33% share in TPES excl. hydro by 2030 are set. The target for biofuels share in TPES by 2030 is 18%.
- *Plan for Energy Expansion of Brazil - implemented*: Sets a target of 45% renewable energy share in primary energy (including hydropower) by 2024.

Development related co-benefits and side-effects

Brazil's GDP per capita sits in the bottom half of the G20 countries (Figure 6), while the unemployment rate is the second highest (Figure 7). Hence, the country could benefit from climate mitigation policies that provide economic development co-benefits.

Brazil currently has the lowest share of fossil fuels in primary energy consumption amongst G20 member states, below 60% (Figure 27) due to widespread use of hydropower. The country still has renewable energy support schemes and targets, mainly aimed at non-hydro renewables. A higher share of renewables would benefit energy security further, as the country currently imports more than 10% of its total energy consumption (Figure 11). Furthermore, it could help close the small remaining gap to 100% electricity access (Figure 10) by reaching remote areas with renewable energy.

Nonetheless, when encouraging renewables, Brazil would need to consider the potential negative impacts of biofuels on food security. Although a net cereal exporter (only slightly, by 3%, see Figure 13), Brazil still has an average caloric food deficit depth of 10kcal/capita/day (Figure 14).

Air quality in Brazil does not meet the WHO recommended limit of 10 µg/m3 average annual exposure to PM2.5, but it lies very close to this limit, at 11.4 µg/m3 (Figure 12). Hence, Brazil would not benefit strongly from climate policies that reduce air pollution. However, other health co-benefits, such as transportation noise reduction, road safety improvements and congestion related stress, could be relevant.

Brazil has many freshwater resources and currently uses the smallest percentage of its annual renewable freshwater compared to the other G20 countries (Figure 15). Not surprisingly, given the high GHG emissions, the largest share of water withdrawal is in agriculture (Figure 16). Policies in both agricultural and forestry sectors would help decrease water consumption, and could generate co-benefits for nature conservation.

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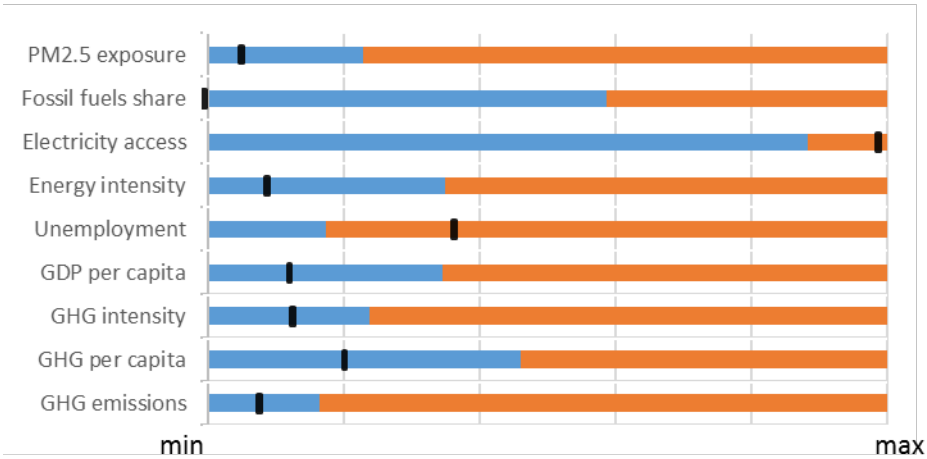

Figure 27: Development indicators in Brazil compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.4. Canada

Canada lies below the average in terms of GHG emissions compared to other G20 member states, both in terms of total emissions and emissions intensity (Figure 30). However, the country has the highest GHG emissions per capita compared to these major economies (Figure 30). Overall, climate mitigation action in Canada covers all sectors of the good practice policy menu (Figure 28), but places higher focus on energy efficiency as a policy area, perhaps due to the country high energy intensity level (Figure 9). Canada's GHG emissions are almost equally distributed across sectors, although electricity and heat (22%) and transport (21%) cover the highest percentage of emissions, followed by industry (16%) and forestry (13%).

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	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (1)				
	GHG reduction target (2)				
	Coordinating body for climate strategy				
	Support for low-emission RD&D (5)				
Electricity and heat		National energy efficiency target	Renewable energy target		
		Highly efficiency power plants (1)	Renewable energy target	CCS support scheme (3)	
		Reduction obligation schemes	Support scheme for renewables (2)		
			Grid infrastructure development (2)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process (2)	Industrial production efficiency	Support for renewables (1)	CCS support scheme (3)	Landfill methane (1)
		Energy reporting and audits (2)	Sustainability standards for biomass		CH4 – oil and gas (2)
		MEPS for equipment (3)			N2O from industry (1)
					Fluorinated gases (1)
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (4)	Support for heating and cooling		
		MEPS for appliances (4)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment	MEPS or support for energy efficient light duty vehicles (3)	Biofuel target	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (4)	Support for biofuels (2)	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (2)				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (1)				

Figure 28: Good-practice policy menu coverage in Canada

Future step in decarbonization could aim to cover the good practice policy menu sections that currently lack climate action, and to focus on the sectors of highest emissions. Furthermore, establishing a coordinating body for climate change could help support climate action design and implementation.

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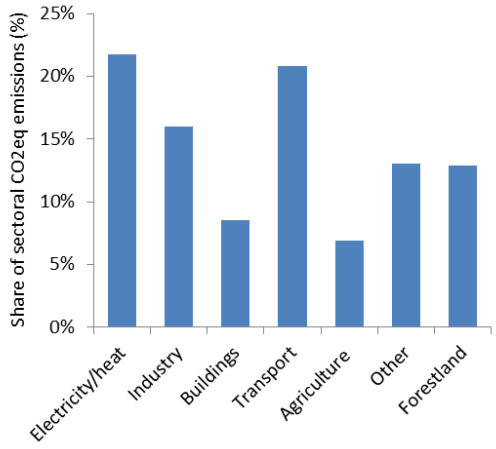

Figure 29: Sectoral GHG emissions as share of total country emissions, Canada 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Canada:

Electricity and heat

- *New coal-fired power plants standards - implemented:* Sets a standard of 420 gCO_2/kWh for coal power plants built after 2015.
- *EcoENERGY for Renewable Power program - implemented*: Supports renewable energy production by providing CAD 0.01/kWh produced for a period of 10 years to projects started before 2011.

Transport

- *On-road vehicles and engine emissions regulations - implemented*: Sets a GHG emissions target for light-duty vehicles of 98 gCO_2/km and an energy efficiency target of 23.2km/l by 2025.
- *Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations - implemented*: Sets a target of 46% fuel consumption reduction for heavy-duty vehicles by 2025, compared to 2010.
- *Renewable Fuels Regulations (Biofuels Bill) - implemented:* Sets targets of 5% bio-ethanol content in gasoline and 2% biodiesel content in diesel fuel and heating oil from 2011 onwards.
- *Marine Vessel Fuel Efficiency Regulations - planned:* Sets a target of 30% energy efficiency improvement by 2025, applying to new vessels of over 400 gross tonnage (international shipping)

Buildings

- *ENERGY STAR for New Homes Standard - implemented*: Addresses energy efficiency in residential buildings via performance codes for insulation and electrical equipment.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a target of 30% GHG emissions reductions (incl. LULUCF) by 2030 compared to 2005.
- *EcoENERGY Efficiency program - implemented*: Aimed to invest $195 million between 2011 and 2016 to improve energy efficiency in the residential, commercial and transport sectors.

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- *Amendment 12B to the Energy Efficiency Regulations - implemented*: Sets a ban on commercialisation of incandescent light bulbs from 2013 onwards.
- *Clean Energy Fund - implemented*: Supported the implementation of demonstration projects for renewable energy and clean energy systems, including carbon capture and storage, between 2010 and 2014. This investment is expected to result in GHG emissions reductions until 2025.

Development related co-benefits and side-effects

Canada had the third highest GDP per capita within the G20 countries (Figure 6), and an average unemployment rate (Figure 30). Economic development co-benefits of climate mitigation would likely not be a priority for the country, except for those that could provide new job opportunities. Canada has a lower than average share of fossil fuels in the total energy consumption (Figure 30), although still above 70% (Figure 8). Furthermore, it exports more than half of its total energy consumption (Figure 11), and has 100% electricity access (Figure 30). Hence, energy security and energy access may not represent high incentives as co-benefits of decarbonization. Moreover, Canada profits from export of fossil fuels, including also tar sands oil.

Canada's annual exposure to PM2.5 is well within the recommended limit (Figure 12), and would not benefit substantially from air pollution reduction co-benefits of mitigation. However, other health-related benefits, such as decreased mining accidents and reduced traffic stress could be beneficial. As an exporter of cereals (more than 50% of its total consumption, see Figure 13), Canada would not be affected by decreased food security if more biofuels would be produced within the country.

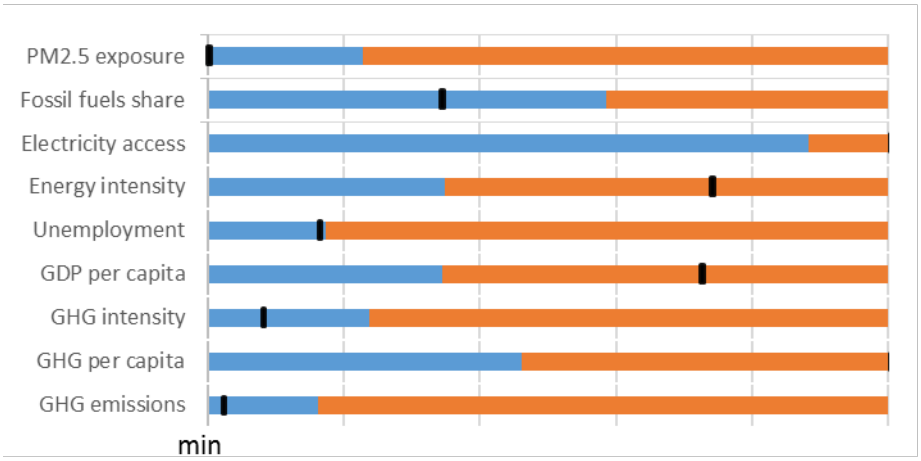

Figure 30: Development indicators in Canada compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.5. China

China was the highest GHG emitter among the G20 countries (and worldwide) in 2014, with an annual level of emissions of more than 12 $GtCO_2eq$ (Figure 3). This emissions level is double that of the next highest emitter, the United States, and more than triple that of the third highest emitter, the European Union. However, the country has a below average level of emissions per capita (Figure 33). Energy intensity is also high in China, the fourth highest within G20 (Figure 9), but GHG emissions intensity is only slightly higher than that of the European Union (Figure 5).

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	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (1)				
	GHG reduction target (3)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D				
		National energy efficiency target (2)	Renewable energy target (3)		
Electricity and heat		Highly efficiency power plants (3)	Renewable energy target (1)	CCS support scheme	
		Reduction obligation schemes	Support scheme for renewables (20)		
			Grid infrastructure development (3)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process (6)	Industrial production efficiency (4)	Support for renewables	CCS support scheme	Landfill methane
		Energy reporting and audits (3)	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment (9)			N2O from industry
					Fluorinated gases (1)
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (3)	Support for heating and cooling		
		MEPS for appliances (1)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment	MEPS or support for energy efficient light duty vehicles (7)	Biofuel target	Modal share shift (1)	
		MEPS or support for energy efficient heavy duty vehicles (4)	Support for biofuels (1)	E-mobility (3)	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions (1)				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (2)				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (11)				

Figure 31: Good-practice policy menu coverage in China

This situation might be due to a large share of emissions and energy intensive industries in the economy and the extensive use of coal power plants. China has climate mitigation policies across all sectors in the good practice policy menu (Figure 31), but shows a stronger focus on renewables in the electricity sector and energy and material efficiency across all relevant sectors. The stronger focus on the electricity and heat sector can be justified by the high GHG emissions levels in this sector (43%, see Figure 32). Next to electricity and heat, industry is the second highest emitting sector (29%). In the industry sector, China mainly focuses on energy and material efficiency. Future steps towards

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decarbonization could increase mitigation in these high emitting sectors and cover policy areas that are currently neglected, such as non-energy in industry.

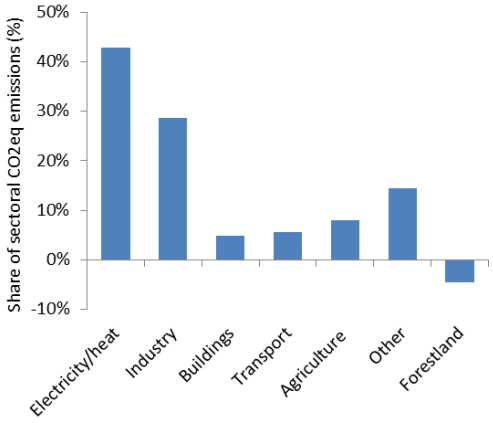

Figure 32: Sectoral GHG emissions as share of total country emissions, China 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in China:

Electricity and heat

- *Action Plan for Upgrading of Coal Power Plants - implemented*: Implements a minimum standard of 310 gce/kWh (gram standard coal per kWh) for coal-fired power plants.
- *Renewable Energy Electricity feed-in tariff - implemented*: Feed-in tariffs for both wind and solar PV electricity production, varying per region.
- *Energy Development Strategy Action Plan (2014-2020) - implemented:* Sets 2020 installed capacity targets of 58 GW nuclear (with additionally 30GW under construction), 350 GW hydropower, 200 GW wind, 30 GW biomass, and 100 GW solar PV and a share of 15% non-fossil fuels in the energy mix. It also sets a planned target of 20% share of non-fossil fuels in the energy mix.

Industry

- *Industrial Energy Performance Standards - implemented:* Energy consumption standards for most industrial sectors, including cement, steel and coke, addressing both old and new plants.
- *Made in China 2025 - implemented*: Targets carbon intensity decrease per industrial value added of 22% by 2020 and 40% by 2025 compared to 2015.
- *Green industry development plan (2016-2020) - implemented*: Targets 18% energy consumption decrease per industrial value added by 2020 compared to 2015.

Transport

- *Energy saving and new energy automotive industry development plan (2012-2020) - implemented:* Sets a 2020 target of 5 million pure-electric and plug-in cars on the road, and a supply capacity of 2 million such cars per year. Furthermore, it sets passenger vehicles energy efficiency and GHG emissions targets of 5 L/100 km and 120 gCO_2/km by 2020.

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- *Management of Subsidy Fund of Private New Energy Vehicles (Interim) - implemented:* Subsidies for pure-electric and plug-in cars are provided, with a value of 3000 CNY/kWh, based on the battery capacity.
- *Vehicle Fuel Economy Standards - implemented*: Light-duty vehicle fuel efficiency standard is 6.9L/100 km from 2014 onwards. Heavy-duty vehicle standards are 15 L/100 km to 25 L/100 km (depending on weight) for medium-duty trucks and 28 L/100 km to 45 L/100 km for heavy-duty trucks.
- *13th Five-Year Plan (2016-2020*) - planned: Aims to remove 4 million high emissions vehicles by 2020.

Buildings

- *National Building Energy Standard - implemented*: 30% of new buildings meet an energy consumption standard of 120 kWh/m^2 in 2020.

Agriculture and forestry

- *Intended Nationally Determine Contribution (INDC) - planned:* Aims to increase forest stock by 4.5 billion cubic meters by 2030 compared to 2005.
- *13th Five-Year Plan (2016-2020*) - *implemented*: Sets a target of 23.04% forest coverage by 2020. Furthermore, it aims to turn 1 million ha of marginal cropland into grassland or forest land.
- *National Plan for Tackling Climate Change (2014-2020) - implemented*: Aims to increase forest resources by expanding forest area by 40 million ha by 2020 and forest stocks by 1.3 million m^3 by 2020 compared to 2005.

Cross-sectoral

- *Intended Nationally Determine Contribution (INDC) - planned:* Sets CO_2 emissions intensity reduction target of 60%-65% by 2030 compared to 2005. Aims to have a share of 20% non-fossil fuels in primary energy, and sets goals of HFC-22 emissions reductions of 35% by 2020 and 68% by 2030 compared to 2010.
- *National Plan for Tackling Climate Change (2014-2020) - implemented*: Sets 2020 target of 15% share of non-fossil fuels in primary energy consumption. Furthermore, the plan aims to reduce carbon intensity per unit GDP by 40-45% by 2020 compared to 2005.
- *Medium and Long Term Development Plan for Renewable Energy - implemented:* Sets a biofuel production target of 12 million tonnes/year (10 million biodiesel and 2 million ethanol) in 2020.
- *Energy Development Strategy Action Plan (2014-2020) - implemented:* Sets a coal consumption cap of 4.2 Gt/year, representing 62% of the total energy mix, and gas production value of 185 billion m^3/year, equivalent to 10% in the energy mix by 2020. It also sets a 2030 target of 20% share of non-fossil fuels in primary energy mix.
- *13th Five-Year Plan (2016-2020) - implemented:* Aims for a 15% reduction in energy intensity of GDP and 18% reduction in carbon intensity of GDP by 2020 compared to 2015. The plan also sets a total energy consumption cap of 5Gtce/year (5 billion standard coal equivalent tonnes per year).

Development related co-benefits and side-effects

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

China has a low GDP per capita compared to other G20 countries (Figure 33) and would profit from climate mitigation co-benefits in support of this development area. Furthermore, it currently has a share of fossil fuels in total energy consumption of almost 90% (Figure 8). A switch to alternative fuels could, with some exceptions, lead to improved work safety and water and ecosystems benefits. Furthermore, use of renewables and diversification of energy production sources would improve energy security, a benefit that could be important for China, considering that it is currently a net importer of energy (Figure 11). However, biofuel production may not be a beneficial option, given that the country is currently slightly dependent on cereal imports (Figure 13) and competition between biofuels and food could add further pressure on food security. China's highest water use is in the agriculture sector (Figure 16). Tackling GHG emissions from this sector should consider water use impacts as well.

One of the important benefits that China could gain from climate mitigation is improved air quality, as China currently has the third highest PM2.5 mean annual exposure within G20, after Saudi Arabia and India (Figure 33).

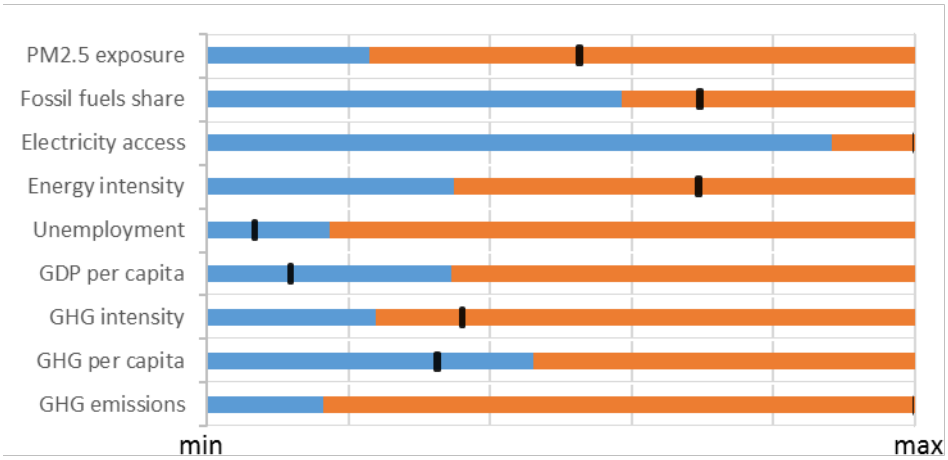

Figure 33: Development indicators in China compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.6. European Union

The European Union (EU) is the third highest GHG emitter within G20 countries, with total emissions levels of approximately 3.8GtCO_2eq in 2014 (Figure 3). However, EU has the lowest GHG emissions intensity levels (Figure 5) and below average GHG emissions per capita (Figure 36). Furthermore, it also has one of the lowest levels for energy intensity (Figure 9). EU has a high coverage of the good practice policy menu, with policies across all sectors and policy areas. Covered here are only EU-wide policies, not policies of EU member states. Electricity and heat is the sector responsible for the highest share of GHG emissions (37%), followed by transport (22%), industry (17%) and buildings (15%) (Figure 35).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (2)				
	GHG reduction target (5)				
	Coordinating body for climate strategy				
	Support for low-emission RD&D (2)				
		National energy efficiency target (2)	Renewable energy target (2)		
Electricity and heat		Highly efficiency power plants (3)	Renewable energy target	CCS support scheme (1)	
		Reduction obligation schemes	Support scheme for renewables (2)		
			Grid infrastructure development (1)		
			Sustainability standards for biomass use (1)		
	Overarching carbon pricing scheme or emissions limit (1)				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process (1)	Industrial production efficiency (3)	Support for renewables (1)	CCS support scheme (1)	Landfill methane (1)
		Energy reporting and audits (2)	Sustainability standards for biomass (1)		CH4 – oil and gas (1)
		MEPS for equipment (3)			N2O from industry (1)
					Fluorinated gases (3)
	Overarching carbon pricing scheme or emissions limit (1)				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (3)	Support for heating and cooling		
		MEPS for appliances (3)	Support for hot water and cooking		
			Sustainability standards for biomass (1)		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment (1)	MEPS or support for energy efficient light duty vehicles (4)	Biofuel target (2)	Modal share shift (2)	
		MEPS or support for energy efficient heavy duty vehicles (2)	Support for biofuels (1)	E-mobility	
			Sustainability standards for biomass (1)		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products				
	Incentives to reduce CO2 emissions from agriculture (1)				
	Incentives to reduce CH4 emissions from agriculture (1)				
	Incentives to reduce N2O emissions from agriculture (1)				
	Incentives to reduce deforestation (5)				

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Figure 34: Good-practice policy menu in the European Union

Future steps towards decarbonization could focus on these high-emissions sectors and the good practice policy menu areas that are currently neglected at the EU level, such as E-mobility or renewables in the buildings sector.

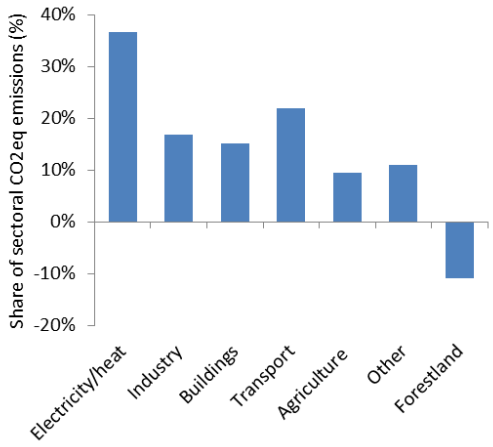

Figure 35: Sectoral GHG emissions as share of total country emissions, European Union 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in EU:

Transport

- *Emission performance standards for new light commercial vehicles (Regulation (EU) No. 510/2011) - implemented:* Mandates an average CO_2 emissions limit of 175 gCO_2/km for light-duty vehicles from 2011, and sets a target of 147 gCO_2/km in 2020.
- *Emission performance standards for new passenger cars (Regulation (EC) No. 443/2009) - implemented:* The regulation mandates an average CO_2 emissions limit of 120 gCO_2/km for passenger vehicles from 2012, and sets a target of 95 gCO_2/km in 2020.
- *Directive 2009/28/EC Biofuel target - implemented*: Sets a 2020 target for renewable share (biofuels and renewable electricity) of 10% in transport energy use.
- *Fuel Quality (Directive 2009/30/EC) - implemented:* Allows commercialisation of 7% biodiesel content in diesel oil and 10% ethanol in gasoline. Furthermore, it mandates a 10% emissions reduction target in the fuel production lifecycle by 2020, compared to 2010.
- *Roadmap to single European transport area - planned:* This long-term strategy has a number of targets within the transport sector, including 20% GHG emissions reductions by 2030 compared to 2008 and 60% by 2050 compared to 1990, 50% reduction in conventionally-fuelled cars in cities by 2030 and 100% reduction by 2050.

Buildings

- *Directive 2010/31/EU on the energy performance of buildings - implemented:* Sets a target for all newly constructed buildings (both residential and non-residential) to have near-zero emissions performance by 2020.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a target of 40% GHG emissions reduction (incl. LULUCF) by 2030 compared to 1990.
- *2020 Climate and Energy Package - implemented*: Sets the following 2020 targets: 20% GHG emissions reduction (including LULUCF) compared to 1990, 20% renewables share in energy consumption, and 20% energy consumption reduction compared to BAU.
- *2030 Climate and Energy Package - planned*: Sets the following 2030 targets: at least 40% GHG emissions reduction (including LULUCF) compared to 1990, at least 27% renewables share in energy consumption, and at least 27% energy consumption reduction compared to BAU.
- *Directive 2012/27/EU on Energy efficiency (amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC) - implemented:* Mandates annual energy savings of 1.5% of total sales for energy distributors or retail energy sales companies (does not apply to small companies).
- *EU Emission Trading System (EU ETS) (Directive 2009/29/EC amending Directive 2003/87/EC) - implemented:* Includes a large share of industries and electricity and heat producers (covering 1800 $MtCO_2eq$). Sets a target of 21% GHG emissions reductions by 2020 compared to 2005, in sectors covered by the system.
- *Eco-design (Directive 2009/125/EC) - implemented:* Sets energy consumption standards for both residential and industrial energy-related equipment.
- *Fluorinated greenhouse gases (Regulation No. 517/2014, repealing Regulation No. 842/2006) - implemented:* Sets a target for non-CO_2 emissions reductions, including fluorinated GHGs, but excluding emissions from agriculture, of 72-73% by 2030 and 70-78% by 2050 compared to 1990.

Development related co-benefits and side-effects

EU has an above average GDP per capita (Figure 36), but a high unemployment rate (above 8.5%, see Figure 7). Therefore, climate mitigation action that leads to an increase in job opportunities would be highly beneficial for EU. EU has a below average share of fossil fuels in total energy consumption, but the level is high, above 70% (see Figure 36 and Figure 8). Furthermore, the country is currently importing approximately 50% of its total energy consumption (Figure 11), placing it in a vulnerable position concerning energy security. Diversification of energy resources, increase in the share of renewables, and energy efficiency improvements could help EU increase its energy security. EU average annual exposure to PM2.5 is only slightly above recommended levels (Figure 12). Hence, air quality improvement would only be an important benefit of decarbonization for currently highly polluted areas.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

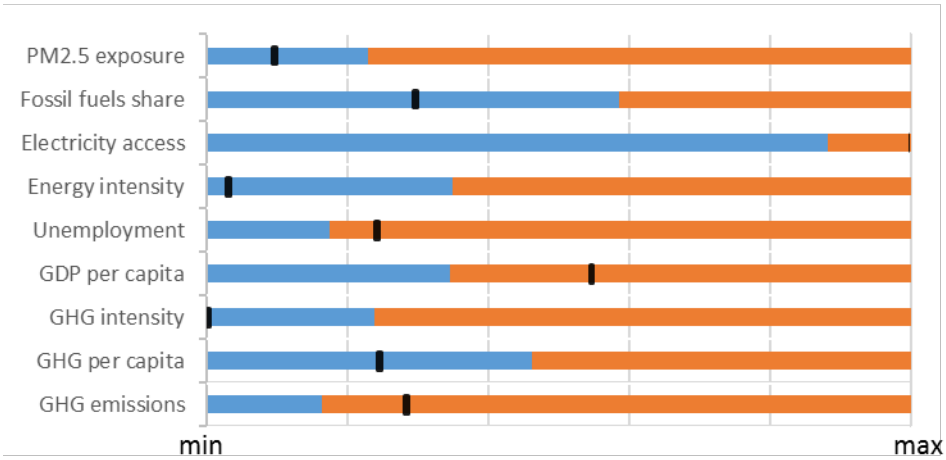

Figure 36: Development indicators in European Union compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.7. India

India is the fourth highest emitter in G20, with emissions of above 3GtCO_2eq (Figure 3). Furthermore, it has above average emissions intensity levels (Figure 5). However, India is the G20 member country with the lowest GHG emissions level per capita (Figure 4). India has climate mitigation policies across all sectors and covers most policy areas, but with strongest focus on renewables in the electricity and heat sector (Figure 37). The country's GHG emissions are dominated by the electricity and heat sector (38%), followed by agriculture (25%) and industry (17%) (Figure 38). Although agriculture has a very large share of emissions, more policies were identified in the forestry sector.

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	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (1)				
	GHG reduction target (1)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D (1)				
		National energy efficiency target	Renewable energy target		
Electricity and heat		Highly efficiency power plants (1)	Renewable energy target (4)	CCS support scheme	
		Reduction obligation schemes (1)	Support scheme for renewables (15)		
			Grid infrastructure development (2)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit (1)				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency (4)	Support for renewables (2)	CCS support scheme	Landfill methane
		Energy reporting and audits (2)	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment (1)			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit (1)				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning (2)	MEPS or fiscal/financial incentives (2)	Support for heating and cooling (1)		
		MEPS for appliances (1)	Support for hot water and cooking (1)		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment (1)	MEPS or support for energy efficient light duty vehicles (4)	Biofuel target	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (3)	Support for biofuels (3)	E-mobility (1)	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (1)				
	Incentives to reduce CO2 emissions from agriculture (1)				
	Incentives to reduce CH4 emissions from agriculture (1)				
	Incentives to reduce N2O emissions from agriculture (1)				
	Incentives to reduce deforestation (10)				

Figure 37: Good-practice policy menu coverage in India

Future steps towards low-carbon transition should focus on the sectors of high emissions, and policy areas which are currently not covered, such as material efficiency and non-energy in the industry sector.

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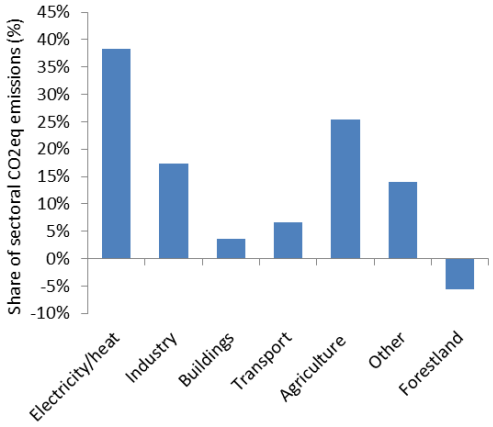

Figure 38: Sectoral GHG emissions as share of total country emissions, India 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in India:

Electricity and heat

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a financially conditional target of 40% share of renewables in electricity production by 2030, including 100 GW solar installed capacity and 60 GW wind installed capacity by 2022
- *National Solar Mission (Phase I and II) – planned:* Sets a target of 100 GW installed capacity of solar electricity by 2022.
- *National Wind Mission - planned*: Sets a target of 60 GW installed wind power capacity by 2022.
- *Government Assistance for Small Hydropower Stations - planned:* Sets a target of 5 GW small hydro installed capacity by 2022, supported by economic incentives
- *Central Financial Assistance (CFA) for Biogas Plants - implemented:* Sets a target of 10 GW biogas installed capacity by 2022, supported by economic incentives.
- *Renewable Purchase Obligations - implemented*: Mandates electricity producers to purchase a percentage of the total generation from renewables. The national target was set at 6% in 2010/11 and is to be progressively increased by 1% each year, reaching 15% by 2020.
- *Twelfth Five Year Plan (2012–2017) - implemented:* Use of supercritical power plants as part of the focus area 'Advanced coal technologies', resulting in efficiency improvements equivalent to a power plant standard of 840 gCO_2/kWh.

Industry

- *Perform, Achieve, Trade (PAT) Scheme - implemented*: Sets a target of 2.2 Mtoe reduction in total industrial energy consumption by 2015 compared to BAU and 7 Mtoe by 2020.

Transport

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

- *National Electric Mobility Mission Plan - planned*: Sets a target of 6-7 million annual sales of hybrid and electric vehicles from 2020 onwards.
- *Vehicle energy consumption standards - planned*: Light-duty vehicle GHG emissions standards are 130 gCO_2/km by 2016 and 113 gCO_2/km by 2021.
- *National Policy on Biofuels - implemented:* Sets a mandatory ethanol blending volume of 5% in petrol from 2007, and 10% from 2008. Planned targets of 20% for both biodiesel blend in diesel and bioethanol blend in petrol, from 2017 onwards are also set.

Agriculture and forestry

- *National Green India Mission (GIM) - planned:* Sets a target of 5 million ha forest area increase by 2030 compared to 2005, expected to lead to 13 $MtCO_2e$ emissions reduction for the same period.
- *Green Highways (Plantation, Transplantation, Beautification and Maintenance) - planned:* Aims to increase tree plantations along highways, expected to lead to cumulative GHG emissions reductions of 2$MtCO_2eq$ between 2005 and 2030.
- *Intended Nationally Determined Contribution (INDC) - planned:* Aims to create an additional carbon sink of 2.5-3 $GtCO_2eq$ in the forestry sector.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets an emissions intensity (GHG/GDP) reduction target of 33%-35% by 2030 compared to 2005.

Development related co-benefits and side-effects

India has the lowest GDP per capita among G20 countries (Figure 39). Hence, economic co-benefits of climate mitigation would be a gain that should be maximized. With the low unemployment rate (Figure 39), new job opportunities could mainly bring higher quality jobs to India as important co-benefit. In terms of energy, India suffers the lowest electricity coverage of population in G20, just below 80% (Figure 10), and is dependent on energy imports for one third of its total energy consumption (Figure 11). The country could, therefore, highly benefit from positive impacts of renewables on both energy access and energy security. While India has the third lowest share of fossil fuels in total energy consumption in G20, this proportion is still very high, above 70% (Figure 8). Next to renewables, energy efficiency improvements would also increase energy security in the country.

Although energy security could be improved by an increase in renewable energy sources, biofuel production may also have negative effects for India. Current cereal import dependency ratio in India is close to positive (Figure 13), and the country suffers the highest food deficit depth among G20 countries (Figure 39). Resource competition between biofuels and food might push India into an even more vulnerable position with regard to food security.

Informed choices of climate mitigation policies in the agricultural sector could increase food security and lower disproportionate share of water used in this sector, 90% (Figure 16). Air quality in India is very poor, with PM2.5 mean annual exposure of almost 7.5 times the recommended limit (Figure 12). Air quality improvement co-benefits of climate mitigation would therefore, be highly important for India.

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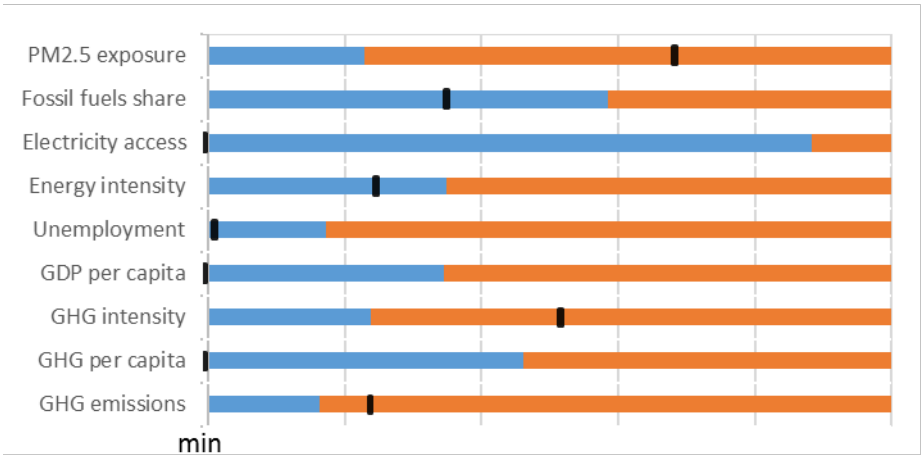

Figure 39: Development indicators in India compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.8. Indonesia

Indonesia had an average GHG emissions level compared to other G20 countries in 2014, approximately 2.7GtCO_2eq, but the highest GHG intensity (Figure3, Figure 42). However, its GHG emissions per capita are rather low (Figure 4). Indonesia's GHG emissions are dominated by the forestry sector (58%), followed by electricity and heat (9%), agriculture and industry (9%) (Figure 41). Good practice policy menu coverage appears to be in line with sectoral emissions, with a large number of policies implemented in the forestry sector (Figure 40). Next to forestry, renewables in the electricity and heat sector is another area of high coverage. However, many policy areas are still not covered by climate policies.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (1)				
	GHG reduction target (1)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D (1)				
		National energy efficiency target (1)	Renewable energy target (2)		
Electricity and heat		Highly efficiency power plants (1)	Renewable energy target (2)	CCS support scheme	
		Reduction obligation schemes	Support scheme for renewables (10)		
			Grid infrastructure development (1)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process (1)	Industrial production efficiency	Support for renewables	CCS support scheme	Landfill methane
		Energy reporting and audits (1)	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment (1)			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (1)	Support for heating and cooling		
		MEPS for appliances	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment	MEPS or support for energy efficient light duty vehicles (2)	Biofuel target (1)	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (1)	Support for biofuels (2)	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions (1)				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (2)				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture (1)				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (22)				

Figure 40: Good-practice policy menu coverage in Indonesia

Future decarbonisation steps could focus on high- emissions sectors and aim to cover neglected policy areas, such as industrial production efficiency and non-energy related emissions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

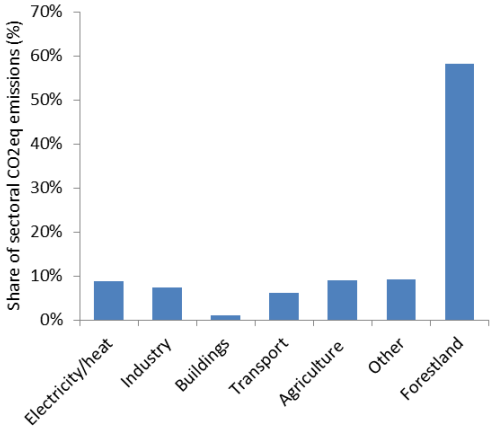

Figure 41: Sectoral GHG emissions as share of total country emissions, Indonesia 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Indonesia:

Electricity and heat

- *National Electricity Plan (RUKN) - implemented:* Sets a target of 25% share of non-fossil electricity production (including nuclear) by 2025.
- *Electricity Supply Business Plan (RUPTL) (2016-2025) - implemented:* Aims to install additional renewable energy capacity of 2 GW hydropower, 0.7 GW geothermal, and 0.2 GW wind/solar between 2015 and 2019. Furthermore, the plan sets a target of 99.7% electrification rate by 2025.
- *Electricity Purchase from Small and Medium Scale Renewable Energy and Excess Power (No. 4/2012) - implemented:* Provides feed-in tariffs for small and medium scale renewable energy producers.
- *Ceiling Price for Geothermal (Ministerial Regulation No. 17/2014) - implemented:* Geothermal energy price is capped at a few Rp/kWh, differentiated by region.

Transport

- *Biofuel Blending (Ministry Regulation No. 25/2013) - implemented:* Mandates shares of 20% bio-ethanol in gasoline and 25% biodiesel in diesel by 2025.

Forestry

- *Forest Law Enforcement National Strategy (FLENS) - implemented:* Aims to curb illegal logging and reduce current deforestation rate by 20–50 Mm^3 per year between 2015 and 2025.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Aims to reduce GHG emissions (incl. LULUCF) by 26% by 2020 and 29% by 2030 compared to BAU. The financially conditional target is up to 41% GHG emissions reduction by 2030 compared to BAU.
- *Energy efficiency labelling program - implemented*: Voluntary labelling program that covers televisions, refrigerators, air conditioners, ballasts and washing machines.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

- *National Energy Policy (Government Regulation No. 79/2014) - planned:* Sets a target of 0% share of gas import in TPES by 2025. Furthermore, it plans a share of new and renewable energy (incl. nuclear) in TPES of 19% by 2025. An additional 5 GW gas fired power capacity is required to meet the planned target of 23% renewable energy (incl. nuclear). Note that there are some differences in the goals expressed in various planning documents.

Development related co-benefits and side-effects

Indonesia has a very low GDP per capita compared to other G20 countries, higher only than India (Figure 6). Therefore, economic co-benefits of climate mitigation would be an important gain for Indonesia. Given the below average unemployment rate in the country (Figure 42), new job opportunities related to climate mitigation may not be an important gain to increase employment rate per se, but it could benefit the country through higher quality jobs. Indonesia has a low energy intensity level (Figure 42). Furthermore, it has the second lowest share of fossil fuels in total energy consumption within G20, approximately 66% (Figure 8). An increase in the use of renewable resource could benefit the remaining isolated areas that have no access to electricity (Figure 42). However, the country currently benefits economically from exports of energy, exporting more than its total domestic consumption (Figure 11).

Annual mean exposure to PM2.5 in Indonesia is approximately 50% above the recommended value (Figure 12), although below average compared to other G20 countries (Figure 42). Implementing additional climate mitigation policies, such as decreased use of coal and support for E-mobility, would improve the air quality of the country. However, biofuel production as a climate mitigation measure could lead to an increase to the existing food security issue. Indonesia is currently dependent on important for around 13% of its cereals consumption (Figure 13), and has the third highest depth of food deficit in G20 (Figure 14). Moreover, above 80% of water use is for the agriculture sector (Figure 16). Benefits of selected climate mitigation policies in the agriculture sector should consider both food security and water use.

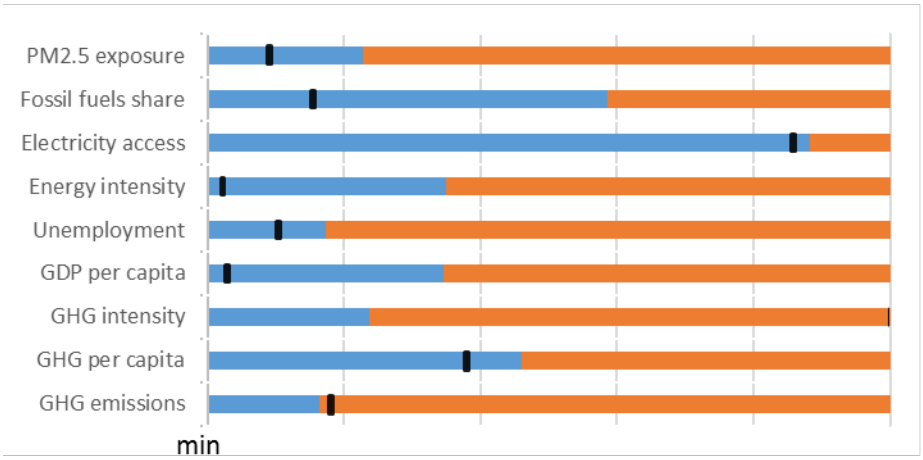

Figure 42: Development indicators in Indonesia compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.9. Japan

Japan had below average GHG emissions in 2014 (Figure 45), and well below average GHG emissions intensity in G20 (Figure 5). However, the country's GHG emissions per capita places Japan in the G20 upper half (Figure 45). The main GHG emitting sector in Japan is electricity and heat (46%), followed by industry (29%) and transport (20%) (Figure 44). While almost all sectors of the good practice policy menu are covered by implemented climate policies, certain areas are not included. For instance, policies that address GHG emissions in the agriculture sector were not found. However agricultural emissions share is only 2% (Figure 44). In the future, Japan could aim to cover the remaining areas, such as biofuels in transport and material efficiency in industry.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy				
	GHG reduction target (2)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D (1)				
		National energy efficiency target	Renewable energy target		
Electricity and heat		Highly efficiency power plants (6)	Renewable energy target (1)	CCS support scheme	
		Reduction obligation schemes	Support scheme for renewables (5)		
			Grid infrastructure development (1)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit (1)				
	Energy and other taxes (2)				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency (4)	Support for renewables	CCS support scheme (1)	Landfill methane
		Energy reporting and audits (3)	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment (2)			N2O from industry
					Fluorinated gases (1)
	Overarching carbon pricing scheme or emissions limit (3)				
	Energy and other taxes (1)				
	No fossil fuel subsidies				
Buildings	Urban planning (1)	MEPS or fiscal/financial incentives (8)	Support for heating and cooling (1)		
		MEPS for appliances (1)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes (1)				
	No fossil fuel subsidies				
Transport	Urban planning and investment (3)	MEPS or support for energy efficient light duty vehicles (4)	Biofuel target	Modal share shift (1)	
		MEPS or support for energy efficient heavy duty vehicles (4)	Support for biofuels	E-mobility (1)	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions (2)				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (4)				

Figure 43: Good-practice policy menu coverage in Japan

Furthermore, an implemented climate strategy could bring focus and support for climate action.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

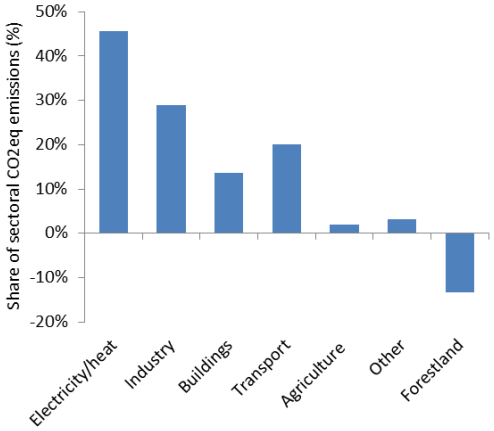

Figure 44: Sectoral GHG emissions as share of total country emissions, Japan 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Japan:

Electricity and heat

- *Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities (Law No. 108 of 2011) - implemented:* Sets a renewable energy consumption tax of JPY 2.25/ kWh (since 2016). Furthermore, it provides feed in tariffs based on the size of the power plants for onshore and offshore wind energy, geothermal energy, small and micro hydropower, solar PV and bioenergy (non-wood and wood biomass, waste, biogas and methane).
- *4th Strategic Energy Plan - implemented*: Sets targets for electricity sources in 2030: 20%-22% nuclear, 22%-24% renewables (including hydropower), 26% coal, 27% liquefied natural gas, and 3% oil.

Industry

- *Law Concerning the Rational Use of Energy (Energy Conservation Act) (Law No.49 of 1979) - implemented:* Sets a requirement of 1% decrease in energy consumption for industries consuming more than 1500kL oil equivalent annually (90% of the sector) and enforces it by a non-compliance fine of JPY 1 million.
- *Act on Rational Use and Proper Management of Fluorocarbons - implemented:* Aims to reduce F-gas emissions by 9.7-15.6 $MtCO_2e$ by 2020, compared to BAU.

Transport

- *Eco-Car Tax Break and Subsidies for Vehicles - implemented*: Subsidies are provided upon purchase of environmentally friendly cars. In 2016, JPY 15 million were distributed (up to JPY 160.000 per unit). Furthermore, tax reliefs are provided in relation to the acquisition tax and the automobile weight-related tax.
- *Fuel Efficiency Standards for Vehicles - Top Runner Program - implemented*: Sets fuel consumption standards of 16.8km/L in 2015, and 20.3km/L by 2020.
- *Environment-related tax on vehicle:* Two taxes - *implemented*: one relates to emissions, and the other is applied as a percentage of the acquisition value, based on weight.

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Buildings

- *Regulation and Standard for Housing and Building (Energy Conservation Act) - implemented:* Sets building energy use standards ranging from 290 MJ/m^3/year to 460 MJ/m^3/year, depending on climate zone.

Forestry

- *J-Credit Scheme - implemented*: Provides emission reduction certificates for forest management-related GHG emissions reductions.
- *Basic Plan for Forest and Forestry - implemented*: Sets a target of 3.5% (44 $MtCO_2e$) emissions reductions from forest sinks by 2020, compared to 1990.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a target of 26% GHG emissions reduction (incl. LULUCF) by 2030, compared to 2013
- *Act Partially Amending the Law on Special Tax Measures (Tax Reform Act 2012) (Law No. 16 of 2012) - implemented:* Fossil fuels are taxed through a special tax measure and a climate mitigation tax as follows: JPY 2,040/kl + JPY 760/kl (added climate mitigation tax) on crude oil, JPY 1,080/t + JPY 780/t (added climate mitigation tax) on gaseous fuels and JPY 700/t + JPY 670/t (added climate mitigation tax) on coal.
- *Energy Tax on Fossil Fuels - implemented*: Energy taxes apply to fossil fuels as follows – JPY 53.8/L (gasoline tax and local gasoline excise tax) on gasoline, JPY 17.5/kg on oil and gas, JPY 32.1/L on diesel oil, JPY 26/L on aviation fuel, and an electric power development promotion tax of JPY 375/MWh of electricity sold.
- *2030 Outlook for Energy Supply and Demand - implemented:* Sets a target of 10% energy use reduction by 2030, compared to 2010.

Development related co-benefits and side-effects

Japan has a high GDP per capita among G20 members and the lowest unemployment rate (Figure 45). It is, therefore, likely that economic co-benefits of climate action would not represent a priority for the country. However, in terms of energy, the country is highly dependent on imports, relying on other countries for more than 90% of its total consumption (Figure 11). This situation places the country in a very vulnerable position from the perspective of energy security. In 2014, Japan relied on fossil fuels for almost 95% of its total energy consumption (Figure 8). Increasing the production of energy from renewable resources would significantly increase energy security in the country. However, biofuel production may not be a feasible option for Japan, given its vulnerable food security position. The country currently relies on cereal imports for almost 80% of its total consumption (Figure 13). Finally, although mean annual exposure to PM2.5 is below the average of G20, this value is still above the recommended limit. Introducing new and more stringent climate mitigation policies would likely improve air quality as a co-benefit.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

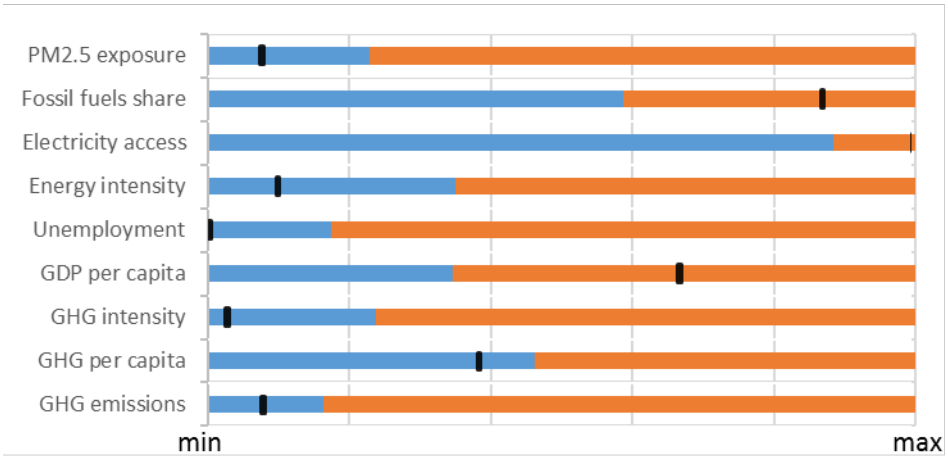

Figure 45: Development indicators in Japan compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.10. Republic of Korea

The Republic of Korea (Korea) had low GHG emission in 2014, compared to other G20 countries, approximately 0.7GtCO_2eq, as well as below average GHG emissions intensity (Figure 48). However, its GHG emissions per capita the second largest for the same year (Figure 4). GHG emissions in Korea emerge disproportionately from the electricity and heat sector (56%), followed by Industry (19%) and transport (15%) (Figure 47). Korea has implemented climate policies across all sectors, except forestry (Figure 46). Most policies in the country focus on renewables in the electricity and heat sector, and on energy efficiency across all relevant sectors.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (2)				
	GHG reduction target (2)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D				
		National energy efficiency target (1)	Renewable energy target (2)		
Electricity and heat		Highly efficiency power plants (2)	Renewable energy target (3)	CCS support scheme (1)	
		Reduction obligation schemes	Support scheme for renewables (7)		
			Grid infrastructure development (2)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit (2)				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process (1)	Industrial production efficiency (5)	Support for renewables (3)	CCS support scheme (1)	Landfill methane (3)
		Energy reporting and audits (3)	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment (1)			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit (2)				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (3)	Support for heating and cooling (1)		
		MEPS for appliances (1)	Support for hot water and cooking (1)		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment (2)	MEPS or support for energy efficient light duty vehicles (4)	Biofuel target	Modal share shift (2)	
		MEPS or support for energy efficient heavy duty vehicles (3)	Support for biofuels (2)	E-mobility (2)	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture (1)				
	Incentives to reduce N2O emissions from agriculture (1)				
	Incentives to reduce deforestation				

Figure 46: Good-practice policy menu in the Republic of Korea

Future decarbonisation steps could aim to cover the remaining sections of the good practice policy menu, but with focus on highly emitting sectors, for instance, by introducing energy/fuel taxes in the three sectors of highest emissions.

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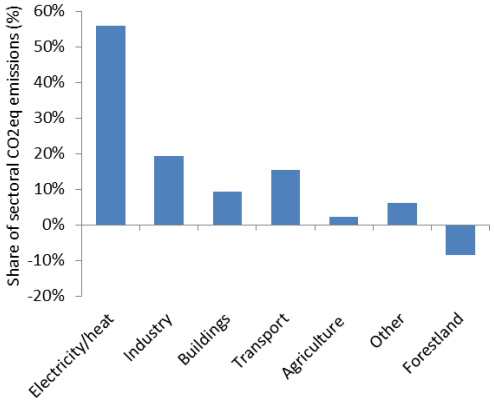

Figure 47: Sectoral GHG emissions as share of total country emissions, Korea Rep. 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Republic of Korea:

Electricity and heat

- *7th Basic Plan for Long-Term Electricity Supply and Demand 2015-2029 - implemented*: Sets a renewable electricity target of 11.7% of total generation and 20.1% of total generation capacity by 2029 (including fuel cells and integrated gasification combined cycle). Installed capacity targets for the same year are as follows: 1.8 GW hydropower, 0.8 GW onshore wind, 1.0 GW offshore wind, 16.6 GW solar, 0.2 GW bioenergy and 0.2 GW waste. The plan also aims for an electricity consumption decrease of 14.3% and peak demand decrease of 12% by 2029 compared to BAU *(planned).*
- *Renewable Portfolio Standard (RPS) - implemented:* Sets a requirement of 10% renewable electricity production covering 90% of all electricity production.
- *One Million Green Homes - implemented*: This name of the policy was changed to 'Home subsidy program' in 2013 and now provides subsidies for installation of solar PV in the residential sector and aims for 100,000 solar roof tops by 2020.
- *2nd National Energy Master Plan - planned:* Sets a target of 15% reduction in total electricity production by 2035 compared to BAU.
- *4th National Basic Plan for Renewable Energies (2014-2035) - planned:* Sets a target of 13.4% renewables share in electricity production by 2035.

Industry

- *Greenhouse Gas Reduction Roadmap - planned:* Sets a target of 81.3% GHG emissions reduction in the industry sector by 2020 compared to BAU.

Buildings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

- *Building Energy Code (Building Standards - New Building) - implemented*: Requires thermal insulation performance improvement of 25.8% for buildings with floor area larger than 500 square meters and requires building permits for new buildings with gross area above this limit.
- *Energy Efficiency Labelling and Standard - implemented*: Sets energy use standards and requires energy efficiency labels for appliances.
- *Greenhouse Gas Reduction Roadmap - implemented:* Sets a target of 26.9% emissions reductions in the building sector.

Transport

- *New automotive emissions standards - implemented*: Sets passenger vehicles GHG emissions standards of 97 gCO_2/km, and fuel consumption standards of 24.3 km/L by 2020.
- *Development and Distribution Plan for Electric Vehicles - implemented:* The program aims to distribute 200,000 electric/hybrid vehicles between 2010 and 2020.
- *Renewable Fuel Standard (2015-2020) - implemented:* Sets a standard of 3% biofuel share in petrol/diesel by 2018.
- *Greenhouse Gas Reduction Roadmap - planned:* Sets a target of 34.4% GHG emissions reduction in the transport sector by 2020 compared to BAU.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a target of 37% GHG emissions reduction (excl. LULUCF) by 2030 compared to BAU.
- *Emissions Trading Scheme - implemented*: Aims to cover 66% of total GHG emissions in 2017.
- *Greenhouse Gas Reduction Roadmap - planned:* Sets a target of 30% total GHG emissions reductions by 2020 and 37% by 2030 compared to BAU.
- *2nd National Energy Master Plan - planned:* Sets a target of 13% final energy consumption reduction by 2035 compared to BAU.
- *4th National Basic Plan for Renewable Energies (2014-2035) - planned:* Sets a target of 11% renewables share in TPES by 2035.

Development related co-benefits and side-effects

Korea has an above average GDP per capita and the third lowest unemployment rate within G20, below average (Figure 48). Therefore, economic co-benefits of climate mitigation would likely represent a lower priority for the country. However, similar to Japan, the country has a very vulnerable situation in terms of energy security, currently importing more than 80% of its total energy consumption (Figure 11). The country reliance on fossil fuels is also above 80% of the total energy consumption (Figure 8). Increasing the share of renewable energy production in the country would substantially benefit Korea by improving energy security levels. Increasing energy efficiency would also decrease energy insecurity. The country has an above average energy intensity level (Figure 48). However, this could be caused both by energy inefficiency in energy consuming sectors and by the structure of the economy (higher share of energy intense economic sectors).

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While a higher share of renewables could improve energy security, production of biofuels could worsen the vulnerable food security position of the country. Korea depends on imports for close to 75% of its total cereal consumption (Figure 13) and land competition with biofuels could increase this value.

Korea has an average annual mean exposure to PM2.5 among the G20 countries (Figure 48), but the absolute value is almost three times above the recommended limit. Implementing new and more stringent mitigation policies, such as a regulation of non-energy related emissions from industry, would benefit the country air quality.

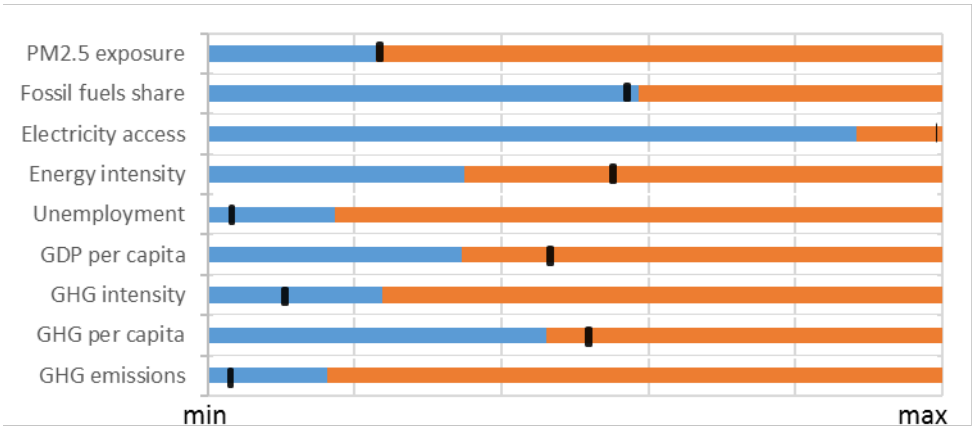

Figure 48: Development indicators in Republic of Korea compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.11. Mexico

Mexico has low total GHG emissions, low GHG emissions per capita and below average GHG emissions intensity compared to other G20 countries (Figure 51). The main sources of GHG emissions are from the electricity and heat (30%) and transport (26%) sectors, followed by agriculture (14%) and industry (11%) (Figure 50). While the country has implemented mitigation policies in all relevant sectors, the focus is mainly on renewables in electricity and heat and energy efficiency in all relevant sectors (Figure 49). While the two highest emitting sectors are well covered, the following two have only few policies. In the future, the country could focus on more strongly addressing these sectors, for instance, through regulatory instruments in the industry sector, and not only reporting and audits. Similarly, the transport sector could also cover biofuels, modal shift and E-mobility.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (3)				
	GHG reduction target (2)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D (1)				
		National energy efficiency target	Renewable energy target (1)		
Electricity and heat		Highly efficiency power plants (1)	Renewable energy target (3)	CCS support scheme (1)	
		Reduction obligation schemes	Support scheme for renewables (6)		
			Grid infrastructure development (2)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency	Support for renewables	CCS support scheme	Landfill methane
		Energy reporting and audits (1)	Sustainability standards for biomass		CH4 – oil and gas (1)
		MEPS for equipment			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning (1)	MEPS or fiscal/financial incentives (2)	Support for heating and cooling		
		MEPS for appliances (1)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment (1)	MEPS or support for energy efficient light duty vehicles (2)	Biofuel target	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (2)	Support for biofuels	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (1)				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (3)				

Figure 49: Good-practice policy menu coverage in Mexico

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

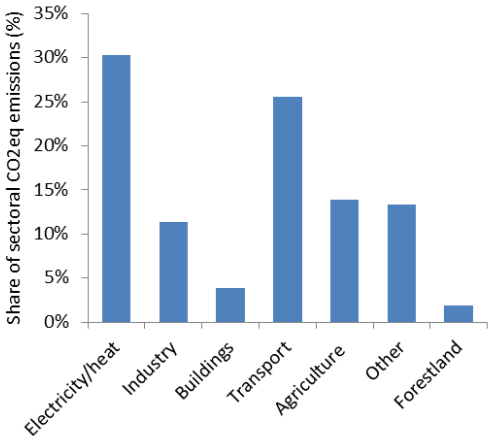

Figure 50: Sectoral GHG emissions as share of total country emissions, Mexico 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Mexico:

Electricity and heat

- *Energy Transition Law - implemented*: Sets targets for share of clean sources (emissions below 100 kg/MWh) in electricity generation of 25% in 2018, 30% in 2021 and 35% in 2024.
- *Renewable energy auction scheme - implemented*: Mexico had its first auction scheme for wind and solar in 2016, with values of US$45/MWh for solar and US$48/MWh for wind.
- *Accelerated Depreciation for Investments with Environmental Benefits - implemented:* Investments in clean energy projects can be deduced by up to 100% in the first year through tax reliefs.
- *Grid interconnection contract for renewable energy - implemented:* Renewable electricity is granted transmission discounts of 50% to 70%.

Industry

- *Energy Reform Package - implemented*: Sets targets for oil and gas production. Oil production targets are 3 million barrels in 2018 and 3.5 million barrels in 2025, while gas production targets are 8000 million cubic feet in 2018 and 10400 million cubic feet in 2025.
- *Carbon tax - implemented:* Carbon tax on fossil fuel production of US$3.5/t from 2014.
- *Performance criteria and application for flaring and ventilation of natural gas (CNH.06.001/09) - implemented:* Aims to reduce natural gas flaring and ventilation by 80% to 95% of the average of previous years , starting in 2009.

Transport

- *Light Duty Vehicles CO_2 Emissions Standards - implemented*: Light duty vehicle emissions standards set from 2016 are between 163.6 gCO_2/km (for cars with a surface smaller than 3.81 m^2) and 227.6 gCO_2/km (for cars with a surface larger than 6.13 m^2).
- *Gasoline Heavy Duty Vehicle Emissions Standards - implemented:* Heavy duty vehicle emissions standards are set from 2012.

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Agriculture and Forestry

- *General Law for Sustainable Forest Development - implemented*: Sets various targets for improved forest management by 2018, such as 58.7% of the forest resources to be sustainably harvested, 10.2% of forest area to be included in the 'payment for ecosystems services' scheme, and 94% of the forest to be certified under 'good forest management practice'. Additionally, the credit for forest development and conservation is to be increased by 30% in 2018 compared to 2012. It also aims for 0% wood sold on illegal markets by 2018 *(planned)*.
- *Intended Nationally Determined Contribution (INDC) - planned:* Sets 0% deforestation rate target by 2030.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets an unconditional target of 25% GHG emissions reduction and a conditional target of 40% by 2030 compared to BAU.
- *Special Programme on Climate Change 2014-2018 - planned*: Sets a target of 30% emissions reduction by 2020 compared to BAU, and 50% by 2050 compared to 2000. This program also targets 21.23 $MtCO_2e$ GHG emissions reductions between 2018 and 2050, as a result of implemented REDD+ projects.
- *National Programme for Sustainable Use of Energy (2014-2018) - implemented:* Aims for an energy intensity level in 2018 that is the same as or lower than the level of 2012.

Development related co-benefits and side-effects

Mexico has low GDP per capita and low unemployment rate relative to other G20 members (Figure 51). Economic co-benefits of climate mitigation would likely be of high interest for the country. Furthermore, although decreasing the unemployment rate may not be a high priority, higher quality job opportunities in climate mitigation areas could be a valuable benefit. Mexico has approximately 90% share of fossil fuels in total energy consumption (Figure 8) and is a net exporter of energy (Figure 11). However, there is still a small percentage of population that needs to be reached by electricity sources (Figure 10). Mexico could use the benefit of easy access that renewable sources provide to increase its population coverage.

However, biofuel production might not be a feasible option as the country currently depends on imports for 30% of cereals consumption (Figure 13). Land-use change for biofuel production could increase this figure and worsen food insecurity.

Mexico's annual exposure to PM2.5 is low in G20, but twice the recommended limit (Figure 12). Air quality could be improved as a co-benefit of climate mitigation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

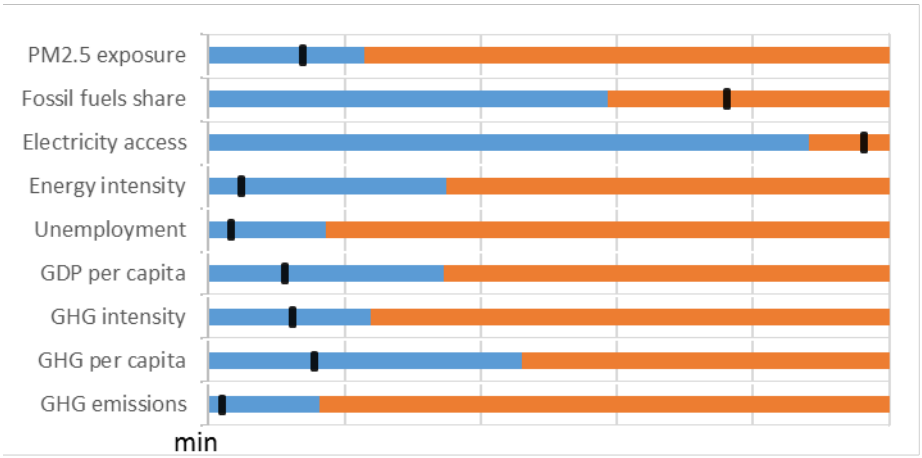

Figure 51: Development indicators in Mexico compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.12. Russian Federation

Russian Federation (Russia) has average GHG emissions, compared to other G20 members but above average GHG emissions intensity and GHG emissions per capita (Figure 54). The sector of highest emissions in Russia is electricity and heat (44%), followed by industry (18%) and transport (12%) (Figure 53). The has mitigation policies in all economic sectors except agriculture, although this sector accounts for 4% of total emissions (Figure 53). However, the country has a low number of policies and a relatively low coverage of the good practice policy menu. Future steps for a low-carbon transition could aim to reach a higher coverage of the menu, implementing policies such as industrial production efficiency, or biofuels in transport. Furthermore, establishing a coordinating body for climate change would ensure stronger support for climate policy design and implementation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (1)				
	GHG reduction target (2)				
	Coordinating body for climate strategy				
	Support for low-emission RD&D				
		National energy efficiency target (1)	Renewable energy target		
Electricity and heat		Highly efficiency power plants (3)	Renewable energy target (1)	CCS support scheme	
		Reduction obligation schemes	Support scheme for renewables (3)		
			Grid infrastructure development (1)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency	Support for renewables	CCS support scheme	Landfill methane
		Energy reporting and audits (2)	Sustainability standards for biomass		CH4 – oil and gas (3)
		MEPS for equipment (1)			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (4)	Support for heating and cooling		
		MEPS for appliances (1)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment	MEPS or support for energy efficient light duty vehicles (1)	Biofuel target	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (1)	Support for biofuels	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (2)				

Figure 52: Good-practice policy menu coverage in the Russian Federation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

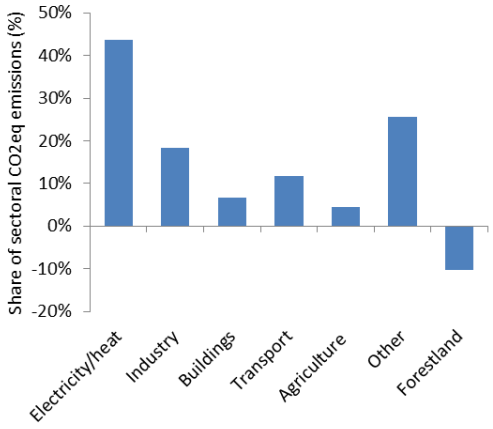

Figure 53: Sectoral GHG emissions as share of total country emissions, Russian Federation 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Russian Federation:

Electricity and heat

- *State Program on Energy efficiency and Energy Development (approved by Government Decree No 321) - implemented:* Sets a target for renewables share in electricity generation of 2.5% in 2020 (excluding large hydro >25MW).
- *Decree No. 449 on the Mechanism for the Promotion of Renewable Energy on the Wholesale Electricity and Market - implemented:* Sets installed capacity targets of 3600 MW wind power, 1520 MW solar power, and 751 MW small-scale hydropower. Furthermore, the decree creates a scheme of 15-year periods of regulated capacity prices for renewables, to support these targets.
- *Energy Strategy to 2030 - planned:* Aims to reduce electricity consumption by no less than 1.6 times in 2030 compared to 2005.

Industry

- *Legislation on the limitations of associated gas flaring - implemented:* Sets gas flaring limit of 5% (95% use of petroleum gas) from 2012 onwards.

Transport

- *Vehicle emissions standards - implemented*: Russian standards are based on European program for vehicle fuel efficiency and emissions, adopting Euro 5 standards for both light-duty and heavy-duty vehicles since 2016. Furthermore, vehicle registration tax increases with emissions and vehicle and engine size.

Forestry

- *National Strategy of Forestry Development by 2020 - implemented:* Aims to increase forest intensification and the harvest of wood by 5.8% per year from 2007 to 2020.

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Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Aims to limit GHG emissions to 70%-75% of 1990 levels by 2030. A similar target (75%) was previously set by the Presidential Decree 752.
- *State Program on Energy efficiency and Energy Development (approved by Government Decree No 321) - planned:* Sets a 40% energy intensity (energy per unit GDP) reduction target by 2020 compared to 2007.
- *Energy efficiency legislation (Federal Law 261-FZ, On Saving Energy and Increasing Energy Efficiency and Amending Certain Legislative Acts of the Russian Federation) - implemented:* Sets mandatory energy consumption savings for government-funded organisations (absolute consumption) of 3% per year for 5 years since 2009. Additionally, an investment tax credit of up to 30% of tax is set for energy efficiency investments. Furthermore, the law bans inefficient light bulbs (25 Watts or more) starting in 2014.
- *Energy Strategy to 2030 - planned:* Sets a 56% energy intensity (energy per unit GDP) reduction target by 2030 compared to 2005. Additionally, it sets targets of 46%-47% share of gas and 13%-14% share of non-fossil fuels in primary energy consumption by 2030. The strategy also aims for no less than 3 times decrease in energy export share of GDP and no less than 1.7 times decrease in share of fuel and energy complex in GDP and in exports.

Development related co-benefits and side-effects

Russia has a low GDP per capita relative to other G20 countries (Figure 54). Hence, economic co-benefits of climate mitigation could be maximized to improve the country position. However, given the low unemployment rate (Figure 7), job opportunities might not represent a high priority amongst climate mitigation economic co-benefits.

Russia relies on fossil fuels for more than 90% of its total energy consumption (Figure 8). The country could benefit by increasing its share of renewable energy, including biofuels, without a substantial impact on food security, given that Russia is a net cereal exporter (Figure 13). However, the country benefits economically from exports of energy, exporting more than 80% of its domestic energy consumption (Figure 11). As a result, mitigation co-benefits of energy security may not be a strong incentive for Russia. However, strong reliance on energy exports can make the country economically vulnerable.

Mean annual exposure to PM2.5 is below the average relative to other G20 members, but it lies above the recommended limit (Figure 12). Air quality improvements would be a valuable co-benefit of climate mitigation.

Unlike most other G20 members who use the largest share of water for agriculture, Russia consumes approximately 60% of its energy for industrial purposes (Figure 16). Improvement in material and process efficiency, and a switch to sources of energy of low water footprint (e.g. solar PV and wind) would help decrease water usage.

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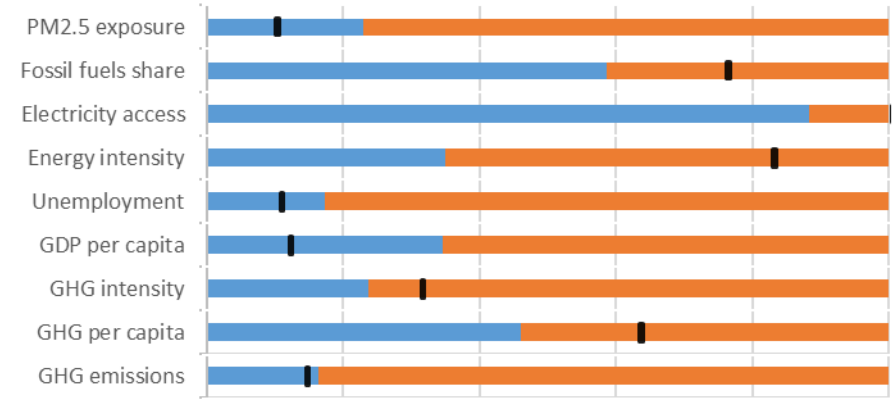

Figure 54: Development indicators in Russian Federation compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.13. Saudi Arabia

Saudi Arabia has low GHG emission compared to other G20 member states, and only slightly above average GHG emissions intensity (Figure 57). However, it is the highest GHG emitter per capita among the group (Figure 57). The main source of GHG emissions in Saudi Arabia is the electricity and heat sector (49%), covering almost a half of the total emissions. Transport (20%) and Industry (17%) and the next highest emitting sectors, the three covering almost 90% of all country emissions (Figure 56). Saudi Arabia has climate mitigation policies in all sectors, except for agriculture and forestry (Figure 55), but this could be explained by the low agriculture emissions (1%) and the lack of forests. However, the good practice policy menu has a low coverage overall.

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	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy				
	GHG reduction target (1)				
	Coordinating body for climate strategy				
	Support for low-emission RD&D				
Electricity and heat		**National energy efficiency target (1)**	Renewable energy target		
		Highly efficiency power plants (1)	**Renewable energy target (1)**	CCS support scheme	
		Reduction obligation schemes	**Support scheme for renewables (1)**		
			Grid infrastructure development		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process	**Industrial production efficiency (1)**	Support for renewables	CCS support scheme	Landfill methane
		Energy reporting and audits (1)	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment (1)			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives	Support for heating and cooling		
		MEPS for appliances (1)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	**Urban planning and investment (1)**	**MEPS or support for energy efficient light duty vehicles (1)**	Biofuel target	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles	Support for biofuels	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation				

Figure 55: Good-practice policy menu coverage in Saudi Arabia

To strengthen its climate mitigation action, Saudi Arabia could aim to cover more policy areas in the relevant sectors, with higher focus on the three sectors of highest emissions. Furthermore, preparing a climate change strategy and establishing a coordinating body for climate change would provide stronger focus for stringent climate action.

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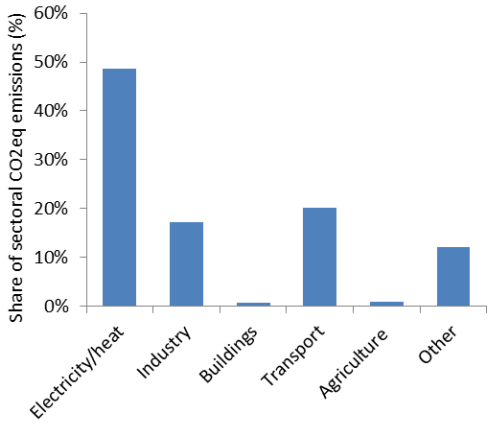

Figure 56: Sectoral GHG emissions as share of total country emissions, Saudi Arabia 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Saudi Arabia:

Electricity and heat

- *Royal Decree establishing King Abdullah City for Atomic and Renewable Energy - implemented*: Sets renewable energy installed capacity targets of 41 GW solar, 9 GW wind, 3 GW waste-to-energy, and 1 GW geothermal by 2040.
- *National Energy Efficiency Programme 2008 - planned*: Aims to increase energy efficiency in electricity by 30% between 2005 and 2030.

Transport

- *Corporate Average Fuel Economy Standards (CAFE) - implemented:* Standards for passenger cars and light trucks. The standards for passenger cars in 2015 were between 11.9 km/l (lower limit) and 15.3 km/l (upper limit), while the 2020 target is between 13.9 km/l and 18.5 km/l. For light trucks, the 2015 standard was between 9.6 km/l and 12.7 km/l, while the 2020 target is between 10.7 km/l and 15.7 km/l.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Aims to reduce GHG emissions up to 130 $MtCO_2eq$ annually until 2030.
- *10^{th} Development Plan Saudi Arabia (2015-2019) – planned:* Aims to increase the share of non-oil sectors from 59.1% in 2014 to 66% in 2019

Development related co-benefits and side-effects

Saudi Arabia has average GDP per capita and below average unemployment rate (Figure 57). Hence, economic development co-benefits of climate mitigation would not play a very important role, but could still contribute substantially.

Saudi Arabia is the only G20 country that relies entirely on fossil fuels for its energy consumption (Figure 8). The country is rich in fossil fuel resources and exports almost two times the amount of energy that

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is consumed domestically (Figure 11). While Saudi Arabia is in a good position in terms of energy security, the strong economic reliance on fossil fuel exports leads to economic vulnerability.

Saudi Arabia has the highest mean annual exposure to PM2.5, more than 10 times the recommended value (Figure 12). This high value is mainly due to dust. Improving air quality should be a priority for Saudi Arabia, and related climate mitigation co-benefits can help in this direction.

Saudi Arabia is also in a vulnerable position concerning food security, currently importing close to 90% of its cereal consumption (Figure 13), and suffering from food deficit (Figure 14). Furthermore, the country experiences very high pressure on its water resources, currently withdrawing more than 9 times its available renewable resources (Figure 15). The country uses water in a proportion of almost 90% for agriculture (Figure 16). Hence, when implementing climate mitigation policies in the agricultural sector, water conservation co-benefits should be maximized.

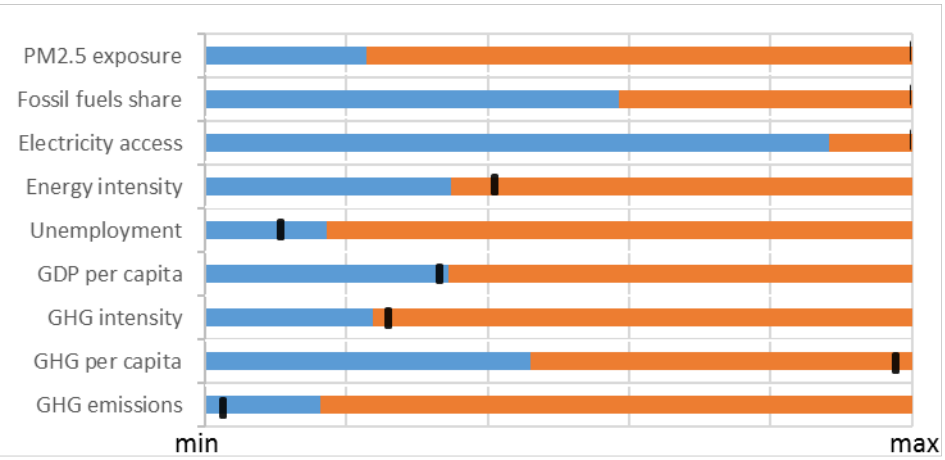

Figure 57: Development indicators in Saudi Arabia compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.14. South Africa

South Africa has very low total GHG emissions relative to other G20 members but above average GHG emissions per capita and the highest GHG emissions intensity among G20 members (Figure 60). The electricity and heat sector is responsible for more than half of the total GHG emissions (55%), followed by industry (12%) and transport (9%) (Figure 59). South Africa has a low coverage of the good practice policy menu, although it has policies in all economic sectors, except agriculture (Figure 58). Future climate mitigation action could focus mainly on the electricity and heat sector, increasing efficiency and the share of renewables. Furthermore, the country could aim to cover neglected climate mitigation areas, such as non-energy related emissions in industry and vehicle efficiency standards.

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (2)				
	GHG reduction target (2)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D				
		National energy efficiency target	Renewable energy target		
Electricity and heat		Highly efficiency power plants (2)	Renewable energy target (1)	CCS support scheme	
		Reduction obligation schemes	Support scheme for renewables (6)		
			Grid infrastructure development (2)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency (1)	Support for renewables	CCS support scheme	Landfill methane
		Energy reporting and audits	Sustainability standards for biomass		CH4 – oil and gas
		MEPS for equipment			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (2)	Support for heating and cooling		
		MEPS for appliances (1)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment (1)	MEPS or support for energy efficient light duty vehicles	Biofuel target (1)	Modal share shift (1)	
		MEPS or support for energy efficient heavy duty vehicles	Support for biofuels (2)	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions (2)				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (2)				

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Figure 58: Good-practice policy menu in South Africa

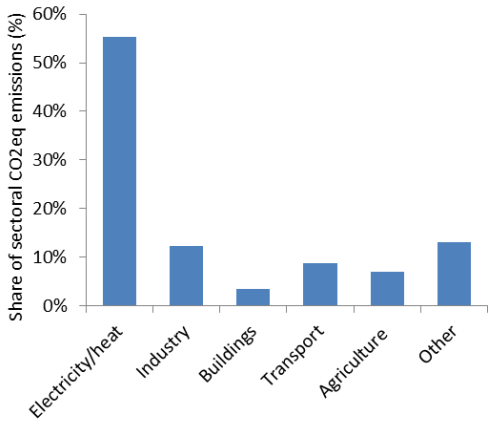

Figure 59: Sectoral GHG emissions as share of total country emissions, South Africa 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in South Africa:

Electricity and heat

- *Integrated Resource Electricity Plan (2010 – 2030) - implemented*: Sets renewable energy targets in total installed capacity of 21% excluding hydropower and 26.3% including hydropower by 2030. Capacity addition targets between 2010 and 2030 are 0.7 GW hydro, 9.2 GW wind, 1 GW concentrated solar power, 8.4 GW solar PV, and 11.4 nuclear *(nuclear capacity is planned)*. The plan also sets a target for the use of coal, decreasing to 50% share in electricity generation by 2030 *(planned)*.
- *Renewable Energy Independent Power Producer Programme (REIPPP) - implemented:* Public procurement programme (20-year payment period) for qualifying renewable sources (onshore wind, solar PV, solar thermal, biomass solid, biogas, landfill gas and small hydro plants). A ceiling tariff level is established for each technology in the auctions.
- *National Development Plan – planned:* Aims for 600 gCO_2eq/KWh emissions standards in the electricity sector by 2030.

Transport

- *Biofuels Industrial Strategy - implemented:* Mandates a 2%-10% share of bioethanol in petrol and 5% share of biodiesel in diesel from 2015 onwards.

Buildings

- *National Building Regulation - implemented*: Building standards apply to both existing and new residential buildings and require an energy use of maximum 200 $kWh/m^2/year$.
- *National Development Plan - planned*: Sets zero emissions building standards by 2030.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a target of GHG emissions within the range 398-614 $MtCO_2eq$ by 2025 and 2030.

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- *Carbon Tax – planned*: Aims for a carbon price of R6-R48/tCO_2e by 2017-2020.

Development related co-benefits and side-effects

South Africa has a low GDP per capita relative to G20 levels (Figure 60), and the highest unemployment rate, above 25% (Figure 7). Therefore, economic-related mitigation co-benefits would be a priority for the country.

The percentage of population with access to electricity in South Africa is approximately 85%, the second lowest in G20 (Figure 10). The country could aim to reach this remote population with renewable electricity sources, benefiting from the easy access provided by these. South Africa currently has a share of fossil fuels in total energy consumption of more than 87% (Figure 8), above the G20 average (Figure 60). However, while a substantial proportion of the population still requires access to electricity, South Africa is a net energy exporter, exporting almost 70% of its total domestic consumption (Figure 11).

Mean annual exposure to PM2.5 is almost equal to the G20 average, but 3 times above the recommended limit (Figure 12). Air quality could be improved by mitigation policies that provide such co-benefits.

South Africa has a food deficit of more than 10 kcal/capita/day (Figure 14) and depends on imports for a small percentage of cereal consumption (Figure 13). To ensure that food security in not decreased further, mitigation policies that may lead to land-use competition should be avoided.

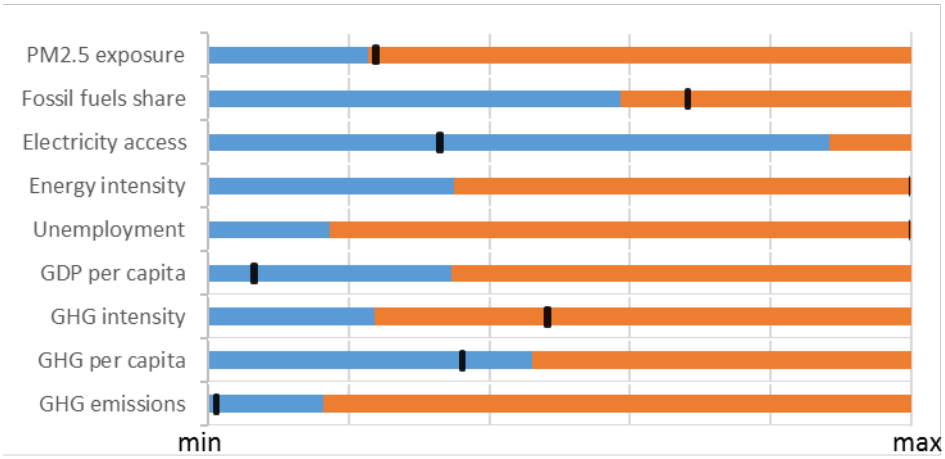

Figure 60: Development indicators in South Africa compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.15. Turkey

Turkey has the lowest GHG emissions in G20, and also below average GHG intensity and GHG emissions per capita, although the latter indicators places it at the top of G20 members (Figure 63). The country highest emitting sector is electricity and heat (35%), followed by industry (19%), buildings (15%), and transport (14%) (Figure 62). Turkey has implemented mitigation policies in all sectors, but with a stronger focus on renewables in electricity and heat and energy efficiency across all relevant sectors (Figure 61). However, a number of policy areas such as renewables in transport, buildings and industry, material and processes efficiency, or E-mobility are not covered. Furthermore, the country has no overarching carbon pricing nor energy or other taxes. Future steps towards decarbonisation could focus on addressing the policy areas that are currently neglected and on increasing the stringency in the electricity and heat sector.

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	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (2)				
	GHG reduction target (1)				
	Coordinating body for climate strategy (1)				
	Support for low-emission RD&D (1)				
		National energy efficiency target (3)	Renewable energy target (1)		
Electricity and heat		Highly efficiency power plants (2)	Renewable energy target (2)	CCS support scheme	
		Reduction obligation schemes	Support scheme for renewables (4)		
			Grid infrastructure development (2)		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process	Industrial production efficiency (2)	Support for renewables	CCS support scheme	Landfill methane
		Energy reporting and audits (2)	Sustainability standards for biomass		CH4 – oil and gas (1)
		MEPS for equipment (1)			N2O from industry
					Fluorinated gases
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning (2)	MEPS or fiscal/financial incentives (6)	Support for heating and cooling		
		MEPS for appliances (1)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment (1)	MEPS or support for energy efficient light duty vehicles (1)	Biofuel target	Modal share shift (1)	
		MEPS or support for energy efficient heavy duty vehicles (1)	Support for biofuels	E-mobility	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (2)				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture				
	Incentives to reduce N2O emissions from agriculture (1)				
	Incentives to reduce deforestation (4)				

Figure 61: Good-practice policy menu coverage in Turkey

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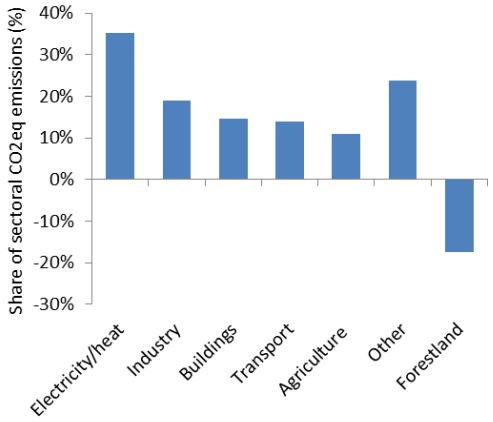

Figure 62: Sectoral GHG emissions as share of total country emissions, Turkey 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in Turkey:

Electricity and heat

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets targets for installed capacity of 10 GW solar power, 16 GW wind power and 1 commissioned nuclear plant by 2030.
- *Act No. 5346 on Utilization of Renewable Energy Sources for the Purposes of Generating Electrical Energy - implemented*: Sets a target of 30% renewables share in electricity production by 2023.
- *National Renewable Energy Action Plan for Turkey - implemented*: Sets a target of 20.5% renewables in final energy consumption by 2023 *(planned)*. Aims to have 61 GW renewables installed capacity by 2023: 34 GW hydro, 20 GW wind, 5 GW solar PV and CSP, 1 GW geothermal and 1 GW biomass.

Transport

- *Climate Change Action Plan (2011-2023) - planned*: Targets for modal share in 2023 are set as follows: 15%/10% share of railroads in freight/passenger transport, 10%/4% share of seaways in freight/passenger transport, and below 60%/72% share of highways in freight/passenger transport.

Buildings

- *Regulation on Energy Performance in Buildings - implemented*: Codes and standards are set for buildings and certificates are issued for new buildings and buildings that are rented or bought after 2011. Buildings with more than 2000 m² of usable space must have central heating system, while buildings with more than 20.000 m² may also be subject to required use of renewables and cogeneration sources.
- *Energy efficiency Strategy Paper (2012-2023) - planned*: Aims for a 20% share of renewables in annual energy demand of new buildings from 2017.

Forestry

- *Climate Change Action Plan 2011-2023 - planned:* Aims to reduce deforestation by 20% by 2020 compared to 2007, and a 15% increase in carbon sequestration over the same period.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a 21% GHG emissions reduction (incl. LULUCF) target by 2030 compared to BAU.
- *Energy efficiency Strategy Paper 2012-2023 - planned*: Aims for a 20% energy intensity (GJ/GDP) reduction by 2023 compared to 2008.

Development related co-benefits and side-effects

Turkey has a relatively low GDP per capita and an above-average unemployment rate (Figure 63). Hence, it would be important for the country to seek to maximize economic co-benefits of climate mitigation.

Turkey has the lowest energy intensity in G20, but it relies on imports for close to 75% of its total energy consumption (Figure 11). This places the country in a vulnerable position regarding energy security. Improving energy efficiency and increasing the share of renewables would substantially benefit Turkey by improving its energy security. The current share of fossil fuels in total energy consumption is approximately 90% (Figure 8). Among the renewable energy sources, biofuels could have a negative impact on the country's relatively vulnerable food security. Turkey relies on imports for a very small proportion of its cereal consumption and still have a small food deficit (Figure 13, Figure 14).

Mean annual exposure to PM2.5 is above the G20 average, more than 3.5 times above the recommended limit (Figure 12). Mitigation policies that maximize air pollution reduction would be beneficial for air quality improvement.

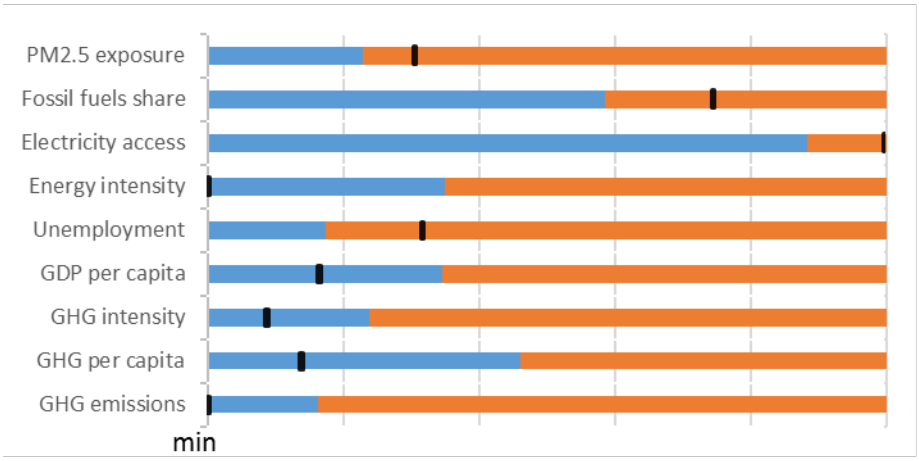

Figure 63: Development indicators in Turkey compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represents the split between values below and above G20 average, respectively. The black line represents the country value.

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4.2.16. United States

United States (US) has the second highest GHG emissions worldwide (Figure 3), and the fourth highest GHG emissions per capita, but below average GHG emissions intensity among G20 countries (Figure 66). The largest shares of emissions can be attributed to the electricity and heat sector (43%) and the transport sector (27%), followed by industry (16%) (Figure 65). US has implemented policies in all sectors, but it does not have a high overall coverage of the good practice policy menu (Figure 64). Future mitigation steps could focus on covering policy areas where no policies exist, such as renewables in buildings, urban planning and investment in transport, overarching carbon pricing and energy taxes. Establishing a coordinating body for climate change would provide further support for mitigation design and implementation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642147 (CD-LINKS).

	Changing activity	Energy efficiency	Renewables	Nuclear or CCS or fuel switch	Non-energy
General	Climate strategy (1)				
	GHG reduction target (2)				
	Coordinating body for climate strategy				
	Support for low-emission RD&D (2)				
		National energy efficiency target (1)	Renewable energy target		
Electricity and heat		Highly efficiency power plants (14)	Renewable energy target (1)	CCS support scheme (4)	
		Reduction obligation schemes (2)	Support scheme for renewables (21)		
			Grid infrastructure development		
			Sustainability standards for biomass use		
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Industry	Material/process (3)	Industrial production efficiency (9)	Support for renewables (4)	CCS support scheme (4)	Landfill methane (5)
		Energy reporting and audits (2)	Sustainability standards for biomass		CH4 – oil and gas (3)
		MEPS for equipment (8)			N2O from industry (5)
					Fluorinated gases (6)
	Overarching carbon pricing scheme or emissions limit				
	Energy and other taxes				
	No fossil fuel subsidies				
Buildings	Urban planning	MEPS or fiscal/financial incentives (2)	Support for heating and cooling		
		MEPS for appliances (2)	Support for hot water and cooking		
			Sustainability standards for biomass		
	Energy and other taxes				
	No fossil fuel subsidies				
Transport	Urban planning and investment	MEPS or support for energy efficient light duty vehicles (6)	Biofuel target	Modal share shift	
		MEPS or support for energy efficient heavy duty vehicles (7)	Support for biofuels (10)	E-mobility (1)	
			Sustainability standards for biomass		
	Tax on fuel and/or emissions (1)				
	No fossil fuel subsidies				
Agriculture and forestry	Standards and support for sustainable agricultural practices and use of agricultural products (6)				
	Incentives to reduce CO2 emissions from agriculture				
	Incentives to reduce CH4 emissions from agriculture (1)				
	Incentives to reduce N2O emissions from agriculture				
	Incentives to reduce deforestation (3)				

Figure 64: Good-practice policy menu coverage in the United States

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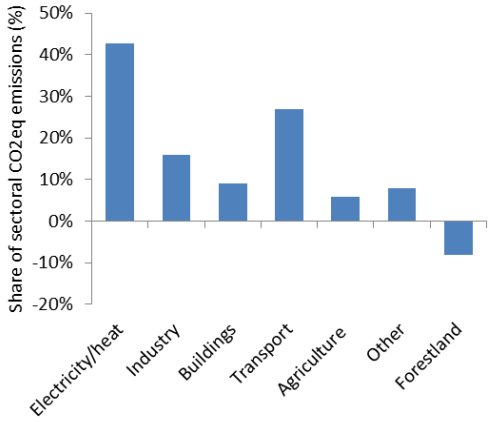

Figure 65: Sectoral GHG emissions as share of total country emissions, US 2010

High impact GHG emissions reduction policies

The following policies were identified as most important for GHG emissions reduction in US:

Electricity and heat

- *The President's Climate Action Plan (Renewable Energy Target) - planned:* Sets a target of 100% increase in renewable electricity generation (kWh of wind/solar/geothermal) by 2020 compared to 2012. This plan is for a large part backed by state renewable targets that are estimated to achieve 10.6% renewable electricity production by 2020. This policy was removed under Trump administration.
- *Clean Power Plan - planned*: Sets GHG emissions standards for new power plants after 2014 of 450 gCO_2/kWh. The plan also sets a target of 32% reduction in GHG emissions from the electricity sector by 2030 compared to 2005.

Industry

- *Strategy to reduce methane emissions - implemented*: Sets a target of 40%-45% CH_4 emissions reductions from oil and gas production by 2025 compared to 2012 levels.

Transport

- *Light-duty emissions regulation - implemented:* Fuel efficiency standard for light trucks and passenger cars is 55 mpg (23.2 km/l) by 2025.
- *Heavy-duty emissions regulation - implemented:* Fuel efficiency standard for medium trucks is 7.3 mpg (3.1 km/l) by 2018 and 10.9 mpg (4.6 km/l) by 2027. Fuel efficiency standard for heavy trucks is 5.7 mpg (2.4 km/l) by 2018 and 8.2 mpg (3.5 km/l) by 2027.
- *Renewable Fuel Standard (RFS) Program - implemented*: Sets a target share of 10.1% biofuel in fuel from 2014 onwards, and a biofuel volume target of 36 billion gallons by 2022.

Buildings

- *Building Energy Codes - implemented*: Building energy standards aim to reduce annual final energy use by 250 PJ by 2020, compared to 2012, and by 350 PJ by 2030, compared to 2012.

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- *Federal Appliance Standards - implemented:* Aims to achieve 3 billion metric tons of carbon emissions avoided by 2030, compared to 2012, through energy savings from appliance standards. This is estimated to lead to 20% reduction in energy intensity (MJ/m^2).
- *Better Plants, Better Buildings - implemented*: Targets a 20% reduction in energy intensity (MJ/m^2) between 2010 and 2025 for commercial and residential buildings. Furthermore, it encourages industries to reduce energy intensity by 25% over a period of 10 years, through a partnership of 160 industrial companies.

Agriculture and Forestry

- *Conservation Reserve Program - implemented:* Encourages farmers to remove highly erodible cropland or other environmentally sensitive acreage from agricultural production.
- *Forest Ecosystem Restoration and Hazardous Fuels Reduction Programs - implemented:* Aims to restore the health of nation's forests, woodlands and rangelands.
- *USDA's Building Blocks for Climate Smart Agriculture & Forestry - planned:* Sets targets of 120MtCO_2e GHG emissions reductions by 2025 compared to BAU and total sequestration increased by 48 MtCO_2e by 2025, compared to BAU.

Cross-sectoral

- *Intended Nationally Determined Contribution (INDC) - planned:* Sets a target of 26%-28% GHG emissions reduction (incl. LULUCF) by 2030 compared to 2005.
- *Significant New Alternatives Policy (SNAP) Program - implemented:* Sets a target of 85% HFC emissions reduction by 2033 compared to 2008-2010 levels.
- *Blueprint for a secure energy future - implemented*: Sets a target of 50% oil import (EJ) reduction by 2020 compared to 2010.
- *Accelerate Energy Productivity 2030 - planned:* Aims to increase energy productivity (US$(2005)/EJ) by 100% between 2010 and 2030.

Development related co-benefits and side-effects

US has the highest GDP per capita and unemployment rates below the G20 average (Figure 66). Therefore, economic co-benefits of climate mitigation are likely not a priority for the country. However, in terms of energy, the country would profit from energy security co-benefits. US is currently importing approximately 9% of its total energy consumption (Figure 11). Stronger energy efficiency policies and an increase in the share of fossil fuels would help US improve its energy security status. The current share of fossil fuels in total energy consumption is approximately 83%, equal to the G20 average (Figure 8 and Figure 66).

Mean annual exposure to PM2.5 in US is below the recommended limit (Figure 12). Hence, mitigation co-benefits of air pollution reduction may not be a high priority for the country.

US exports approximately 25% of its domestic cereal consumption value (Figure 13). Hence, climate mitigation policies that could lead to land-use competition, such as biofuel production and afforestation, would not have a significant impact on domestic food security if only exports are decreased.

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US is one of the few G20 countries where water use is not dominated by agriculture, but rather by industry (more than 50%) (Figure 16). Climate policies that increase water conservation in industry could help reduce water consumption in the sector.

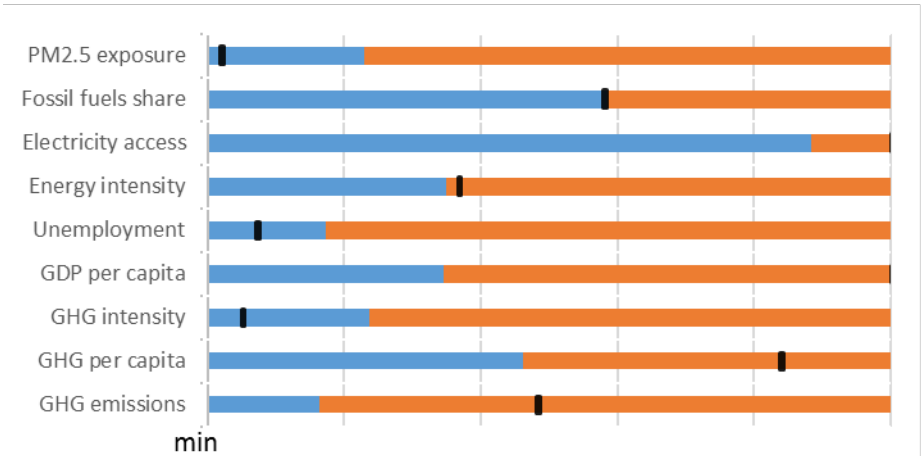

Figure 66: Development indicators in United States compared to minimum, maximum and average values amongst G20 countries. The blue-orange bar colour split represent the split between values below and above G20 average, respectively. The black line represents the country value.

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Annex 1. Climate and development policies database

To facilitate the analyses in this research, extensive data collection of climate and development policies in major economies was undertaken. This data collection was built on the Climate Policy Database initiated by NewClimate Institute, and part of the details in this annex were also presented in a dedicated report by NewClimate Institute[20]. For this study, the database was updated by Wageningen University and Research (WU) and PBL, with valuable support from a number of CD-LINKS project partners. In its current state, the database is compiled from a number of public sources (see Table 6), complemented by own country-specific primary research.

Table 6: Climate policies sources compiled in the database

Name	Sectors covered	Countries	Type	Website
Database of State Incentives for Renewables & Efficiency	Renewables; Energy Efficiency	US - Federal & States	Database	http://www.dsireusa.org/
IEA Addressing Climate Change	All	50 countries including all IEA countries	Database	http://www.iea.org/policiesandmeasures/climatechange/
IEA Global Renewable Energy	Renewables	126 countries including all IEA countries	Database	http://www.iea.org/policiesandmeasures/renewableenergy/
IEA Energy Efficiency	Energy Efficiency – All sectors	66 countries including all IEA countries	Database	http://www.iea.org/policiesandmeasures/energyefficiency/
IEA Building Energy Efficiency	Energy Efficiency in Buildings	34 countries including all IEA countries	Database	http://www.iea.org/beep/
IEA Clean Coal Database	Emissions standards	46 countries including all IEA countries	Database	http://www.iea-coal.org.uk/site/2010/database-section/emission-standards?
Transport Policy Database	Transport	Worldwide – 8 countries	Country Profiles	http://transportpolicy.net/
Climate Action Tracker	All	30 countries	Country Profiles	http://climateactiontracker.org/countries.html
UNFCCC National Communications	All	Worldwide	Country Profiles	http://unfccc.int/national_reports/items/1408.php
LSE Global Climate Legislation Study	All	Worldwide	Report/ Database	http://www.lse.ac.uk/GranthamInstitute/legislation/the-global-climate-legislation-database/
OECD Fossil Fuel Support	All	OECD countries	Database	http://stats.oecd.org/Index.aspx?DataSetCode=FFS_AUS
Columbia Law School Database	All	Worldwide	Country Profiles/ Database	http://web.law.columbia.edu/climate-change/resources/climate-change-laws-world#http://web.law.columbia.edu/climate-cha
ICAP ETS Map	Industry	Worldwide	Country Profiles/ Database	https://icapcarbonaction.com/ets-map
OECD Taxing Energy Use 2015	All	OECD countries plus 7 major non-OECD emitting countries	Report/ Database	http://www.oecd.org/tax/taxing-energy-use-2015-9789264232334-en.htm
Wageningen University MSc Thesis	Cross-sectoral	Selected countries	Report	Bulder (2013)
WRI SD-PAMS	All	Selected countries	Database	http://projects.wri.org/sd-pams-database

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The Climate Policy Database is made publically available through the Semantic Media Wiki platform at www.climatepolicydatabase.org (Figure 67), and was built to allow future collaboration in data collection and in-built analysis, with the aim to cover all climate-related policies across all economic sectors and geographical regions. Currently, it contains records of more than 3200 policies across 113 countries, with a focus on the 30 highest GHG emitting nations.

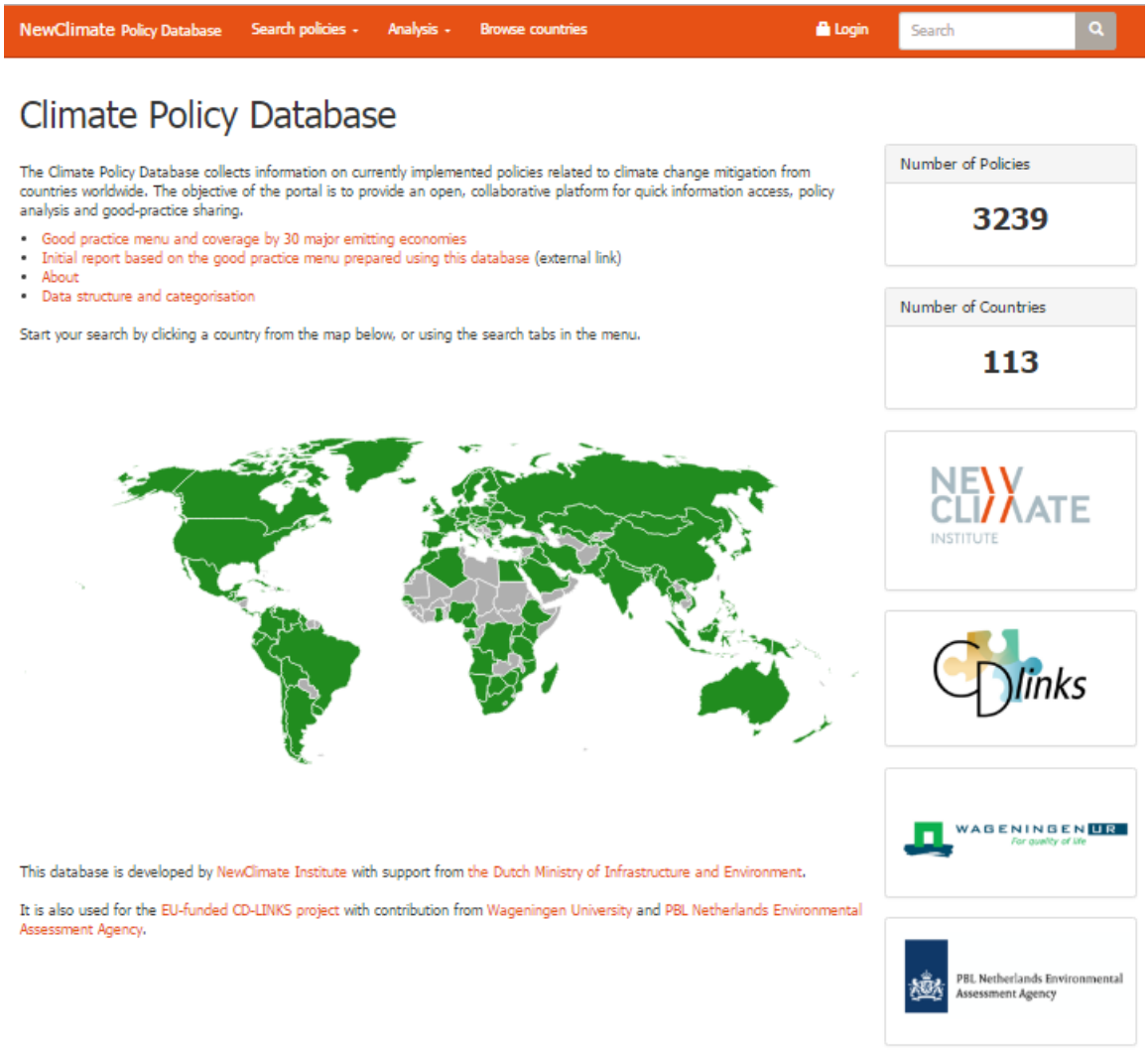

Figure 67. Homepage of Climate Policy Database (www.climatepolicydatabase.org)

Database structure

Each policy in the database has a comprehensive record providing information on the following fields (when available): name of policy, jurisdiction, supranational region, country, region, sub-national region or state, city or local, policy objective, type of policy instrument, sector name, policy description, policy type, policy stringency, implementation state, date of decision, start date of implementation, end date of implementation, high impact, impact indicator, source of reference, supports policies, supported by

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policies, comments, and status (final/draft) (see example Figure 68). Some of the major additions of the CD-LINKS project in terms of policy record fields were:

- 'High impact', currently indicating whether a policy is expected to have a high impact on GHG emissions;
- 'Policy objective', indicating what development areas the policy has direct impact on, covering mitigation, adaptation, air pollution, energy security, energy access, land use, food security, water, and economic development;
- 'Impact indicator', providing values of generic indicators (e.g. Vehicle emissions standard (gCO_2/km)) that appear in the policy as such or that are translated as part of the analysis; and
- 'Supports policies' and 'Is supported by policies', indicating when two policies are linked, for instance, when a feed-in tariff measure was implemented to support a renewable energy target.

The following sectors and sub-sectors are covered in the database:

- *General*, referring to policies that cover all sectors;
- *Electricity and heat:* Nuclear, Coal, Oil, Gas, Renewables, CCS;
- *Industry*[17]: Industrial energy related, Fluorinated gases, Industrial N_2O, Industrial process CO_2, Waste (CH_4), Oil and gas production (CH_4);
- *Buildings*: Heating and cooling, Hot water and cooking, Appliances;
- *Transport*: Light duty vehicles, Heavy duty vehicles, Electro-mobility, Air, Rail, Shipping; and
- *Agriculture and forestry*: Agricultural CO_2, Agricultural N_2O, Agricultural CH_4, Forestry.

The following policy types are covered in the database:

- Changing activity;
- Energy efficiency;
- Renewables;
- Nuclear or CCS or fuel switch; and
- Non-energy.

The list of policy instruments used in the database are provided in Table A.2. The policy instruments typology was developed based on the IEA policies and measures database (http://www.iea.org/policiesandmeasures/), to which a set of new categories were added. To accommodate the new policy objectives, the following two instruments were added as part of the CD-LINKS project: 'Industrial air pollution standards' and 'Vehicle air pollution standards'.

[17] Including fossil fuel extraction sector and energy transformation sectors other than electricity and heat such as oil refineries.

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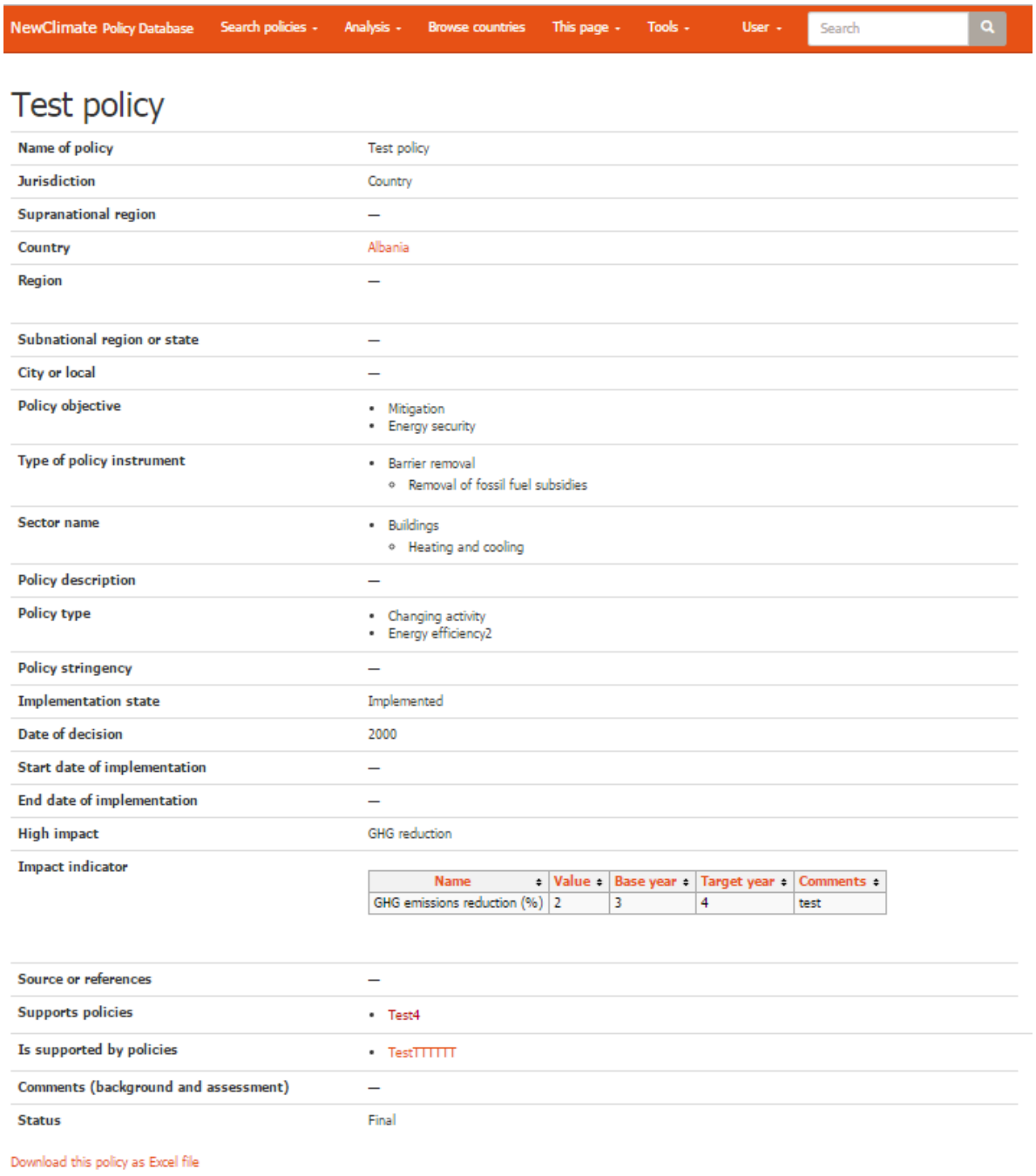

Figure 68: Example policy record in Climate Policy Database

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Table 7: Policy instruments in the database

Instrument category	Sub-category	Policy instrument
Economic instruments	Direct investment	Funds to sub-national governments
		Infrastructure investments
		Procurement rules
		RD&D funding
	Fiscal or financial incentives	CO_2 taxes
		Energy and other taxes
		Feed-in tariffs or premiums
		Grants and subsidies
		Loans
		Tax relief
		User changes
		Tendering schemes
		Retirement premium
		User charges
	Market-based instruments	GHG emissions allowances
		GHG emission reduction crediting and offsetting mechanism
		Green certificates
		White certificates
Regulatory instruments	Codes and standards	Building codes and standards
		Industrial air pollution standards
		Product Standards
		Sectoral Standards
		Vehicle air pollution standards
		Vehicle fuel-economy and emissions standards
		Auditing
		Monitoring
		Obligation schemes
		Other mandatory requirements
Information and education	Performance label	Comparison label
		Endorsement label
		Advice and aid in implementation
		Information provision
		Professional training and qualification
Policy support		Institutional creation
		Strategic planning
RD&D	Research programme	Technology deployment and diffusion
		Technology development
		Demonstration project
Voluntary approaches		Negotiated agreements (public/private sector)
		Public voluntary schemes
		Unilateral commitments (private sector)
Barrier removal		Net metering
		Removal of fossil-fuel subsidies
		Removal of split incentives
		Grid access and priority for renewables
Climate strategy		Formal & legally binding climate strategy
		Political & non-binding climate strategy
		Coordinating body for climate strategy
Target		Energy efficiency target

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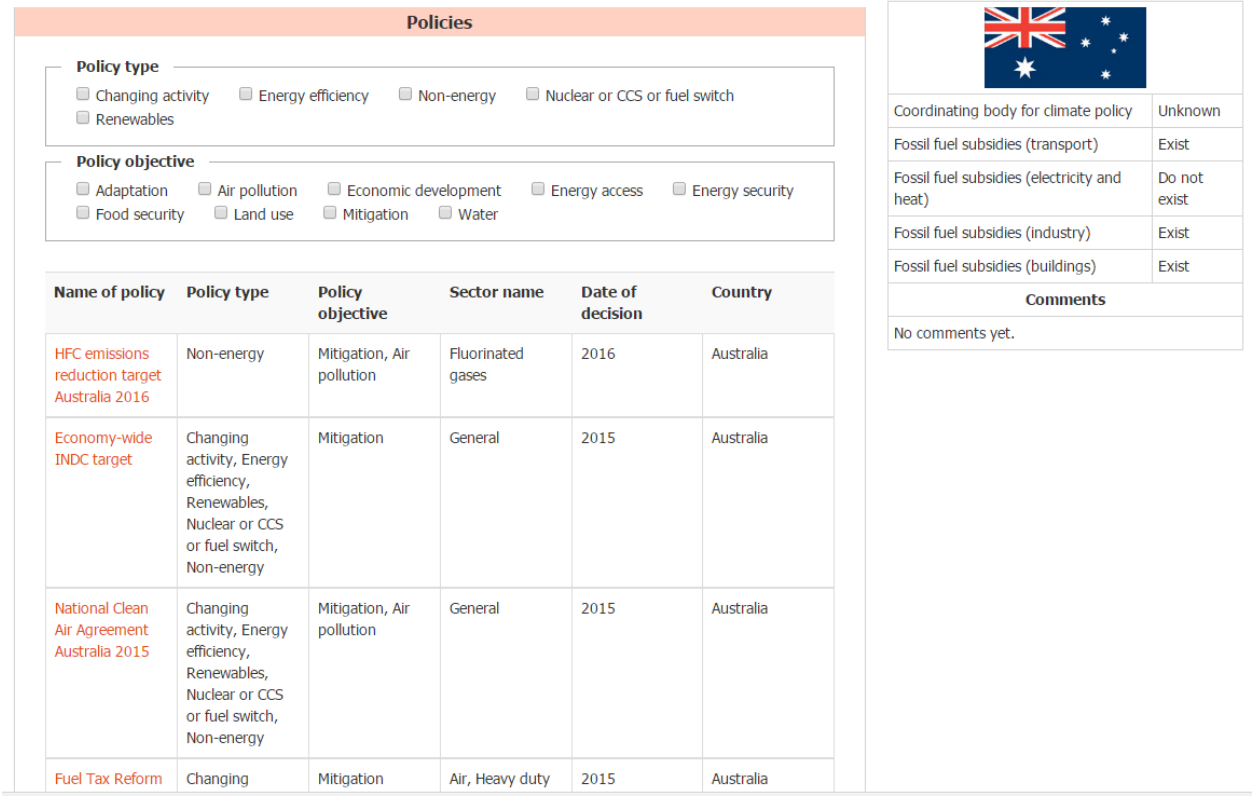
Country page

In addition to the policy records themselves, each country has its own page. This page comprises of the good practice policy menu (presented in the country profiles of this study), a list of all the policies available in the database for that country, and some additional details concerning the coordinating body for climate change and fossil fuel subsidies (Figure 69). In addition to individual countries in the database, the European Union is also treated as one country, having a dedicated page. EU member states are addressed individually on separate country pages.



Policies

Policy type

Changing activity | Energy efficiency | Non-energy | Nuclear or CCS or fuel switch | Renewables

Policy objective

Adaptation | Air pollution | Economic development | Energy access | Energy security | Food security | Land use | Mitigation | Water

Name of policy	Policy type	Policy objective	Sector name	Date of decision	Country
HFC emissions reduction target Australia 2016	Non-energy	Mitigation, Air pollution	Fluorinated gases	2016	Australia
Economy-wide INDC target	Changing activity, Energy efficiency, Renewables, Nuclear or CCS or fuel switch, Non-energy	Mitigation	General	2015	Australia
National Clean Air Agreement Australia 2015	Changing activity, Energy efficiency, Renewables, Nuclear or CCS or fuel switch, Non-energy	Mitigation, Air pollution	General	2015	Australia
Fuel Tax Reform	Changing	Mitigation	Air, Heavy duty	2015	Australia

Coordinating body for climate policy	Unknown
Fossil fuel subsidies (transport)	Exist
Fossil fuel subsidies (electricity and heat)	Do not exist
Fossil fuel subsidies (industry)	Exist
Fossil fuel subsidies (buildings)	Exist
Comments	
No comments yet.	

Figure 69: Screenshot of a country page information additional to the coverage of a good practice policy menu

CD-LINKS policy inventory

The inventory of high GHG reduction policies identified in this study is presented on a dedicated page of the Climate Policy Database website. On the main page of this analysis (Figure 70), the good practice policy menu showing the overall policy coverage of the G20 countries is shown (also presented in section 4.1. of this study), followed by a list of all assessed countries (Figure 71). Accessing a country from this dedicated page provide the list of high-impact climate mitigation policies selected for that country (Figure 72). Although some details are already provided on the page, the complete policy records can be accessed directly.

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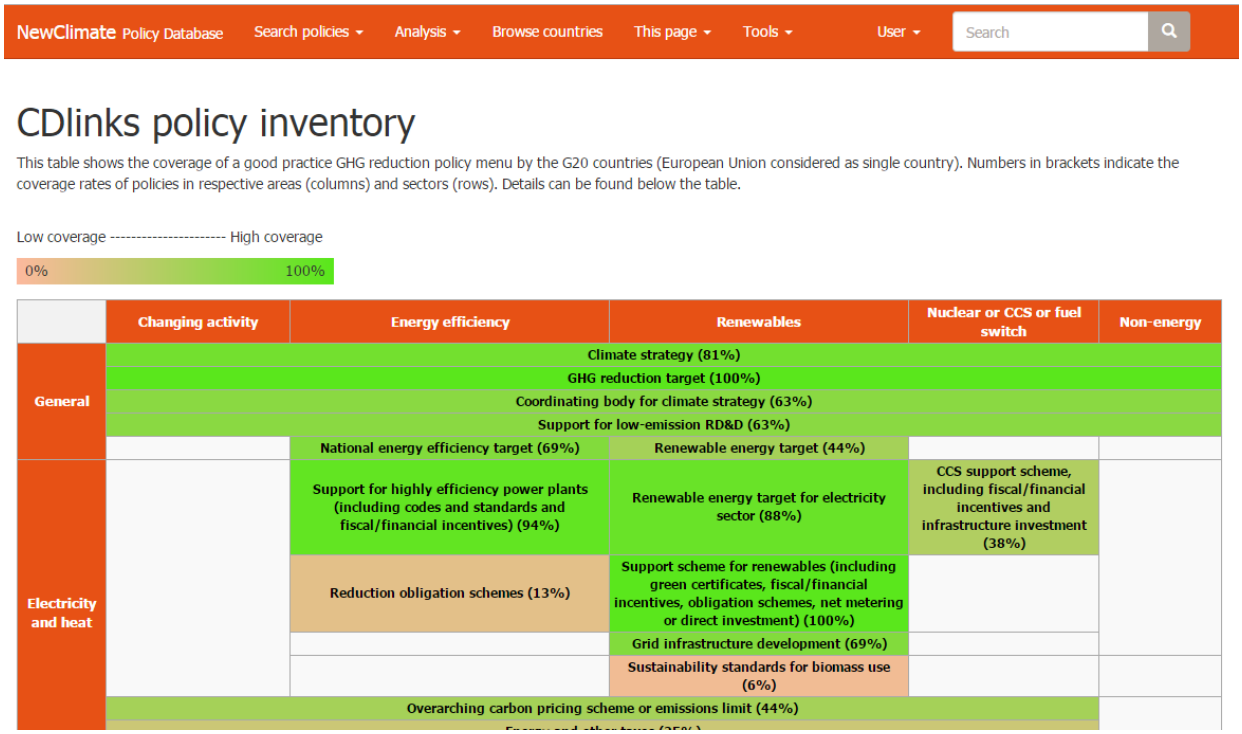

Figure 70: Screenshot of CD-LINKS policy inventory

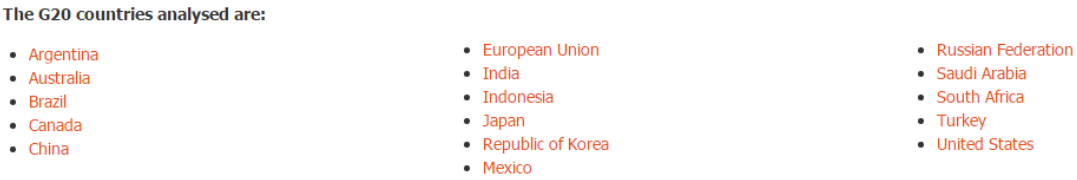

Figure 71: Countries that appear on the CD-LINKS policy inventory page and can be accessed directly

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Policies

Name of policy	Policy objective	Sector name	Policy type	Implementation state	Policy description
Fuel Efficiency Standards for Vehicles - Top Runner Program Japan 1979	Mitigation	Transport Light duty vehicles Heavy duty vehicles	Energy efficiency	Implemented	Light-duty vehicles: Current standards (2010): - Passenger cars: 15.1 km/L (153.8 g CO2/km), a 22.8% increase over 1995 performance of 12.3 km/L (188.8 g CO2/km), - Light trucks (2.5 t): 16.3 km/L (124.4 g CO2/km), a 13.2% increase over 1995 performance of 14.4 km/L (161.2 g CO2/km). Fleet average fuel economy 2015 target: - Passenger cars: 16.8 km/L, a 23.5% increase over 2004 performance of 13.6 km/L - Light trucks (3.5 t): 15.2 km/L, a 12.6% increase over 2004 performance of 13.5 km/L - Small busses: 8.9 km/L, a 7.2% increase over 2004 performance of 8.3 km/L." "When the 2020 targets are met, the fleet average fuel economy is estimated to be 20.3 km/L for passenger cars, a 24.1% increase over the actual 2009 levels of 16.3 km/L and 19.6% increase over MY2015 performance of 17.0 km/L." (Source: http://transportpolicy.net/index.php?title=Japan:_Light-duty:_Fuel_Economy) Heavy-duty vehicles: Fleet average fuel economy of 2015: - For trucks: 7.09 km/L (369.6 g CO2/km), a 12.2% improvement over 2002 performance of 6.32 km/L (414.6 g CO2/km), - For buses: 6.30 km/L (416.0 g CO2/km), a 12.1% improvement over 2002 performance of 5.62 km/L (466.3 g CO2/km). A list of standards for both light duty and heavy duty vehicles by vehicle size for target years up to 2022 can be accessed here: http://www.mlit.go.jp/common/000991480.pdf
Environmet-related tax on vehicle Japan	Mitigation Air pollution	Transport	Changing activity Energy efficiency Nuclear or CCS or fuel switch	Implemented	Motor Vehicle Weight Tax: Inspected automobile to receive the certification of vehicle inspection and be inspected and notified light vehicle to receive the designation of vehicle number. General finances (407/1000 of the tax revenue is granted as general fund of cities). Part of the tax revenue is issued as compensation expense of Pollution-Related Health Damage. Automobile Tax: Example: Passenger and Private Cars, Total emissions of 1.5-2 litres, JPY 39,500/year Light Vehicle Tax: Example: Light Vehicle and Private Car, JPY 7,200/year Automobile Acquisition Tax: Private Car - 5% of acquisition price; Car for Business and Light Vehicle - 3% of acquisition price
Eco-Car Tax Break and Subsidies for Vehicles Japan 2009	Mitigation	Transport Electro-mobility Light duty vehicles	Energy efficiency Nuclear or CCS or fuel switch	Implemented	The effectiveness of the standards is enhanced by financial incentives—such as progressive taxes levied on the vehicle weight and engine displacement. Early compliance of this sort is rewarded through tax breaks for vehicles exceeding their targets ahead of schedule. In addition to the tax-break program, Japan also has a subsidy program. In its fiscal year 2016 the budget will be ¥15 billion for the subsidy program, down from ¥20 billion in fiscal year 2015. Currently, subsidies for clean diesel vehicles stand at up to ¥160,000 per unit.
Act Partially					The government will introduce "Carbon Dioxide Tax of Global Warming Countermeasure" with the aim of controlling the emission of energy-originated CO2 which accounts for about 90% of greenhouse gas causing global warming. The government will add the following tax rates corresponding to the amount of CO2 emission on the petroleum and coal tax on fossil fuel. Added tax rate:

Figure 72: Screenshot on high-impact policy inventory dedicated page for Japan

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Annex 2. Potential co-benefits and adverse side-effects of climate mitigation identified in the IPCC Assessment Report 5

Table 6.7 | Potential co-benefits (green arrows ↑) and adverse side-effects (orange arrows ↑) of the main sectoral mitigation measures; arrows pointing up/down denote a positive/negative effect on the respective objective or concern; a question mark (?) denotes an uncertain net effect. Co-benefits and adverse side-effects depend on local circumstances as well as on the implementation practice, pace, and scale (see Tables 7.3, 8.4, 9.7, 10.5, 11.9, 11.12). Column two provides the contribution of different sectoral mitigation strategies to stringent mitigation scenarios reaching atmospheric CO_2eq concentrations of 430–530ppm in 2100. The interquartile ranges of the scenario results for the year 2050 show that there is flexibility in the choice of mitigation strategies within and across sectors consistent with low-concentration goals (see Sections 6.4 and 6.8). Scenario results for energy supply and end-use sectors are based on the AR5 Scenario Database (see Annex II.10). For an assessment of macroeconomic, cross-sectoral effects associated with mitigation policies (e.g., on energy prices, consumption, growth, and trade), see Sections 3.9, 6.3.6, 13.2.2.3, and 14.4.2. The uncertainty qualifiers in brackets denote the level of evidence and agreement on the respective effects. Abbreviations for evidence: l = limited, m = medium, r = robust; for agreement: l = low, m = medium, h = high.

Sectoral mitigation measures	Integrated model results for stringent mitigation scenarios			Effect on additional objectives/concerns			
				Economic	Social	Environmental	Other
Energy Supply	Deployment[1] 2010	Deployment[1] 2050	Rate of change [%/yr]	*For possible upstream effects of biomass supply for bioenergy, see AFOLU.*			
Nuclear replacing coal power	10 EJ/yr	(4–22) *17–47* EJ/yr	(–2–2) *1–4*	↑ Energy security (reduced exposure to fuel price volatility) (**m/m**) ↑ Local employment impact (but uncertain net effect) (**l/m**) ↑ Legacy cost of waste and abandoned reactors (**m/h**)	Health impact via ↓ Air pollution and coal mining accidents (**m/h**) ↑ Nuclear accidents and waste treatment, uranium mining and milling (**m/l**) ↑ Safety and waste concerns (**r/h**)	Ecosystem impact via ↓ Air pollution (**m/h**) and coal mining (**l/h**) ↑ Nuclear accidents (**m/m**)	Proliferation risk (**m/m**)
Renewable energy (wind, photovoltaic (PV), concentrated solar power (CSP), hydro, geothermal, bioenergy) replacing coal	62 EJ/yr	(66–125) *194–282* EJ/y	(0.2–2) *3–4*	↑ Energy security (resource sufficiency, diversity in the near/medium term) (**r/m**) ↑ Local employment impact (but uncertain net effect) (**m/m**) ↑ Irrigation, flood control, navigation, water availability (for multipurpose use of reservoirs and regulated rivers) (**m/h**) ↑ Extra measures to match demand (for PV, wind and some CSP) (**r/h**)	Health impact via ↓ Air pollution (except bioenergy) (**r/h**) ↓ Coal mining accidents (**m/h**) ↑ Contribution to (off-grid) energy access (**m/l**) ? Project-specific public acceptance concerns (e.g., visibility of wind) (**l/m**) ↑ Threat of displacement (for large hydro) (**m/h**)	Ecosystem impact via ↓ Air pollution (except bioenergy) (**m/h**) ↓ Coal mining (**l/h**) ↑ Habitat impact (for some hydro) (**m/m**) ↑ Landscape and wildlife impact (for wind) **m/m**) ↓ Water use (for wind and PV) (**m/m**) ↑ Water use (for bioenergy, CSP, geothermal, and reservoir hydro) (**m/h**)	Higher use of critical metals for PV and direct drive wind turbines (**r/m**)
Fossil CCS replacing coal	0 Gt CO_2/yr stored	(0) *4–12* CO_2/yr stored	(0) *NA*	↑ Preservation vs. lock-in of human and physical capital in the fossil industry (**m/m**)	Health impact via ↑ Risk of CO_2 leakage (**m/m**) ↑ Upstream supply-chain activities (**m/h**) ↑ Safety concerns (CO_2 storage and transport) (**m/h**)	↑ Ecosystem impact via upstream supply-chain activities (**m/m**) ↑ Water use (**m/h**)	Long-term monitoring of CO_2 storage (**m/h**)
BECCS replacing coal	0 Gt CO_2/yr	(0) *0–6* CO_2/yr	*NA*	*See fossil CCS where applicable. For possible upstream effect of biomass supply, see agriculture, forestry, and other land use (AFOLU).*			
Methane leakage prevention, capture or treatment	NA	NA	NA	↑ Energy security (potential to use gas in some cases) (**l/h**)	↓ Health impact via reduced air pollution (**m/m**) ↑ Occupational safety at coal mines (**m/m**)	↓ Ecosystem impact via reduced air pollution (**l/m**)	

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Sectoral mitigation measures	Integrated model results for stringent mitigation scenarios	Effect on additional objectives/concerns			
		Economic	Social	Environmental	Other
Transport	Scenario results	*For possible upstream effects of low-carbon electricity, see Energy Supply. For possible upstream effects of biomass supply, see AFOLU.*			
Reduction of fuel carbon intensity: electricity, hydrogen (H_2), compressed natural gas (CNG), biofuels	*Interquartile ranges for the whole sector in 2050 with 430–530ppm CO_2eq concentrations in 2100 (see Figures 6.37 & 6.38):* 1) Final energy low-carbon fuel shares 27–41% 2) Final energy reduction relative to baseline 20–45%	↑ Energy security (diversification, reduced oil dependence and exposure to oil price volatility) (m/m) ↑ Technological spillovers (e.g., battery technologies for consumer electronics) (l/l)	Health impact via urban air pollution by ? CNG, biofuels: net effect unclear (m/l) ↓ Electricity, H_2: reducing most pollutants (r/h) ↑ Diesel: potentially increasing pollution (l/m) ↓ Health impact via reduced noise (electrification and fuel cell LDVs) (l/m) ↓ Road safety (silent electric LDVs at low speed) (l/l)	Ecosystem impact of electricity and hydrogen via ↓ Urban air pollution (m/m) ↑ Material use (unsustainable resource mining) (l/l) ? Ecosystem impact of biofuels: *see AFOLU*	
Reduction of energy intensity		↑ Energy security (reduced oil dependence and exposure to oil price volatility) (m/m)	↓ Health impact via reduced urban air pollution (r/h) ↑ Road safety (via increased crash-worthiness) (m/m)	↓ Ecosystem and biodiversity impact via reduced urban air pollution (m/h)	
Compact urban form and improved transport infrastructure **Modal shift**		↑ Energy security (reduced oil dependence and exposure to oil price volatility) (m/m) ↑ Productivity (reduced urban congestion and travel times, affordable and accessible transport) (m/h) ? Employment opportunities in the public transport sector vs car manufacturing jobs (l/m)	Health impact for non-motorized modes via ↓ Increased physical activity (r/h) ↑ Potentially higher exposure to air pollution (r/h) ↓ Noise (modal shift and travel reduction) (r/h) ↑ Equitable mobility access to employment opportunities, particularly in developing countries (DCs) (r/h) ↑ Road safety (via modal shift and/or infrastructure for pedestrians and cyclists) (r/h)	Ecosystem impact via reduced ↓ Urban air pollution (r/h) ↓ Land-use competition (m/m)	
Journey distance reduction and avoidance		↑ Energy security (reduced oil dependence and exposure to oil price volatility) (r/h) ↑ Productivity (reduced urban congestion, travel times, walking) (r/h)	↓ Health impact (for non-motorized transport modes) (r/h)	Ecosystem impact via ↓ Urban air pollution (r/h) ↑ New/shorter shipping routes (r/h) ↓ Land-use competition from transport infrastructure (r/h)	
Buildings	Scenario results	*For possible upstream effects of fuel switching and RES, see Energy Supply.*			
Fuel switching, incorporation of renewable energy, green roofs, and other measures reduding GHG emissions intensity	*Interquartile ranges for the whole sector in 2050 with 430–530ppm CO_2eq concentrations in 2100 (see Figures 6.37 & 6.38):* 1) Final energy low-carbon fuel shares 51–60% 2) Final energy reduction relative to baseline 14–35%	↑ Energy security (m/h) ↑ Employment impact (m/m) ↑ Lower need for energy subsidies (l/l) ↑ Asset values of buildings (l/m)	Fuel poverty (residential) via ↓ Energy demand (m/h) ↑ Energy cost (l/m) ↓ Energy access (for higher energy cost) (l/m) ↑ Productive time for women/children (for replaced traditional cookstoves) (m/h)	Health impact in residential buildings via ↓ Outdoor air pollution (r/h) ↓ Indoor air pollution (in DCs) (r/h) ↓ Fuel poverty (r/h) ↓ Ecosystem impact (less outdoor air pollution) (r/h) ↑ Urban biodiversity (for green roofs) (m/m)	Reduced Urban Heat Island (UHI) effect (l/m)
Retrofits of existing buildings (e.g., cool roof, passive solar, etc.) **Exemplary new buildings** **Efficient equipment**		↑ Energy security (m/h) ↑ Employment impact (m/m) ↑ Productivity (for commercial buildings) (m/h) ↑ Lower need for energy subsidies (l/l) ↑ Asset values of buildings (l/m) ↑ Disaster resilience (l/m)	↓ Fuel poverty (for retrofits and efficient equipment) (m/h) ↓ Energy access (higher cost for housing due to the investments needed) (l/m) ↑ Thermal comfort (for retrofits and exemplary new buildings) (m/h) ↑ Productive time for women and children (for replaced traditional cookstoves) (m/h)	Health impact via ↓ Outdoor air pollution (r/h) ↓ Indoor air pollution (for efficient cookstoves) (r/h) ↓ Improved indoor environmental conditions (m/h) ↓ Fuel poverty (r/h) ↓ Insufficient ventilation (m/m) ↓ Ecosystem impact (less outdoor air pollution) (r/h) ↓ Water consumption and sewage production (l/l)	Reduced UHI effect (retrofits and new exemplary buildings) (l/m)
Behavioural changes reducing energy demand		↑ Energy security (m/h) ↑ Lower need for energy subsidies (l/l)		↓ Health impact via less outdoor air pollution (r/h) and improved indoor environmental conditions (m/h) ↓ Ecosystem impact (less outdoor air pollution) (r/h)	

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Sectoral mitigation measures	Integrated model results for stringent mitigation scenarios	Effect on additional objectives/concerns			
		Economic	Social	Environmental	Other
Industry	Scenario results	*For possible upstream effects of low-carbon energy supply (incl CCS), see energy supply and of biomass supply, see AFOLU.*			
CO_2 and non-CO_2 GHG emissions intensity reduction	*Interquartile ranges for the whole sector in 2050 with 430–530 ppm CO_2eq concentrations in 2100 (see Figures 6.37 & 6.38):* 1) Final energy low-carbon fuel shares: 44–57 % 2) Final energy reduction relative to baseline: 22–38 %	↑ Competitiveness and productivity (**m/h**)	↓ Health impact via reduced local air pollution and better work conditions (for perfluorinated compounds (PFCs) from aluminium) (**m/m**)	↓ Ecosystem impact via reduced local air pollution and reduced water pollution (**m/m**) ↑ Water conservation (**l/m**)	
Technical energy efficiency improvements via new processes and technologies		↑ Energy security (via lower energy intensity) (**m/m**) ↑ Employment impact (**l/l**) ↑ Competitiveness and productivity (**m/h**) ↑ Technological spillovers in DCs (due to supply chain linkages) (**l/l**)	↓ Health impact via reduced local pollution (**l/m**) ↑ New business opportunities (**m/m**) ↑ Water availability and quality (**l/l**) ↑ Safety, working conditions and job satisfaction (**m/m**)	Ecosystem impact via ↓ Fossil fuel extraction (**l/l**) ↓ Local pollution and waste (**m/m**)	
Material efficiency of goods, recycling		↓ National sales tax revenue in medium term (**l/l**) ↑ Employment impact in waste recycling market (**l/l**) ↑ Competitiveness in manufacturing (**l/l**) ↑ New infrastructure for industrial clusters (**l/l**)	↓ Health impacts and safety concerns (**l/m**) ↑ New business opportunities (**m/m**) ↓ Local conflicts (reduced resource extraction) (**l/m**)	↓ Ecosystem impact via reduced local air and water pollution and waste material disposal (**m/m**) ↓ Use of raw/virgin materials and natural resources implying reduced unsustainable resource mining (**l/l**)	
Product demand reductions		↓ National sales tax revenue (medium term) (**l/l**)	↑ Wellbeing via diverse lifestyle choices (**l/l**)	↓ Post-consumption waste (**l/l**)	
AFOLU	Scenario results	*Note: co-benefits and adverse side-effects depend on the development context and the scale of the intervention (size).*			
Supply side: Forestry, land-based agriculture, livestock, integrated systems and bioenergy (**marked by †**) **Demand side:** Reduced losses in the food supply chain, changes in human diets, changes in demand for wood and forestry products	Ranges for cumulative land-related emissions reductions relative to baseline for CH_4, CO_2, and N_2O in idealized implementation scenarios with 450 CO_2eq ppm concentrations in 2100 (see Table 11.10): CH_4: 2–18 % CO_2: −104–423 % N_2O: 8–17 %	† Employment impact via ↑ Entrepreneurship development (**m/h**) ↓ Use of less labor-intensive (**m/m**) Technologies in agriculture ↑† Diversification of income sources and access to markets (**r/h**) ↑† Additional income to (sustainable) landscape management (**m/h**) ↑† Income concentration (**m/m**) ↑† Energy security (resource sufficiency) (**m/h**) ↑ Innovative financing mechanisms for sustainable resource management (**m/h**) ↑ Technology innovation and transfer (**m/m**)	↑† Food-crops production through integrated systems and sustainable agriculture intensification (**r/m**) ↓† Food production (locally) due to large-scale monocultures of non-food crops (**r/l**) ↑ Cultural habitats and recreational areas via (sustainable) forest management and conservation (**m/m**) ↑† Human health and animal welfare e.g., through less pesticides, reduced burning practices and practices like agroforestry and silvo-pastoral systems (**m/h**) ↓† Human health when using burning practices (in agriculture or bioenergy) (**m/m**) † Gender, intra- and inter-generational equity via ↑ Participation and fair benefit sharing (**r/h**) ↑ Concentration of benefits (**m/m**)	↑ Provision of ecosystem services via Ecosystem conservation and sustainable management as well as sustainable agriculture (**r/h**) ↑† Large-scale monocultures (**r/h**) ↑† Land use competition (**r/m**) ↑ Soil quality (**r/h**) ↓ Erosion (**r/h**) ↑ Ecosystem resilience (**m/h**) ↑ Albedo and evaporation (**r/h**)	*Institutional aspects:* ↑↓† Tenure and use rights at the local level (for indigenous people and local communities) especially when implementing activities in natural forests (**r/h**) ↑↓ Access to participative mechanisms for land management decisions (**r/h**) ↑ Enforcement of existing policies for sustainable resource management (**r/h**)
Human Settlements and Infrastructure		*For co-benefits and adverse side-effects of compact urban form and improved transport infrastructure, see also Transport.*			
Compact development and infrastructure		↑ Innovation, productivity and efficient resource use and delivery (**r/h**) ↑ Higher rents and property values (**m/m**)	↑ Health from increased physical activity: *see Transport*	↑ Preservation of open space (**m/m**)	
Increased accessibility		↑ Commute savings (**r/h**)	↑ Health from increased physical activity: *see Transport* ↑ Social interaction and mental health (**m/m**)	↑ Air quality and reduced ecosystem and health impacts (**m/h**)	
Mixed land use		↑ Commute savings (**r/h**) ↑↑ Higher rents and property values (**m/m**)	↑ Health from increased physical activity (**r/h**) ↑ Social interaction and mental health (**l/m**)	↑ Air quality and reduced ecosystem and health impacts (**m/h**)	

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