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Transitioning to Low-Carbon Economies under the 2030 Agenda: Minimizing Trade-Offs and Enhancing Co-Benefits of Climate-Change Action for the SDGs

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Abstract: The 2030 Agenda with its Sustainable Development Goals (SDGs) and the Paris Agreement on climate change were adopted in 2015. Although independently defined, the two agreements are strongly interlinked. We developed a framework that scores the impacts of climate-change actions on all SDG targets based on directionality (i.e., trade-offs or co-benefits) and likelihood of occurrence (i.e., ubiquitous or context-dependent), and categorizes them by dependence on four key context dimensions—geographical, governance, time horizon and limited natural resources. Through an extensive literature review, we found that climate-change mitigation measures directly affect most SDGs and their targets, mostly through co-benefits. Improving energy efficiency, reducing energy-services demand and switching to renewables provide the most co-benefits. In contrast, carbon capture and storage and nuclear energy likely lead to multiple trade-offs. We show how understanding the relevant context dimensions facilitates policy design and policy mixes that enhance co-benefits and minimize trade-offs. Finally, by assessing the prevalence of climate-change mitigation measures in G20 countries, we found that measures with more co-benefits are more frequently adopted. Our study advances the knowledge of climate–SDG interactions, contributing to climate and sustainable development governance research, and facilitating policy design for a joint implementation of the Paris Agreement and the 2030 Agenda.

Keywords: climate change; sustainable development goals; climate-change policy; policy coherence; G20; domestic policies

Citation: Iacobuţă, G.I.; Höhne, N.; van Soest, H.L.; Leemans, R. Transitioning to Low-Carbon Economies under the 2030 Agenda: Minimizing Trade-Offs and Enhancing Co-Benefits of Climate-Change Action for the SDGs. *Sustainability* **2021**, *13*, 10774. https://doi.org/10.3390/su131910774

Academic Editor: Silvio Matassa

Received: 17 July 2021
Accepted: 23 August 2021
Published: 28 September 2021

1. Introduction

The Paris Agreement [1] on climate change and the 2030 Agenda [2] on sustainable development (in this study we refer to 'sustainable development' in the context of the 2030 Agenda, but we use a broader understanding of 'development', as a multitude of social, economic and environmental objectives that may not always individually align with sustainability objectives) are two major international agreements that were adopted in 2015 by parties under the United Nations Framework Convention of Climate Change (UNFCCC; Paris Agreement) and the United Nations General Assembly (2030 Agenda), both covering most of the world's countries. The Paris Agreement's main goal is to limit global temperature increase to well below 2 °C and to strive for a limit of 1.5 °C, while managing unavoidable climate-change impacts. The 2030 Agenda, on the other hand, covers a wide range of social, economic and environmental issues represented through a set of 17 Sustainable Development Goals (SDGs) and 169 respective targets. Both agendas are universal in nature, meaning that all countries must take action towards the achievement of these common goals.

Although developed independently, the Paris Agreement and the 2030 Agenda are strongly interlinked. First, the 2030 Agenda directly addresses climate change through SDG 13. Second, the Paris Agreement emphasizes the importance of sustainable development considerations when addressing climate change. Third, climate change itself is recognized to hinder development efforts worldwide [3,4]. At the level of implementation, climate-change measures have numerous direct and indirect (i.e., second-order) impacts on most other development areas and related SDGs [3,5–9]. Likewise, the means of reaching various SDGs most often affect future greenhouse gas (GHG) emission levels [10,11]. Importantly, countries' Nationally Determined Contributions (NDCs), which are the main national implementation strategies of the Paris Agreement, put forward climate-relevant actions (we refer to 'climat**e[**-change/relevant] action' as state and non-state policies and measures that have the effect of addressing climate change (whether intentionally or not, i.e., climate-change relevant)) that are directly linked to all SDGs [12,13].

The links between climate and development actions have been studied for decades [14], motivated by the importance of climate-change policy integration with the traditional development agenda [15,16]. Hence, a large body of literature addresses climate–development synergies and trade-offs. While some studies undertake comprehensive climate–development assessments [9,17,18], others focus on the nexus between climate-change actions and individual development areas, such as air quality [19–21], food security [22,23], energy security [21,24], energy poverty [25–27] or energy more broadly [28,29].

More recent studies have analysed the impacts of climate change and climate-change actions on the SDGs specifically, both for climate-change mitigation (reducing GHG emissions) and for climate adaptation (addressing climate-change impacts) [3,30]. Among these studies, the SCAN-tool (SDG Climate Action Nexus tool (SCAN-tool), https://ambitiontoaction.net/scan_tool/, accessed on 9 July 2020) built on an earlier version of the impact analysis presented as the first step in our study [31]. These studies typically use literature review and expert judgement to classify climate-change–SDG interactions based on numerical scales that indicate trade-offs and co-benefits, and the strength or nature of the interactions. Such analyses and classifications have elucidated a wide breadth of climate-change–SDG interlinkages and have highlighted that, although most interlinkages represent co-benefits, there are also important trade-offs that could undermine achieving either the climate goals or the SDGs.

Focusing on climate-relevant policies and measures that are firmly within the national sustainable development priorities of countries, is essential to ensure that climate-change and development policy coherence (policy coherence is defined by the OECD (2018, p. 83) as "matching of policies, processes and institutions at all government and governance levels to avoid contradictions and trade-offs in policy making") is achieved and goals are jointly reached [32,33]. As such, the choice of low-carbon transition pathways to mitigate climate change is highly important as this determines whether other development objectives are met [8]. Yet, while the existing literature provides mostly comprehensive overviews of climate and development interlinkages, available classifications are not explicit on the implementation contexts of interlinkages and how these will favour different policy approaches. The need for a better understanding of such contexts was emphasized early on in the SDG interlinkages classification literature (e.g., [34]) and later elaborately explained [35].

In our study, we seek to fill some of these literature gaps by exploring three research questions: (1) What are the impacts of climate-change mitigation measures on the SDGs and when do they occur?; (2) How do key context dimensions influence the occurrence and magnitude of climate-change mitigation measures' impacts and the possibilities to address these impacts through policy?; and (3) What is the influence of climate-change mitigation measures' impacts on the SDGs on the adoption of these measures in the G20 member states?

To answer the first research question, we review the literature on climate and development links to systematically identify (possible) direct policy impacts of 33 climate-change mitigation areas and technologies on 53 relevant development areas and respective SDG targets. Our mapping of these impacts differs from and adds to the previous literature in the following ways: (1) it categorizes climate-change–SDG linkages by specific development areas, some of which cut across multiple SDGs and SDG targets; (2) it addresses each type of renewable energy technology separately under the measures for low-carbon fuel switch; (3) it includes the impacts of energy taxation and of CO_2 taxes in the energy and agriculture sectors; and (4) it applies a scoring method that focuses on whether policy impacts occur at all times or only in specific circumstances. The last point is of particular policy relevance as this indicates whether complementary policies or policy designs could be used to manifest co-benefits (i.e., when they only occur under specific circumstances) or only to enhance these impacts (i.e., if they always occur with the respective climate measure). Similarly, in the opposite direction, our analyses will indicate whether trade-offs could be avoided altogether or whether they can only be reduced.

Most importantly, to address the second research question, we address the key gap of implementation-context effects on climate-change–SDG interlinkages by classifying all identified policy impacts across the context dimensions adapted from Nilsson et al. [35]: time horizon, geographical (local), governance and natural resources (the latter being added to their three dimensions). These four context dimensions provide additional information about these impacts and elucidate concrete types of policies and policy designs that could be used to maximize co-benefits and minimize trade-offs. In this sense, we have built a comprehensive and highly informative database of climate-change and SDG policies and their impacts, and respective context dimensions, which can score and categorize the benefits of and trade-offs between climate-change mitigation and development policies. Its output should inform policy-making processes and enhance policy coherence between climate and development objectives.

Finally, for the third research question, we consider the climate-change mitigation measures currently implemented in the G20 member countries to assess potential preferences for specific types of climate measures and respective development impacts. This assessment acts as an example of a potential application of the developed climate-change–SDG scoring framework and helps to determine to what extent policy coherence is already addressed in some of the largest GHG-emitting countries. Jointly, the G20 countries were responsible for 75% of global GHG emissions in 2018, including land use and land-use change [36].

As countries are currently developing more ambitious NDCs under the Paris Agreement and sustainable development strategies to concurrently achieve the 17 SDGs, a good understanding of climate-change–SDG interlinkages and ways to enhance policy coherence or respective strategies is essential. Our impact classification approach could support relevant state and non-state actors, and researchers who address issues of climate-change–development policies integration and institutional cooperation for jointly implementing the Paris Agreement and Agenda 2030. Moreover, our approach could also be applied to assess the impacts of measures related to any other development area, not only climate change.

2. Materials and Methods

The scope of our study extends to relevant climate-mitigation measures across all economic sectors (electricity and heat, industry, buildings, transport, agriculture and forestry) and all relevant SDGs. In that sense, it covers policy instruments from a wide range of policy areas: the switch to low-carbon energy production sources (including in the transport sector), assessed by source; changing activities or behaviours that reduce demand for energy and materials; energy efficiency improvements; non-energy-related measures that reduce GHG emissions, in particular in the industry sector; energy taxes and CO_2 taxes in the energy and agricultural sectors; agricultural, forestry and other land-use measures (AFOLU), including reduction in livestock consumption; and education, training and awareness raising. The analysed set of policy measures was adapted from previous reports of the Intergovernmental Panel on Climate Change (IPCC) (IPCC [17], Table TS.3, and Roy et al. [3], Table 5.2). However, it ignored measures that require international cooperation such as ocean enhanced weathering, ocean fertilization or other types of geoengineering. We only considered policies and measures that are commonly implemented with the objective to reduce GHG emissions, and not also more general economic and social reforms that would affect GHG emissions indirectly. The complete list of climate-change policies and measures is presented in the following section, along with the results. Concerning development areas, this study addresses all SDGs and their respective targets, with the exception of targets that address 'means of implementation' and of SDGs 16 (promote just, peaceful and inclusive societies) and 17 (partnerships), which focus on governance approaches rather than development outcomes.

The first step in our study was to conduct a thorough review of both the academic and grey literature to identify a wide range of development impacts of climate-change mitigation measures. We started from existing reviews of climate-change mitigation impacts on development and extracted all relevant impacts, i.e., where impacts of climate-change mitigation on an SDG-related area were specifically indicated, and cited studies [3,6,17]. Next, we conducted a systematic search for other relevant literature in Google Scholar (to capture both scientific and grey literature) through the use of keywords. Here, we focused on the first five pages of Google Scholar to capture the most relevant results, and went a few pages beyond if results continued to be relevant. The used keywords were combinations of specific climate-change mitigation measures (listed above) and the broader SDG development areas (e.g., 'health' for SDG 3, 'water' for SDG 6, 'industry' or 'infrastructure' for SDG 9). In addition, the text of the SDG targets was textually analysed (through reading by co-authors) to identify more specific development areas (see in the next paragraph, Table 1) that could be affected by climate-change mitigation measures, based on the authors' judgement. These potential new impact areas were used as keywords to further refine and deepen the literature search. The abstracts of papers with titles that appeared to speak to our inquiry were read in full. Where the abstracts showed high relevance, the full papers were consulted and identified climate–development impacts were extracted. Beyond the broader literature on climate-change–development impacts, we also used empirical analyses and qualitative case studies relevant to the development impacts assessed to fill remaining gaps from the overarching literature. The objective of this exercise was to identify all potential climate-change–development impacts and not to assess the level of scientific consensus or to provide a complete account of the literature. In our account of impacts per SDG presented in the Supplementary Materials (Word document), we highlight key exemplifying literature for each impact. The literature review process is further described in Figure 1.

Table 1. Identified development areas affected by climate-change mitigation and their corresponding SDG targets. The symbols indicate if the respective development area is primarily of an economic (diamond), social (circle) or environmental nature (square). Some development areas are relevant to more than one of these three dimensions, but we only highlight the most predominant.

Development Theme	SDG Targets	Development Theme	SDG Targets
◆ Affordable energy (poverty)	1.2, 7.1, 11.1	◆ Economic diversification	8.2, 8.3, 9.5
● Energy access	1.4, 7.1, 11.1	◆ Tech./infrastructure upgrade	8.2, 9.5
● Land access	1.4, 2.3	◆ Economic productivity	8.2
● Food availability	2.1	◆ Decent/safe jobs	8.3, 8.8
◆ Agricultural jobs	2.3	■ Resource efficiency	8.4, 9.4, 12.2, 12.5
◆ Agricultural productivity	2.3, 2.4	■ Growth w/out env. degradation	8.4
◆ Farmers' income	2.3	◆ Job creation	8.5
◆ Agri. infrastructure/knowledge	2.3	◆ Sustainable infrastructure	9.1, 9.2
◆ Resilient and sust. agriculture	2.4	◆ Sustainable industrialization	9.2
● Communicable diseases	3.3	◆ Inclusive industrialization	9.2
● Non-communicable diseases	3.4	◆ Bottom 40% income growth	10.1
● Mental health	3.4	● Inclusiveness	10.2
● Road safety	3.6, 11.2	● Adequate housing	11.1
■ Non-thermal water pollution	3.9, 6.3, 14.1	● Affordable housing	11.1
■ Air quality	3.9, 11.6, 12.4	● Public transport	11.2
■ Soil quality	3.9, 12.4, 15.3	■ Sustainable transport	11.2
● Training and education	4.3, 4.4, 4.5, 4.7, 12.8	■ Sustainable settlements	11.3
● Female discrimination	5.1	■ Ecosystems/nature conservation	11.4, 15.1, 15.5
● Domestic work support	5.4	■ Environmetal impact of cities	11.6
● Water efficiency & access	6.1, 6.4	■ Waste management	11.6, 12.5
■ Thermal water pollution	6.3, 14.1	■ Sust. corporate practices	12.2, 12.6
■ Water ecosystems	6.6, 15.1	■ Sust. forest management	12.2, 15.2
● Modern energy sources	7.1	■ Food waste	12.3
● Reliable energy	7.1	■ Sust. public procurement	12.7
■ Renewable energy	7.2	■ Coastal ecosystems protection	14.2, 14.5
◆ Energy efficiency	7.3	◆ Marine economies	14.7
◆ Sustained economic growth	8.1, 8.3		

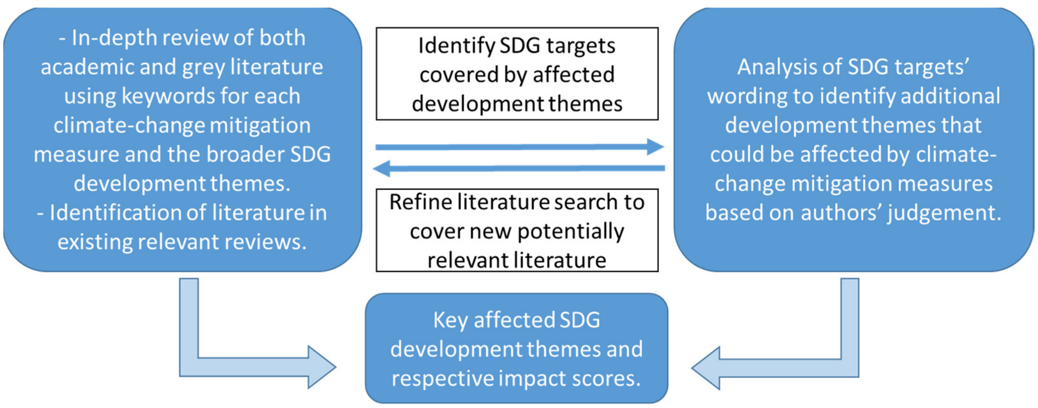

Figure 1. Methodological approach used to identify the key SDG development areas affected by assessed climate-change mitigation measures.

The complete list of 53 development areas that were extracted from SDG targets through textual analysis and identified in our literature review of climate–development interactions is presented in Table 1. Due to the interlinked nature of the SDGs, some key development areas are recurrent and appear in more than one SDG target. For example, air pollution is part of targets on cities (SDG11), health (SDG3), and responsible consumption and production (SDG12).

The identified interactions between climate-change mitigation measures and specific development areas were scored from −2 to 2 based on impact direction (trade-offs/co-benefits) and the dependence of impact occurrence on the local context or the implementation approach (Table 2). The most widely used scoring method for SDG interactions so far is the seven-tier scale developed by Nilsson et al. (2016), which was applied, for instance, by Roy et al. [3] and Nerini et al. [30] for climate-change mitigation measures, by McCollum et al. [29] for SDG 7 (energy), by Coopman et al. [37] for SDG 12 (sustainable production and consumption) and by ICSU [38], Nilsson et al. [39] and Weitz et al. [40] to a variety of SDGs. However, as our study does not assess bi-directional interactions between SDGs, nor indirect interactions, but rather focuses on the direct impacts of different types of climate-change mitigation measures on all other SDGs, we could apply a narrower scale. Moreover, as the dependence of an impact on the context or implementation approach can inform whether the impact can be fully or only partly addressed, our scale additionally provides information on the impact occurrence dependence.

Table 2. Scoring method for impacts of (climate-change mitigation) policies and measures on SDGs.

2	1	0	−1	−2
This action always leads to the specified co-benefit. This impact can be enhanced by addressing the relevant context dimensions.	This action can lead to a co-benefit. This impact can be manifested and enhanced by addressing the relevant context dimensions.	The action can lead to a co-benefit or a trade-off. Favourable outcomes can be pursued by addressing the relevant context dimensions.	This action can lead to a trade-off. This impact can be reduced or completely avoided by addressing the relevant context dimensions.	This action always leads to a trade-off. This impact can be reduced by addressing the relevant context dimensions.

An example of a climate-change–development impact that would occur under any circumstance is, for instance, the resulting air pollution reduction if fossil-fuel power plants are replaced by solar photovoltaics (PV). An impact that would occur only under specific circumstances is, for instance, the displacement of local communities as a result of hydropower projects. This would occur only if communities exist in the area where projects are implemented. An understanding of the impact context dependence informs policy makers with regard to the space of action available. More precisely, the scoring indicates whether trade-offs could be fully eliminated (−1, 0) or only attenuated (−2), and similarly, whether certain enablers are necessary to obtain specific co-benefits (0, 1) or whether those co-benefits are always attained and further action could be taken to enhance them (2).

The scoring was conducted by three of the co-authors. In this process, one co-author suggested the initial draft scoring and the other two authors provided feedback and suggestions for other scoring when disagreement occurred. Full agreement was sought based on specified rationale for each suggestion. Beyond the identified literature, the co-authors additionally made a judgement on whether specific impacts could be expanded to other climate-change mitigation measures that were similar to those where impacts were identified (e.g., some impacts generated by reduced demand for energy services were similar to those related to energy efficiency improvements).

Nevertheless, the occurrence and strength of the impacts of climate-mitigation measures are strongly dependent on a country's development context and on the way in which these measures are actually implemented. Beyond simple scoring of interactions, Nilsson et al. [35] point out that "to support policy efforts at appropriate levels of decision-making, the contextual dimensions must be front and centre of the assessment process" (page 1491). In that regard, they identified their three key dimensions.

We categorize all SDG impacts based on our four dimensions (time horizon, geographical, governance and natural resources). This categorization aims to add depth to the original scoring framework, and to add value to policy design and decision making on policy mixes and instrument selection by a better understanding of the nature of policy impacts. The context dimensions were defined as follows:

- **Time horizon (*when*)** → Indicates that a policy impact may manifest in the opposite direction in the short term as opposed to the long term;
- **Local (geographical) (*where*)** → Indicates that the policy impact's occurrence or magnitude would be influenced by the location where a specific project is implemented, or where a measure takes effect;
- **Governance (*how*)** → Indicates that the policy impact occurrence and magnitude relate to the implementation approach through: choice of technology or (guidelines on) processes, or applicability of policy. This dimension does not cover governance effectiveness or other aspects of governance; and
- **Natural resources (i.e., limited fuels) (*what*)** → Indicates that the policy impact occurrence and magnitude depend on availability of limited natural resources nationally (in particular fossil and radioactive fuels). This category does not include renewable energy resources.

In our analysis, we only considered direct (first-order) impacts of climate-change mitigation policies and measures. Indirect impacts of climate-change mitigation measures (i.e., second-order impacts) and the impacts of climate change per se were excluded from the assessment to avoid double-counting of SDG linkages and to maintain the focus on climate-change policies and actions. For instance, the use of renewable energy sources for GHG emission reduction can facilitate expansion of electricity in remote areas and help achieve the SDG 7 target on electricity access (direct impact). In turn, increased access to electricity can further become an enabler for improved education, access to health services and increased economic activities, among others. In our study, only the impact on SDG 7 would be indicated, as a direct impact.

Moreover, as we aim to analyse the impacts of climate-change mitigation, we assumed that the climate measures would reduce GHG emissions. Hence, where applicable, we assumed that these measures would replace or reduce the use of higher-carbon fossil-fuel energy (e.g., natural gas replaces coal) and scored the impacts relative to such a fossil-fuel alternative. These assumptions are necessary to distinguish between the impacts of a carbon-intensive versus those of a climate-mitigation scenario, hence assessing the co-benefits and trade-offs of a low-carbon transition.

In the final part of our study, we use data on climate-change mitigation policies and measures currently in force in the G20 member states (including the European Union as one and excluding individual EU member states due to insufficient data) to determine which types of policies and measures are more frequently adopted by these countries. Here we focus on the same policy types, instruments and sectors as in the first part. We assume that types of climate measures that predominantly offer co-benefits would be favoured by more countries, and therefore assess a potential correlation between the overall number of positively affected SDG targets as weighted by the score given in the scoring framework, and the number of G20 member states that adopted these measures. The data on climate-change mitigation policies and measures in these countries were extracted from the Climate-Policy Database (climatepolicydatabase.org), based on the 2020 update by Nascimento et al. [36].

3. Results and Discussion

In this section, we present the identified impacts of climate-change mitigation measures on other SDGs, including their scoring and categorization across the context dimensions. While here we only show the overarching results of our analysis, we provide an extensive textual description of the SDG impacts, including key literature, in the Supplementary Materials (Word document). Moreover, the Excel file in the Supplementary

Materials was designed to act as a research and policy tool, whereby all impacts are presented in a comprehensive interactive table that indicates the impact scores and context dimensions and provides descriptive information on the impacts in pop-up boxes. Finally, we present the results of the G20 climate-change policy analysis to shed light on how climate–development impacts determine policy preferences.

3.1. Identification of Climate-Change Mitigation Impacts on the SDGs

We found that climate-change mitigation measures affect the SDGs in many different ways, but mostly through co-benefits. The overview of impacts presented in Figure 2 shows that measures that improve energy efficiency and those that reduce demand for material and energy services through strategic planning and changes of activities and processes (i.e., changing activities) mainly result in co-benefits across all SDGs. Furthermore, when compared with fossil-fuel alternatives, renewable energy sources also have mostly co-benefits, especially for solar PV, tidal and wave energy, solar and geothermal heating, and wind. Consequently, if fuelled by clean energy sources, electric vehicles (EVs) would also predominantly provide co-benefits, although some trade-offs remain, such as battery production and disposal.

Nevertheless, trade-offs of climate-change mitigation are most often the deal breakers of ambitious climate-change policies and actions and require special attention when designing climate-change strategies. Nuclear energy and (bioenergy) carbon capture and storage ((BE)CCS), followed by natural gas and biofuels, are climate-change mitigation measures with a larger number of trade-offs across most development areas analysed. In fact, CCS (applied to fossil-fuel energy production) has the lowest overall score when impact scores are summed across all relevant development areas (Figure 2) (By overall score we mean the direct addition of all scores of a given measure. Hence, if a measure has more co-benefits, i.e., more positive scores +1 and +2, than trade-offs, i.e., negative scores, i.e., −1 and −2, it will have a positive overall score. In general, a larger number of co-benefits would result in a higher score.). It is the only other climate-change mitigation measure with a negative overall score next to energy/CO_2 and agriculture taxes. Although CCS and BECCS apply similar technologies, (fossil fuel) CCS continues all trade-offs related to fossil fuels and adds to them through increased energy demand for system operation. Nevertheless, while CCS requires additional energy to reduce the impacts of fossil-fuel energy production, BECCS provides the benefit of a carbon sink and can, therefore, be counted as productive energy use. Similarly, industrial carbon capture and utilization would increase the productive use of energy and could further improve water-use efficiency if its processes are optimized [41]. Energy and agricultural (CO_2) taxes are also broadly conflicting with other SDGs, especially with poverty alleviation (SDG 1), if the resulting high energy prices are not subsidized or taxes are not exempted for poor households [42,43].

Identified direct climate–development impacts cover a large share of SDG targets (Figure 2). Most affected SDGs through either trade-offs or co-benefits are 6 (clean water and sanitation), 7 (affordable and clean energy), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 11 (sustainable cities and communities) and 12 (responsible consumption and production). Additionally, SDG 2 (zero hunger) has a high target coverage under biofuel and agriculture-related climate measures. The trade-offs of CCS, BECCS and nuclear are most prominent for SDGs 1 (poverty eradication), 6, 7, 8, 11, 14 (life under water) and 15 (life on land). SDGs 4 (quality education), 5 (gender equality) and 10 (reduced inequalities) are largely unaffected by climate-change mitigation measures based on our analysis, as we focus solely on direct impacts. In general, economic and environmental development areas (see Table 1) and respective SDG targets are affected by more climate-mitigation impacts than social development areas. However, if indirect impacts were included, a higher coverage would be observed across SDGs. Future research could apply our scoring framework to assess direct interactions of other SDG targets and ultimately link impacts of all SDGs to help reveal indirect connections across SDGs [35].

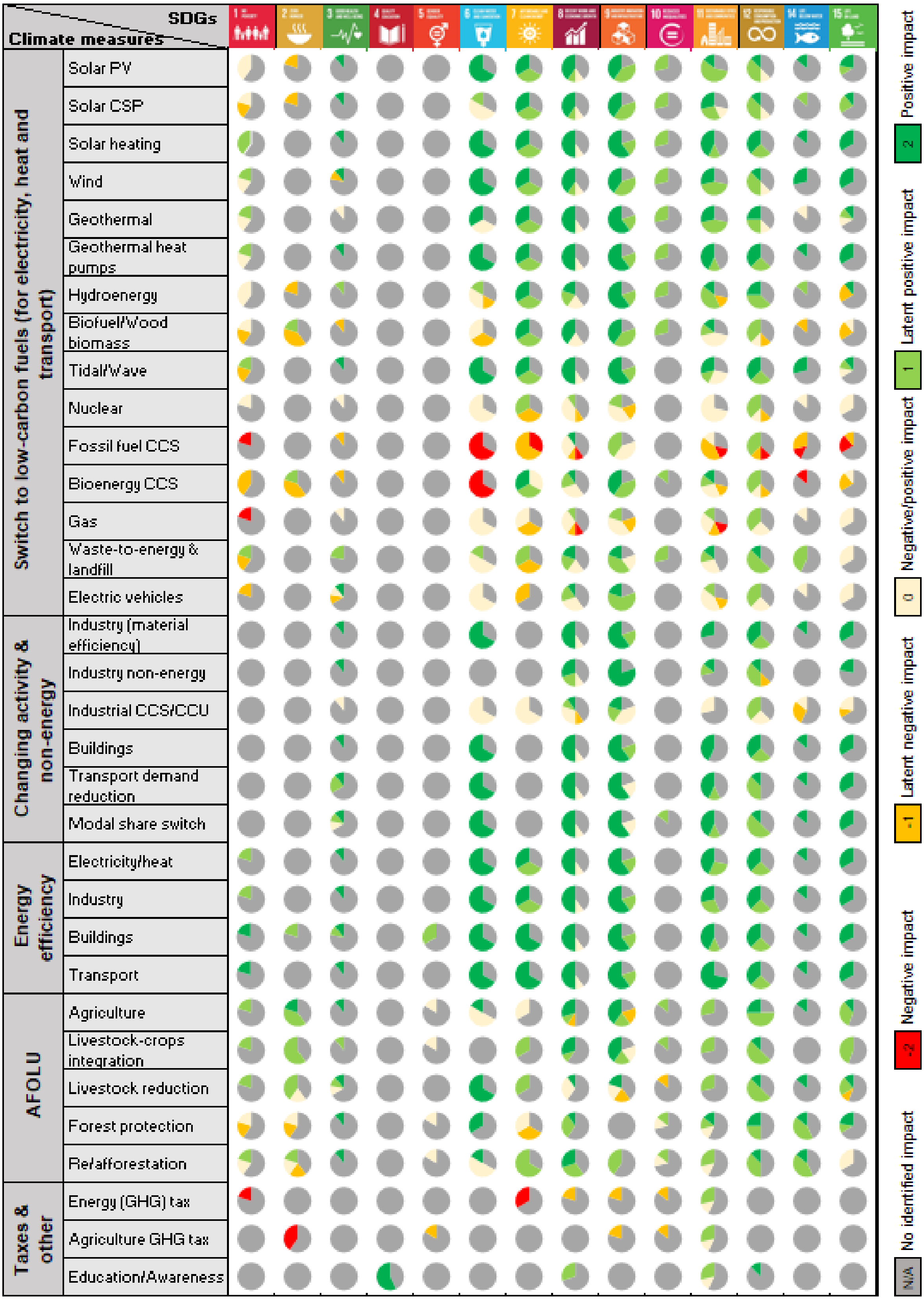

Figure 2. Impacts of climate-change mitigation measures on all relevant SDGs. The pie charts show the share of SDG targets that are affected, on average, in a manner described by each colour in Table 1.

While our scoring approach signifies well all the climate–development interactions across SDGs, further research is needed to indicate the magnitude and relevance of impacts in a country and local context. Nilsson et al. [34] already highlighted the dangers of generalization and the need to interpret impacts based on a country's context. For instance, the risk posed by biofuels to food security would primarily affect countries that are prone to food insecurity. Similarly, poverty-related impacts of energy (CO_2) taxes would be especially relevant in countries with high poverty rates. In a country case study of Sweden, Weitz et al. [40] showed how impact-scoring frameworks can be used to determine interactions between SDGs based on a country context. Furthermore, we assumed that climate measures would replace a more GHG-intensive option or reduce fossil-fuel energy production. Precisely what that replaced option is can make a difference in the magnitude of impacts. To overcome this limitation, comprehensive modelling of climate–development impacts could be employed to determine the quantitative potential of co-benefits and trade-offs. Similarly, considering the stringency of climate measures and countries' development situations in different areas helps to estimate the importance of specific impacts. Beyond interactions within a country, transboundary effects of climate and development actions must be understood to meet the SDGs globally.

We showed that some climate measures provide more co-benefits across the SDGs than others; yet, to reach global GHG-emissions neutrality before the end of the century to stay below the Paris Agreement temperature-increase limit, action must be taken across all economic sectors. Countries will need to take early action in particular in those sectors that are more difficult to decarbonize and require extensive and costly infrastructure to avoid lock-ins and investment losses [44]. While some flexibility exists in the selection of climate measures, this remains limited and identified development impacts will inevitably need to be tackled. For that reason, a better understanding of how countries could mitigate trade-offs of climate-change policies and actions and how co-benefits to the 2030 Agenda could be maximized is essential. In the following section, we discuss how the four context dimensions can be used to address key climate–development impacts and provide a full categorization (by dimension) of the impacts identified in this section.

3.2. Relevance of Context Dimensions in Addressing Climate-Change–SDG Impacts

Our four context dimensions characterize different policy impacts and assess how they could be addressed through policy making. Adjusting the design of climate-change policies or complementing them with adequate development policies can help maximize or minimize impacts [3,35,43]. In the following, we discuss how each context dimension, where relevant, could be engaged to tackle climate-mitigation impacts on the assessed development areas. In this sense, we exemplify how the climate–development scoring framework (further presented in the two Supplementary Materials) is a tool to design individual policies and policy mixes.

Time horizon (*when*). This dimension indicates a difference in the short- vs. long-term effects. For instance, energy efficiency improvements typically require high upfront costs, but the long-term savings will make energy more accessible and affordable [26]. Similarly, new tree plantations (afforestation or reforestation) may take up land areas that were used for food production by local communities. However, if communities are allowed access to the resulting forests, they could benefit from their timber and non-timber products and potential new activities such as ecotourism in the long run [3,45,46].

When the time horizon dimension comes into play, it usually signals an initial higher cost before the co-benefits occur. Policy makers could adequately address the initial higher cost and protect poor households, for instance, by fully covering upfront costs, granting concessional (community) loans or enabling access to other services in the short term. Providing sustainable housing or upgrading informal housing, and providing free rooftop solar energy installations for poor households would eliminate trade-offs of upfront costs and provide multiple benefits [47].

Local (geographical) (*where*). This dimension indicates a difference in impact occurrence and magnitude based on location. In that sense, it also considers situations where the overall national effect probably differs from the local effect (e.g., there could be a loss of jobs locally even if there is a net gain of jobs nationally). Typical aspects of this dimension would relate to: available local renewable energy resources (for instance, the potential of solar or wind energy); the location of potentially affected people (e.g., whether communities would lose access to land, whether they are affected by changes in air or water quality, or whether they would need to be displaced to make space for hydropower-related flooding); the location of potentially affected ecosystems (e.g., ecosystems and respective biodiversity being affected by biofuel production or afforestation); and a difference in impacts locally vs nationally (e.g., loss of jobs locally from fossil-fuel phase-out but increase in jobs in the renewables sector).

When the impact depends on this context dimension, policy makers and project implementers could partly or fully avoid trade-offs or obtain co-benefits by selecting opportune locations for the implementation of measures or directly addressing local issues. For instance, while a switch from fossil-fuel electricity production to non-biomass renewables always improves air quality, countries could choose to first replace fossil-fuel power plants that affect a larger number of people. Similarly, more stringent car-emissions and fuel-efficiency standards could be first imposed in cities, especially in more densely populated neighbourhoods. Trade-offs such as communities' displacement due to hydropower construction could be avoided or limited through provisions on permitted construction locations. The choice of location for marine-based energy production could signify that marine economies and their surrounding environments are affected either through co-benefits or trade-offs based on opportunities and challenges (e.g., aquaculture, shipping and transportation, tourism, other ocean resources or marine habitats protection) [29]. To ensure that livestock demand reduction leads to increased food security, the freed-up land (from livestock and feed) should be at least partly dedicated to agriculture, if feasible. Nevertheless, in some regions, such as sub-Saharan Africa, livestock might still be the most effective food source and replacing it could severely hinder livelihoods [3,17].

Where trade-offs cannot be fully avoided through a choice of location, complementary local measures may need to be implemented. For instance, biofuel production can compete for land with food production, resulting in higher land and food prices. Regulatory measures could define permitted areas for biofuel production where food impacts are expected to be lower. However, a lack of adequate locations probably requires complementary local interventions, such as food production subsidies and/or fixed land prices. Support for increased agricultural productivity to limit the amount of land required for biofuel and food crops locally could reduce land competition [48]. Moreover, bioenergy production can locally increase water demand and water stress, but this can be attenuated through efficient use of water, including by growing respective crops where water is more readily available [49,50].

Phasing out fossil fuels can result in a large number of local job losses, in particular in mining areas. While a switch to renewable energy could create more jobs overall, the effect could be negative in regions with large fossil-fuel extraction industries. If most equipment is produced abroad or in a different region, the number of jobs from installations and maintenance alone may be insufficient [51,52]. Hence, policies could ensure that new renewable energy jobs are created in these affected regions. To enable the transition, retraining programmes for local workers [53,54] and social protection systems for temporary unemployment may be necessary [55,56]. For instance, Altieri et al. [57] suggest that stimulating unskilled agricultural job creation could reduce the impacts of job losses in other sectors. According to them, such an increase, which would be in line with SDG 2, could be generated through an increase in small-holder farming or through tax breaks and labour subsidies. Nevertheless, other local industries would likely also be affected by the lower incomes and likely need stimulus measures during the transition process. This could further provide additional job opportunities and prevent job losses. While locally implemented, these measures also pertain to the governance context.

Governance (*how*). This dimension indicates the relevance of the implementation approach. To address impacts that fall under this dimension, policy makers must consider the choice of technology, the choice of processes (e.g., recycling, regulations on fertilizer use) and the scope of the policy (i.e., who it applies to and how).

Multiple impacts can be addressed through a choice of more suitable technologies and practices. For instance, water demand for CCS can be reduced through system integration of processes [41]. In the energy sector, dry cooling could also reduce water demand [58]. In transport, the risk of increased exhaust inhalation and road accidents as a result of shifting to more cycling can be addressed with adequate infrastructure, such as dedicated cycle paths separated from or at a distance from roads with cars [59]. The choice of specific practices and respective technologies in agricultural and livestock production (e.g., minimum tillage, precision agriculture, inter-cropping, rainwater collection) could influence the magnitude of policy impacts [3]. This is also important in the case of biofuels where multiple risks could be mitigated through clear guidelines and regulations on agricultural practices. Such measures could address nutrient leakage into the soil through limitations on fertilizer use, soil degradation through interdiction of intensive forms of agriculture, and ecosystem degradation through regulations of large-scale monocultures, in particular in vulnerable areas.

The scope of climate-mitigation measures could also play an important role in addressing policy impacts. For instance, if energy (CO_2) taxes pose a risk of energy poverty, policy makers could waive the tax for households with lower incomes, if the tax is directly applied to consumers. Alternatively, if the energy price increase is caused by taxes applied to producers or other measures that affect energy costs and are further passed down to consumers, an attenuation measure could be to subsidize low-income households (possibly from the tax revenue) through: direct cash transfers [60]; tax credits, by providing a certain amount of free electricity; or free access to other services, including energy in other forms (see examples by Winkler [47] on South Africa, Beck et al. [61] and Murray et al. [62] on British Columbia, Canada, and Combet et al. [63] on France). Setting an upper limit for electricity prices could address price increase caused by demand, for instance, due to a higher uptake of EVs and respective demand for electricity.

Considerations of policy scope could also be used to ensure more inclusive approaches. Forest-related projects could negatively affect communities in the area if restrictions of access are introduced. However, these communities could rather benefit from the projects if inclusive measures are implemented, access is allowed, and economic activities such as pollination are supported [46]. Forest certification programmes can be applied to ensure that social, economic and environmental benefits are enhanced and undesirable trade-offs reduced [64,65]. In general, inclusive forestry projects that involve communities and support public–private community partnerships can support Agenda 2030 more broadly [45]. In agriculture, smallholder farmers could be supported to access and benefit from new biofuel markets, for instance, by setting a limit on the maximum share of raw material that fuel producers can purchase from large agri-businesses as opposed to smallholder farmers (an example is Brazil's RenovaBio policy, but more attention is required for improved implementation and inclusion of farmers in decision making [66]).

Climate-related measures can lead to stranded assets, such as earlier retirements of coal power plants and related infrastructure as a result of carbon taxes or strict regulations. While CCS and carbon capture and utilization could be applied later, our results show that these approaches can generate multiple trade-offs. Moreover, not all power plants can be retrofitted in that way. Vogt-Schilb and Hallegatte [44] provide an overview of potential governance approaches to address these impacts. For instance, policy makers could take early action to interdict the construction of such risk assets that are not zero-carbon and do not comply with a 2 °C global target. Alternatively, they could stimulate the inclusion of related risks in investment decisions through adequate transparency, or offer direct incentives, such as performance-based feebates and subsidies. A measure to disincentivize investments could be the progressive phase-in of carbon pricing, starting with lower prices to limit potential stranding of current assets. Carbon taxes and cap-and-trade systems can be designed in a way that compensates owners of polluting assets through partial exemptions, rebates and grandfathered emissions allowances. In the case of assets that are already in place, countries might find themselves constrained to directly compensating owners of stranded assets in some form, for instance, through direct public procurement from owners. The impacts of stranded assets are particularly important in countries that are highly invested in fossil fuels, including through mining of domestic fossil-fuel resources. Hence, these measures are also relevant to policy impacts that are affected by the 'natural resources' dimension discussed below.

Natural resources (i.e., limited fuels) (*what*). We introduced this dimension to cater for impacts that depend on the availability of limited natural resources nationally rather than locally. For instance, countries that depend on imports of energy resources, such as nuclear or fossil fuels, are prone to energy-security issues resulting from price volatility and potential trade obstacles. These issues could be exacerbated by an increased demand for these fuels or reduced by a switch to other energy sources. On the other hand, countries that are producers (and potentially exporters) of such fuels could be more affected by job and revenue losses as a result of measures to phase out these fuels. Exporting countries are also prone to price volatility and demand on the international market.

To mitigate trade-offs linked to the availability of limited natural resources, countries with specific contexts may choose to avoid policies that increase the demand for these fuels and support policies that reduce dependency. Where investments have already been made in the exploitation and use of these limited resources, countries could apply the aforementioned measures to limit the impacts of stranded assets and of job and economic losses. While governments could support private owners of stranded assets in various ways (see previous section), the national economic effects would also need to be addressed. Internationally, support supply-based treaties and the possibility of trading the rights to exploit fossil-fuel reserves could be in the interest of fossil-fuel-rich countries. This allows others to buy and not burn them [67,68]. Finally, although we have not assessed fossil-fuel-subsidies removal as a climate measure, its economic, political and overall effects would be very similar to that of energy (CO_2) taxes and could be addressed in a similar manner [44].

3.3. Prominence of Context Dimensions across Climate-Change–SDG Impacts

We found that the vast majority of climate-mitigation impacts on the SDGs are dependent on the governance (73% of all identified impacts) and the local context (71%) dimensions. The time horizon and natural resources contexts only cover approximately 12% of climate-mitigation impacts each in their area of influence (Figure 3).

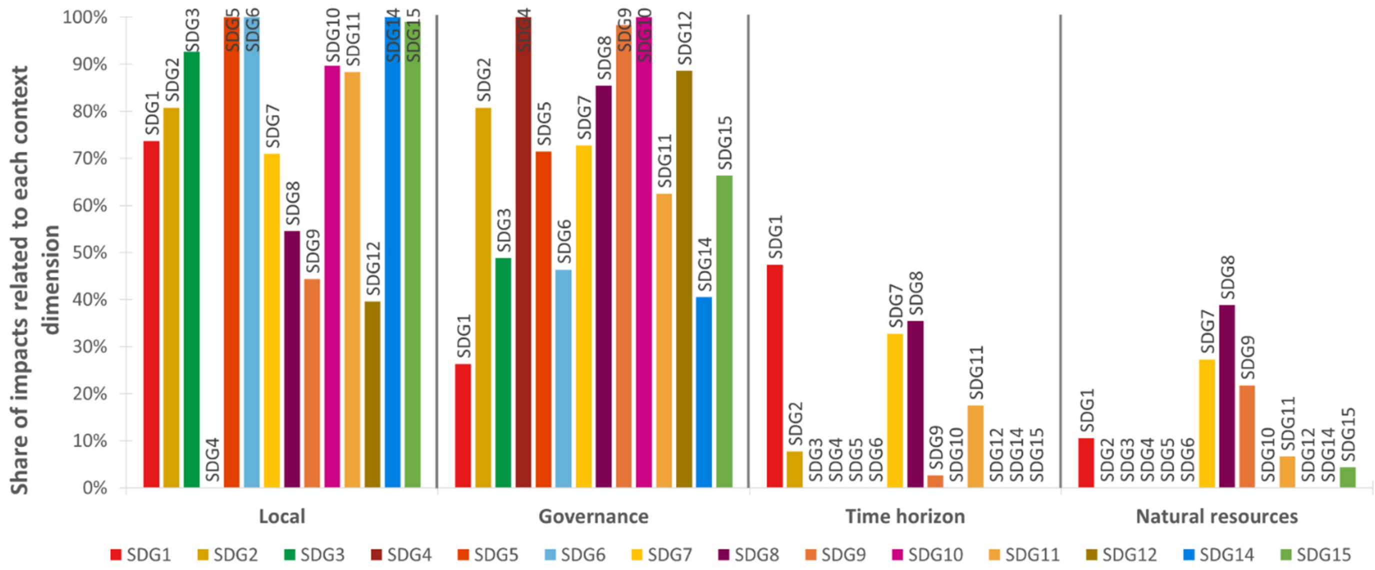

Figure 3. Share of climate-change mitigation policy impacts per SDG, relevant to each of the four context dimensions—local, governance, time horizon and natural resources. The share of impacts is determined as the total number of identified climate-change mitigation policy impacts on an SDG, relevant to one context dimension, relative to all identified climate-change mitigation policy impacts on that SDG (regardless of context dimensions).

Unsurprisingly, the local context is particularly important for the environmental SDGs (i.e., SDGs 6 (water and sanitation), 14 (life under water) and 15 (life on land)) as the impacts of climate-mitigation projects can be bigger in areas closer to important ecosystems. Moreover, as local communities often depend on access to ecosystems to ensure their livelihoods, and as some climate measures affect specific (fossil-fuel-rich) regions more strongly than others, where climate measures are implemented is also particularly important for SDGs 5 (gender equality) and 10 (reducing inequalities). Finally, the local context is important for health. In this case, the number of people who would be positively or negatively affected depends on the density of population in the area of influence of the climate-mitigation measure.

The governance context is particularly important for SDGs 5, 8 (in particular for the employment dimension) and 10, as the governance approach can enhance inclusiveness of relevant groups of stakeholders to benefit from co-benefits and can reduce trade-offs on vulnerable groups. In part, this can also be done through measures that enhance education and training, and raise awareness. These are key targets of SDG 4 (training and education). As the choice of infrastructure, technology and processes is key to the achievement of targets under SDGs 2 (agriculture and food security), 9 (industry and infrastructure) and 12 (sustainable production and consumption), the governance context is also prominent in these areas.

The time horizon is especially relevant for SDG 1 (poverty reduction) and SDG 7 (energy) due to the high upfront costs of renewable energy and energy efficiency improvements. While the installation costs of renewables are still very high, the levelized cost of electricity production (i.e., total costs of energy production, including installation, over longer time periods) is now comparable to and in some places even lower than that of fossil-fuel electricity production [69,70]. Moreover, despite the high upfront costs, energy efficiency improvements lead to financial savings in the long run. The time horizon is also highly relevant for SDG 8 (economic growth and jobs). Although phasing out fossil fuels could have some trade-offs on economic growth through higher energy prices and a decrease in revenue from fossil-fuel exports, it helps decouple countries from dependence on limited resources and potential stranded assets in the long run. On the other hand, renewable energy generation creates a large number of jobs for installation, but requires very few jobs for operation. In that sense, producing renewable energy equipment could help create more jobs.

The availability of limited natural resources for energy production (i.e., nuclear and fossil fuels) determines the magnitude and the direction of the impacts of a switch away from or towards these resources on economic growth and jobs (i.e., SDG 8). Moreover, a switch away from these limited natural resources in countries with strong respective industries could lead to non-inclusive industrialization, especially if these industries cannot easily transition (e.g., fossil-fuel energy producers switching to renewables)—against the target of SDG 9.

In terms of climate-change mitigation measures, the local context and governance dimensions are highly relevant to most measures (Figure 4). However, while governance is not only important to energy (CO_2) and agricultural taxes, but also for training, education and awareness raising, the local context does not play a role in these measures. On the other hand, the local context is particularly important for renewable energy measures as the amount of energy produced is determined by local renewable energy resources. Moreover, economic and employment impacts of a fossil-fuel phase-out are particularly relevant locally in regions of fossil-fuel production. Due to the aforementioned effects, time horizon and natural resources are mainly relevant to climate-change mitigation measures that address energy demand and energy source choice.

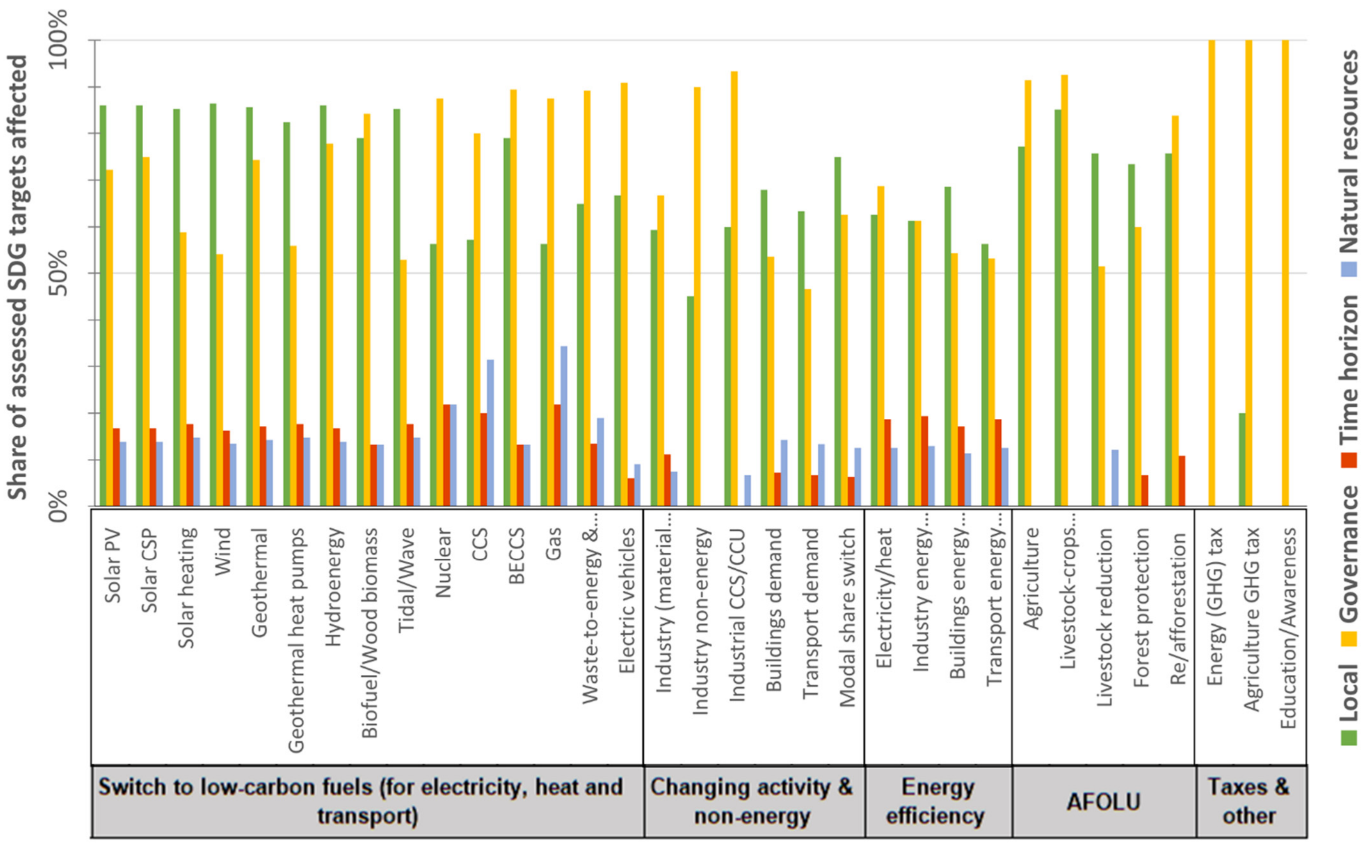

Figure 4. Share of SDG impacts of each climate-change mitigation measure that fall under the four specific context dimensions—local, governance, time horizon and natural resources. The share of impacts is determined as the total share of impacts of a specific climate-mitigation measure across all SDG targets that are relevant to a context dimension relative to the total number of impacts of that specific climate-mitigation measure.

While our study comprehensively captures the relevant context dimensions for all climate-change mitigation impacts on the SDGs, the importance of each dimension may vary across countries. Therefore, the relevance of each impact and of respective context dimensions on a country-by-country basis must essentially be studied in detail. Moreover, while here we have provided several examples of potential policy designs and policy mixes to enhance co-benefits and minimize trade-offs based on the context dimensions, the governance mode and other contextual aspects within a country could make specific types of policies more appealing than others (e.g., regulatory vs market measures). Measures that address climate-change mitigation impacts would need to be tailored to the country's context. From a research perspective, a wide variety of possible policy designs and policy mixes must be identified to highlight best practices for specific country contexts.

The extended range of policy impacts shows that ensuring policy coherence and adequate communication horizontally, across relevant sectors, and vertically, across relevant actors is essential. To that end, our scoring framework of climate-change mitigation impacts on the SDGs becomes a tool for enhanced dialogue between policy makers and relevant actors across governance levels and sectors. Researchers from different academic fields could also engage in such a dialogue. From a research perspective, our results could, for instance, be integrated into models that seek to identify sustainable development pathways to meet multiple SDGs. Moreover, our scoring framework could be used for national broad or detailed case studies on climate-change–SDG interactions with a focus on specific development areas or SDGs.

Beyond the country level, our approach could also be applied in international negotiations and development cooperation. A good understanding of the interlinkages between climate-change action and other SDGs can help to better integrate international climate governance with other strands of international negotiations, such as trade and environmental agreements [71–75]. Such integration is essential to ensure policy coherence and joint implementation of Agenda 2030. Moreover, a better understanding of climate–development interactions is key to effective development cooperation. As every additional global temperature increase can hinder development [4], development actors should be captivated to address climate change. Additionally, development actors also should be able to assess the risk of stranded assets and the benefits and potential trade-offs of climate-relevant projects. Ensuring that climate-change strategies and development strategies are designed and implemented in a coherent manner can increase the efficiency and effectiveness of development cooperation and respective finance [76–78].

Although we carried out a thorough literature review for the interlinkages between climate-change mitigation and other development areas, assuming that some climate-change–SDG interlinkages are still missing in our analysis is reasonable. We possibly have missed some literature, and evidence of some interlinkages maybe has not yet been published. Moreover, although we covered the key context dimensions, other dimensions can be important in specific countries and along with them, their country-specific policy impacts. Hence, the absence of impacts in our scoring framework should not be automatically assumed to be robust. Nevertheless, our analysis is highly comprehensive and represents an important basis for country-level assessments.

3.4. Choice of Climate-Change Mitigation Measures in the G20 Member States

We hypothesize that countries are likely to give a higher priority to climate-change mitigation measures that result in the most co-benefits. Even if all types of climate-mitigation measures eventually need to be adopted to meet the Paris Agreement temperature goal, instantly adopting measures that are characterized by co-benefits likely yields more benefits in the long term. To test this hypothesis on national climate-change policy preferences, we used the Climate Policy Database (as per the latest update by Nascimento et al. [36]) to map climate-change-related policies and measures in the G20 countries.

We found that climate-change mitigation policies that had a higher overall cumulative impact score (i.e., that have more co-benefits and fewer trade-offs) are adopted by most or all G20 countries (Figure 5). Moreover, these highly beneficial policies are also prioritized within countries, being more frequently adopted relative to other relevant policies in each country. These findings demonstrate that climate-change mitigation policies with more co-benefits are, indeed, more often adopted. These policies are particularly related to energy efficiency improvements, renewables (whereby we used the average cumulative score across all renewable sources to address a lack of differentiation in the policy database), and agriculture and forestry. The relatively lower adoption levels of policies and measures that reduce demand for energy and material through structural changes (i.e., changing activities), despite their high cumulative impact scores, appear to reject our hypothesis. However, these measures are most often adopted at a city level (e.g., measures for compact cities) and do, therefore, not focus on national legislative and executive bodies. Furthermore, while climate-change-related policies and measures with substantial development co-benefits are universally attractive, each country has different development priorities and therefore probably benefits more from some types of policies than others. For instance, a switch to renewable energy is likely more pressing and advantageous for energy security purposes in countries that depend on large imports of energy, such as South Korea, Turkey and the European Union, than it is in energy exporters such as Australia and Saudi Arabia. On that note, some policies are also less relevant to some countries than others. For instance, while AFOLU is one of the major emitting sectors in Indonesia and Brazil, it is barely relevant in Saudi Arabia.

Number of policies in each country		Argentina	Australia	Brazil	Canada	China	European Union	India	Indonesia	Japan	Republic of Korea	Mexico	Russian Federation	Saudi Arabia	South Africa	Turkey	United States of America	Perccentage countries	Average level of focus	Total impacts score
Switch to low-carbon energy	Renewables	12	12	12	7	42	18	20	22	20	27	25	12	8	13	14	31	100%	13%	35
	Nuclear	2	0	0	3	3	0	0	1	3	3	0	3	1	2	0	5	63%	1%	2
	CCS	0	1	0	2	0	4	1	0	1	4	1	0	0	0	0	7	50%	1%	-17
	Gas	0	2	3	5	3	5	2	1	5	1	1	5	1	3	2	10	94%	2%	0
	Electric vehicles	1	2	3	4	6	3	5	3	7	8	5	2	0	1	2	2	94%	2%	11
Changing activity & non-energy	Industry non-energy	1	6	5	10	8	16	6	2	7	6	6	6	3	7	2	8	100%	5%	22
	Industry (material efficiency)	2	5	2	6	14	11	3	2	7	6	3	4	2	8	2	3	100%	4%	35
	Buildings	1	4	1	4	7	4	5	1	8	5	3	2	1	3	4	4	100%	2%	38
	Transport	2	3	3	3	8	7	5	1	12	9	5	1	4	10	3	12	100%	4%	35
	Modal share switch	5	3	7	9	10	14	7	7	12	16	9	5	2	8	6	26	100%	6%	37
Energy efficiency	Electricity/heat	4	5	9	6	12	11	4	5	15	23	7	10	5	9	8	33	100%	7%	42
	Industry	5	12	10	12	28	15	8	10	18	13	8	6	5	11	12	15	100%	8%	40
	Buildings	8	21	9	18	20	17	24	10	32	18	28	15	6	14	17	33	100%	13%	47
	Transport	6	15	9	15	16	17	12	8	25	15	10	2	4	8	9	28	100%	8%	44
AFOLU	Agriculture	12	4	13	9	12	5	15	9	9	8	10	2	5	8	13	18	100%	7%	23
	Forestry	14	5	21	12	23	10	24	29	12	9	13	4	5	9	17	18	100%	11%	19
Taxes & Other	Energy (GHG) tax	1	0	1	1	2	1	2	0	3	2	3	1	1	4	1	0	81%	1%	-5
	Agriculture GHG tax	1	0	1	2	1	0	1	0	0	2	2	1	1	3	0	0	63%	1%	-7
	Education/Awareness	4	8	2	4	2	3	3	0	2	5	2	1	1	3	3	41	94%	3%	4

Figure 5. Current climate-change mitigation-relevant policies in G20 countries (Source: Climate Policy Database, updated by Nascimento et al. in review). The first twenty columns show the number of specific types of climate-change mitigation policies in each country. The column 'Percentage countries' shows the share of G20 countries with policies of a given type. 'Average level of focus' shows the average share of a given policy type in the total number of measures per country. 'Total impacts score' shows the sum of these policies impacts for the SDG target, as presented in Figure 2, but using the average across technologies for renewables. Numbers are shown from red (low value) to green (high value) based on values relative to each other along the columns.

While our analysis shows that climate-change mitigation measures with more co-benefits tend to be adopted by more G20 countries, it does not provide any information about the real motivation behind policy adoption nor about the policy stringency or the magnitude of actual impacts. Moreover, we correct for country differences in national policy-type adoption levels and aggregation approaches by comparing policy numbers relative to one another in the same country. However, some policy measures generally have a higher level of aggregation than others. For instance, multiple types of measures and incentives can be implemented to support renewables, energy efficiency and most other policies. However, taxes are a measure in themselves. This was corrected by assessing shares of countries that adopted the policies, but this would not be accurately expressed when assessing the share of policies of each type relative to each other. For a more in-depth understanding of national climate–development policy coherence, the objectives, the ambition levels (i.e., stringency) and the real effects of policy implementation should also be analysed. As (G20) countries must ramp up their climate-mitigation ambition [79], understanding climate-change–SDG interlinkages and addressing major context dimensions are essential to enable the needed ambition and a joint implementation of the Paris Agreement and the 2030 Agenda.

4. Conclusions

Substantial efforts are needed at all policy levels to meet Agenda 2030's SDGs and to ensure that global temperature increase stays well below 2 °C. While these targets were set independently, strong climate–development interconnections suggest that they should be addressed in conjunction rather than in their climate-change or development silos.

We built a comprehensive overview of climate-change mitigation policies' impacts on all SDG targets. We found that climate-change mitigation directly affects 15 out of 17 SDGs. This advocates a high potential success when climate and development issues are simultaneously tackled. Climate-mitigation policy types with many co-benefits are energy efficiency and energy-services demand reduction. When compared with fossil fuels, most renewable energy sources also have multiple co-benefits to sustainable development. The policy areas that appear to have the most trade-offs with the SDGs are nuclear and CCS, followed by biofuels, natural gas and energy (CO_2) and agriculture taxes. Among the SDGs, the environmental and economic SDG targets much better cover policy impacts than the social targets.

Most importantly, our study heeded previous calls to go beyond simple identification and scoring of climate-change mitigation impacts [34] and elucidated how these impacts relate to four key context dimensions (i.e., geographical, governance, time horizon and natural resources). Moreover, we highlighted how an understanding of the impacts' context dimensions facilitates policy design and policy instruments that can directly tackle policy impacts, minimize trade-offs and maximize co-benefits. We found that the governance approach and location choice are particularly important as they are relevant to most identified climate-change–SDG impacts.

Our scoring framework and related analysis developed is especially of interest to policy makers as it helps prioritize climate-action areas of substantial co-benefits and areas where trade-offs must be considered. In this sense, policy makers can use our framework to identify ways to ratchet up climate ambitions, while also efficiently meeting the SDGs. While some climate-change mitigation measures have more co-benefits to sustainable development than others, meeting the international climate targets requires countries to take climate-change mitigation actions across all economic sectors. Smart policy designs that consider co-benefits and trade-offs are essential to facilitate ambitious and effective strategies that jointly implement the Paris Agreement and the 2030 Agenda nationally and internationally. Internationally, countries could consider including climate-change–SDG interactions in their Voluntary National Reports under Agenda 2030, and their NDCs under the Paris Agreement. This likely not only encourages communication between relevant governmental ministries but also enhances policy coherence. The scoring framework could also be applied to facilitate dialogue and enhance coherence nationally and internationally, and between climate and other governance fields.

We found that climate-change mitigation measures that entail higher development benefits are adopted more often in the G20 member states. This suggests that countries seek to capitalize on the co-benefits of climate-change mitigation, but are reluctant to adopt measures that spawn trade-offs with other development areas. While these results are not surprising, they highlight the challenges of ambitious climate-change action and the need for further support to tackle stated challenges. To meet the longer-term goal of net GHG neutrality, all sectors need to reduce GHG emissions. Early action limits lock-in effects and creates flexibility [80], and stops social and environmental trade-offs of fossil fuels.

Our study aimed to advance the knowledge of climate–development synergies and trade-offs that would simultaneously address climate and sustainable development goals. Nevertheless, our scoring framework is surely also applicable to other SDG-action areas to further map interactions among the SDGs, to identify other relevant context dimensions and enhance policy coherence across the SDGs.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su131910774/s1, Excel file S1: Interactive framework of climate-change mitigation measures' impacts on the SDGs, Word Document S1: Literature review on the impacts of climate-change mitigation measures on the SDGs.

Author Contributions: Conceptualization, G.I.I. and N.H.; methodology, G.I.I.; software, G.I.I.; validation, N.H. and H.L.v.S.; formal analysis, G.I.I.; investigation, G.I.I.; resources, H.L.v.S.; data curation, G.I.I.; writing—original draft preparation, G.I.I.; writing—review and editing, R.L., N.H., H.L.v.S.; visualization, G.I.I.; supervision, N.H. and R.L.; project administration, N.H. and R.L.; funding acquisition, N.H., R.L. and G.I.I. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the European Union Horizon 2020 Framework Programme, grant number 642147 (CD-LINKS), the Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung (BMZ), Germany, grant number 2018.9587.9 (Klimalog II), and the Bundesministerium für Bildung und Forschung (BMBF), Germany, grant number 01LS1907B (SHAPE).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data on the impacts of climate-change mitigation measures on the SDGs are available in the Supplementary Materials. Data on climate-relevant policies in the G20 member states were extracted from the Climate Policy Database (www.climatepolicydatabase.org, accessed on 21 October 2020) in October 2020.

Acknowledgments: The authors extend their deep appreciation to Steffen Bauer, Clara Brandi, Sander Chan, Ines Dombrowsky and Daniele Malerba from the German Development Institute (DIE) for their review of an early version of this paper. The authors are also grateful to Jessica Callen from the International Institute for Applied Systems Analysis (IIASA) for her input on impacts of nuclear energy usage and to Sofía Gonzales-Zuñiga and Frauke Röser from the NewClimate Institute for their inputs on renewable energy technologies in an early stage of the climate–SDG impacts framework.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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