Introducing the Sustainable Budgeting Approach

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EXECUTIVE SUMMARY

The Sustainable Budgeting Approach (SBA) is a decision-support tool designed to help policymakers identify and resource strategic policy opportunities that promote national economic development while addressing critical environmental and social objectives. It is easy-to-use, evidence-based, and contextualized for each country. The SBA is intended for use by many stakeholders, such as finance and line ministries, parliaments, supreme auditing institutions, credit rating agencies, investors, businesses, development partners, civil society, and researchers.

The SBA is particularly useful for developing and least-developed countries facing limited financing for sustainable development. It improves transparency and signals potential investment opportunities by making policy choices evidence-based and effective in delivering sustainable growth. Development Finance Institutions, investors, and businesses can benefit from the SBA's insights and integration in budgetary and policy design, enabling them to make more informed decisions about investment allocations. This can support countries, projects, and initiatives that show progress towards integrated solutions for development and environmental objectives.

This document introduces the SBA, calling for all nations to strategically and efficiently utilize their scarce fiscal resources to enhance wellbeing, where wellbeing is driven not only by innovation, good jobs, and growth, but also by a stable climate and healthy ecosystems and landscapes.

Motivation

Determining how to invest limited public resources most efficiently, amid uncertainty and seemingly conflicting goals, can be a challenging task. Without a system for assessing potential impact, it is impossible. In many nations, and particularly in low- and middle-income countries, there is no systematic approach for comparing one policy option to another, nor for assessing the overall impact of budgets. Sometimes there is no planning function within the budget team and very littler information available for making fiscal decisions. This leads to inferior decisions and wastage of precious tax-payer resources. It also leaves budgets liable to external influence and budget offices with little scope for challenging ill-informed requests from line ministries.

When nations do take action to shift an economic, social, or environmental trajectory, development partners often struggle to recognise or verify these shifts, relying on lagging indicators that only show the results of interventions many years after they are taken. For instance, investing in climate action today can sometimes only manifest in reduced emissions a decade down the line. There is a need for systematic tracking of likely investment outcomes through the budget process.

For urgent environmental and social problems, including climate change, most finance ministries lack the tools necessary to mainstream responses in their budget deliberation process. Prior initiatives, like green budget tagging, might have some use in tracking changes in green spending profiles, but are of limited use in making tradeoff decisions—they do not consider the topics of greatest importance to most policymakers (i.e., development, economic progress, or improved wellbeing).

Recent crises, including COVID-19 and the war in Ukraine, brought pronounced attention to this lack of tools. The crises exposed deficits in resilience, of both the economic and environmental sort. In a state of apparent permacrisis, policy makers urgently require tools to guide their fiscal outlays towards economic transitions that support resilience, ultimately to enhance long-term wellbeing.

What is the SBA?

The SBA is a starting point for governments wishing to adopt better budgeting processes, where decisions on how to tax and spend are informed by a wide range of 'green' criteria as well as social and economic criteria. Based on leading socio-economic and environmental science, the SBA can automatically give perspectives for any given policy to help understand its potential developmental, environmental, and social consequences and then boost learning by comparing this policy to similar actions of other nations. The basic approach can be fine-tuned to any individual country based on the priorities of the government and guidance of in-country experts. To assist budget decision making, the SBA:

1. **Provides a taxonomy for categorising policies.** The SBA defines and standardises 40 policy archetypes and 206 subarchetypes to categorise policies based on shared environmental *and* economic characteristics. This is distinct to other taxonomies that categorise policies solely based on *either* environmental *or* economic criteria.

2. **Provides a method to assess potential policy impact** on economic, social, and environmental grounds, for every subarchetype, tuned to individual countries. Many potential assessment criteria are discussed for this purpose, including long-run growth, job creation, greenhouse gas emissions (short and long term), natural capital, air pollution, adaptation and resilience (A&R), wealth inequality, and rural inequality. We propose that selection of core assessment criteria is based on a nation's unique context and domestic priorities. To avoid information overload, which could defeat the SBA's purpose, we advise that governments limit the number of selected core criteria.

We provide indicative global assessment for potential impacts on each of the criteria noted above—one assessment per criteria per subarchetype is appended. Indicative assessments are simple but powerful, based on leading scientific and economic understanding. That said, we propose that deviations from the global assessments are made based on local contexts, with support of an independent panel of local experts. Not included in this iteration, but of importance to fiscal decision making, are health, education, and security impacts, amongst others.

3. **Provides a tool**, adaptable to any nation's unique context, to (a) compare policy options against each other for informed decision making and (b) aggregate net impacts across an entire budget (or a subset thereof). For (a), proposed policies might be compared on the grounds of likely impact to alternative government proposals (see Figure E1) or to a database of over 8,000 other policies and growing (see discussion of the Global Recovery Observatory in the main text). In this way, a proposed policy might be replaced by a superior one or otherwise adapted to better meet the criteria identified as important by government. For (b), applying the tool across entire budgets, perhaps on a recurrent basis over multiple years, a government (finance ministry or line ministry) might track shifts in fiscal policy relating to key economic, social, or environmental criteria, which they deem important. The same use is possible for or other relevant stakeholders, including parliaments, oversight bodies, credit rating agencies, investors and businesses (including sovereign creditors), development partners, civil society, and researchers.

The SBA advances on traditional programmatic budgeting in that it embeds perspectives on the likely environmental, social, and economic impacts of budget measures to aid in decision making. It advances on green budget tagging in that it independently considers potential short- and long-term climate impacts as well as natural capital impacts and air pollution impacts. Additionally, it incorporates economic and social criteria. For each criteria assessment, it provides higher granularity consideration than budget tagging (using a five-point scale for assessments rather than a binary scale of, for example, green/not green). The SBA is similar to SDG budgeting in its coverage of social and environmental criteria but adds economic criteria and, again, uses more informative scaled assessments rather than binary assessments. It is somewhat similar to performance-based (or performance-informed) budgeting in that decisions are made according to key performance indicators set by the government (in the SBA, these are the decision "criteria", mentioned above). However, it is unique in that decisions are made based on standardised ex-ante impact potentials, alleviating the burdens of continuous ex-post impact assessment (or simpler monitoring and evaluation), which might render the approach tiresome or logistically impractical for some governments without significant and continuous external support.

Applying the SBA

This document provides a summary for how the SBA might be fine-tuned and applied to any local context. Figure E1 summarises how the SBA might be used as a tool for (i) tracking and transparency, analysing the overall characteristic of a budget (or a subset of budgetary policies) and (ii) decision making to optimise policy selection according to national priorities.

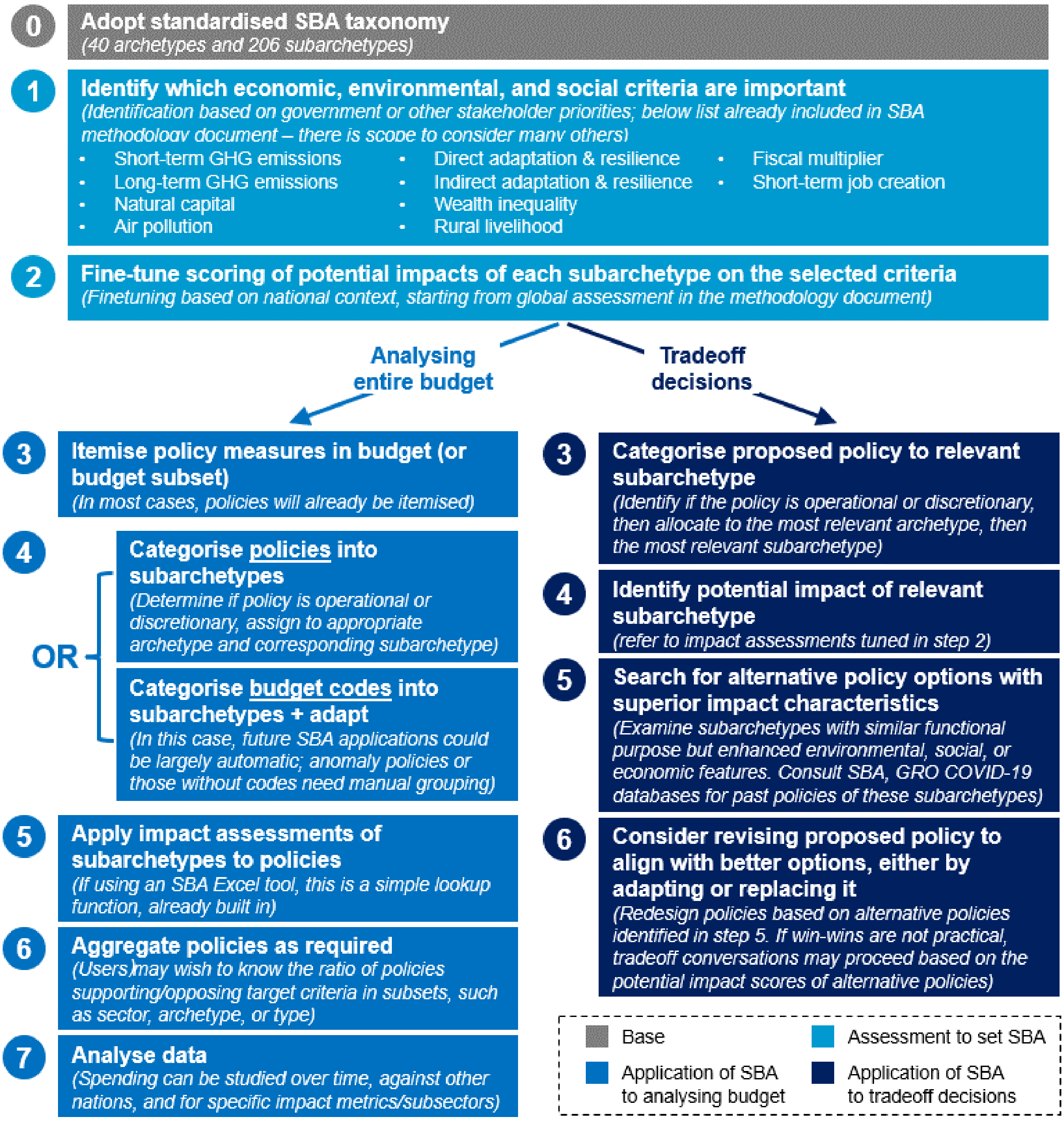

Figure E1. Steps for fine-tuning the SBA to national context, situating it in relation to government priorities, and applying it to either analyse entire budgets or make decisions.

SBA pilot study

A case study application of the SBA is included based on work with the Government of the Gabonese Republic in 2021-2022 (figures E2 and E3). The SBA allowed the Gabonese Ministry of Economy and Finance and Ministry of Water, Forests, the Sea and Environment to better understand the overall "greenness" of the national budget and provided scope to introduce a semi-automated tool to allow the same process to be repeated every year. It has also provided a prompt for nuanced and evidence-based decision making to be systematically incorporated into the budgeting process. Figure E2 illustrates the trade-off decision making function of the SBA, reprinting simplified SBA output to help senior policy officials compare theoretical spending in support of a new gas power plant with an ostensibly more sustainable alternative, investment in a new solar energy generation facility. Figure E3 shows the transparency function of the SBA, revealing the overall environmental characteristics of the Gabonese 2021 budget. Replication of the SBA to Gabon's 2020 and 2022 budgets would reveal how the overall characteristics of the budget have trended over time.

Based on the theoretical framework of the SBA and experience in Gabon, Sections 3 and 4 of this document provide a pathway for interested governments to further explore the opportunities that come with the Sustainable Budgeting Approach.

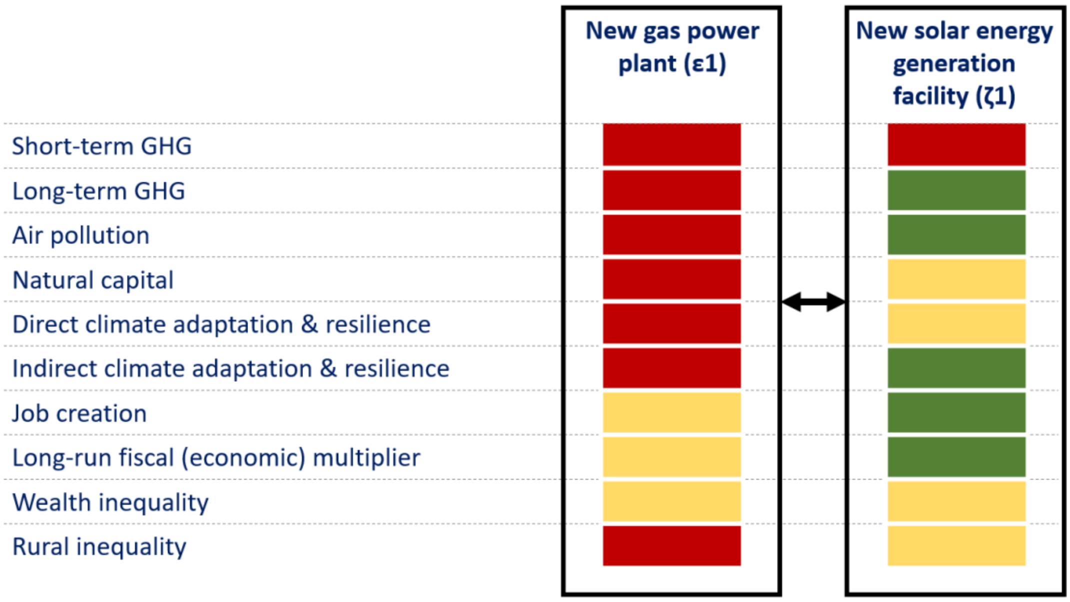

Figure E2. Example trade-off considering two spending policies in Gabon. On the left, public investment in a natural gas plant. On the right, public investment in a solar plant. All assessments of potential impact are only indicative and intend to give a broad unquantified perspective on potential impact. For environmental and social criteria, green suggests net positive impact, yellow suggests neutral and red suggests negative. For economic criteria, green suggests high returns, yellow suggests moderate returns, and red suggests low returns. Policy decisions should certainly include consideration of other impacts not in this figure, for instance: health, education, and security, amongst others.

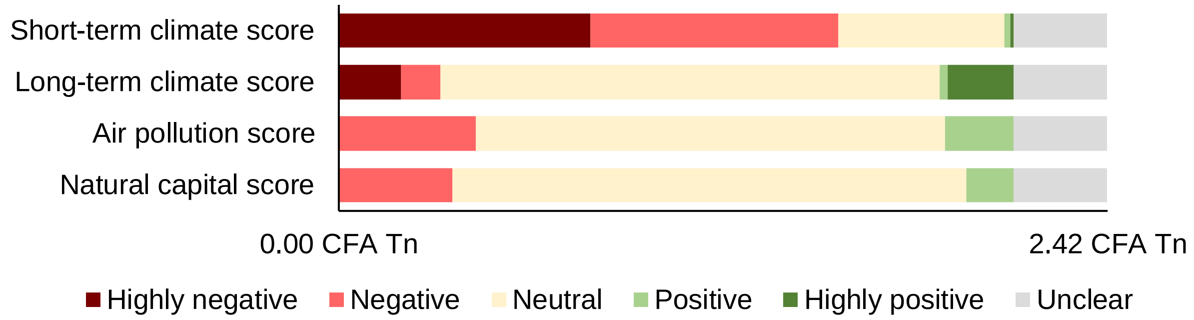

Figure E3. Environmental characteristics of the CFA 2.42 Tn (USD 3.85 B) Gabonese budget in 2021, including reported investment in public-private partnerships. Highly negative and highly positive categories only considered for greenhouse gas (climate) impact.

Core limitations

The SBA is useful in many applications, however, in some circumstances, its value might be limited. Limitations include:

- Ex-ante assessments of potential impact are a coarse placeholder for detailed ex-ante modelling. The SBA categorises policies using 206 subarchetypes—significantly more groupings than alternative taxonomies, allowing for more targeted ex-ante assessments of potential policy impact. However, nuances in policy design can lead to significant variation in potential outcomes within a subarchetype. To mitigate errors, policies considered outliers should be independently assessed for their likely impacts (i.e., outside of the pre-defined subarchetype-level characterisation). The SBA is intended as an entry point for locally-led tradeoff decision making—it is merely the first step on a path towards detailed and locally contextualised economic, social, and environmental impact assessments.
- The SBA, in its current form, assumes static economic conditions and ignores the dynamic interaction effects of policies implemented simultaneously.
- The success of the SBA relies on policy maker willingness to change. The approach sponsors a shift in perspective within finance ministries—towards one in which data is sought out for informed decision making and fiscal flows are considered as an essential part of an interconnected economic-social-environmental system.
- The SBA's usefulness is dependent on the accuracy and clarity of the core data it analyses. Tracking likely policy impacts, on a whole-of-budget level, relies on appropriate categorisation of policies into subarchetypes. In turn, this categorisation is based on government-provided policy descriptions, which might lack detail or be disconnected from practice.

1. INTRODUCTION

A primary function of government is to efficiently collect and allocate funds for the shared benefit of its citizens. In this, two goals of policy makers are to (i) protect present wellbeing and (ii) maximise future wellbeing. [1] However, achieving these goals in complex, changing, and table economic environments is challenging, to say the least.

The goal of maximising future wellbeing is particularly tricky, as policy decisions with payoffs many years in the future require difficult assumptions. How might economic conditions swing? How might technology change? Could consumer preferences shift? Beyond these core assumptions, policy makers must co-optimise for often conflicting objectives: development, inequality reduction, environmental protection, and more.

The challenge of trade-offs in government spending and taxation policy is universal across economies. However, it is particularly pressing for low- and middle-income countries, for whom there is often less margin for error. With limited fiscal space and continuing economic uncertainty, every dollar must be used productively. This is important in an era of apparent permacrisis, where economic, social, and environmental resilience appear lacking.

In many nations, significant policy decisions are often made with incomplete or imperfect information. Policymakers lack necessary details on the potential environmental, social, and development impacts of available policy options. As such, it is very difficult to understand the alignment of policy options with national sustainable development objectives. Poor information can hence bring unintended costs for citizens, businesses, the environment, and future generations, or failure to provide intended benefits. It can also lock-in unsustainable consumption and production patterns, misaligning private sector incentives, which, in turn, influence investment decisions (including for national sustainable development objectives), thereby completing the cycle. In simple terms, incomplete information leads to sub-optimal fiscal decisions which, in turn, leave potential development gains uncaptured.

The Sustainable Budgeting Approach (SBA) first asks policy makers what objectives matter most to their constituents (e.g., long-term growth, job creation, climate mitigation). It then helps them build generalised assessments to understand how different policy archetypes might meet those objectives. Ultimately, this lets a policy maker categorise any policy option into an archetype and quickly understand its likely directional economic, social, and environmental impacts. In this way, the SBA acts

[1] In this report, human wellbeing is driven not only by innovation, good jobs, and growth, but also by a stable climate and healthy ecosystems and landscapes. See Schleicher *et al.*, 2017.

both as a decision-making tool and an aggregated policy assessment tool to understand the likely directional impacts of an entire budget or subset of fiscal policies.

Importantly, the SBA is malleable to the unique circumstances of any country. Across countries, policy archetypes remain the same, but potential policy impacts change. Policy makers can take the guidelines and examples contained within this document as resources to develop their own policy impact assessments. They can then use these assessments systematically to assess fiscal options, guide decisions, and understand the aggregated impact of their budgets. **Importantly, assessments included in this document (Appendix B) are intended to be only a starting point from which interested parties might develop their own context-specific mapping.**

To some degree, implementing the SBA is about fundamentally shifting the mindset of decision makers. This can happen with long-term assistance from partner agencies, but the initial push must come from within.

The SBA is not intended as a silver bullet for fiscal planning, but rather a powerful first step requiring relatively little in the way of policy maker capacity. For nations with more advanced fiscal planning processes, the static economic assumptions in SBA assessments could be adapted to incorporate dynamic considerations, or instead existing dynamic models might be adapted to incorporate all kinds of environmental impact assessments alongside traditional economic measures.

The body of this document is organised as follows. First, we describe the economic and political context in which the SBA is being introduced, with notes on the importance of high-quality fiscal planning and the unique economic circumstances that nations face following any economic shock, for example, COVID-19. Next, we define the objectives of the Sustainable Budgeting Approach. Finally, we provide a detailed introduction of the approach. In the appendices, we include detailed notes on example environmental, social, and economic impact characteristics for the policy archetypes and subarchetypes. Also in the appendices, we provide excerpts from a case study application of the SBA to the Gabonese Republic, as well as notes on future work.

2. CONTEXT

2.1. The role of government

Perspectives on the economic role of government vary widely, with differing philosophical and practical considerations contributed over thousands of years (Gordon, 1975; Tanzi and Schuknecht, 1997). Relevant to fiscal policy, there are differing perspectives on the degree to which a government should influence economic production and the degree to which it should be involved in socialising critical services and non-critical services. In any case, greater government involvement in the form of higher spending (or lower taxation) translates to higher financing needs.

In this document we do not consider “how much should a government tax and spend”, instead we focus on “if a government were to tax and spend, what initiatives should they support”. To this end, we rely on a few fundamental political assumptions. First, we assume that a government’s objective in spending is to protect present wellbeing and maximise future wellbeing. Second, we assume that governments act in accordance with their objectives. Third, we assume that governments are not beholden to political corruption and are not otherwise unduly influenced by special interest representation.

In most countries, none of these assumptions hold absolutely true, as is the nature of the political economy. Yet, each of the assumptions describes an attractive target state and one that we hope all nations strive towards today or will strive towards in the future. The wholesale failing of the first assumption would suggest that an alternative set of assessment criteria might be more applicable to the SBA. That said, in almost all nations, human wellbeing of some form is indeed a priority, and so perhaps the assumption is often strongly or weakly true. Importantly, political realities might somewhat (or significantly) displace a focus on wellbeing for a focus on maintaining power. The failing of the second assumption speaks mostly to questions of information asymmetry and policy maker rationality. We hope that, when provided with sufficient information to make an informed decision, a government will act to meet its objectives. The final assumption is perhaps the most unrealistic as every nation is influenced by corruption and undue influence, although the severity of these issues certainly vary. We hope that where the SBA is introduced to support fiscal planning, less corrupt stakeholders (including public pressure) would be better equipped to hold more corrupt stakeholders to account—they would have the necessary information to identify when inferior investments are being proposed and made.

2.2. A dearth of fiscal planning

National economies are complex systems, highly interdependent and everchanging. National economies also form nodes in the global economy, which is itself a complex system. In this context, optimising fiscal planning for traditional economic metrics, like the fiscal multiplier and job creation is challenging. When non-economic objectives are considered for co-optimisation, which is essential, fiscal decision making becomes even more difficult.

Nevertheless, centuries of policy trial-and-error, plus strong strides in academic research, means that humble efforts to maximise policy impact are not a lost cause. General equilibrium economic modelling efforts, linked to environmental impact factors, can incorporate major interaction effects, and give a quantified view on the potential result of a set of new policies being implemented.[2] Other, simpler quantitative approaches, including input-output modelling, can also be directionally helpful. Even qualitative rules of thumb and policy learning efforts can help policy makers understand the relative strength of one policy option in comparison to another. Of course, while a well-calibrated and comprehensive general equilibrium model might be technically superior to using qualitative rules of thumb, developing nation governments are often capacity-constrained and the latter option can be better than no option.

Oftentimes, despite having tools available, many finance ministries and/or budgetary offices continue to operate with little or effectively zero planning, particularly in vulnerable nations. In many nations, policy decisions are not *driven* by evidence, and even more concerning, in some countries they are not *informed* by evidence. In these cases, policymakers are effectively operating blind, without an understanding of the potential impacts of available policy options. This is a significant threat to national principles of effective governance as the budget is one of the most crucial strategic tools in governance. It enables the anticipation and projection of demands, targets, and results for the upcoming fiscal year. Effective budgetary governance is necessary to prioritize, plan, and allocate the necessary resources, both human and financial, to fund public policies, establish a clear vision of expected outcomes, and make informed decisions to achieve government objectives (OECD, 2015).

How then are fiscal decisions made if not based on potential impact? Sometimes if policy makers do not know the potential policy impacts of any fiscal option, special interest groups and powerful politicians can influence public capital flows with little resistance. In a sense, this is an example of information asymmetry—policy makers that might have positive intentions receive a one-sided perspective on policy impact from proponents (or critics) of the investment in question. In other cases, policies might be selected for little reason at all—perhaps for a lack of other well-developed options, perhaps for ease of implementation, perhaps due to policy momentum, or perhaps for another reason.

[2] Of course, these are imperfect and rely heavily on input parameters, but they do nonetheless hold value.

In any case, fiscal decisions made without precedence to estimates of potential impact are problematic for obvious reasons. Inferior fiscal decisions are likely to have inferior, and perhaps negative, impacts on wellbeing. For instance, support for a new coal-fired electricity generation facility, perhaps at the behest of a coal lobby, might create jobs in the short term, but will certainly predicate job losses in the long-term—and of course bring major climate impacts. The damages of poor fiscal actions can be particularly detrimental in vulnerable economies, where governments have exceptionally low access to capital and often low operational capacity. Low access to capital means that there is less room for waste in efforts to maximise wellbeing. Across all economies, it is clear that poorly selected fiscal policies are unlikely to achieve their fundamental long-term goal, which is to maximise future wellbeing.

2.3. Existing taxonomies

The United Nations System of National Accounts (UN SNA) provides an integrated framework for measuring and categorising economic activity, of many varieties (UN, 2000). It includes a broad framework of categories for grouping fiscal spending and taxation measures, used as a base by many countries for structuring their own budget reporting. UN SNA is, however, unsuitable for assessments of potential policy impact beyond GDP. This is because (a) it groups policies based on sectors rather than shared economic or environmental characteristics and (b), in many cases, the groupings are too broad to enable relevant assessments of potential impact. Recent natural capital adaptations to the UN SNA, for instance, the UN-supported System of Environmental Economic Accounting (United Nations *et al.*, 2014), are useful for tracking environmental assets over time, however, it shares classification categories with UN SNA. In short, UN SNA, SEEA, and taxonomies like them, are useful for unified tracking of national performance on one or two criteria, but not for multi-criteria impact assessments nor for tradeoff decision making; they have a different purpose to the SBA.

The European Union has recently developed a taxonomy for sustainable finance (European Union, 2020). This taxonomy, and similar taxonomies from France (Alexandre *et al.*, 2019), Indonesia (Otoritas Jasa Keuangan, 2022), and elsewhere, define categories based on climate relevance, with little consideration for economic characteristics. Furthermore, like the UN SNA, most categories that are assessed tend to be broad, limiting any potential impact assessments (even assessments on "environment" are only binary or on a 3-pt scale: green, neutral, harmful).

2.4. Green budgeting and climate budget tagging

The broad term "green budgeting" covers various measures to incorporate climate and environmental considerations in the budgeting process. A report from the European Commission, IMF, and OECD (Battersby *et al.*, 2021) include in their descriptions of green budgeting: (i) the greening of medium-term budget frameworks, (ii) introducing climate change in fiscal-risk assessments and management, (iii) tagging budgetary items for their green impact, (iv) policy evaluations and environmental impact assessments, (v) green spending reviews, and (vi) green accounting statements. Green budgeting, under most current definitions, is distinct from what is termed "sustainable budgeting" in this paper, in that it considers climate priorities in isolation from economic, development, and social criteria. The OECD notes seven areas needing progress in support of green budgeting practices (Blazey and Lelong, 2022):

- define *green* in terms of the results to be achieved,
- integrate green impacts into all governmental policies,
- align the relevant governmental commitments that apply to budgeting,
- apply a consistent basis to prioritising the activities that matter most to climate and environmental goals,
- analyse green budget proposals on merit, separate from funding,
- leverage existing budgeting frameworks to implement green budgeting, and
- strengthen accountability and transparency requirements for the implementation of green initiatives.

Budget tagging initiatives have received significant attention, having been proposed and implemented in several nations. Many budget tagging exercises focus on identifying policies that might support climate mitigation priorities, "climate budget tagging" or "green budget tagging".[3] Some exercises consider policies that might support other facets of the Sustainable Development Goals (SDGs), "SDG budgeting". In either case, the aim is to help policymakers and observers better understand, track (for meeting transparency objectives), and act in support of climate and/or other social/environmental objectives. Some existing tagging initiatives have ostensibly been effective in meeting this purpose (World Bank, 2021a) and spurred other nations to follow suit (OECD, 2021a) . There is also potential for those that perform highly on green budget tracking to use the system to demonstrate progress to donors and the private sector.

[3] By way of example, see Lelong and Wendling (2020) in France and Rulliadi (2019) in Indonesia. A 2021 report from the World Bank, *Climate Change Budget Tagging*, provides a review of international experience across 18 methodologies.

Yet, it is debatable whether climate tagging efforts have any impact on decision making, in part because the two-point Likert scales (for climate, “green” or “not green”), common in green budgeting, focus on only the environmental axis of impact, which is itself often considered less relevant in decisions made by nations seeking to develop. Evidence of how governments use climate tagging in practice suggests that even if tagging is completed regularly, it is an exercise in tracking and seldom integrated into budget decision making. Furthermore, most countries only track the positive classifications of their tagging, choosing to not bring attention to negative classifications. Most countries also only apply their tagging procedures to a limited portion of their budget (e.g., only energy or only capital budget expenditures), intentionally excluding most spending (especially excluding taxation). In many developing nations where these efforts take place, there is no pre-existing and systematic approach to making impact-based trade-off decisions in the Ministry of Finance; it is then unclear where new information from budget tagging could filter in. In many low- and middle-income nations, fiscal decisions are not made in reference to forecast economic impacts, never mind environmental considerations. For new information from climate/green/SDG tagging to be of any use, these nations first require a fundamental shift in their planning processes and framing of fiscal investments. The SBA attempts to fast-track this shift; more on that in a later section.

A 2021 World Bank report provides a helpful review of national approaches to green budget tagging, considering 18 national and subnational governments. Additional budget tagging guides have been developed by the OECD (2021), the IMF (2021), the IADB (Pizarro *et al.*, 2021), and the European Commission (2022). The World Bank report delineates two approaches to the definition of climate-relevant activities in green budget tagging objective-based definitions and policy-based definitions. Objective-based definitions identify climate-positive activities based on their *intended* impact (often using the Rio markers) while policy-based ones consider the activities directly “referenced in national climate change policy documents” and usually consider 10-20 policy types.

The report notes several continuing challenges to green budget tagging approaches:

- They are constrained by the pre-existing budgeting system, frameworks, and programmatic categories that are in place (including the level of detail presented for each policy),
- They do not consider policy alignment with broader national goals, nor policy efficiency or effectiveness,
- They make major omissions in coverage of budgetary items. Most notably, out of all surveyed countries, only France and Finland include tax expenditures and subsidies in their tagging and only four countries consider transfers to state-owned enterprises,

- They mostly do not identify activities with an adverse impact on climate change (and other objectives), focusing instead on positive policies, and
- They are hard work, representing "a significant burden on budget officials". This is particularly the case in nations with less technical capacity. The report notes that "complex and costly tagging systems, particularly in the absence of strong political ownership, are unlikely to be sustained without ongoing external financial and technical support". Importantly, providing this kind of ongoing financial support could limit internal ownership of the exercise.

Reviewers to an earlier version of this document noted that other challenges include the lack of safeguards against greenwashing in budget tagging and the risk for crucial definitions to be influenced by politics (e.g., definitions for "green").

Although primarily designed as a tool for trade-off decision-making, the SBA also serves the objectives of budget tagging. It categorises fiscal allocations based on climate and other SDG characteristics, doing so at a much higher granularity than existing budget tagging approaches (i.e., policy level rather than programmatic level) and with paired analysis for development/economic and social criteria. While climate budget tagging gives a theoretical broad lens on climate impact (for example), the SBA provides a practical multi-objective trade off budgeting tool, flexible to country needs, and designed to be used by policy makers on a day-to-day basis. In this way, it is unhelpful to consider the SBA as a new iteration of climate budget tagging—rather, it should be seen as a mainstream results-based budgeting tool, designed to support economic progress, while also protecting the environment and meeting social priorities.

2.5. Resilience to economic shocks and recovering from the COVID-19 crisis

Economic shocks from crises like COVID-19 and the war in Ukraine, along with secondary shocks from policy responses, underscore global gaps in economic resilience (Sadler *et al.*, 2023, Voegele, 2022). In a permacrisis era, enhancing resilience—economic, social, and environmental—prepares nations for future crises (Marotta *et al.*, 2023). However, the understanding of fiscal policy's influence on resilience is limited, and no tool currently exists to support policymakers in systematically enhancing the resilience of their budgets.

The SBA is one tool that could support governments in their efforts to boost resilience. To do so, it draws heavily on research about effective and green COVID-19 recovery policies. That said, it is certainly not limited to COVID-19 applications—indeed, it is useful both inside and outside of shocks. Many COVID-19 studies explored opportunities to design pandemic-recovery initiatives that both reinvigorate economic production and support social and environmental objectives, suggesting that in many cases, "green" recovery initiatives can outperform "traditional" alternatives in effectiveness and efficiency (Batini *et al.*, 2022; Hasna, 2022; Hepburn *et al.*, 2020; O'Callaghan and Murdock, 2021). Notably, this research identified clear opportunities to proactively use fiscal investment in COVID-19 recovery with social and environmental objectives in mind, potentially bringing significant positive impacts. Sadler *et al.* (2023) investigated the adaptation and resilience characteristics of COVID-19 spending, revealing many missed opportunities to advance climate resilience through fiscal injections. The study implies that similar weak trends likely exist for economic and social resilience progress. OECD (2020a) provided additional perspectives on how green budgeting, specifically, could support the COVID-19 recovery while Vardon *et al.* (2023) did the same for natural capital accounting and Patel *et al.* (2022) assessed impacts on natural capital.

Despite evidence supporting the economic benefits of a green recovery, not all nations had the same capacity to pursue it. Developing countries, for example, were forced to grapple with significantly limited fiscal space, and potentially with unexpected hurdles to implementation resulting from complex domestic social and political contexts. Indeed, although the COVID-19 crisis was global, the demands of pandemic recovery were not the same for all nations.

2.5.1 Economic shocks and vulnerable nations

Prior to the COVID-19 pandemic, many countries had been making strong progress on development. Based on data contained in the *SDG Index and Dashboards Report 2019* (Bertelsmann Stiftung and SDSN, 2019), a majority of OECD countries had been on track to meet targets for Quality Education (SDG 4), Decent Work and Economic Growth (SDG 8), and Industry, Innovation and Infrastructure (SDG 9). Most East and South Asian countries were on track to meeting targets for No Poverty (SDG 1) and Decent Work and Economic Growth (SDG 8). Eastern European and Central Asian countries were, on average, on track to meet targets for No Poverty (SDG 1) and Affordable and Clean Energy (SDG 7). Most Latin American and Caribbean countries were on track for Affordable and Clean Energy (SDG 7). Most Middle Eastern and North African countries were on track for No Poverty (SDG 1). Most Sub-Saharan African countries were on track for Climate Action (SDG 13).

Yet, despite progress on some goals, even before COVID-19, many countries' development remained constrained with inadequate support from international partners. Even then, progress on some SDG targets was moving backwards in some regions: decreasing trends were observed for Life on Land (SDG 15) in East and South Asia; Partnerships for the Goals (SDG 17) in Eastern Europe and Central Asia; No Poverty (SDG 1) in Latin America and the Caribbean; and Peace, Justice and Strong Institutions

(SDG 16) in Sub-Saharan Africa (Bertelsmann Stiftung and SDSN, 2019). For 26 countries in sub-Saharan Africa, the number of people living in extreme poverty increased between 2010 and 2020 (Suckling *et al.*, 2022). Stagnation was also common, with inadequate progress on most goals across regions. Thus, even before COVID-19, and across regions, gaps towards the 2030 Sustainable Development Goals were significant and, in some cases, increasing, and international support had not gone far enough to bridge these gaps.

The COVID-19 pandemic dramatically exacerbated pre-existing economic and development challenges and this is just one example of any number of relevant shocks. Particularly in developing economies, increased costs, declining foreign investment under unstable conditions, and insufficient foreign aid mounted pressure on national budgets, severely restricting the ability of governments to invest in necessary recovery initiatives. New challenges emerged, for instance in a major decline in tax revenue in most countries (IMF, 2020). Operating under already limited fiscal space, governments of developing countries were forced to cope with higher essential spending needs, in part linked to expanded health and social care costs, while attempting to contain public debt and contend with lower taxes. The greatest GDP contraction in 2020 was experienced by developing countries in Latin America and the Caribbean, at 7% (Werner *et al.*, 2021), and a rapid full recovery of the labour market in the short term appeared implausible (ECLAC, 2021). In Sub-Saharan Africa, recovery from both the health crisis and its resulting economic devastation was significantly slower than in advanced economies, with advanced economies projected to recover back to their pre-crisis output paths by 2023, at which point Sub-Saharan Africa would still be on a path 5.6% lower than pre-crisis projections (IMF, 2021b).

Inter-country variation in COVID-19 response and impact was also significant. Pre-pandemic levels of economic development and resilience varied strongly between countries. For instance, if measured by national reductions in extreme poverty, China and India were on the strongest upward trajectory between 2010 and 2020, while many countries in Sub-Saharan Africa, as well as countries affected by conflict and fragility such as Yemen, saw increasing poverty (Suckling *et al.*, 2022). By virtue of these different starting points, the COVID-19 pandemic had differentiated impacts on nations. Countries with significantly limited fiscal space pre-crisis were generally hit harder than those with greater flexibility in their fiscal and monetary policy options (Gaspar *et al.*, 2020), and these same countries are clearly the least likely to be able to support expensive recovery initiatives. This again speaks to resilience. The prospect of global recovery relied in part on global solidarity to ensure that recovery needs were met even in those countries where burdens drastically outweighed available resources. Unfortunately, such action did not come to pass.

The crisis and the various hurdles preventing prompt recovery have had a range of negative consequences. In 39 out of 45 Sub-Saharan African countries, inequality worsened over the course of the pandemic (IMF, 2021b). The havoc wreaked by the pandemic also delayed or prevented the achievement of already urgent sustainable development goals, with severe consequences. On current trends, for example, there will be 48.1 million deaths of children under the age of 5 between 2020 and 2030, 11 million more than there would have been if all countries met the SDG target on under-5 mortality (Sharrow *et al.*, 2022).

One of the most significant challenges faced by developing countries in their recovery from the COVID-19 crisis, and their ongoing development, was and is restricted fiscal space. This challenge is common across many kinds of economic shocks and COVID-19 is just one example. To a large extent, the pandemic worsened the pre-existing fiscal constraints of developing economies, with lower overall output from which governments could draw resources. Difficult fiscal positions were exacerbated by decreased tax revenue, as well as by the failure of international solidarity in distributing supplementary funds which could be effectively used for crisis recovery. Donor commitments remain unfulfilled on many fronts: promises of 0.7% of GDP to international development in the *Doha Declaration on Financing for Development Agenda* and the *Addis Ababa Action Agenda* have not been met (Nordic Statistics, 2022), and climate finance commitments under article 9 of the Paris Agreement are far from being reached (Carty and Kowalzig, 2022).

Due to severely restricted fiscal space, recovery investments in developing, and particularly least developed, countries were dramatically lower than in other parts of the world. Data from the Global Recovery Observatory (O'Callaghan *et al.*, 2021) highlights the minor funds made available for COVID-19 recovery spending in least developed countries (LDCs), as low as USD $64 per capita. Recovery spending from other developing nations was an order of magnitude above spending in LDCs at USD $726 per capita. Advanced economies, meanwhile, were on an entirely separate scale, with more than USD $15,000 per capita spent (O'Callaghan *et al.*, 2021). While inequality within regions has grown because of the pandemic, the greatest increase in inequality is likely to come between regions. Per capita recovery spending in most African states, for instance, was less than 1/250th that of advanced economies, driving the wedge ever further between developed and developing countries, and threatening global stability.

Across the world and particularly in developing economies, increased costs, declining foreign investment under unstable conditions, and insufficient foreign aid mounted pressure on national budgets, severely restricting the ability of governments to invest in recovery initiatives made necessary by the devastation of the COVID-19 pandemic. Operating with already limited fiscal space, and collapsed taxation revenues, governments also had to cope with expanded health and social care costs. Pre-existing development challenges saw their difficulty and urgency magnified by the effects of the pandemic. Experience and research both show that there were opportunities, in recovery spending and elsewhere, to achieve progress simultaneously on climate and the economy (Hepburn *et al.*, 2020; O'Callaghan *et al.*, 2022; O'Callaghan and Murdock, 2021), but so far this opportunity has been lost in most developing economies (O'Callaghan *et al.*, 2021).

Together, the factors discussed in this subsection suggest that the SBA's function to support trade-off decision making could be particularly helpful for developing countries striving for sustainable development. This was recognised by African Ministers of Finance, at the 2022 International Cooperation Forum and African Ministers of Finance, Economy and Environment Meeting for COP27. The ministers resolved to "Support the development of capacity and institutionalisation of a Sustainable Budgeting Approach, integrating climate goals within national fiscal frameworks" (ICF, 2022, resolution 31).

3. OBJECTIVES OF THE SBA

3.1. Core objective

The primary purpose of the SBA is to help government officials make better informed fiscal decisions by providing evidence-based perspectives on the potential economic, environmental, and social impacts of different policy types. To this end, the SBA is likely to be most useful in budgetary offices and ministries that lack—or wish to strengthen—systematic, evidence-based, and multi-dimensional planning procedures. Low- and middle-income countries might be particularly interested in exploring the SBA for these reasons, but it is relevant for high-income nations too.

3.2. Supplementary objectives

3.2.1. For policymakers

Alongside its role supporting decision making, the SBA can be used by policymakers, both of finance ministries and line ministries, to:

- **Systematically identify new policy ideas.** By collating and reporting policy measures from many nations, in unified and granular categories (subarchetypes), countries using the SBA will contribute to a rich database for policy learning. This is differentiated from international systems of national accounting (e.g., UN SNA) in that reports are at the policy level rather than at a programmatic or sectoral level (which is much broader). Practically, a policymaker proposing a policy measure provides details for the measure to the database and is then automatically able to view all similar policy measures introduced by other nations—including those with similar economic functions but stronger environmental benefits. The precursor to the SBA, the Global Recovery Observatory (GRO), in its tracking of COVID-19 measures, already provides over 8,000 examples of fiscal policy categorised in 221 subarchetype categories. This list includes over 1,000 examples of green policies with descriptions and sources. As the SBA is applied to 'normal' budgeting cycles (annual or multiannual), even more policies will be identified and categorised, expanding the set that a policy maker might learn from.
- **Track the overall environmental, development, or social characteristics of an entire budget (expenditure and taxation revenue).** Once all budget policies have been categorised using the SBA fiscal taxonomy, the user of the SBA can compute the aggregate appropriations of a budget (or budget subset) on any of the SBA's economic/development, social, or environmental criteria. These figures could be tracked over time to understand trends in fiscal efforts and/or compared to other nations that use the SBA taxonomy. Note that at this stage the SBA does not incorporate interaction effects between policies, potentially impacting the accuracy of figures on aggregate budget impact.
- **For finance ministries, enable clear objective-based fiscal decision making.** Application of the SBA could help finance ministries ex-ante ascertain the degree to which line ministry spending proposals support national objectives (formulated in SBA metrics), including on climate. On this basis, finance ministries would have justification for proposed amendments to line ministry proposals to better meet national objectives.
- **For line ministries, provide guidance for formulating sustainable policy proposals.** Line ministries could apply the SBA to proposed policies to understand their likely performance against the criteria used by the finance ministry for decision making. With this information,

line ministries could then adapt their proposals to better align with national priorities and score better on the selected SBA criteria. For this purpose, line ministries might also look to the SBA and GRO policy databases for inspiration of how other nations have previously approached similar choices.

- **Support debt initiatives.** Many sovereign debt initiatives—including bond issuances, debt swaps, debt holiday programs, and sovereign-sovereign guarantees—can be usefully paired with development and/or environmental priorities to support these priorities while also reducing the cost of finance or increasing access to finance. For instance, borrower-defined Key Performance Indicators in sustainable sovereign-sovereign guarantees, sustainability-linked bonds, green bonds, blue bonds, and SDG bonds. The SBA could be used for setting and measuring progress on indicators over time. It could be used on its own or in combination with trailing indicators like ten-year changes in greenhouse gas emissions. An approach like this would support borrower interests while also opening new avenues for sustainable investment from creditors and development partners. There are also benefits of using the SBA in these scenarios for positive influence on credit ratings agencies; this benefit is explored in the next subsection.

While the core objectives of the SBA might be most relevant to vulnerable countries without effective fiscal planning processes, these supplementary objectives are useful for all kinds of governments—even those already employing robust trade-off procedures in decision making.

3.2.2. For other users

For civil society, the SBA can act as a transparency tool to highlight the characteristics of a government's fiscal actions in comparison to other nations. This is particularly important as a number processing bias means that members of the public do not fully appreciate the relative magnitude of different fiscal investments. A lack of familiarity with large numbers means that they might not always be properly processed by the human brain—indeed, neuropsychological research suggests that large numbers are often processed logarithmically while small numbers are processed linearly (Dehaene *et al.*, 2009; Hyde and Spelke, 2009). As they have done with GRO data, civil society could use SBA data comparisons as an input to advocacy efforts calling for changes in fiscal allocations.

For businesses and investors, SBA data could be a useful indicator on government priorities and the future direction of an economy. In this way, it is a transparency tool. In turn, this could shape investment decisions and patterns. With significantly more data, over several years, businesses might also use SBA records to understand which geographies might offer the strongest commercial opportunities relevant to their own strategies. It is worth noting that further work could adapt the taxonomy to understand the potential impacts of private sector financial flows.

For credit ratings agencies, SBA data could provide an additional indicator to inform sovereign rating recommendations. By considering changes in the resilience, climate, social, and economic characteristics of a budget over time, ratings agencies could gain insight into the pace of economic transition and government interest in transition. This is important because if a government were to initiate a shift to protect their long-term economic production through better spending practices, we know this would strengthen ability to repay future debts, particularly during crises (see Dibley *et al.*, 2021). This should, in turn, translate to a higher (safer) rating and a lower cost of finance in the short term.

For parliaments, the SBA could be designed to directly incorporate metrics of interest to parliament (e.g., job creation or climate mitigation). It could then be applied as a transparency tool to understand how budgets are, or are not, supporting parliamentary priorities. Beyond transparency initiatives, the SBA could also be used by parliaments as a staging tool to link long-term planning to budgets—if a parliament were, for example, to legislate a long-term plan for sectoral transformation, it might incorporate annual targets for fiscal policy to stage the implementation of the plan (e.g., X% of budget supporting climate objectives by 20XX, Y% by 20YY).

For oversight bodies, for example, independent fiscal institutions, the SBA provides a valuable tool for observation and tracking in line with national priorities. Using green priorities as an example, the SBA can support two to three of the four areas identified by the OECD (Cameron et al., 2022) for independent fiscal institutions to support governments greening their budgets. The SBA can help monitoring of compliance with green budgeting (through its data for likely climate-impact), programme evaluation with a green perspective (using its taxonomy for categorising policies by focus), and general research on climate, ecosystems, and the circular green economy (which is required to inform its climate-impact assessments).

For researchers, the highly detailed SBA datasets open countless new opportunities for fundamental research. As an indication, the GRO dataset is already being used in econometric, machine learning, and policy research applications. Wide dissemination of SBA data in research communities might also help direct new research to the areas that are receiving greatest policy attention (and highlight which areas perhaps need greater advocacy to prompt more policy attention). Finally, as a leading indicator on future changes in climate emissions, SBA fiscal data could be integrated into climate models to improve accuracy.

For development partners, SBA could usefully provide measures on the aggregate environmental and social characteristics of national budgets. This could be used as an additional indicator to shape how and where to direct future aid disbursements. It might also be used to inform which sectors in a particular economy might best benefit from support and collaboration. As in the case of businesses and investors, credible and transparent data on national or sub-national policy choices and their alignment with long-run growth and environmental objectives could also help lower sovereign borrowing costs (Dibley *et al.*, 2021).

3.3. Limitations

Several core limitations must be addressed from the outset. First, ex-ante assessments of policy impact are a coarse placeholder for detailed ex-ante modelling and ex-post studies; while the SBA provides much more detailed perspectives than alternatives like budget tagging, it is best used as a directional indicator rather than for strict impact quantification. Second, in its current form, the SBA assumes static economic conditions and ignores the dynamic interaction effects of policies implemented simultaneously. Third, the success of SBA relies on policy maker willingness to change. Finally, SBA findings depend on descriptions of policy actions provided by governments, which might lack detail or be disconnected from practice.

3.3.1. Considerations for ex-ante assessment

Generalised Likert impact assessments are provided for environmental and social metrics, with generalised methods described for economic metrics. For environmental and social metrics, while every effort has been made to maximise the accuracy of assessments, the nature of fiscal policy is that small changes in policy design and minor variations in the macroeconomic environment can significantly policy effect impact. For any policy archetype, it is hence possible that badly designed policy is unable to match the generalised potential impact assessments of the archetype.

The supplementary materials of O'Callaghan (2022) note three core limitations in ex-ante assessment. First, generalisation is required to categorise policies into predefined archetypes and subarchetypes. Although, significantly less generalisation is required for the SBA (with 250 subarchetypes) than for all policy-based budgets in existing green budget tagging efforts (World Bank, 2021a), which have at most

50 categories. Second, policy details can change between announcement and implementation. Third, policy implementation can fail.

O'Callaghan (2022) explains:

- *First, when considering global collections of policy packages, the large number of individual policies prevent tailored impact assessment. Archetype methods allow for like policies to be grouped into a set of categories or 'archetypes. In this case, archetypes are assessed instead of individual policies. The higher the number of archetypes, the more individualized the impact assessment and the higher the accuracy. However, even with hundreds of archetypes, there will always be some level of policy variation that cannot be captured amongst the thousands of policies. Importantly, when considering aggregate global views on policy impact, concerns on policy variation might be withdrawn as a very high sample size might mean that impact variations effectively cancel each other around a global mean, defined by each archetype.*
- *Second, since the time between initial policy announcement and policy implementation can be significant—sometimes several years for recovery investments—the details of a policy can change significantly before any funds are spent. This is particularly true in periods of economic uncertainty, as seen over 2020-2021. We refer to this as the spending-expenditure anomaly, where fiscal spending describes initial ratified plans and expenditure describes actuals. Unfortunately, the details of this anomaly are seldom clear as policy changes are seldom released by governments on a timely basis, if at all. Beyond that, GRO researchers focus on new policies rather than changes to old policies as they update the dataset. Where data is available (e.g., the UK), we have attempted to record expenditure progress against spending. Future work should consider forthcoming government expenditure disclosures and reconcile these against the policy data of the present study.*
- *Third, any number of factors can stifle policy implementation, meaning that policy outcomes do not match original intent. Such factors might be influenced by internal and/or macroeconomic circumstances. To this end, it is essential that rigorous ex-post analyses are built into investment programs. With significantly more ex-post data, across regions, ex-post assessments of the outcomes of future measures could be dramatically improved. For instance, with a large enough training set of data, deep learning processes might identify factors likely to influence implementation and shape policy impact.*

Despite these obvious limitations, ex-ante assessments do have some use. Even the most basic directional indicators can provide valuable perspective to policymakers seeking help. Precedent studies, like Edward Barbier's (2010) analysis of Global Financial Crisis (GFC) fiscal policy, show that even simple frameworks can be useful for understanding environmental impacts ex-ante. This approach lay the foundation for ex-ante fiscal policy environmental assessment and shaped the methodology of O'Callaghan (2022), which in turn shaped the methodology of the SBA.

3.3.2. Static economic conditions

The core function of the SBA is to provide a directional perspective on how any single policy change might impact economic, environmental, and social outcomes in a nation. However, it is often the case that a government announces or implements multiple interventions simultaneously. Since economies are complex and interconnected systems, it is common for policies to have interaction effects on each other, meaning that the combined impact of two or more policy interventions might not be equal to the sum of the parts. These interaction effects are likely to be particularly complex and difficult to ascertain on economic impact measures, compared to many environmental measures.

While this limitation is certainly applicable to the SBA, since the SBA provides only directional qualitative perspectives on potential impact, the limitation might not always be all that consequential. That said, without a general equilibrium model, it will be difficult to know with any certainty how consequential any interaction effect might be on economic grounds. As such, the user should take care whenever applying the SBA to any impact aggregation exercise and should also consider whether there might be pronounced concern for interaction effects in policy comparison exercises.

3.3.3. Willingness for change

Integrating the SBA into national or subnational fiscal planning is of little use if local policy makers are not fully bought in to the effort to improve their own fiscal practices. The SBA is not a silver bullet to decide trade-offs and fix all fiscal holes. In fact, in some cases, it will make decisions more difficult by providing policy makers with additional information that challenges their priors. Without buy-in of senior policymakers and a mandate to implement SBA principles, it will be difficult for any supporting entity to make progress. Similarly, without provision of complete fiscal data, the effectiveness of the SBA application will be limited. To this end, policymakers must be willing to consider spending data as well as taxation data, which is often forgotten.

Of course, the benefits of effective and evidence-based fiscal planning can support everyone's objectives. Good fiscal planning should boost wellbeing for the population relative to a counterfactual, and ceteris paribus, improved prosperity might increase support for a ruling government at the ballot box. Within a ministry, if effective fiscal planning is championed by an influential leader, the benefits could flow across the entire government and lead to an overhaul in fiscal thinking. In turn, that change could significantly improve social outcomes and centre environmental protection—which then encourages international investment and aid. These are the kinds of narratives that should be communicated to policy makers in advance of attempts to integrate the SBA.

3.3.4. Policy descriptions

Categorisation of policies to the SBA taxonomy relies on descriptions provided by government, either in formal budget documentation, or informally. Often, policy descriptions are vague, either intentionally or unintentionally, meaning that policies might be classified as "uncertain", with no potential for directional impact assessment. In less severe cases, vague policies might be classified into an archetype grouping but not classified at the subarchetype level. As explained in Section 4.3, the default in this scenario is to categorise the policy as a traditional measure rather than as a green measure, introducing potential room for error.

In some cases, policy descriptions are specific but too broad to be reasonably categorised. For instance, a policy might describe "investment in infrastructure, including roads, rail, and utility assets". In these cases, the SBA user might elect to split the policy into three and allocate spending evenly across each named category. While this solution has merit, it is certainly suboptimal; it is clearly rare for policies to be split equally by value and it assumes that policymakers are comprehensive and transparent in listing investment areas.

Finally, it is conceivable that in some circumstances, policy descriptions provided by policymakers reflect the most positive lens on their actions. It is hence important for the user of the SBA to critically interpret policy descriptions in completing their categorisation of policies.

4. USING THE SUSTAINABLE BUDGETING APPROACH

The Sustainable Budgeting Approach is a direct extension of the GRO methodology, which was created in 2020 to track pandemic-related fiscal spending. The GRO tracked fiscal policies in 89 countries and used a novel taxonomy approach to assess the potential social, environmental, and economic impacts of each spending item. The methodology was revised in 2021 and 2022. GRO was created and run by Oxford University in partnership with the Green Fiscal Policy Network, the United Nations Environment Program, the United Nations Development Program, and the United Nations Partnership for Action on Green Economy. There is scope to further expand the Sustainable Budgeting Approach to consider non-fiscal financial flows, both in non-taxation sourcing of public finance and in private flows; this is left for future work.

The SBA expands on GRO In several ways:

- It adapts the recovery fiscal taxonomy into a general fiscal taxonomy. In this process, archetypes and subarchetype categories are recast. The SBA includes 40 archetypes and 206 subarchetypes plus a ‘cost of debt’ category (see *Appendix A. Definitions for Archetypes*), while GRO included 42 archetypes and 221 archetypes. Previous “rescue” and “recovery” groupings used in GRO are only applicable in the context of economic response to crisis; SBA uses the groupings of “operational” (i.e., recurrent budget) and “discretionary” (i.e., capital budget) archetypes.
- It adds loose guidance on how the directional economic characteristics of policy subarchetypes might be assessed in any country of interest.
- It incorporates heavily updated environmental impact assessments and some updated social impact assessments, provided in
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- Appendix B. Example policy impact assessments.
- It provides instructions for how a government might apply the methodology. This contrasts to GRO, where all policy recording, categorisation, and assessment was undertaken by Oxford.
- It introduces a pliable excel tool for applying the SBA to national budgets. The tool is introduced in a case study application for the Government of the Republic of Gabon.

The taxonomy and assessments contained in this document were developed using three primary inputs:

- the GRO and associated methodology documentation (O'Callaghan et al., 2021), including the precedent academic paper of Hepburn *et al.* (2020),
- the perspectives of policy staff, academics, and other fiscal policy experts, and
- leading academic literature, sometimes supported by grey literature.

The SBA is very much an incomplete method that offers significant opportunities for user improvement. Opportunities for future work are explored briefly in the conclusion, with a potential advanced taxonomy approach presented in

Appendix C. Future taxonomy structures.

4.1. How to use SBA: summary

As outlined above, the SBA is a method for interpreting the environmental, social, and environmental characteristics of a fiscal policy or a group of policies (for instance, a national budget. The SBA is designed to interpret any fiscal policy type, either on the expenditure or taxation side. It could also be adapted to non-financial measures, provided appropriate expert oversight. Potential non-financial applications might include assessing regulatory interventions, institutional arrangements, or even setting national objectives and strategies. The approach is designed to be flexible to potential changes in the mode and format of government budgetary publications. The value and validity of the approach increases with higher levels of policy granularity.

Applying the SBA requires first a robust assessment of the potential economic, environmental, and social impacts of archetypes and subarchetypes (assessment process), and second, an application of those assessments to the policies under consideration (application process). The first process is effectively a once-off exercise in establishing a universal national framework, while the second process is the practice of applying that framework on an annual, semi-annual, or multiannual basis. The first process can be lengthy and will ideally be completed in partnership with local and/or global experts (it might also be updated every few years based on updated information). By contrast, the second process is considered very simple and can be undertaken many times by local policy makers, without external support, based on the framework established in the first process.

4.1.1 SBA assessment process

For any country, the SBA assessment process is only two steps:

1. **Establish which economic, environmental, and social criteria are important.**

   In the current iteration of this document, we provide ten impact criteria for policy consideration. The starting environmental impact criteria are (i) short-term net greenhouse gas (GHG) emissions impact, (ii) long-term net GHG emissions impact, (iii) natural capital (or perhaps biodiversity) impact, (iv) air pollution impact, (v) direct adaptation and resilience impact, and (vi) indirect adaptation and resilience impact. The starting social impact criteria are (i) wealth inequality and (ii) rural livelihood. The starting economic criteria are (i) fiscal multiplier and (ii) short-term job creation.[4] It is certainly possible to expand this list to include additional considerations; to that end, it is up to the user of the SBA to determine which additional criteria might be useful.

2. Use academic literature, modelling, and expert insight to fine-tune the potential impacts of each subarchetype.

Indicative impact assessments for each of the six starting environmental criteria and two starting social criteria are included in

[4] All mentions of job creation in this document refer to short-term job creation (i.e., during the construction phase for discretionary-type archetypes.

Appendix B. Example policy impact assessments. Also in Appendix B, some baseline literature is provided to inform economic impact assessments. These indicative assessments are useful in isolation, however, every nation is different and the potential impacts of subarchetypes are likely to vary between countries. Hence, it is valuable to fine-tune the global assessments to domestic context. This is particularly true on economic metrics where small differences in economic structures (domestic production vs imports, labour skill distribution, contractor capacity, private sector incentives etc) can significantly impact the economic impact of a fiscal policy. When first fine-tuning the global SBA assessments to their country, a policy maker or partner should look to existing academic, grey, and internal government studies that consider the domestic impacts of past investments. If there is capacity for basic input-output modelling or an alternative, the policy maker or partner might also consider using this method to analyse each subarchetype in generalised terms. Finally, a policy maker or partner could also seek the guidance of local and global experts to provide perspectives on what the likely impacts of a policy subarchetype might look like in the domestic context.

An optional and very simple extra step is to create composite scores for each subarchetype. For instance, to consider overall environmental performance, a 'green' composite score could be defined as any policy that has either a positive impact on net GHG, natural capital, or air pollution.

4.1.2 SBA application process

The SBA application process takes five steps (below), of which steps 2 and 3 are direct uses of the framework established in the assessment process (above):

1. **Itemise policy measures reported in annual and semi-annual budgets.**

   First, the policymaker must identify the policy set to be analysed. This might be just a few policies, selected for the purpose of comparing impact. Alternatively, it might be a very large group of policies to ascertain the characteristics of an entire budget (or a contained sub-budget group). In the case of analysing an entire budget, it is in the best interests of the policymaker to find the most granular breakdown of policies that is possible and the broadest group of policies that is possible. In this endeavour, a few common themes should be noted:

   - Spending and taxation measures are inconsistently reported within and across countries, but most often appear in standard annual or semi-annual budgetary announcement documents,
   - Investment measures (i.e., the capital budget) sometimes appear in separate documents and at a higher granularity than recurrent budget items,

- Spending in Public Private Partnerships (PPPs) and State-Owned Enterprises (SOEs) is sometimes reported in budget documents, sometimes reported in other documents, and sometimes not reported at all, and
- Taxation measures, and especially differential tax subsidies, are often absent from budget documents. The Global Tax Expenditure database reports that 116 out of 218 surveyed countries have never reported any official tax expenditure data and according to the Open Budget Survey, only 10 countries report all tax expenditures (GTED, 2022; International Budget Partnership, 2021). Nevertheless, the user of the SBA is encouraged to seek details of these measures out wherever possible.

2. Categorise policies using the taxonomy (assign archetypes)

In the second step, the policymaker uses the archetype and subarchetype definitions contained in the SBA to categorise policies by group, archetype, and subarchetype. For group, the taxonomy differentiates between 'operational' spending and 'discretionary' spending. The taxonomy includes 40 policy archetypes (17 operational, 23 discretionary) and 206 subarchetypes (70 operational, 136 discretionary), as well as a 'cost of debt' category to account for interest payments.

Under most programmatic budget frameworks, this categorisation step could be completed at the program level as a once-off, allowing for automatic categorisation of all programmed budget items in future budget cycles. In some cases, exceptional policy items might not meet the program-level categorisation and user discretion might be necessary. Similarly, some budget items might be non-programmed/off-program, requiring manual consideration in every budget cycle.

For example, a generic policy with description "Funds to build new paediatrics wing at public hospital" would likely be categorised as discretionary spending of the Health (β) archetype and the Health-Physical (β1) subarchetype. For countries using programmatic budgets, instead of considering the policy, the relevant program, say "Ministry of Health-Hospitals-Region X-Infrastructure", would be analysed and linked to the β1 subarchetype—all future spending related to that program would then be automatically linked to the same subarchetype.

3. Apply assessments from taxonomy to policies

By categorising each policy in step 2, the user has established a direct link to the potential policy impacts defined in the SBA assessment process. This is because each subarchetype is associated with environmental, economic, and social impact scores.

4. Aggregate policies

If the user wishes to consider the combined impact of a group of policies (i.e., a complete budget or a subset thereof), policies be aggregated by sector, by archetype, by type (investment vs non-investment), and more. This provides a high-level perspective on national performance in fiscal spending. While this view might also be useful for considering overall environmental spending (e.g., green vs neutral vs dirty as in example graphs presented for the Gabon case study later in this document), the SBA is best used for individual impact criteria (e.g., natural capital impacts OR short-term GHG emissions OR other).

5. Analyse data

For any assessment criterion, policymakers can make simplified judgements about not only past performance, but also future opportunities. This is possible by aggregating policy scores on any desired criteria. If this approach were applied internationally, policymakers would be able to compare their spending with other nations—both regionally and globally. This could inform discussion on how to improve spending and taxation in line with peers and provide opportunities to share best practice.

4.2. Sustainable budgeting taxonomy and its scoring

4.2.1. Design

Archetypes and subarchetypes are designed to be collectively exhaustive at each level, mutually exclusive at each level, and framed so that differences in environmental impact might be discernible at the subarchetype level. The taxonomy can be applied in reference to both tax and expenditure policy measures. For tax measures, the taxonomy considers the net government-forecasted financial impact of tax measures on the recipients (e.g., a tax reduction of 5% with impact over $1bn in revenue for solar energy generation has a $50mn net financial benefit on the solar energy generators—this would be recorded as $50mn for subarchetype δ1).

4.2.2. Categories

All archetypes and subarchetypes fit into two major categories—operational measures (i.e., recurrent budget) and discretionary measures (otherwise referred to as investment/expansion measures, i.e., capital budget). Operational measures are those required to maintain normal functioning of society, and might include paying government employees, social security, and maintaining health systems as they are. Discretionary measures are once-off measures used to change or otherwise enhance the functioning of an economy, and might include investment in new public infrastructure, development of new tourism programs, and temporary agricultural subsidies to shift production patterns. To some degree, the line between operational and discretionary measures is pliable and should be determined by the preferences of local government. In some cases, there may be little benefit in delineating between the two categories and a government might elect to treat all fiscal measures equally. This would, of course, render efforts to compare and learn from other nations more challenging.

4.2.3. Impact assessment

Assessments of potential impact on economic, social, and environmental criteria at the national (or subnational) level allow policies to be compared across all the most relevant dimensions. With an understanding of full potential impacts, external commentators would also have an informed lens on what the current priorities of the government are.

To boost validity and gain domestic buy-in, economic, social, and environmental impacts must be determined in direct partnership with policy makers and civil society, who know their country better than external experts. Practically, this might involve establishing a diverse panel of local independent experts, perhaps one or two international experts if needed, and budget staff. The panel would consider global and local evidence to identify which (and how) global impact assessments might need to be adjusted to the local context. Indicative global impact perspectives are provided in

Appendix B. Example policy impact assessments. In appendix B, assessments are made for potential environmental impact across six categories: short-term net GHG emissions impact, long-term net GHG emissions impact, natural capital impact, air pollution impact, direct adaptation and resilience impact, and indirect adaptation and resilience impact. For social impact criteria they are across two categories: wealth inequality and rural livelihood. For economic criteria they are also across two categories but are markedly less specific because of the extreme variation in economic impacts that is likely across nations: fiscal multiplier and short-term job creation. Climate mitigation impacts are the only impact criteria currently assessed independently over the short and long term—there is certainly scope to do this for other criteria in future iterations. Forthcoming work from the International Labour Organization (ILO) on the job creation impacts of fiscal policy options should provide further useful detail.

All assessments consider the impact of policy versus a scenario in which no intervention is made (rather than a scenario in which an alternative intervention is made). As such, each of the impact assessments for subarchetypes can be generalized using a broad range of academic literature rather than relying on independent modelling for every single policy. While accurately modelling every policy option is certainly a superior approach for policy making, unfortunately modelling capabilities are often lacking in vulnerable countries, where there are simply not enough adequately trained staff. In our taxonomy, GHG assessments include a temporal component, where the net effect is assessed both in the short term (while policies are being implemented) and long term (following from policy implementation). Certainly, this temporal split is also possible for other criteria (e.g., wealth inequality) and is left for future work. On the side of potential GHG impact, splitting between short- and long-term impact enables greater nuance for green assessments and ensures that non-uniform emission life cycles are considered. Whilst long-term emissions are clearly of greater environmental significance, short-term emissions are often politically relevant as governments strive to meet emissions targets that are specific to a particular year under international agreements (e.g., Nationally Determined Contributions under the Paris Agreement; see UNFCCC, n.d.). As an example of varied emissions profiles, it is important to recognise the short-term GHG impacts of clean energy infrastructure (e.g., through material use) and the long-term effects of reducing GHG emissions through the provision of clean energy. In our taxonomy, short-term effects are defined as those that will come during policy implementation, usually on the scale of months to a few years. Long-term effects are those expected to continue over the course of decades, outlasting the economic impacts of the crisis that spawned the investment. The user of the taxonomy can set the relative weights of short-term and long-term GHG emissions as they please. We recommend a 20%:80% weighting (short-term:long-term) in the first instance, given that recurring emissions savings are often more meaningful than a singular release of emissions. A similar weighting structure is used in the GRO methodology document (O'Callaghan et al., 2021), with the following explanation:

> *Most GHG emissions (notably excluding CH4) do not have a natural atmospheric sink and therefore accumulate in the atmosphere. In this case, since long-term impacts act over a greater time horizon, the net GHG impacts are significantly higher than short-term impacts, which act over a shorter horizon. It is noted that short-term emissions are often politically relevant as governments strive to meet year-by-year emissions targets under international agreements. In this case, depending on the policies under consideration, it may be in a government's political interests to re-weight the short- vs long-term attribution to emphasise short-term impacts. However, this is clearly not the optimum outcome for limiting climate change.*

Ongoing work by the UNEP and partners will allow for more granular natural capital and air pollution impacts to be uncovered over time. Yet, given that temporal variability can be much more complex for natural capital and air pollution impacts than for GHG emissions (i.e., they depend more on the details of the policies than the types of policies), it will be important for policymakers to apply these themselves for any desired temporal distinction (i.e., short- vs long-term impacts).

There is also scope to expand the set of social impact criteria to include other SDGs, like healthcare, education, electrification, or gender. This could build from SDG-tagging work already completed in some countries. While, theoretically, SBA could incorporate an unlimited number of assessment criteria, the set of criteria relevant to making budget decisions should be determined by the democratically elected government of the time. That said, other stakeholders, including civil society and development partners, might benefit from being able to track and compare a broader set of assessment criteria.

Subarchetypes are all assessed using simple Likert scales. For GHG, a five-point Likert scale is used, while for other impacts, a three-point scale is used. While five-point scales allow for more nuance in policy deliberation, for many impact types there is insufficient evidence by which to turn 3-point assessments into five-point assessments. The academic literature is, for instance, far richer on topics of climate mitigation than climate adaptation. In many cases, assessments of impacts are explicitly linked to GRO assessments, which are in turn based primarily on literature and consultation of leading experts at private, public, and research institutions.

On the five-point Likert scale, “-2” reflects a substantial increase in GHG emissions, “-1” reflects a moderate increase, “0” reflects little or no change, “+1” reflects a moderate decrease, and “+2” reflects a large decrease. A negative score implies that the national rate of emissions is likely to increase in comparison to a scenario where the investment is not made, and a positive score implies that the national rate of emissions is likely to reduce compared to a scenario where the investment is not made.

Mirroring the definitions used in GRO (O’Callaghan et al., 2021):

> ***Air pollution*** *is defined as the presence of small anthropogenically-released particles in the atmosphere that are harmful to humans when inhaled. Common air pollutants include nitrogen dioxide, sulfur dioxide, and particulate matter. For air pollution, an archetype rating of ‘Regress’ (-1) indicates that the implementation of the policy archetype would lead to an increase in harmful atmospheric particles. ‘Little net change’ (0) indicates an overall negligible or net-zero effect on air pollution. ‘Improve’ (+1) indicates a decrease in harmful atmospheric particles as a direct effect of the archetype.*
>
> ***Natural capital*** *is defined as the stock of the world’s natural assets, both renewable and non-renewable. This includes water, soil, forests, green spaces, and ecological systems. For policy impacts on natural capital, an archetype rating of ‘Regress’ (-1) indicates an expected decline in the quantity or quality of natural capital as a result of implementing the policy. ‘Little net change’ (0) indicates an expected overall negligible or net-zero effect on natural capital. ‘Improve’ (+1) indicates an expected increase in the quantity or quality of natural capital.*

The potential impact assessments included in

Appendix B. Example policy impact assessments *l*ean heavily on a recent taxonomy review exercise conducted by Hashim Zaman, Steven King, and James Vause through the UNEP World Conservation Monitoring Centre (Zaman *et al.*, 2022). The exercise concerns the GRO archetypes, but similarities between archetypes have allowed for many passages in Zaman *et al.* to be incorporated into the appendix.

New definitions have been introduced for direct and indirect adaptation and resilience, as specified below:

> ***Direct adaptation and resilience*** *refers to efforts to moderate or avoid harm, or respond to disturbances, to physical (i.e., man-made) capital and natural capital stocks. Direct adaptation and resilience initiatives may include, for example, reinforcement of roads or building seawalls, as well as restoration of degraded ecosystems.*
>
> ***Indirect adaptation and resilience*** *refers to efforts to moderate or avoid harm, or respond to disturbances, to social, economic and political systems and institutions. Indirect adaptation and resilience initiatives may include, for example, educational programs on climate change adaptation, or conducting community-based adaptation planning. Many direct adaptation and resilience initiatives also have impacts for indirect adaptation and resilience; for instance, investment in bolstering the resilience of physical healthcare facilities also enhances the adaptive capacity of impacted communities.*

For social impact, the following definitions are used, also repeated from the GRO:

> ***Wealth inequality*** *is defined as the uneven distribution of assets like cash and property throughout a population. For wealth inequality, an archetype rating of 'Regress' (-1) indicates an expected increase in the variance of population wealth distribution because of the policy. 'Little net change' (0) indicates an expected overall negligible effect on population wealth distribution. 'Improve' (+1) indicates an expected reduction in the variance of population wealth distribution.*
>
> ***Rural livelihood*** *concerns the quality of life of individuals and communities specifically living in rural environments. In this way, rural livelihood assessments are a subset of overall quality of life assessments. Rural communities often face different challenges to non-rural communities, and it is therefore useful for researchers 18and policymakers to be able to evaluate specific impacts for rural communities. The purpose of this indicator is to identify*

archetypes that have particularly pronounced ability to uplift rural businesses and residents. For rural livelihood, an archetype rating of 'Regress' (-1) indicates an expected reduction in average quality of life for domestic rural populations because of the policy. 'Little net change' (0) indicates an expected overall negligible effect on rural quality of life in domestic rural populations. 'Improve' (+1) indicates an expected increase to net quality of life in domestic rural populations.

Importantly, all assessments of potential environmental and social impact contained within this document, as well as economic comments, are very much preliminary and not in any way targeted for country use. They should be updated as policy officials are able to consider each factor more closely in their country. No assessment should be taken as absolute truth for any archetype—policies are often nuanced and, in some cases, even the large set of subarchetypes defined here will be insufficient for capturing important economic, environmental, and social differences in policy outcomes. As such, we recommend that manual overrides are considered and used when necessary. There should be a transparent and consultative process for making such overrides (i.e., members from across different ministries should be consulted and be empowered to dissent). Similarly, the selected metrics for assessment in this methodology document are intended only to demonstrate what might be possible; certainly, governments should use other metrics where these suit their sovereign priorities and international obligations better.

4.3. Policy archetypes and subarchetypes

Assigning policies to archetypes and subarchetypes is a relatively straightforward exercise and need not take an enormous amount of time. Even if thousands of policies must be manually categorised, for an expert familiar with the fiscal taxonomy of the SBA, this should not require more than a few days (usually far less)—unless the policy descriptions are themselves unclear and require clarification. In many nations, pre-set budget codes can greatly simplify the categorisation process—in this case, instead of assigning archetypes to policies, archetypes are assigned to budget codes and then respectively passed on to all policies listed under each budget code. To increase accuracy, we advise that any categorisation process is completed twice, by two independent researchers or policy makers—when the categorisations of the two individuals do not match, there should be deliberations to see if a shared consensus might be reached—if no consensus is reached, a third researcher or policy maker should provide a deciding opinion.

We note that recent applications of recurrent neural network models might help automate the process of assigning policy archetypes (or impacts) to policies (see O'Callaghan, 2022). If such methods were to be used, the backend would likely be developed in global aggregate, ready for country-specific application with a simple interface (i.e., policy makers would not have to engage in any coding themselves). However, further training data would be required to facilitate this approach, and so it is unlikely to be available for policy maker use in the first few instances that the SBA is used.

The SBA fiscal taxonomy defines forty core archetypes for categorising policies. These are:

Operational archetypes

A	Core government operations
B	Health (operational)
C	Education (operational)
D	Socio-cultural programs (operational)
E	Traditional energy (operational)
F	Clean energy (operational)
G	Traditional transportation (operational)
H	Clean and/or resilient transportation (operational)
I	Communications (operational)
J	Other utilities (operational)
K	Military (operational)
L	Emergency response services (operational)
M	Natural capital, parks, forestry and other environmental (operational)
N	Worker retraining and job creation (operational)
O	Social welfare / social security (operational)
P	Other traditional operations
Q	Other clean and/or resilient operations

Discretionary archetypes

α	Core government service expansion
β	Health (discretionary)
γ	Education (discretionary)
δ	Socio-cultural programs (discretionary)
ε	Traditional energy (discretionary)
ζ	Clean energy (discretionary)
η	Traditional transportation (discretionary)
θ	Clean and/or resilient transportation (discretionary)
ι	Communications (discretionary)
κ	Other utilities (discretionary)
λ	Military (discretionary)
μ	Emergency response services (discretionary)
ν	Natural capital, parks, forestry and other environmental (discretionary)
ξ	Agriculture and fisheries (discretionary)
ο	Disaster preparedness investment (discretionary)
π	Green housing and real estate (discretionary)
ρ	Traditional housing and real estate (discretionary)

σ Materials (discretionary)
τ Other large-scale infrastructure (discretionary)
υ General R&D (discretionary)
ф Clean R&D (discretionary)
χ Other traditional investment
ψ Other clean and/or resilient investment

In the SBA fiscal taxonomy, each policy archetype contains between one and eleven subarchetypes. Most archetypes also include a generic "other and general" category with a reference that includes the number "99". There are 207 policy subarchetypes in total, included in **TABLE 1**.

TABLE 1. Policy archetypes and subarchetypes in SBA fiscal taxonomy. OP = Operational-type policy. DI = discretionary-type policy. Note: For policies grouped in "Other and general" subarchetypes, assessments will tend to align with the general average or assumed norm of the archetype. For instance, for archetypes with both green and neutral subarchetypes, the related environmental assessments will generally be neutral rather than green. For government to demonstrate environmental sustainability for related policies they must provide adequate descriptions.

Ref	Archetype name	Subarchetype name
A1	Core government operations (OP)	Core government operations
B1	Health (OP)	Physical
B2	Health (OP)	Mental
B99	Health (OP)	Other and general
C1	Education (OP)	Primary
C2	Education (OP)	Secondary
C3	Education (OP)	Tertiary
C99	Education (OP)	Other and general
D1	Socio-cultural programs (OP)	Arts and culture
D2	Socio-cultural programs (OP)	Tourism–- traditional
D3	Socio-cultural programs (OP)	Tourism–- green and/or resilient
D4	Socio-cultural programs (OP)	Leisure services
D99	Socio-cultural programs (OP)	Other and general
E1	Traditional energy (OP)	Power plants
E2	Traditional energy (OP)	Refineries
E3	Traditional energy (OP)	Coal mines and oil/gas fields
E4	Traditional energy (OP)	Infrastructure for transport and transmission of fossil energy inputs/outputs
E99	Traditional energy (OP)	Other and general
F1	Clean energy (OP)	Renewable energy generation facilities
F2	Clean energy (OP)	Nuclear energy generation facilities
F3	Clean energy (OP)	Biofuel and other renewable fuel production
F4	Clean energy (OP)	Transmission networks

F5	Clean energy (OP)	Distribution networks
F6	Clean energy (OP)	Hydrogen
F7	Clean energy (OP)	Battery and storage
F8	Clean energy (OP)	Carbon capture and storage/utilisation
F99	Clean energy (OP)	Other and general
G1	Traditional transportation (OP)	Roads (including operations and repairs)
G2	Traditional transportation (OP)	Airports (including operations and repairs)
G3	Traditional transportation (OP)	Ports and other maritime infrastructure (including operations and repairs)
G99	Traditional transportation (OP)	Other and general
H1	Clean and/or resilient transportation (OP)	Bus operations–- fossil fuel powered
H2	Clean and/or resilient transportation (OP)	Bus operations–- clean fuel powered
H3	Clean and/or resilient transportation (OP)	Rail and tram operations–- fossil fuel powered
H4	Clean and/or resilient transportation (OP)	Rail and tram operations–- clean fuel powered
H99	Clean and/or resilient transportation (OP)	Other and general
I1	Communications (OP)	Telephone and basic services
I2	Communications (OP)	Internet services
I99	Communications (OP)	Other and general
J1	Other utilities (OP)	Water services
J2	Other utilities (OP)	Waste services
J99	Other utilities (OP)	Other and general
K1	Military (OP)	Army
K2	Military (OP)	Navy
K3	Military (OP)	Airforce
K99	Military (OP)	Other and general
L1	Emergency response services (OP)	Police and law enforcement
L2	Emergency response services (OP)	Fire and rescue
L3	Emergency response services (OP)	Emergency medical services
L4	Emergency response services (OP)	Disaster relief
L5	Emergency response services (OP)	Animal control
L99	Emergency response services (OP)	Other and general
M1	Natural capital, parks, forestry and other environmental (OP)	Public parks and green spaces management
M2	Natural capital, parks, forestry and other environmental (OP)	Forestry management
M99	Natural capital, parks, forestry and other environmental (OP)	Other and general
N1	Worker retraining and job creation (OP)	Traditional worker retraining and job creation
N2	Worker retraining and job creation (OP)	Green worker retraining and job creation–- climate mitigation
N3	Worker retraining and job creation (OP)	Green worker retraining and job creation–- adaptation
N4	Worker retraining and job creation (OP)	Green worker retraining and job creation–- unclassified/mixed
N99	Worker retraining and job creation (OP)	Other and general
O1	Social welfare / social security (OP)	Unemployment payments
O2	Social welfare / social security (OP)	Food stamps

O3	Social welfare / social security (OP)	Utility fee support
O4	Social welfare / social security (OP)	Social housing
O5	Social welfare / social security (OP)	Disability services
O6	Social welfare / social security (OP)	Veterans' affairs
O7	Social welfare / social security (OP)	Social work initiatives
O99	Social welfare / social security (OP)	Other and general
P1	Other traditional operations (OP)	Other
Q1	Other clean and/or resilient operations (OP)	Other
α1	Core government service expansion (DI)	Core government service expansion
β1	Health (DI)	Physical
β2	Health (DI)	Mental
β99	Health (DI)	Other and general
γ1	Education (DI)	Primary
γ2	Education (DI)	Secondary
γ3	Education (DI)	Tertiary
γ99	Education (DI)	Other and general
δ1	Socio-cultural programs (DI)	Arts and culture
δ2	Socio-cultural programs (DI)	Tourism–- traditional
δ3	Socio-cultural programs (DI)	Tourism–- green and/or resilient
δ4	Socio-cultural programs (DI)	Hospitality services
δ99	Socio-cultural programs (DI)	Other and general
ε1	Traditional energy (DI)	New or refurbished power plants
ε2	Traditional energy (DI)	New or refurbished refineries
ε3	Traditional energy (DI)	New or refurbished coal mines and oil/gas fields
ε4	Traditional energy (DI)	New or refurbished infrastructure for transport and transmission of fossil energy inputs/outputs
ε99	Traditional energy (DI)	Other and general
ζ1	Clean energy (DI)	New or refurbished renewable energy generation facilities
ζ2	Clean energy (DI)	New or refurbished nuclear energy generation facilities
ζ3	Clean energy (DI)	New biofuel and other renewable fuel infrastructure
ζ4	Clean energy (DI)	Upgraded (or new) transmission infrastructure
ζ5	Clean energy (DI)	Upgraded (or new) distribution infrastructure including smart grids
ζ6	Clean energy (DI)	Hydrogen infrastructure
ζ7	Clean energy (DI)	Battery and storage infrastructure
ζ8	Clean energy (DI)	Carbon capture and storage/utilisation infrastructure
ζ9	Clean energy (DI)	Other initiatives to clean existing dirty energy assets
ζ10	Clean energy (DI)	Improve resilience of existing traditional energy infrastructure
ζ11	Clean energy (DI)	Improve resilience of existing clean energy infrastructure
ζ99	Clean energy (DI)	Other and general

η1	Traditional transportation (DI)	Road construction
η2	Traditional transportation (DI)	ICE automobile investment
η3	Traditional transportation (DI)	Airport construction and expansion
η4	Traditional transportation (DI)	Fossil fuel-powered aviation investment
η5	Traditional transportation (DI)	Port and maritime construction and expansion
η6	Traditional transportation (DI)	Fossil fuel-powered shipping investment
η99	Traditional transportation (DI)	Other and general
θ1	Clean and/or resilient transportation (DI)	Electric vehicle investment
θ2	Clean and/or resilient transportation (DI)	Electric vehicle charging infrastructure
θ3	Clean and/or resilient transportation (DI)	Fossil fuel-powered bus investment
θ4	Clean and/or resilient transportation (DI)	Rail and tram line construction
θ5	Clean and/or resilient transportation (DI)	Trains and trams investment
θ6	Clean and/or resilient transportation (DI)	Public transport digitalisation efforts
θ7	Clean and/or resilient transportation (DI)	Cycling and walking infrastructure
θ8	Clean and/or resilient transportation (DI)	Improving efficiency in dirty transport
θ9	Clean and/or resilient transportation (DI)	Improving resilience of existing traditional transportation infrastructure and networks
θ10	Clean and/or resilient transportation (DI)	Improving resilience of existing clean transportation infrastructure and networks
θ99	Clean and/or resilient transportation (DI)	Other and general
ι1	Communications (DI)	Telephone and basic cellular investment
ι2	Communications (DI)	Broadband investment
ι3	Communications (DI)	Civil cybersecurity programmes
ι4	Communications (DI)	Implementing digital programmes
ι5	Communications (DI)	Improving resilience of existing communications infrastructure
ι99	Communications (DI)	Other and general
κ1	Other utilities (DI)	Water sourcing
κ2	Other utilities (DI)	Water transportation/piping infrastructure
κ3	Other utilities (DI)	Water treatment infrastructure
κ4	Other utilities (DI)	Waste processing investment
κ5	Other utilities (DI)	Recycling investment
κ99	Other utilities (DI)	Other and general
λ1	Military (DI)	Army
λ2	Military (DI)	Navy
λ3	Military (DI)	Airforce
λ99	Military (DI)	Other and general
μ1	Emergency response services (DI)	Police and law enforcement equipment and/or infrastructure
μ2	Emergency response services (DI)	Fire and rescue equipment and/or infrastructure
μ3	Emergency response services (DI)	Emergency medical services equipment and/or infrastructure
μ4	Emergency response services (DI)	Disaster relief supplies, equipment, and/or infrastructure
μ5	Emergency response services (DI)	Animal control equipment and/or infrastructure
μ99	Emergency response services (DI)	Other and general

ν1	Natural capital, parks, forestry and other environmental (DI)	Public parks and green spaces investment
ν2	Natural capital, parks, forestry and other environmental (DI)	Environmental re(building) initiatives including afforestation, reforestation, and environmental rehabilitation
ν3	Natural capital, parks, forestry and other environmental (DI)	Environmental protection initiatives including conservation and natural infrastructure resilience
ν4	Natural capital, parks, forestry and other environmental (DI)	Sustainable forestry investment
ν5	Natural capital, parks, forestry and other environmental (DI)	Forestry investment leading to unsustainable deforestation
ν99	Natural capital, parks, forestry and other environmental (DI)	Other and general
ξ1	Agriculture and fisheries (DI)	General agricultural investment
ξ2	Agriculture and fisheries (DI)	Clean and/or resilient agricultural practices (e.g., adaptive cropping, education on A&R, agroecology etc)
ξ3	Agriculture and fisheries (DI)	General fisheries investment
ξ4	Agriculture and fisheries (DI)	Clean and/or resilient fisheries practices (e.g., wild fishery management)
ξ5	Agriculture and fisheries (DI)	General investment in resilient land management
ξ99	Agriculture and fisheries (DI)	Other and general
ο1	Disaster preparedness investment (DI)	Investment in risk assessment and early warning systems
ο2	Disaster preparedness investment (DI)	Procurement of emergency response equipment
ο3	Disaster preparedness investment (DI)	Investment in emergency response systems
ο4	Disaster preparedness investment (DI)	Other direct (physical) climate change adaptation and resilience measures
ο5	Disaster preparedness investment (DI)	Other indirect (economic, political) climate change adaptation and resilience measures
ο99	Disaster preparedness investment (DI)	Other and general
π1	Green housing and real estate (DI)	Clean and/or resilient housing construction
π2	Green housing and real estate (DI)	Clean and/or resilient housing heating and insulation retrofits
π3	Green housing and real estate (DI)	Clean and/or resilient housing rooftop solar retrofits
π4	Green housing and real estate (DI)	Clean and/or resilient housing electrification investment
π5	Green housing and real estate (DI)	Clean and/or resilient public/corporate building construction
π6	Green housing and real estate (DI)	Clean and/or resilient public/corporate building heating and insulation retrofits
π7	Green housing and real estate (DI)	Clean and/or resilient public/corporate building rooftop solar retrofits
π8	Green housing and real estate (DI)	Clean and/or resilient public/corporate building electrification investment
π9	Green housing and real estate (DI)	Clean and/or resilient small-scale urban development programs

π99	Green housing and real estate (DI)	Other and general
ρ1	Traditional housing & real estate (DI)	Traditional housing construction
ρ2	Traditional housing & real estate (DI)	Traditional housing renovations
ρ3	Traditional housing & real estate (DI)	Traditional public/corporate building construction
ρ4	Traditional housing & real estate (DI)	Traditional public/corporate building renovations
ρ5	Traditional housing & real estate (DI)	Traditional small-scale non-residential urban development programs
ρ99	Traditional housing & real estate (DI)	Other and general
σ1	Materials (DI)	Mining–- exploration
σ2	Materials (DI)	Mining–- extraction
σ3	Materials (DI)	Mining–- transportation
σ4	Materials (DI)	Furniture production and processing
σ5	Materials (DI)	Metals production and processing
σ6	Materials (DI)	Chemicals production and processing
σ7	Materials (DI)	Paper production and processing
σ8	Materials (DI)	Plastics production and processing
σ99	Materials (DI)	Other and general
τ1	Other large-scale infrastructure (DI)	Large-scale urban infrastructure–- general
τ2	Other large-scale infrastructure (DI)	Large-scale urban infrastructure for climate resilience
τ3	Other large-scale infrastructure (DI)	Large-scale regional infrastructure–- general
τ4	Other large-scale infrastructure (DI)	Large-scale regional infrastructure for climate resilience
τ5	Other large-scale infrastructure (DI)	Large-scale space infrastructure
T99	Other large-scale infrastructure (DI)	Other and general
υ1	General R&D (DI)	Traditional energy programs
υ2	General R&D (DI)	Traditional transport programs
υ3	General R&D (DI)	Traditional manufacturing programs
υ4	General R&D (DI)	Traditional agriculture programs
υ5	General R&D (DI)	Health programs
υ6	General R&D (DI)	Computing and digitisation programs
υ7	General R&D (DI)	Space programs
υ99	General R&D (DI)	Other and general
ϕ1	Clean R&D (DI)	Clean and/or resilient energy programs
ϕ2	Clean R&D (DI)	Clean and/or resilient transport programs
ϕ3	Clean R&D (DI)	Clean and/or resilient manufacturing programs
ϕ4	Clean R&D (DI)	Clean and/or resilient agriculture programs
ϕ5	Clean R&D (DI)	Other climate mitigation programs
ϕ6	Clean R&D (DI)	Other climate resilience programs
ϕ99	Clean R&D (DI)	Other and general
χ1	Other traditional investment	Other
ψ1	Other clean and/or resilient investment	Other
Debt		

Appendix B. Example policy impact assessments provides potential environmental and social impacts for each subarchetype, using the methodology described above. It also provides indicative economic examples for each subarchetype. For impact aggregation, archetypes are divided into twelve sectors: Core Government, Military, Communication Services, Consumer Discretionary, Consumer Staples, Education/training, Energy, Health Care, Industrials, Materials, Transportation, and Utilities. For policies grouped in "Other and general" subarchetypes, assessments will tend to align with the general average or assumed norm of the archetype. For instance, for archetypes with both green and neutral subarchetypes, the related environmental assessments will generally be neutral rather than green. In our own application of the SBA to government budgets, we consider that for a policy to be categorised in one of the more environmentally sustainable archetypes, the policy must include an adequate description that notes its environmental characteristics; in other words, if a policy doesn't include an appropriate description, our default is to categorise the policy as a traditional measure rather than as a green measure.

4.4. Relevant data sources

Annual expenditure budgets are readily available in most countries. Ideally, these will be published in a tabulated format online and with consistent policy coding. Budgets might be published alongside investment annexes, which provide higher granularity for discretionary-type spending. SOE annexes and differential taxation annexes might also be provided. In many nations, off-budget tax expenditures should also be procured to ensure that the full impacts of the budget are understood, at least internally.

4.5. Itemising policies

Policymakers can use the sustainable budgeting approach to (i) compare individual policies and (ii) to consider the potential impacts of a set of policies. In either case, policymakers must begin by itemising all policies to be considered and noting whether any policies are a subset of broader budget measures recorded elsewhere (to avoid double counting). If tabulated, the table might list the relevant policies in the first column, the value of each policy in the second column, and the related budget codes (if available) in the third column. If any policy is a subset of a broader policy group in the budget, this should be recorded by noting its 'level' in a fourth column—the highest-level policy of each grouping will be considered in the analysis. It might also be helpful to maintain a record of other budget categorisation that the policy might be associated with in a fifth column—although this is not essential. See an example in TABLE 2 from the pilot SBA study in Gabon.

TABLE 2. Example itemisation for a small subset of policies in the 2021 budget of Gabon.

Code title	Total value (CFA)	Budget code	Level
State external action	24,191,505,537	1	Level 1
Foreign Affairs	16,772,119,252	1.101	Level 2
Title 2. Personnel expenditure	3,822,230,024	1.101.2	Level 3
Title 3. Expenditure on goods and services	12,094,509,841	1.101.3	Level 3
Title 4. Transfer expenses	855,379,387	1.101.4	Level 3
Title 5. Capital expenditure	0	1.101.5	Level 3
African integration and international cooperation	908,202,554	1.108	Level 2
Title 2. Personnel expenditure	*144,046,200*	*1.108.2*	*Level 3*
Title 3. Expenditure on goods and services	*250,815,000*	*1.108.3*	*Level 3*
Title 4. Transfer expenses	*513,341,354*	*1.108.4*	*Level 3*
Popular education	98,458,000	6.297	Level 2
Title 2. Personnel expenditure	*45,958,000*	*6.297.2*	*Level 3*
Title 3. Expenditure on goods and services	*50,000,000*	*6.297.3*	*Level 3*
Title 4. Transfer expenses	*2,500,000*	*6.297.4*	*Level 3*
Equipment of the defense forces	47,954,257,086	7.318	Level 2
Title 2. Personnel expenditure	*32,553,380,086*	*7.318.2*	*Level 3*
Title 3. Expenditure on goods and services	*400,877,000*	*7.318.3*	*Level 3*
Title 5. Capital expenditure	*15,000,000,000*	*7.318.5*	*Level 3*

4.6. Categorise codes and projects

To assign archetypes to new codes and new investments, policymakers must first familiarize themselves with the full sustainable budgeting taxonomy provided in *Appendix A. Definitions for Archetypes* and the excel sheet titled 'Fiscal taxonomy'. Assigning an archetype is most easily done using the following steps:

1. **Consider whether code/project is operational or discretionary.** This step is not strictly necessary but can be helpful for countries wishing to distinguish between financial flows based on their flexibility to be redirected. In that vein, operational measures are those required to maintain normal functioning of existing public systems, and might include paying government employees, maintaining health systems as they already stand, maintaining the existing levels and kinds of energy supply (e.g., by paying fees to existing energy generators to continue operating), etc. Discretionary measures are those used to change/enhance the functioning of society, and might include investment in new public infra-structure, subsidies

for new investment to companies of almost any sector, development of new tourism programs, consumer or business agriculture/food subsidies which shift production away from the natural societal equilibrium, fuel subsidies etc. It is often safe to assume that all new measures in an investment annex are discretionary measures. Operational measures are labelled “A” to “Q” while discretionary measures are “α” to “ψ”.

2. **Consider which sector.** To simplify steps 3 and 4, it might be helpful to consider which sector the code/project is most relevant to.

3. **Consider which archetype.** Most sectors have only a few relevant archetypes in both the operational and discretionary categories. Determining which archetype is the most appropriate is simply a matter of reading each archetype description and sorting based on the description.

4. **Consider which subarchetype.** Once an archetype has been identified, most codes/projects can be linked to a more detailed subarchetype. In some cases, there is insufficient detail to make such an allocation; in this case, the code/project should be assigned to a “other and general” subarchetype, usually associated with the reference “_99” where the blank represents the archetype letter.

An example is provided in TABLE 3 for the case study of Gabon.

TABLE 3. Example categorisation for a small subset of policies in the 2021 budget of Gabon.

Code title	**Total value (CFA)**	**Budget code**	**Level**	**Archetype**	**Subarchetype**	**Reference**
State external action	24,191,505,537	1	Level 1	A	1	A1
Foreign Affairs	16,772,119,252	1.101	Level 2	A	1	A1
Title 2. Personnel expenditure	*3,822,230,024*	*1.101.2*	*Level 3*	*A*	*1*	*A1*
Title 3. Expenditure on goods and services	*12,094,509,841*	*1.101.3*	*Level 3*	*A*	*1*	*A1*
Title 4. Transfer expenses	*855,379,387*	*1.101.4*	*Level 3*	*A*	*1*	*A1*
Title 5. Capital expenditure	*0*	*1.101.5*	*Level 3*	*α*	*1*	*α1*
African integration and international cooperation	908,202,554	1.108	Level 2	A	1	A1
Title 2. Personnel expenditure	*144,046,200*	*1.108.2*	*Level 3*	*A*	*1*	*A1*

Title 3. Expenditure on goods and services	*250,815,000*	*1.108.3*	*Level 3*	*A*	*1*	*A1*
Title 4. Transfer expenses	*513,341,354*	*1.108.4*	*Level 3*	*A*	*1*	*A1*
Popular education	98,458,000	6.297	Level 2	C	99	C99
Title 2. Personnel expenditure	*45,958,000*	*6.297.2*	*Level 3*	*C*	*99*	*C99*
Title 3. Expenditure on goods and services	*50,000,000*	*6.297.3*	*Level 3*	*C*	*99*	*C99*
Title 4. Transfer expenses	*2,500,000*	*6.297.4*	*Level 3*	*C*	*99*	*C99*
Equipment of the defense forces	47,954,257,086	7.318	Level 2	K	4	K4
Title 2. Personnel expenditure	*32,553,380,086*	*7.318.2*	*Level 3*	*K*	*4*	*K4*
Title 3. Expenditure on goods and services	*400,877,000*	*7.318.3*	*Level 3*	*K*	*4*	*K4*
Title 5. Capital expenditure	*15,000,000,000*	*7.318.5*	*Level 3*	*λ*	*4*	*λ4*

The SBA fiscal taxonomy paired with the subarchetype impact assessments fine-tuned to country context (see SBA assessment process in section 4.1) allows policies to be associated with the potential impacts of each subarchetype (see an example for Gabon in **TABLE 4**). The process of linking a policy to a set of likely directional impacts is most easily completed with a structured excel document and lookup function, or a programming script.

TABLE 4. Example environmental impact scores automatically paired for a small subset of policies in the 2021 budget of Gabon.

Code title	Budget code	Reference	Short-term GHG score (-2 to +2)	Long-term GHG score (-2 to +2)	Air pollution score (-1 to +1)	Natural capital score (-1 to +1)
State external action	1	A1	-1	0	0	0
Foreign Affairs	1.101	A1	-1	0	0	0
Title 2. Personnel expenditure	*1.101.2*	*A1*	*-1*	*0*	*0*	*0*
Title 3. Expenditure on goods and services	*1.101.3*	*A1*	*-1*	*0*	*0*	*0*
Title 4. Transfer expenses	*1.101.4*	*A1*	*-1*	*0*	*0*	*0*
Title 5. Capital expenditure	*1.101.5*	*α1*	*-1*	*0*	*0*	*0*
African integration and international cooperation	1.108	A1	-1	0	0	0
Title 2. Personnel expenditure	*1.108.2*	*A1*	*-1*	*0*	*0*	*0*
Title 3. Expenditure on goods and services	*1.108.3*	*A1*	*-1*	*0*	*0*	*0*
Title 4. Transfer expenses	*1.108.4*	*A1*	*-1*	*0*	*0*	*0*
Popular education	6.297	C99	0	0	0	0
Title 2. Personnel expenditure	*6.297.2*	*C99*	*0*	*0*	*0*	*0*
Title 3. Expenditure on goods and services	*6.297.3*	*C99*	*0*	*0*	*0*	*0*
Title 4. Transfer expenses	*6.297.4*	*C99*	*0*	*0*	*0*	*0*
Equipment of the defense forces	7.318	K4	-2	-2	-1	0
Title 2. Personnel expenditure	*7.318.2*	*K4*	*-2*	*-2*	*-1*	*0*

Title 3. Expenditure on goods and services	*7.318.3*	*K4*	*-2*	*-2*	*-1*	*0*
Title 5. Capital expenditure	*7.318.5*	*λ4*	*-2*	*-2*	*-1*	*-1*

4.7. Aggregate policy impact

Policy impact can be aggregated by archetype, sector, nationally, or by any other relevant macro category. Impact can be aggregated (i) using potential impact scores (e.g., on the -2 to +2 Likert scale for greenhouse gas emissions and -1 to +1 for other environmental impacts) or, (ii) when prioritising environmental impact, using simple green-neutral-dirty designations. In both cases, it is helpful to consider aggregate policy impact both with and without funds for PPPs and SOEs.

For (i), aggregating impact is simply a matter of, for every policy, multiplying the policy value by the score of the relevant impact metric and then summing the products for all measures in the relevant aggregation category (e.g., per sector). This sum is then divided by the total value of all relevant policies.

For (ii), the process is even simpler. The user simply sums all policies of the desired designation (green, neutral, or dirty). 'Green' policies are defined as those that have either a positive impact on net GHG, natural capital, or air pollution. Example formulas are included in the excel document for considering national, sectoral, and archetype-based outcomes, both including and excluding PPP investment.

4.8. Determine superior policies

Once policies have been assessed for their potential impacts, policymakers might wish to identify alternative options that possess more positive environmental, social, or economic characteristics. They might also consider refining or adapting existing policy proposals for a similar purpose. There are several mechanisms for assessing alternative policy options and adaptations at the draft budget stage. First, policymakers might scour the existing fiscal taxonomy to find subarchetypes with similar industrial functions or similar descriptions but better (more positive) potential impact assessments. Second, policymakers might review, for inspiration, more than eight-thousand policy actions taken by eighty-nine other nations in the GRO. This data includes over five hundred environmentally positive policies across sectors. Of course, this dataset will be expanded over time with SBA policy examples.

4.9. Case study highlights: Gabon

A pilot application of the SBA was introduced in the Republic of Gabon in 2021-2022 with support from UNDP. The study was conducted in direct partnership with domestic policy makers across multiple ministries and with input from civil society groups and core multilateral partners including UNEP, the World Bank, and the IMF. This first SBA application focused only on the environmental characteristics of the Gabonese budget, leaving economic and social considerations to future work. The results were received well and led to several policymaker workshops hosted both physically and virtually. The pilot led to wider regional engagement on SBA at the Eighth Session of the Africa Regional Forum on Sustainable Development (organised by UNECA and the Government of Rwanda) and global engagement at COP26 in Glasgow and COP27 in Sharm El Sheikh.

In Gabon, budgets are provided in initial form (LFI/BLA) and supplementary form (PLFR/LFR) on an annual basis. A useful investment annex is published alongside the budgets (e.g., *2021 Annexe Au Projet De Loi De Finances Rectificative*). Taxation and other revenues are not usefully itemised in the budget, either by initiative or by sector (incorporating taxation into future budgets is a significant opportunity to improve fiscal transparency).

The annual budget and its supplement provide 450-500 expenditure policy lines. These policy lines are aggregated into ~300 level 2 policy categories, and, in turn, into ~50 level 1 policy categories. The level 1 categories each cover a distinct function of government, while the level 2 categories are more proximate to government objectives and hence more appropriate for policy archetyping. Level 3 categories label six types of expenses. The level 3 categories are:

- Title 1. Financial charges of the debt
- Title 2. Personnel expenditure
- Title 3. Expenditure on goods and services
- Title 4. Transfer expenses
- Title 5. Investment expenditure
- Title 6. Other expenditure

The investment annex provides a more granular account for spending in all title 5 policies. The annex is also coded, with level 1 categories the same as those used in the budget. The annex includes level 2, level 3, and level 4 categories to reflect progressively more granular policy descriptions. Level 4 categories provide project names. For archetyping purposes, level 4 categories are the most appropriate, provided that project names are self-explanatory or otherwise that further project details are available. The investment annex contains approximately 340 level 4 projects.

As the Gabonese budget contains standardised budget codes, we were able to simplify the categorisation exercise by mostly categorising budget codes rather than individual policies in the LFI and investment annexe. In some cases, policies within a budget code were quite distinct from each other in their descriptions (likely to have different environmental impacts) and required independent consideration. In other cases, policies in the investment annexe were uncoded or unclearly coded, and so these policies had to be manually archetyped. **FIGURE 1** shows the spread of policies in the 2021 budget for Gabon by archetype, categorised with a macro environmental impact indicator of clean-neutral-dirty. **FIGURE 2** provides a net perspective on the simplified environmental characteristics Gabonese spending by spending type. Figure 3 considers net impact across environmental factors of interest. It reveals that most of the fiscal expenditure (excluding taxation expenditure) is likely to, on net, support an increase in GHG emissions in the short-term. In the long-term, the net impact appears more mixed, with some spending leading to higher emissions and some supporting lower emissions. Likely impacts on air pollution and natural capital appear slightly more negative, compared to long-term emissions. Figure 4 considers the theoretical case of a policy proposal for a new gas-fired electricity generation asset, highlighting the likely directional impacts on social, environmental, and economic criteria. By considering alternative policy options, it is clear that a similar investment in clean energy generation could have similarly strong (or perhaps stronger) positive economic impacts, while also delivering strong social and environmental impacts. Further results are included in

Appendix D. Case study: Gabon.

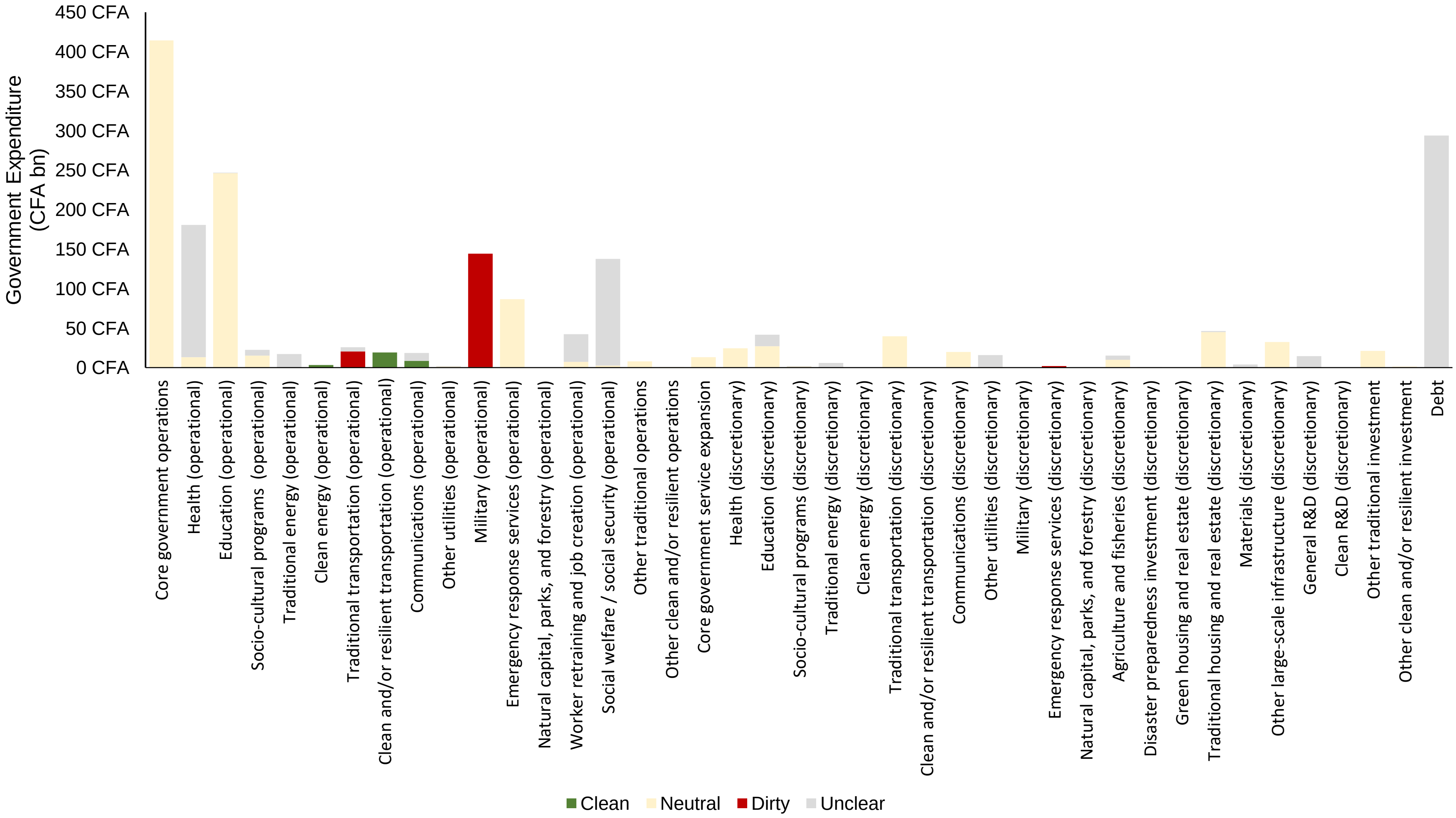

FIGURE 1. 2021 spending in Gabon's budget and investment annexe, categorised by archetype and macro environmental characteristics.

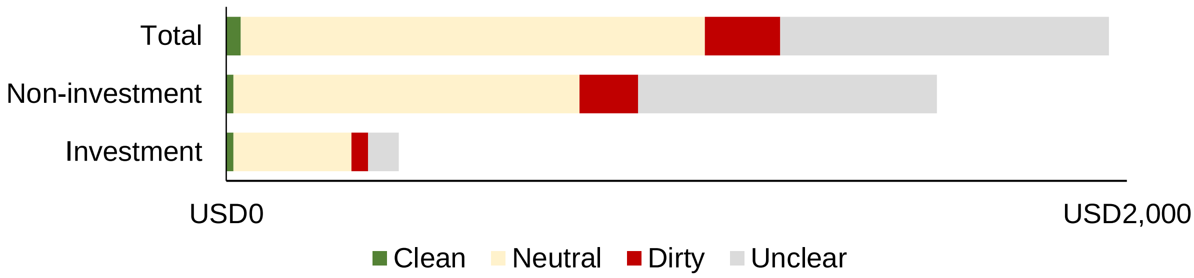

FIGURE 2. Core public expenditure (excluding reported investment in public private partnerships) categorized for environmental impact.

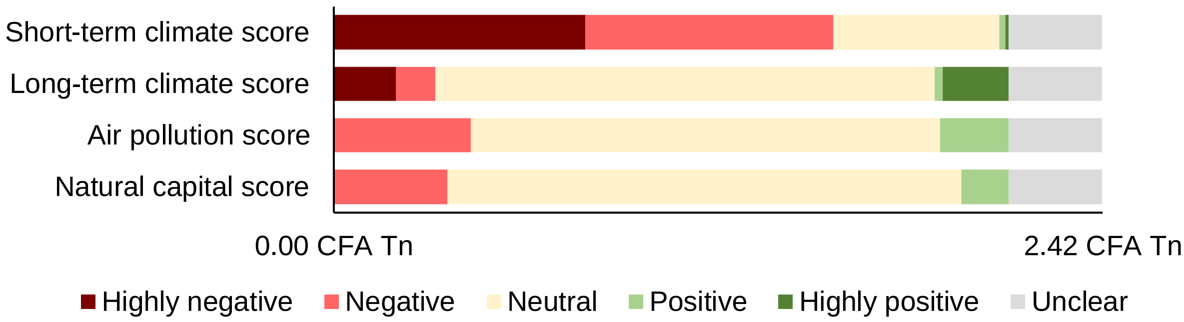

FIGURE 3. Environmental characteristics of the complete Gabonese budget in 2021 (including reported investment in public-private partnerships). Highly negative and highly positive categories only considered for greenhouse gas (climate) impact.

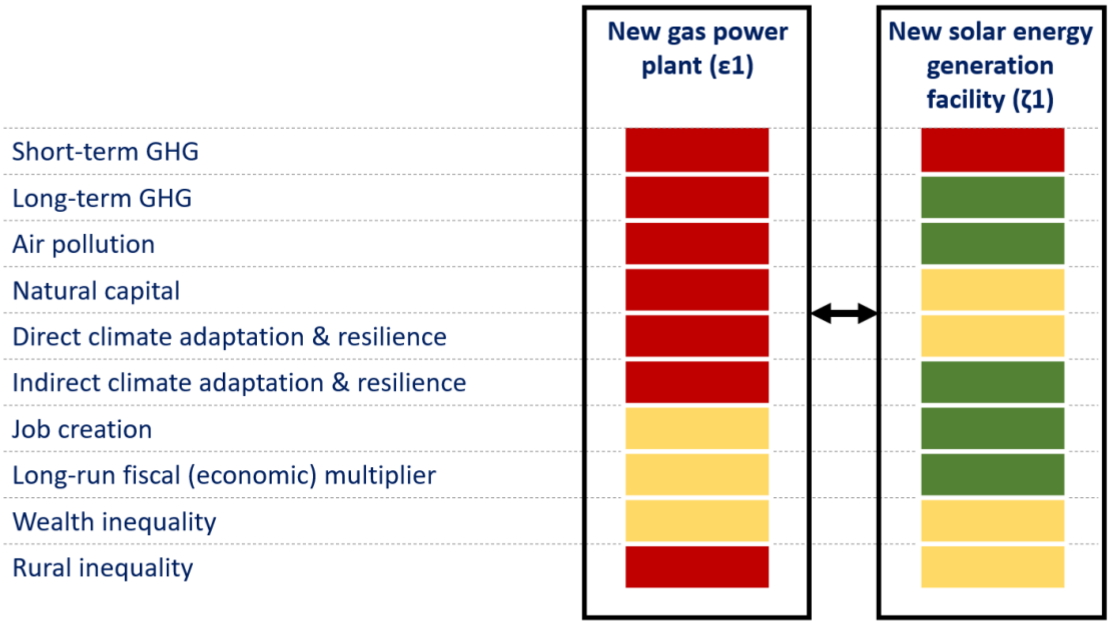

FIGURE 4. Example trade-off considering two spending policies in Gabon. On the left, public investment in a natural gas plant. On the right, public investment in a solar plant. All assessments of potential impact are only indicative and intend to give a broad unquantified perspective on potential impact. Policy decisions should certainly include consideration of other impacts not in this figure, for instance: health, education, and security, amongst others.

During a September 2021 visit to Libreville and in following engagement, we found wide enthusiasm for the proposal to incorporate the SBA into normal fiscal planning processes, without exception. Yet, stakeholders did provide several helpful reflections that might usefully inform how other nations consider the SBA. As described in the Gabon report prepared for UNDP, these are:

i. ***The process for embedding the approach would need to be co-designed*** *by members of the ministère du budget et des comptes publics and the ministère des Eaux, de la Forêt, de la Mer et de l'Environnement. The design process should also be consultative of all other ministries as all budget proposals from each ministry would be assessed under the approach. Indeed, these other ministries might look to embed their own sustainable budgeting checks to inform how they prioritise investments. Ideally, local policymakers would also reflect on revenue and debt figures, which were not made available to the writers of this report. There is significant potential to improve sustainability and development outcomes by revisiting taxation policy and more.*

ii. ***The government would require significant initial support and minor ongoing support from partner institutions.*** *Initially, support would be needed to (a) complement the efforts of finance and environment officials to build consensus and understanding of the approach across the government and (b) build capacity in junior policymakers, who will frequently have to apply and update the approach. In the longer term, minor support might be required to help ensure that policy makers are getting the most out of their sustainable budgeting practices, for instance, by making comparisons to other nations and by motivating additional green foreign aid based on a potentially green economy.*

iii. ***Non-fiscal policy options could be helpfully considered*** *in a sustainable budgeting approach—for instance, on sustainable regulatory measures. In this, participants wisely noted that Gabon has at its disposal not only spending and taxation measures. Indeed, there have been several environmentally positive and environmentally negative examples of regulatory changes in Gabon's history.*

It was also noted, on several occasions, that as the first pilot nation for this sustainable budgeting framework, Gabonese policymakers could play a role of regional and potentially global leadership on the topic. With a demonstrated history of environmental progress compared to its neighbours, and recent prominence on the international stage, Gabon could reinforce its position as an emerging environmental leader.

Gabon is now considering the mechanics by which a Sustainable Budgeting Approach might be embedded into their budgeting process. The initiative has support both within the environment and finance ministries.

5. CONCLUSION

Effective fiscal management, for the purpose of maximising wellbeing, is a core objective of any democratic government. Yet, complex, highly interconnected and difficult-to-predict economic systems make optimising fiscal allocations for future societal benefit no easy task. In many vulnerable nations, fiscal planning systems do not exist or are unfit for purpose. Where systems do exist, they often focus disproportionately on traditional economic criteria like fiscal multipliers and job creation, neglecting other essential influencers of human development like natural and social capital.

This document introduces the Sustainable Budgeting Approach as a tool to help governments easily consider the potential environmental, economic, and social consequences of policy options in their fiscal decision making. In contrast to other approaches, the SBA's fiscal taxonomy groups policy based *both* on shared economic and environmental characteristics. For policy impact assessment, the approach relies on leading academic knowledge, synthesised in a format useful to policy makers. The SBA is designed to be flexible to national context and modular so that governments might analyse policy options based on their internal priorities. While it is possible to develop an unlimited number of indicators in an SBA, it is up to government to determine which are relevant for decision making. This document summarises these features and provides detailed instructions for how the SBA might be applied to any nation. Excerpts from a recent case study of the SBA in Gabon are provided as further guidance.

It is likely that the SBA will continue to be refined and improved. Major opportunities for future work include:

- **Alternative fiscal taxonomy structures.** The taxonomy defined in this iteration of the SBA is already significantly more granular than other fiscal taxonomies (more categories) and unique in its categorisation approach (archetypes are defined based on shared economic and environmental characteristics). Nevertheless, the taxonomy could become more nuanced by introducing additional levels of categorisation beyond the archetype and subarchetype levels. For instance, defining the recipients that benefit from a policy, the type of product or service that is directly supported (e.g., personnel, equipment, systems), and/or the mechanism of funds disbursement. One potential option is explored in

- *Appendix C. Future taxonomy* structures.
- **Additional impact assessments.** Health, education, security, and non-climate resilience outcomes can be essential in budget decision making yet are not included in the current iteration of the SBA. Depending on the interested country, policy makers might wish to add such assessments and others.
- **Refined impact assessments.** The current SBA iteration includes indicative potential impact assessments for 206 subarchetypes on eight criteria, totalling over 1,600 individual assessments. However, many of these assessments are highly preliminary, even at the global scale, and would benefit from significantly more attention and refinement.
- **Integration with economic modelling.** The SBA's intent in its current form is only to provide directional, and highly caveated, perspectives on potential impact, and to do so in static economic terms. It would be possible to instead use dynamic economic modelling techniques to develop more targeted impact perspectives on policy options for any given country while maintaining the same broad spending categories defined in the SBA fiscal taxonomy. Recent work by the Danish Ministry of Finance and the Danish Research Institute for Economic Analysis and Modelling (DREAM) with the OECD discusses how climate factors, for example, can be integrated into macroeconomic modelling (see OECD, 2021b).
- **Automated policy recording, categorisation, and assessment with machine learning.** As explored by O'Callaghan (2022), machine learning techniques can be applied to fiscal policy analysis using taxonomy-based approaches. Such techniques rely on high quality and extensive training data, as might be constructed through manual application of the SBA in many countries. The benefits of automated fiscal analysis would be to (a) reduce the workload associated with applying the SBA and (b) to further increase the objectivity of the process. To be clear, the intent would be to embed machine learning techniques into a future iteration of the tool to assist policymakers in the more manual parts of the SBA process. Policy makers would not be expected to use machine learning themselves in calibrating the tool.
- **Integrated data analysis.** One of the benefits of comprehensively applying the SBA to a full national (or subnational) budget is the high-granularity data that is acquired. This data can be analysed independently, temporally, and/or compared with other nations. Effective analysis of this data could unlock significant new insights not yet available to a policy maker or other stakeholder. Future iterations of the SBA might include suggestions for effective data analysis and provide examples.

6. DISCLAIMER

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APPENDIX A. DEFINITIONS FOR ARCHETYPES

TABLE A1. Brief definitions for archetypes in SBA fiscal taxonomy. OP = Operational-type policy. DI = discretionary-type policy.

Ref	Archetype name
A	**Core government operations (OP)** *Covers funds to support continued function of core government operations. For instance, foreign affairs services, national councils, parliament, the judicial system and courts, governance practices, and more. Also included in this archetype are regular disbursements to subnational entities for general support where the impacted sectors are unclear. Note that this archetype is perhaps the broadest of all as it can sometimes be used as a catch-all for operational-type policies not covered by other archetypes.* • A1. Core government operations
B	**Health (OP)** *Covers ongoing public costs related to maintaining existing health systems and programs.* • B1. Physical • B2. Mental • B3. Other and general
C	**Education (OP)** *Covers ongoing public costs related to maintaining existing education systems and programs.* • C1. Primary • C2. Secondary • C3. Tertiary • C99. Other and general
D	**Socio-cultural programs (OP)** *Covers ongoing public costs related to maintaining existing socio-cultural programs including arts, culture, tourism, and leisure services.* • D1. Arts and culture • D2. Tourism - traditional • D3. Tourism - green and/or resilient • D4. Leisure services • D99. Other and general
E	**Traditional energy (OP)** *Covers ongoing public costs related to maintaining existing traditional energy production and distribution systems.* • E1. Power plants • E2. Refineries • E3. Coal mines and oil/gas fields • E4. Infrastructure for transport and transmission of fossil energy inputs/outputs • E99. Other and general
F	**Clean energy (OP)**

	Covers ongoing public costs related to maintaining existing clean energy production and distribution systems. • F1. Renewable energy generation facilities • F2. Nuclear energy generation facilities • F3. Biofuel and other renewable fuel production • F4. Transmission networks • F5. Distribution networks • F6. Hydrogen • F7. Battery and storage • F8. Carbon capture and storage/utilisation • F99. Other and general
G	**Traditional transportation (OP)** *Covers ongoing public costs related to maintaining existing traditional transportation systems.* • G1. Roads (including operations and repairs) • G2. Airports (including operations and repairs) • G3. Ports and other maritime infrastructure (including operations and repairs) • G99. Other and general
H	Clean and/or resilient transportation (OP) *Covers ongoing public costs related to maintaining existing clean and/or resilient transportation systems.* • H1. Bus operations - fossil fuel powered • H2. Bus operations - clean fuel powered • H3. Rail and tram operations - fossil fuel powered • H4. Rail and tram operations - clean fuel powered • H99. Other and general
I	Communications (OP) *Covers ongoing public costs related to maintaining existing communication systems.* • I1. Telephone and basic services • I2. Internet services • I99. Other and general
J	Other utilities (OP) *Covers ongoing public costs related to maintaining existing water and waste services, and other utilities.* • J1. Water services • J2. Waste services • J99. Other and general
K	Military (OP) *Covers ongoing public costs related to maintaining existing military structures and operations.* • K1. Army • K2. Navy • K3. Airforce

- K99. Other and general

L	Emergency response services (OP) *Covers ongoing public costs related to maintaining existing emergency response services.* • L1. Police and law enforcement • L2. Fire and rescue • L3. Emergency medical services • L4. Disaster relief • L5. Animal control • L99. Other and general
M	Natural capital, parks, forestry and other environmental (OP) *Covers ongoing public costs related to maintaining existing natural capital, parks, forestry operations, and other environmental programs.* • M1. Public parks and green spaces management • M2. Forestry management • M99. Other and general
N	Worker retraining and job creation (OP) *Covers ongoing public costs related to maintaining existing worker retraining and job creation systems.* • N1. Traditional worker retraining and job creation • N2. Green worker retraining and job creation - climate mitigation • N3. Green worker retraining and job creation - adaptation • N4. Green worker retraining and job creation - unclassified/mixed • N99. Other and general
O	Social welfare / social security (OP) *Covers ongoing public costs related to maintaining existing social welfare or social security systems.* • O1. Unemployment payments • O2. Food stamps • O3. Utility fee support • O4. Social housing • O5. Disability services • O6. Veterans' affairs • O7. Social work initiatives • O99. Other and general
P	Other traditional operations (OP) *Covers ongoing public costs related to maintaining existing traditional operations not covered by other categories.* • P1. Other
Q	Other clean and/or resilient operations (OP) *Covers ongoing public costs related to maintaining existing clean and/or resilient operations not covered by other categories.* • Q1. Other
α	Core government service expansion (DI)

Covers funds to support expansion of core government operations. Also included in this archetype is expansion of disbursements to subnational entities for general support where the impacted sectors are unclear. Like its operational counterpart, can sometimes be used as a catch-all for discretionary-type policies not covered by other archetypes.

- α1. Core government service expansion

β Health (DI)

Covers investments in expansions of the healthcare system, including mental health, aged care and technological upgrades.

- β1. Physical
- β2. Mental
- β99. Other and general

γ Education (DI)

Covers investments in expansions of the education system, including injections to fund improved teacher training, in-classroom and digital materials, and other education capital for pre-primary, primary, and secondary. Includes increased support for tertiary sectors in high-productivity sectors, as well as scholarship funding.

- γ1. Primary
- γ2. Secondary
- γ3. Tertiary
- γ99. Other and general

δ Socio-cultural programs (DI)

Covers investments in new socio-cultural programs or expansion of existing programs, including non-profits.

- δ1. Arts and culture
- δ2. Tourism - traditional
- δ3. Tourism - green and/or resilient
- δ4. Hospitality services
- δ99. Other and general

ε Traditional energy (DI)

Covers investments in new or expanded traditional energy production and distribution systems, particularly fossil fuels and related infrastructure.

- ε1. New or refurbished power plants
- ε2. New or refurbished refineries
- ε3. New or refurbished coal mines and oil/gas fields
- ε4. New or refurbished infrastructure for transport and transmission of fossil energy inputs/outputs
- ε99. Other and general

ζ Clean energy (DI)

Covers investments in new or expanded clean energy production and distribution systems. Includes increased spending in clean electricity, and heat generation and storage; upgraded transmission or hydrogen infrastructure.

- ζ1. New or refurbished renewable energy generation facilities
- ζ2. New or refurbished nuclear energy generation facilities

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- ζ3. New biofuel and other renewable fuel infrastructure
- ζ4. Upgraded (or new) transmission infrastructure
- ζ5. Upgraded (or new) distribution infrastructure including smart grids
- ζ6. Hydrogen infrastructure
- ζ7. Battery and storage infrastructure
- ζ8. Carbon capture and storage/utilisation infrastructure
- ζ9. Other initiatives to clean existing dirty energy assets
- ζ10. Improve resilience of existing traditional energy infrastructure
- ζ11. Improve resilience of existing clean energy infrastructure
- ζ99. Other and general

η Traditional transportation (DI)

Covers investments in new or expanded traditional transportation systems, including road upgrades as well as airport and port infrastructure.

- η1. Road construction
- η2. ICE automobile investment
- η3. Airport construction and expansion
- η4. Fossil fuel-powered aviation investment
- η5. Port and maritime construction and expansion
- η6. Fossil fuel-powered shipping investment
- η99. Other and general

θ Clean and/or resilient transportation (DI)

Covers investments in new or expanded clean and/or resilient transportation systems, including new or expanded public transport systems; increasing public transport capacity and transport digitalisation; cycling and walking infrastructure; and electric vehicle (EV) charging infrastructure.

- θ1. Electric vehicle investment
- θ2. Electric vehicle charging infrastructure
- θ3. Fossil fuel-powered bus investment
- θ4. Rail and tram line construction
- θ5. Trains and trams investment
- θ6. Public transport digitalisation efforts
- θ7. Cycling and walking infrastructure
- θ8. Improving efficiency in dirty transport
- θ9. Improving resilience of existing traditional transportation infrastructure and networks
- θ10. Improving resilience of existing clean transportation infrastructure and networks
- θ99. Other and general

ι Communications (DI)

Covers investment in policies designed to expand existing communication infrastructure or create new infrastructure, including provisions for remote learning and broadband. Soft infrastructure including digital programs and cybersecurity are also included.

- ι1. Telephone and basic cellular investment
- ι2. Broadband investment
- ι3. Civil cybersecurity programmes
- ι4. Implementing digital programmes
- ι5. Improving resilience of existing communications infrastructure

- ι99. Other and general

κ	Other utilities (DI) *Covers investments in new or expanded water and waste services and other utilities.* • κ1. Water sourcing • κ2. Water transportation/piping infrastructure • κ3. Water treatment infrastructure • κ4. Waste processing investment • κ5. Recycling investment • κ99. Other and general
λ	Military (DI) *Covers investments in new or expanded military structures and operations, including armed capacity and arsenals.* • λ1. Army • λ2. Navy • λ3. Airforce • λ99. Other and general
μ	Emergency response services (DI) *Covers investments in new or expanded emergency response services, including new equipment or infrastructure (which is not simply replacing used material for maintenance purposes).* • μ1. Police and law enforcement equipment and/or infrastructure • μ2. Fire and rescue equipment and/or infrastructure • μ3. Emergency medical services equipment and/or infrastructure • μ4. Disaster relief supplies, equipment, and/or infrastructure • μ5. Animal control equipment and/or infrastructure • μ99. Other and general
ν	Natural capital, parks, forestry and other environmental (DI) *Covers investments in new or expanded natural capital, parks, forestry operations, and other environmental programs. Includes upgrading public parks, green spaces, national parks, tree planting and biodiversity protection, ecological conservation initiatives, and ecological system services.* • ν1. Public parks and green spaces investment • ν2. Environmental re(building) initiatives including afforestation, reforestation, and environmental rehabilitation • ν3. Environmental protection initiatives including conservation and natural infrastructure resilience • ν4. Sustainable forestry investment • ν5. Forestry investment leading to unsustainable deforestation • ν99. Other and general
ξ	Agriculture and fisheries (DI) *Covers investments in new or expanded agriculture and fisheries systems and operations.* • ξ1. General agricultural investment • ξ2. Clean and/or resilient agricultural practices (e.g., adaptive cropping, education on A&R, agroecology etc) • ξ3. General fisheries investment

- ξ4. Clean and/or resilient fisheries practices (e.g., wild fishery management)
- ξ5. General investment in resilient land management
- ξ99. Other and general

ο	Disaster preparedness investment (DI) *Covers investments in new or expanded disaster preparedness programs, including spending in preparation for future pandemics, fires, floods, cyclones, and other extreme events.* • ο1. Investment in risk assessment and early warning systems • ο2. Procurement of emergency response equipment • ο3. Investment in emergency response systems • ο4. Other direct (physical) climate change adaptation and resilience measures • ο5. Other indirect (economic, political) climate change adaptation and resilience measures • ο99. Other and general
π	Green housing and real estate (DI) *Covers investments in new, expanded, or upgraded green housing and real estate. Includes upgrades aiming to increase thermal efficiency through improved insulation, improved energy efficiency of appliances, and clean heating (heat pumps or heat networks).* • π1. Clean and/or resilient housing construction • π2. Clean and/or resilient housing heating and insulation retrofits • π3. Clean and/or resilient housing rooftop solar retrofits • π4. Clean and/or resilient housing electrification investment • π5. Clean and/or resilient public/corporate building construction • π6. Clean and/or resilient public/corporate building heating and insulation retrofits • π7. Clean and/or resilient public/corporate building rooftop solar retrofits • π8. Clean and/or resilient public/corporate building electrification investment • π9. Clean and/or resilient small-scale urban development programs • π99. Other and general
ρ	Traditional housing and real estate (DI) *Covers investments in new or expanded traditional housing and real estate.* • ρ1. Traditional housing construction • ρ2. Traditional housing renovations • ρ3. Traditional public/corporate building construction • ρ4. Traditional public/corporate building renovations • ρ5. Traditional small-scale non-residential urban development programs • ρ99. Other and general
σ	Materials (DI) *Covers investments in new or expanded materials extraction, production, and distribution systems.* • σ1. Mining - exploration • σ2. Mining - extraction • σ3. Mining - transportation • σ4. Furniture production and processing • σ5. Metals production and processing • σ6. Chemicals production and processing • σ7. Paper production and processing • σ8. Plastics production and processing

- σ99. Other and general

τ	Other large-scale infrastructure (DI) *Covers investments in new or expanded large-scale infrastructure not covered by other categories.* • τ1. Large-scale urban infrastructure - general • τ2. Large-scale urban infrastructure for climate resilience • τ3. Large-scale regional infrastructure - general • τ4. Large-scale regional infrastructure for climate resilience • τ5. Large-scale space infrastructure • τ99. Other and general	
υ1	General R&D (DI) *Covers investments in research and development programs and support for innovative businesses, without regard for environmental impact.* • υ1. Traditional energy programs • υ2. Traditional transport programs • υ3. Traditional manufacturing programs • υ4. Traditional agriculture programs • υ5. Health programs • υ6. Computing and digitisation programs • υ7. Space programs • υ99. Other and general	
ф1	Clean R&D (DI) *Covers investments in research and development programs and support for innovative businesses specifically aiming for environmental benefits. Specifically includes green technologies, such as electrolysis, heat pumps, energy storage, plant genetics, and greenhouse gas removal.* • ф1. Clean and/or resilient energy programs • ф2. Clean and/or resilient transport programs • ф3. Clean and/or resilient manufacturing programs • ф4. Clean and/or resilient agriculture programs • ф5. Other climate mitigation programs • ф6. Other climate resilience programs • ф99. Other and general	
χ1	Other traditional investment *Covers investments in other new or expanded traditional operations not covered by other categories.* • χ1. Other	
ψ1	Other clean and/or resilient investment *Covers investments in other new or expanded clean and/or resilient operations not covered by other categories.* • ψ1. Other	
Debt		

APPENDIX B. EXAMPLE POLICY IMPACT ASSESSMENTS

Potential policy impacts are assessed here in a general sense, noting that there are nuances at the country level that should be considered before application of the SBA. The "assessment process" for considering such nuance is described in section 4. In the following descriptions, potential environmental and social impacts are assessed at the archetype level, and in some cases, at the subarchetype level. Subarchetype assessments are included only when there is significant deviation in perceived impacts between subarchetypes within the parent archetype.

Since likely economic impacts fluctuate greatly between economies, based on fundamental economic structures, economic impact assessments are not included in the below. Instead, notes are provided on how economic considerations might be considered and what existing literature might be available. Importantly, literature relating to operational forms of spending is extremely sparse and we are unable to provide any useful generic guides for this kind of spending. Forthcoming jobs analysis from the ILO should allow for more detailed economic considerations in the SBA.

Table B1 summarises potential impacts across archetypes for the current 6 environmental indicators and 2 social indicators. In this assessment, archetypes are broadly categorised as operational-type (recurrent budget) and discretionary-type (capital budget).

Each archetype potential impact assessment is structured as follows:

Archetype name

Indicative assessment of impacts on short- and long-term GHG emissions

Indicative assessment of impacts on natural capital

Indicative assessment of impacts on air pollution

Indicative assessment of direct impacts on environmental adaptation and resilience

Indicative assessment of indirect impacts on environmental adaptation and resilience

Indicative assessment of impacts on wealth inequality

Indicative assessment of impacts on rural livelihoods

Notes relevant to potential impacts on economic criteria (only some archetypes)

TABLE B1. Summary of archetype assessments. Short-term GHG emissions (SE); Long-term GHG emissions (LE); Air pollution (AP); natural capital (NC); income inequality (II); rural livelihood (RL); direct adaptation and resilience (DAR); indirect adaptation and resilience (DIR).

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
A	**Core government operations (OP)**								
A1	Core government operations	0	0	0	0	0	0	0	0
B	**Health (OP)**								
B1	Physical	-1	0	0	0	0	0	+1	+1
B2	Mental	0	0	0	0	0	0	+1	+1
B99	Other and general	-1	0	0	0	0	0	+1	+1
C	**Education (OP)**								
C1	Primary	0	0	0	0	0	0	+1	+1
C2	Secondary	0	0	0	0	0	0	+1	+1
C3	Tertiary	0	0	0	0	0	0	+1	+1
C99	Other and general	0	0	0	0	0	0	+1	+1
D	**Socio-cultural programs (OP)**								
D1	Arts and culture	0	0	0	0	0	0	0	0
D2	Tourism - traditional	-1	-2	-1	-1	0	0	0	0
D3	Tourism - green and/or resilient	0	+1	0	+1	0	0	0	0
D4	Leisure services	-1	0	0	0	0	0	0	0
D99	Other and general	0	0	0	0	0	0	0	0
E	**Traditional energy (OP)**								
E1	Power plants	-2	-2	-1	-1	-1	-1	0	-1
E2	Refineries	-2	-2	-1	-1	-1	-1	0	-1
E3	Coal mines and oil/gas fields	-2	-2	-1	-1	-1	-1	0	-1
E4	Infrastructure for transport and transmission of fossil energy inputs/outputs	-2	-2	-1	-1	-1	-1	0	-1
E99	Other and general	-2	-2	-1	-1	-1	-1	0	-1
F	**Clean energy (OP)**								
F1	Renewable energy generation facilities	+2	+2	+1	0	0	+1	0	0
F2	Nuclear energy generation facilities	+2	+2	+1	0	0	+1	0	0
F3	Biofuel and other renewable fuel production	+2	+2	+1	-1	0	+1	0	0
F4	Transmission networks	+2	+2	+1	0	0	+1	0	0
F5	Distribution networks	+2	+2	+1	0	0	+1	0	0
F6	Hydrogen	+2	+2	+1	0	0	+1	0	0
F7	Battery and storage	+2	+2	+1	-1	0	+1	0	0

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
F8	Carbon capture and storage/utilisation	+2	+2	+1	0	0	+1	0	0
F99	Other and general	+2	+2	+1	0	0	+1	0	0
G	**Traditional transportation (OP)**								
G1	Roads (including operations and repairs)	-1	-2	-1	-1	-1	-1	0	+1
G2	Airports (including operations and repairs)	-1	-2	-1	-1	-1	-1	0	+1
G3	Ports and other maritime infrastructure (including operations and repairs)	-1	-2	-1	-1	-1	-1	0	+1
G99	Other and general	-1	-2	-1	-1	-1	-1	0	+1
H	**Clean and/or resilient transportation (OP)**								
H1	Bus operations - fossil fuel powered	-1	+2	+1	-1	0	+1	0	0
H2	Bus operations - clean fuel powered	-1	+2	+1	-1	0	+1	0	0
H3	Rail and tram operations - fossil fuel powered	-1	+2	+1	-1	0	+1	0	0
H4	Rail and tram operations - clean fuel powered	-1	+2	+1	-1	0	+1	0	0
H99	Other and general	-1	+2	+1	-1	0	+1	0	0
I	**Communications (OP)**								
I1	Telephone and basic services	0	0	0	0	0	+1	0	+1
I2	Internet services	0	0	0	0	0	+1	0	+1
I99	Other and general	0	0	0	0	0	+1	0	+1
J	**Other utilities (OP)**								
J1	Water services	0	0	0	+1	0	0	0	0
J2	Waste services	0	0	0	+1	0	0	0	0
J99	Other and general	0	0	0	+1	0	0	0	0
K	**Military (OP)**								
K1	Army	-2	-2	-1	-1	0	0	-1	0
K2	Navy	-2	-2	-1	-1	0	0	-1	0
K3	Airforce	-2	-2	-1	-1	0	0	-1	0
K99	Other and general	-2	-2	-1	-1	0	0	-1	0
L	**Emergency response services (OP)**								
L1	Police and law enforcement	-1	0	0	0	+1	+1	0	0
L2	Fire and rescue	-1	0	0	0	+1	+1	0	0
L3	Emergency medical services	-1	0	0	0	+1	+1	0	0
L4	Disaster relief	-1	0	0	0	+1	+1	0	0
L5	Animal control	-1	0	0	0	+1	+1	0	0
L99	Other and general	-1	0	0	0	+1	+1	0	0

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
M	**Natural capital, parks, forestry, and other environmental (OP)**								
M1	Public parks and green spaces management	+1	+2	+1	+1	+1	+1	0	0
M2	Forestry management	0	0	0	0	0	0	0	0
M99	Other and general	+1	+2	+1	+1	+1	+1	0	0
N	**Worker retraining and job creation (OP)**								
N1	Traditional worker retraining and job creation	0	0	0	0	0	+1	+1	0
N2	Green worker retraining and job creation - climate mitigation	+1	+2	+1	+1	0	+1	+1	0
N3	Green worker retraining and job creation - adaptation	+1	+2	+1	0	+1	+1	+1	0
N4	Green worker retraining and job creation - unclassified/mixed	+1	+2	+1	0	+1	+1	+1	0
N99	Other and general	0	0	0	0	0	+1	+1	0
O	**Social welfare / social security (OP)**								
O1	Unemployment payments	0	0	0	0	0	+1	+1	+1
O2	Food stamps	0	0	0	0	0	+1	+1	+1
O3	Utility fee support	0	0	0	0	0	+1	+1	+1
O4	Social housing	0	0	0	0	0	+1	+1	+1
O5	Disability services	0	0	0	0	0	+1	+1	+1
O6	Veterans' affairs	0	0	0	0	0	+1	+1	+1
O7	Social work initiatives	0	0	0	0	0	+1	+1	+1
O99	Other and general	0	0	0	0	0	+1	+1	+1
P	**Other traditional operations (OP)**								
P1	Other	0	0	0	0	0	0	0	0
Q	**Other clean and/or resilient operations (OP)**								
Q1	Other	+1	+1	+1	+1	+1	+1	0	0
α	**Core government service expansion (DI)**								
α1	Core government service expansion	0	0	0	0	0	0	0	0
β	**Health (DI)**								
β1	Physical	-2	-1	0	-1	0	+1	+1	+1
β2	Mental	-1	0	0	0	0	+1	+1	+1
β99	Other and general	-2	-1	0	-1	0	+1	+1	+1
γ	**Education (DI)**								
γ1	Primary	0	0	0	0	0	0	+1	+1
γ2	Secondary	0	0	0	0	0	0	+1	+1
γ3	Tertiary	0	0	0	0	0	0	+1	+1

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
γ99	Other and general	0	0	0	0	0	0	+1	+1
δ	**Socio-cultural programs (DI)**								
δ1	Arts and culture	0	0	0	0	0	0	0	0
δ2	Tourism - traditional	-1	-2	-1	-1	0	0	0	0
δ3	Tourism - green and/or resilient	0	+1	0	+1	0	0	0	0
δ4	Hospitality services	-1	0	0	0	0	0	0	0
δ99	Other and general	0	0	0	0	0	0	0	0
ε	**Traditional energy (DI)**								
ε1	New or refurbished power plants	-2	-2	-1	-1	-1	-1	0	-1
ε2	New or refurbished refineries	-2	-2	-1	-1	-1	-1	0	-1
ε3	New or refurbished coal mines and oil/gas fields	-2	-2	-1	-1	-1	-1	0	-1
ε4	New or refurbished infrastructure for transport and transmission of fossil energy inputs/outputs	-2	-2	-1	-1	-1	-1	0	-1
ε99	Other and general	-2	-2	-1	-1	-1	-1	0	-1
ζ	**Clean energy (DI)**								
ζ1	New or refurbished renewable energy generation facilities	-2	+2	+1	0	0	+1	0	0
ζ2	New or refurbished nuclear energy generation facilities	-2	+2	+1	0	0	+1	0	0
ζ3	New biofuel and other renewable fuel infrastructure	-2	+2	+1	0	0	+1	0	0
ζ4	Upgraded (or new) transmission infrastructure	-2	+2	+1	0	0	+1	0	0
ζ5	Upgraded (or new) distribution infrastructure including smart grids	-2	+2	+1	0	0	+1	0	0
ζ6	Hydrogen infrastructure	-2	+2	+1	0	0	+1	0	0
ζ7	Battery and storage infrastructure	-2	+2	+1	-1	0	+1	0	0
ζ8	Carbon capture and storage/utilisation infrastructure	-2	+2	+1	0	0	+1	0	0
ζ9	Other initiatives to clean existing dirty energy assets	0	+2	+1	0	0	+1	0	0

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
ζ10	Improve resilience of existing traditional energy infrastructure	0	+2	+1	0	0	+1	0	0
ζ11	Improve resilience of existing clean energy infrastructure	0	+2	+1	0	0	+1	0	0
ζ99	Other and general	-1	+2	+1	0	0	+1	0	0
η	**Traditional transportation (DI)**								
η1	Road construction	-2	-2	-1	-1	-1	-1	0	+1
η2	ICE automobile investment	-2	-2	-1	-1	-1	-1	0	+1
η3	Airport construction and expansion	-2	-2	-1	-1	-1	-1	0	+1
η4	Fossil fuel-powered aviation investment	-2	-2	-1	-1	-1	-1	0	+1
η5	Port and maritime construction and expansion	-2	-2	-1	-1	-1	-1	0	+1
η6	Fossil fuel-powered shipping investment	-2	-2	-1	-1	-1	-1	0	+1
η99	Other and general	-2	-2	-1	-1	-1	-1	0	+1
θ	**Clean and/or resilient transportation (DI)**								
θ1	Electric vehicle investment	-2	+2	+1	-1	0	+1	0	0
θ2	Electric vehicle charging infrastructure	-2	+2	+1	-1	0	+1	0	0
θ3	Fossil fuel-powered bus investment	-2	+2	+1	-1	0	+1	0	0
θ4	Rail and tram line construction	-2	+2	+1	-1	0	+1	0	0
θ5	Trains and trams investment	-2	+2	+1	-1	0	+1	0	0
θ6	Public transport digitalisation efforts	0	+2	+1	0	0	+1	0	0
θ7	Cycling and walking infrastructure	-2	+2	+1	-1	0	+1	0	0
θ8	Improving efficiency in dirty transport	0	+2	+1	0	0	+1	0	0
θ9	Improving resilience of existing traditional transportation infrastructure and networks	0	+2	+1	0	0	+1	0	0
θ10	Improving resilience of existing clean transportation	0	+2	+1	0	0	+1	0	0

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
	infrastructure and networks								
θ99	Other and general	-2	+2	+1	-1	0	+1	0	0
ι	**Communications (DI)**								
ι1	Telephone and basic cellular investment	0	0	0	0	0	+1	0	+1
ι2	Broadband investment	0	0	0	0	0	+1	0	+1
ι3	Civil cybersecurity programmes	0	0	0	0	0	+1	0	0
ι4	Implementing digital programmes	0	0	0	0	0	+1	0	0
ι5	Improving resilience of existing communications infrastructure	0	0	0	0	0	+1	0	+1
ι99	Other and general	0	0	0	0	0	0	0	0
κ	**Other utilities (DI)**								
κ1	Water sourcing	0	0	0	+1	0	0	0	0
κ2	Water transportation/piping infrastructure	0	0	0	+1	0	0	0	0
κ3	Water treatment infrastructure	0	0	0	+1	0	0	0	0
κ4	Waste processing investment	0	0	0	+1	0	0	0	0
κ5	Recycling investment	0	+1	0	+1	0	0	0	0
κ99	Other and general	0	0	0	+1	0	0	0	0
λ	**Military (DI)**								
λ1	Army	-2	-2	-1	-1	0	0	-1	0
λ2	Navy	-2	-2	-1	-1	0	0	-1	0
λ3	Airforce	-2	-2	-1	-1	0	0	-1	0
λ99	Other and general	-2	-2	-1	-1	0	0	-1	0
μ	**Emergency response services (DI)**								
μ1	Police and law enforcement equipment and/or infrastructure	-1	0	0	0	+1	+1	0	0
μ2	Fire and rescue equipment and/or infrastructure	-1	0	0	0	+1	+1	0	0
μ3	Emergency medical services equipment and/or infrastructure	-1	0	0	0	+1	+1	0	0
μ4	Disaster relief supplies, equipment, and/or infrastructure	-1	0	0	0	+1	+1	0	0
μ5	Animal control equipment and/or infrastructure	-1	0	0	0	+1	+1	0	0
μ99	Other and general	-1	0	0	0	+1	+1	0	0

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
ν	**Natural capital, parks, forestry, and other environmental (DI)**								
ν1	Public parks and green spaces investment	+1	+2	+1	+1	+1	+1	0	0
ν2	Environmental re(building) initiatives including afforestation, reforestation, and environmental rehabilitation	+1	+2	+1	+1	+1	+1	0	0
ν3	Environmental protection initiatives including conservation and natural infrastructure resilience	+1	+2	+1	+1	+1	+1	0	0
ν4	Sustainable forestry investment	+1	+2	+1	+1	+1	+1	0	0
ν5	Forestry investment leading to unsustainable deforestation	-1	-2	-1	-1	-1	-1	0	0
ν99	Other and general	+1	+2	+1	+1	+1	+1	0	0
ξ	**Agriculture and fisheries (DI)**								
ξ1	General agricultural investment	-1	-1	0	-1	0	-1	+1	+1
ξ2	Clean and/or resilient agricultural practices (e.g., adaptive cropping, education on A&R, agroecology etc)	+1	+2	0	+1	+1	+1	+1	+1
ξ3	General fisheries investment	-1	-1	0	-1	0	-1	+1	+1
ξ4	Clean and/or resilient fisheries practices (e.g., wild fishery management)	+1	+1	0	+1	+1	+1	+1	+1
ξ5	General investment in resilient land management	+1	+1	0	+1	+1	+1	+1	+1
ξ99	Other and general	0	0	0	0	0	0	+1	+1
ο	**Disaster preparedness investment (DI)**								
ο1	Investment in risk assessment and early warning systems	0	0	0	0	+1	+1	+1	+1
ο2	Procurement of emergency response equipment	-1	0	0	0	+1	+1	+1	+1
ο3	Investment in emergency response systems	-1	0	0	0	+1	+1	+1	+1

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
o4	Other direct (physical) climate change adaptation and resilience measures	-1	0	0	0	+1	+1	+1	+1
o5	Other indirect (economic, political) climate change adaptation and resilience measures	0	0	0	0	+1	+1	+1	+1
o99	Other and general	0	0	0	0	+1	+1	+1	+1
π	**Green housing and real estate (DI)**								
π1	Clean and/or resilient housing construction	-2	+2	0	0	+1	0	+1	0
π2	Clean and/or resilient housing heating and insulation retrofits	0	+2	0	+1	+1	0	+1	0
π3	Clean and/or resilient housing rooftop solar retrofits	0	+2	0	+1	+1	0	+1	0
π4	Clean and/or resilient housing electrification investment	0	+2	0	+1	+1	0	+1	0
π5	Clean and/or resilient public/corporate building construction	-2	+2	0	0	+1	+1	+1	0
π6	Clean and/or resilient public/corporate building heating and insulation retrofits	0	+2	0	+1	+1	+1	+1	0
π7	Clean and/or resilient public/corporate building rooftop solar retrofits	0	+2	0	+1	+1	+1	+1	0
π8	Clean and/or resilient public/corporate building electrification investment	0	+2	0	+1	+1	+1	+1	0
π9	Clean and/or resilient small-scale urban development programs	-2	+2	0	0	+1	+1	+1	0
π99	Other and general	-2	+2	0	0	+1	0	+1	0
ρ	**Traditional housing and real estate (DI)**								
ρ1	Traditional housing construction	-2	0	0	-1	0	0	+1	0
ρ2	Traditional housing renovations	0	0	0	0	0	0	+1	0
ρ3	Traditional public/corporate building construction	-2	0	0	-1	0	+1	+1	0

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
ρ4	Traditional public/corporate building renovations	0	0	0	0	0	+1	+1	0
ρ5	Traditional small-scale non-residential urban development programs	-2	0	0	-1	0	0	+1	0
ρ99	Other and general	-2	0	0	-1	0	0	+1	0
σ	**Materials (DI)**								
σ1	Mining - exploration	-1	-1	-1	-1	0	0	0	0
σ2	Mining - extraction	-1	-1	-1	-1	0	0	0	0
σ3	Mining - transportation	-1	-1	-1	-1	0	0	0	0
σ4	Furniture production and processing	-1	-1	-1	-1	0	0	0	0
σ5	Metals production and processing	-1	-1	-1	-1	0	0	0	0
σ6	Chemicals production and processing	-1	-1	-1	-1	0	0	0	0
σ7	Paper production and processing	-1	-1	-1	-1	0	0	0	0
σ8	Plastics production and processing	-1	-1	-1	-1	0	0	0	0
σ99	Other and general	-1	-1	-1	-1	0	0	0	0
τ	**Other large-scale infrastructure (DI)**								
τ1	Large-scale urban infrastructure - general	-1	0	-1	-1	0	0	0	0
τ2	Large-scale urban infrastructure for climate resilience	-1	0	-1	-1	+1	+1	0	0
τ3	Large-scale regional infrastructure - general	-1	0	-1	-1	0	0	0	0
τ4	Large-scale regional infrastructure for climate resilience	-1	0	-1	-1	+1	+1	0	0
τ5	Large-scale space infrastructure	-1	0	-1	-1	0	0	0	0
T99	Other and general	-1	0	-1	-1	0	0	0	0
υ	**General R&D (DI)**								
υ1	Traditional energy programs	0	0	0	0	0	0	-1	0
υ2	Traditional transport programs	0	0	0	0	0	0	-1	0
υ3	Traditional manufacturing programs	0	0	0	0	0	0	-1	0
υ4	Traditional agriculture programs	0	0	0	0	0	0	-1	+1
υ5	Health programs	0	+1	0	0	0	0	-1	0

Ref	Subarchetype name	SE	LE	AP	NC	DAR	IAR	II	RL
υ6	Computing and digitisation programs	0	+1	0	0	0	0	-1	0
υ7	Space programs	0	-1	0	0	0	0	-1	0
υ99	Other and general	0	0	0	0	0	0	-1	0
ϕ	**Clean R&D (DI)**								
ϕ1	Clean and/or resilient energy programs	0	+2	+1	+1	+1	+1	0	0
ϕ2	Clean and/or resilient transport programs	0	+2	+1	+1	+1	+1	0	0
ϕ3	Clean and/or resilient manufacturing programs	0	+2	+1	+1	+1	+1	0	0
ϕ4	Clean and/or resilient agriculture programs	0	+2	+1	+1	+1	+1	0	+1
ϕ5	Other climate mitigation programs	0	+2	+1	+1	0	0	0	0
ϕ6	Other climate resilience programs	0	+2	+1	0	+1	+1	0	0
ϕ99	Other and general	0	+2	+1	+1	+1	+1	0	0
χ	**Other traditional investment**								
χ1	Other	0	0	0	0	0	0	0	0
ψ	**Other clean and/or resilient investment**								
ψ1	Other	+1	+1	+1	+1	+1	+1	0	0
Debt	**Debt**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Operational-type archetypes

Note that there is a dearth of academic publication considering the economic characteristics of operational-type government policy as distinct from investment-type policy. Given this, we refrain from making economic comment on most operational-type measures.

A. Core government operations

Impacts on short- and long-term GHG emissions—We note that there is wide variation in practices that may be supported by spending in this category. It is therefore difficult to assign GHG emissions scores. However, in general, considering that spending in this archetype is likely to mostly address labour costs and basic services that would be associated with any workplace (e.g., electricity), it seems unlikely that there would be an associated increase in emissions (either short or long term) compared to the situation in which the spending did not occur. This is of course a broad generalisation, and we encourage the SBA user to consider manual assessment of GHG impact for policy items that might be spurring new emissions. This might be the case, for example, for indiscriminate support of some subnational entities, which could spur increased consumption, in turn moderately increasing short-term GHG emissions (Dubois *et al.*, 2019). Overall, for this policy, we suggest that the user consider a starting point of little change in GHG emissions in both the short and long term (0).

Impacts on natural capital—There is little evidence of significant natural capital effects resulting from these policies, especially given that they are non-infrastructural. We therefore expect little net change in natural capital (0) because of these policies.

Impacts on air pollution—There is little evidence of significant air pollution effects resulting from these policies, especially given that they are temporary measures. We therefore expect little net change (0) because of these policies.

Direct impacts on environmental adaptation and resilience—Core support of government operations does not directly enhance adaptation or resilience unless funds are specifically earmarked for environmental activities (Schröter-Schlaack *et al.*, 2014). These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Continued support of core government services is unlikely to have a meaningful down-the-line impact on environmental resilience, although impacts on general forms of resilience could be supported with baseline adaptive capacity that comes from having centrally-coordinated policy staff available to respond to a changing external environment. For the case where funds are directed to subnational public entities, there might be an argument that spending indirectly strengthens adaptive capacity since local officials have more information on the conditions in the regions in which they live than national officials. Consequently, they can be better able to deliver public services that offer environmental benefits. Nzau (2014) concludes that "one dollar spent at the sub-national level would result in more welfare to the people and greater impact than the same amount of money spent at the national level". However, given the breadth of this archetype, the SBA users are advised to begin with the assumption that indirect impacts on A&R are low (0).

Impacts on wealth inequality—There is little evidence of significant wealth inequality impacts resulting from these policies. Perhaps, in the instance of subnational disbursements, states and localities might choose to target received funds towards low-income individuals more than is done at the national level, but this would be an edge case compared to most policies recorded in this category. We therefore expect, as a baseline, little net change (0) in wealth inequality because of the average policy in this category.

Impacts on rural livelihoods—There is little evidence to suggest that support for general government operations, or indeed subnational public entities, has significant impacts on rural communities beyond what is expected for the general population, unless the policies are specifically targeted to those communities. We therefore expect little net change (0) because of these policies.

Notes relevant to potential impacts on economic criteria—According to one study considering 31 European countries, general investment in public systems seems effective for fostering economic growth when it supports the creation of human capital and the functioning of economic affairs and public services, including basic R&D and the operability of public institutions (Saccone *et al.*, 2022). That said, investments to sustain existing systems might not have the same impact characteristics as investments to expand systems, and in some cases, inefficient and low-productivity public service systems might deliver quite poor fiscal multipliers. We also note that the induced effects of spending on public services, particularly government services, are likely to be quite high—however the directionality of those effects (positive or negative) might be highly debated. For instance, support of the judiciary is often described as a key enabler of rule of law, which enables a competitive business landscape, however, over-reaching judicial systems might be described as limiting economic activities.

B. Health (operational)

Impacts on short- and long-term GHG emissions—The majority of the policies usually associated with this archetype are designed to maintain healthcare capacity and services. Manufacturing of medical goods is usually associated with a short-term increase in GHG emissions (Belkhir and Elmeligi, 2019). The continued operation of health care facilities, say for the period of one year, will generally correspond to a continuation of demand for high GHG medical services, however, these services each have a one-time impact on GHG emissions (i.e., in the consumption of the materials) and are not ongoing. We therefore expect moderate increases in GHG emissions in the short term (-1) and little net change from this spending in the long-term (0).

Measures categorized as mental health support (B1) are often service based, sometimes digital, and involve little manufacturing. There is little evidence to suggest meaningful negative GHG impacts of this subarchetype at any stage of its implementation, therefore we expect little net change (0) in short-term GHG emissions.

Impacts on natural capital—Some healthcare activities, including both materials production and service provision, can generate significant waste streams that can impact natural capital. Lenzen *et al.*, (2020) estimate that the health care sector is responsible for between 1 and 5% of global environmental impacts (depending on the indicator used) and this may exceed 5% in some countries. This is corroborated by many case study analyses (e.g. Hasan and Rahman, 2018; Kwikiriza *et al.*, 2019). At the same time, however, effective management of hospital waste can significantly reduce natural capital burdens (Khan *et al.*, 2019). The operational side of health spending does not have the same detrimental effects of new hospitals that are discussed for the archetype β. On net, we expect a minor negative to neutral impact of operational health spending on natural capital compared to other spending, provided that high-quality environmental controls are established (0). Of course, in many nations, these controls do not exist, and the natural capital assessment should in those cases be reconsidered.

Impacts on air pollution—There is little evidence of significant air pollution effects resulting directly from healthcare services support. Therefore, we expect little net change (0) because of these policies.

Direct impacts on environmental adaptation and resilience—While healthcare services support is crucial for ensuring the physical resilience of facilities to climate change, these policies are focused on ongoing operational investments. Investments in healthcare services for future emergencies, such as climate-related disasters, are captured separately. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Characteristics are shared with the direct impacts assessment above (0).

Impacts on wealth inequality—Wealth inequality is generally associated with poorer health outcomes (Nowatzki, 2012). The impact of ongoing health spending on inequality is likely to depend principally on the beneficiaries of the spending. Generally, health spending might disproportionately boost health outcomes for less wealthy individuals as they are more likely to rely on public healthcare systems and not receive adequate healthcare in the absence of those systems. Of course, there will be significant variation in these outcomes depending on the policy. In the general case, we asses that ongoing health spending is likely to reduce wealth inequality (+1).

Impacts on rural livelihoods—Rural communities are less likely to have access to good quality health care in comparison to urban communities (Merwin *et al.*, 2006), thus they are likely to face a higher marginal benefit from healthcare investment. We therefore expect an improvement in rural livelihoods (+1) because of these policies.

C. Education (operational)

Impacts on short- and long-term GHG emissions—Investments in educational equipment are likely to have a smaller immediate impact than, for instance, construction, but still increase emissions (-1). Staff and scholarships are unlikely to have a significant impact beyond the status quo (0). In the longer term, the majority of new GHG emissions are likely to be from electricity consumption and manufacturing of educational materials, which is only indirectly linked to funding for education. Therefore, we expect little net change long-term (0) from education spending.

For funding to support understanding of climate change mitigation, adaptation, and/or resilience, funding could conceivably reduce GHG emissions in the long term. Educational programs can mitigate climate change by instilling behavioural change towards lower-emissions lifestyles, social structures, and economies (Anderson, 2012). However, the pathways through which educational programs impact GHG emissions are indirect, and there has been limited evidence demonstrating tangible outcomes of educational programs on emissions reductions so far (Anderson, 2012). In the absence of greater evidence, it is difficult to decisively assess the impact of these policies; we suggest a low direct impact (0) on GHG emissions in the short-term and a hopefully positive impact in the longer-term (+1).

Impacts on natural capital—There may be some long-term natural capital benefits resulting from higher education attainment and therefore ecological literacy (Howell, 1992) This effect is likely small for non-targeted educational investment, and significantly variable by country and education system. Therefore, little net change (0) is likely to result from these policies in general.

For targeted climate change education, there is evidence that this will have significant effects on developing capacity for climate change mitigation and adaptation, amplified by multiplier effects as people share what they learn, resulting in increased public demand for climate, conservation, and natural capital enhancement measures (Stevenson *et al.*, 2017). Thus, targeted climate change education is expected to have a positive impact (+1).

Impacts on air pollution—There have been few significant links found between the education sector and air pollution, thus there is little net change (0) expected as a result of these policies.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that general operational support for education has substantial direct impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—As above, there is little evidence for a link between general operational support for education and impacts on climate change adaptation and resilience. It may be argued that support for education increases the general adaptability of societies to the effects of climate change by creating a pool of relevant skills and knowledge. However, unless investment is directly earmarked for climate adaptation and resilience, the effect of this is likely minimal. The expected effect on indirect adaptation and resilience is therefore neutral (0).

Impacts on wealth inequality—Education has been shown to have significant positive impacts on wealth inequality through increasing capacity of children, even from lower income backgrounds, to attain higher paying jobs (Abdullah *et al.*, 2015). We therefore expect these policies to result in improvements in wealth inequality (+1)

Impacts on rural livelihoods—There exists significant disparities in educational access between rural and non-rural communities (Byun *et al.*, 2012), and education has been shown to be a vital component of combating rural poverty (Schafft, 2016). We therefore expect these policies to result in improvements in rural livelihoods (+1).

D. Socio-cultural programs (operational)

Impacts on short- and long-term GHG emissions—There is little evidence to suggest that social and cultural initiatives, in general, have any significant impact on greenhouse house emissions. We, therefore, expect little net change (0) because of general socio-cultural policies.

Overall, the tourism and leisure industries contribute significantly to global GHG emissions (Gössling and Peeters, 2015; Lenzen *et al.*, 2018; Peeters and Dubois, 2010). Depending on the scope of emissions included and assessment methodology used, these industries generate between 4.4% - 8% of worldwide CO2e emissions (Lenzen *et al.*, 2018; Peeters and Dubois, 2010). The sector is growing due to heightened demand, entailing upward trends in GHG emissions (Gössling and Peeters, 2015; Lenzen *et al.*, 2018). Further, there seems to be limited scope to reduce emissions through technological or processual improvements (ibid). Recent assessments have placed tourism and leisure behind manufacturing and construction in terms of the carbon multiplier, which is a ratio of CO2e emissions per US dollar generated in economic value, demonstrating the high carbon intensity of the industry (Lenzen *et al.*, 2018). The high carbon intensity of tourism and leisure is driven primarily by its extensive transportation needs, entailing a strong correlation between the level of emissions per tourist and distance travelled (Dubois, Ceron, 2006; Filimonau *et al.* 2014; Gössling *et al.* 2005; Lenzen *et al.* 2018).

General hospitality infrastructure also contributes significantly to sectoral GHG emissions (Rahman *et al.* 2012). Hospitality sites, and in particular large hotels, are among the least sustainable building types in terms of energy consumption (Beccali *et al.*, 2009; Rahman *et al.*, 2012). Further, the active tourism and leisure industries require the support of manufacturing (to meet often high shopping demands of tourists) and agriculture (to provide the necessary quantity of food and beverages). The above general evidence is supported by a wide array of national case studies, showcasing substantial increases in CO2e emissions due to the growth of the tourism and leisure industries (Katircioğlu, 2014; Katircioglu *et al.*, 2014; Tang *et al.*, 2014). Domestic practices, most importantly sourcing energy from renewable sources, decrease the carbon footprint associated with providing for tourists (Lenzen *et al.*, 2018).

Support for general tourism and hospitality services could allow continuation of carbon-heavy BAU practices in the leisure and tourism sector in the short term. We expect these policies to have substantial emission-increasing effects in long run (-2).

Specific support for greener and/or more resilient tourism including ecotourism is likely to reduce long-term emissions compared to the status quo scenario of no green spending. Green or sustainable tourism initiatives can be categorised as either: i) making existing tourism more sustainable, such as through energy efficiency improvements, switching to renewable energy sources and encouraging shorter travel distances; or ii) investing in new eco-tourism initiatives, such as sustainable safaris and lodging. Efforts to make existing tourism more sustainable have typically been outweighed by simultaneous growth in the industry in general, resulting on net in higher GHG emissions in the short-term, despite ongoing efforts to reduce the industry's GHG impact (Lenzen *et al.*, 2018). In the case of new investment in eco-tourism, Higham (2007) finds that eco-tourism has a high transportation component and, in some cases, can outweigh conventional tourism in terms of its carbon footprint, due to high material costs, the fossil fuel intensive profile of current transportation options, and the reluctance of consumers to voluntarily reduce their personal tourism carbon footprints (Khanra *et al.*, 2021). However, many other green tourism initiatives, like improving energy efficiency in hotels, can demonstrably reduce carbon emissions. Overall, compared to a scenario in which these policies were not implemented, we therefore expect them to have little net impact on GHG emissions in the short-term (0) and a small positive impact in the long-term (+1).

Spending on arts and cultural activities is expected to bring limited impact to GHG emissions in both the short and long run (0) as these policies do not target the biggest factors contributing to the tourism and leisure industries' carbon footprint.

Measures to promote leisure participation are expected to bring some emission-increasing effects on GHG emission levels in the short run (-1) and little impact in the long run (0). While it depends very much on the initiative in question, spending to promote leisure participation usually occurs at the domestic level, thus incentivizing shorter distances for travel, with corresponding reductions in GHG emissions.

Impacts on natural capital—There is little evidence to suggest that general socio-cultural programs have significant impacts on natural capital. We therefore expect little net change (0) as a result of these policies.

Incentives for the tourism industry are expected to have negative impacts on natural capital (-1), particularly marine life and coastal environments (Burak *et al.*, 2004). Tourism can severely impact natural capital through excessive energy use, transportation, waste generation and water consumption (Zahedi, 2008).

Tourism's three principal environmental impacts include the depletion of natural resources, pollution and land degradation (Lemma, 2014). Support for tourism with no green conditions can result in general infrastructure development in ecologically rich areas, resulting in water degradation, biodiversity loss, soil erosion, and waste generation (GreenTumble, 2022). It can also exert great pressure on the local resources such as energy, food, and minerals, including pressure towards deforestation for fuelwood (Sunlu, 2003). Thus, we expect subarchetypes related to support for general tourism to have a negative impact on natural capital.

Eco-tourism, on the other hand, generates greater environmental awareness and scientific knowledge among tourists, informing attitudes towards conservation. Some eco-tourism initiatives also correspond to conservation efforts, including afforestation and repopulation of endangered species (Swanston, 2018). Eco-tourism initiatives are also likely to shift activities in the sector away from negative natural capital impacts. Thus, green and resilient tourism spending in particular is expected to have a significant positive impact on natural capital over the long term (+1).

We note that there are country-level differences that we are unable to capture with this assessment.

Impacts on air pollution—There is little evidence to suggest that there are significant air pollution consequences of general socio-cultural programs. Therefore, little net change (0) is expected as a result of these policies.

Spending on the tourism industry is expected to have impacts on air pollution through inducing long distance travel, which is pollution intensive (Harrison *et al.*, 2015). We therefore expect air pollution to worsen (-1) as a result of these policies.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that general spending on support for arts and culture organisations has substantial direct impacts for climate change adaptation and resilience, unless it is specifically earmarked for resilience or adaptation purposes, which is rare. These policies are therefore expected to have a neutral (0) impact on direct adaptation and resilience.

Without substantial investments in adaptation and resilience, climate change is expected to have direct, physical impacts on the holiday and leisure sector (Dogru *et al.*, 2019; Walmsley, 2011). Policies which support holiday and leisure businesses with no green conditions will not improve this situation. Policies which include green conditions, such as, for example, requirements for energy efficiency, cannot necessarily be expected to instigate longer-term changes for climate change adaptation and resilience either. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience overall. On the other hand, efforts to specifically adapt and increase the physical resilience of the sector, such as preventing beach erosion, stocking water bodies with adapted species for angling, and setbacks of tourist infrastructure, will have positive direct (+1) outcomes on the adaptation and resilience of the tourism sector (Scott, Hall and Gossling, 2012).

Indirect impacts on environmental adaptation and resilience—As above, whether the policies in question carry green conditions or not, they are unlikely to instigate long-term changes for adaptation and resilience. The expected indirect effect is neutral (0) unless spending is specifically earmarked for adaptation and resilience (particularly in the holiday and leisure sector), in which case it is positive (+1).

Impacts on wealth inequality—Whilst low-income people are likely to benefit significantly from investment in social and cultural programs, as is captured in the quality-of-life measure (Gilmore, 2014), there is little evidence to suggest that there will be and direct impacts on wealth inequality. We therefore expect little net change (0) as a result of these policies.

On tourism-specific archetypes, whilst in some countries, low-income workers may be protected by these programs, there are others in which the exploitation of workers is rife in the tourism and leisure industry. Given these opposing factors, we expect little net change (0) as a result of these policies, noting that there is significant country-level variation which we are unable to capture with this assessment.

Impacts on rural livelihoods—Though increased access to social and cultural programs is beneficial for rural livelihoods and development (Duxbury & Campbell, 2011), it is unlikely that policies in this category will have an outsized impact on rural communities as they are not specifically targeted there. We expect these policies to have little impact (0) on average that is specific to rural communities.

There is little evidence to suggest that leisure industry incentives that are not specifically targeted towards rural communities will have significant effects on rural livelihoods beyond what is expected in the general population. We therefore expect little net change (0) to result from these policies. We note that there is significant country-level variation in this archetype, particularly for tourism incentives which can contribute to poverty reduction in rural areas, but also cause climate related damage to rural areas. We are unfortunately unable to capture this variation in our policy assessment.

E. Traditional energy (operational)

Impacts on short- and long-term GHG emissions—Traditional energy is an emissions-intensive sector, and it is expected that many traditional energy assets will become stranded under business-as-usual conditions with no intervention (IRENA, 2017). We therefore expect support for these businesses to result in increased long-term GHG emissions for an economy. As these policies directly perpetuate fossil fuel production and consumption, they are likely to cause large increases in GHG emissions long term. Therefore, these policies are expected to result in significant increases in GHG emissions (-2) both short and long term.

Impacts on natural capital—Traditional energy projects, especially those involved with the extraction of fossil fuels, can have significant negative impacts on natural capital. Spending on traditional fossil-fuel driven power generation poses concerns for natural capital and the environment (El-Sharkawi, 2021). Its effects can include, among others, soil erosion, vegetation destruction, aquatic ecosystem disturbance and toxic pollution (Lin *et al.*, 2005; Meng, 2017).

Fossil fuel power plant operations have both short- and long-term impacts on water availability and quality, wetlands, vegetation, wildlife, protected species, land and soil quality (El-Sharkawi, 2021). Associated drilling, extraction, transportation, burning and consumption of fossil fuels is land-intensive, significantly affects wildlife, pollutes streams and rivers, and contributes to soil erosion (MET Group, 2020).

Oil, coal and gas refineries are a major source of water and soil pollution (Hazardous Substance Research Center, 2003), including through harmful waste streams and accidental spills which contaminate surface and ground waters (Groundwork, 2020). Effluents from oil refineries such as ammonia, sulphides, phenol, and hydrocarbons can also have adverse impacts for the aquatic environments (Wake, 2005).

Coal mines case destruction of landscapes and habitats, disturbing wildlife and ecosystems (TheWorldCounts, 2021) and resulting in loss of forest cover and biodiversity. They are also associated with soil pollution and deterioration linked to disposal of solid waste, contaminated water and acid mine drainage (Paltasingh & Satapathy, 2021). Coal mines contribute to groundwater contamination through acidic water leakages and chemical and dust pollution (TheWorldCounts, 2021). Transportation of fossil fuels from mines or wells also poses a serious risk of accidents and spillage. Natural gas transmission is prone to methane leakages, while oil spills have adverse impacts on land, biodiversity, and water resources (UCS, 2016).

Spending on efficiency or resilience of fossil fuel energy systems is not the exception in this assessment. Energy efficiency projects may include insulation, weather stripping around windows and doors, and efficient appliances (Huxley-Reicher, 2022). Climate-resilient fossil fuel energy systems, if they exist, require generation diversity, grid automation, distributed resources, and interagency planning (Marcacci, 2019), as well as potentially involving underground distribution networks, improved early warning systems, flood regulating infrastructure, and implementation of smart grids (IEA and OECD, 2015). While these measures can lead to increased energy efficiency and environmental performance, they will also prevent the phasing-out of environmentally destructive traditional energy systems, with overall negative impacts for natural capital.

Therefore, all policies in this archetype are expected to have a negative impact (-1) on natural capital.

Impacts on air pollution—The fossil fuels involved in traditional energy in traditional energy infrastructure are also sources of a number of air pollutants, including sulphur dioxide (Shindell & Smith, 2019). We therefore expect these policies to worsen (-1) air pollution.

Direct impacts on environmental adaptation and resilience—Continued support without green conditions enables energy companies to continue acting in a business-as-usual manner which is incompatible with the realities of climate change. In the long-term, this will reduce the adaptive capacity and resilience of energy companies since they will become more vulnerable to climate change (IEA and OECD, 2015; OECD, 2018). If support policies are short-term, we expect them to have a neutral (0) long-term impact on direct adaptation and resilience, while longer-term maintenance policies are expected to have a negative impact overall (-1).

Measures to maintain the resilience of traditional energy infrastructure range from management and technical solutions to technological and structural measures. Management and technical measures can include vegetation management, load forecasting, and improved early warning systems (IEA and OECD, 2015). Technological and structural measures can include maintaining flood-prone and offshore infrastructure, and the implementation of smart grids and micro grids to better manage generation and distribution (IEA and OECD, 2015). Policies that address these measures specifically are expected to have a positive (+1) direct impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—As above, support which enables traditional energy companies to continue business as usual reduces adaptive capacity and resilience. Short-term support will likely have a neutral impact, while long-term support may have a negative impact on indirect adaptation and resilience.

Maintenance of traditional power plants, for example, has complex impacts on indirect adaptation and resilience. Access to energy is a crucial determinant of development and of adaptive capacity, thus support for energy generation has positive impacts for indirect adaptation (Maller and Strengers, 2011; Scott *et al.*, 2015). Energy can include locally available sources, such as biomass, as well as more infrastructural solutions, such as electricity grids (Scott *et al.*, 2015). However, this archetype captures spending on power plants without consideration for climate change resilience; therefore, the positive impacts of maintaining generation capacity may be outweighed by its vulnerability to future climate impacts (Urban and Mitchell, 2011; IEA, 2021). The maintenance of power plants also provides jobs (a positive for adaptive capacity); however, these jobs are not in a sustainable sector (Pai *et al.*, 2020; Evans & Phelan, 2016). Moreover, in the long-run, traditional power plants will contribute to GHG emissions, thus worsening climate change and, therefore, adaptation outcomes for communities and systems. As such, these policies are expected to have an overall negative (-1) impact on indirect adaptation and resilience.

Policies that focus on maintaining the resilience of energy infrastructure have a positive (+1) indirect impact on adaptation and resilience by enhancing adaptive capacity of individuals and systems.

Impacts on wealth inequality—There is little evidence to suggest that there are significant first order impacts on wealth inequality resulting from traditional energy infrastructure investment. We therefore expect little net change (0) to result from these policies.

Impacts on rural livelihoods—Traditional energy projects are often sited in rural areas and despite some short-term financial gains (Mishra, 2009), rural communities face a number of negative consequences from these policies, including negative health impacts. These policies are therefore expected to generate negative impacts (-1) for rural livelihoods.

F. Clean energy (operational)

Impacts on short- and long-term GHG emissions—For this policy archetype, we expect improvements in GHG emissions in the long term. Clean energy spending facilitates the transition away from fossil fuels and therefore significantly reduces GHG emissions (Shafiei and Salim, 2014). Hence, these policies are expected to result in a significant decrease in emissions both short and long term (+2).

Measures to improve the resilience of existing clean energy infrastructure range from management and technical solutions to technological and structural measures. Management and technical measures can include load forecasting and improved early warning systems (IEA and OECD, 2015). Technological and structural measures can include designing wind turbines for higher wind speeds or maintaining flood-prone and offshore infrastructure (IEA and OECD, 2015). Operational spending does not include materials-intensive new construction initiatives, and in the long-run, more resilient clean energy infrastructure will prolong the lifespan of these facilities, thus enabling greater renewable energy consumption, which in turn decreases greenhouse gas emissions (Shafiei & Salim, 2014; IEA, 2021). Clean energy resilience policies are thus expected to have a positive (+1) long-term impact on greenhouse gas emissions.

Impacts on natural capital—Clean energy spending, whilst it may have some natural capital impacts in its own right, offsets the need for continued fossil fuel use, thereby mitigating further negative natural capital effects that result from traditional energy (Lin *et al.*, 2005; Meng, 2017). Thus, clean energy use reduces the environmental impacts associated with drilling, extraction, transportation, burning and consumption of fossil fuels (MET Group, 2020). As well as reducing

GHGs, this will also reduce other environmental effects of traditional energy generation, such as acid rain from coal burning (Rahman and Castro, 1995) or dissemination of heavy metals from coal ash (Ruhl *et al.*, 2010). Many renewable energies also reduce demand for water as electricity is not generated using steam turbines (Saidur *et al.*, 2011).

However, clean energy also has impacts on natural capital. Solar energy, particularly solar farms, have impacts on natural capital through land use and local reduction of ground temperatures, which may affect ecosystems (Gunerhan *et al.*, 2008). The literature on wind farms is somewhat mixed. Saidur *et al.*, (2011) notes a relatively low impact on natural habitats compared to other energy generation activities. However, wind turbines are linked to avian and bat mortality. Bailey *et al.*, (2014) find that offshore wind farms disturb marine habitats by creating noise and collision risks to marine species, but may also provide shelter and act as artificial reefs.

Energy transmission systems have a physical footprint that requires land, and their development can adversely affect natural habitats through disturbance and fragmentation. Transmission lines also present electrocution and collision risks to birds and bats; however, if suitably planned, transmission infrastructure does not usually pose a major threat to biodiversity (European Commission, 2018). With adequate planning, energy transmission authorities can make choices to improve the quality of nature (National Grid, 2022).

Battery and storage infrastructure solves the issue of cycling between oversupply and shortages in the renewable energy sector, and thus contributes to replacing fossil fuel energy. However, batteries require significant natural capital inputs including lead and lithium-ion (Stoppato *et al.*, 2021). Lithium extraction may lead to leakages into water courses, which can result in pollution and has led to fish and yak poisoning in parts of China (Hineman, 2020). Pumped hydro energy storage (PHES) systems are extremely water-intensive, and may also have significant local environmental impacts associated with impounding water.

As a result of these mixed impacts, we expect, on average, little net change (0) because of these policies.

Some specific forms of renewable energy have more particular natural capital impacts.

Hydropower dams are well known to disrupt river ecosystems, restrict fish migration and cause sediment transfers (Pringle, 2003). Impoundments associated with hydropower also cause massive flooding of natural habitats and change temperature gradients in rivers. On average, hydropower may be predicted to have negative (-1) impacts on natural capital.

Nuclear power is the subject of ongoing debate concerning its environmental benefits and downsides. Nuclear power generation has the smallest land transformation requirement in m2/GWh of the main electricity producing processes (Rusu *et al.*, 2018). However, with present technology, the risk of serious negative environmental impacts resulting from nuclear waste and from accidents remains non-negligible (Prăvălie and Bandoc, 2018). When accidents happen, the impact on natural capital can be dramatic, resulting in massive and long-lasting contamination of land and water; contamination and resulting biodiversity loss is also associated with uranium mining and milling processes (Rusu *et al.*, 2018). Nuclear waste disposal also remains a long-term challenge; though it is long-lived, however, it should be noted that this waste is relatively small in volume when compared to waste produced, for example, when using coal to generate electricity (Vujić *et al.*, 2012). Moreover, new generations of nuclear power plants constructed using present spending will be built with enhanced safety features and closed fuel cycles, which would largely mitigate waste issues. Given these trade-offs in potential environmental risk and reduced environmental pressure, there is no overall net natural capital impact (0) associated with spending on nuclear energy generation.

Biofuels similarly have mixed impacts. Like other renewable energy sources, they have positive effects by replacing fossil fuels. However, biofuel feedstocks require land (Jeswani *et al.*, 2020), which can directly or indirectly lead to ecosystem destruction. Biofuel production is extremely land-intensive, with estimates indicating that 8% to 36% of current cropland would be required to meet 10% of global transport fuel demand in 2030 (Bringezu *et al.*, 2009). It is also associated with deforestation, land degradation, increased water use, fertiliser and pesticide application. Evidence indicates that the use of biofuels has caused great harm to biodiversity and ecosystems in South America and South-East Asia (NERC, 2014). For instance, based on national production targets, it was predicted that direct and indirect land-use change associated with biofuels would lead to loss of 121,970 square kilometres of forest by 2020 (Lapola *et al.*, 2010). The link between forest destruction and biofuel production holds true across 112 countries (Keles *et al.*, 2018). Biofuel production is also a major driver of landscape modification, with links to habitat loss, pollution and invasive species, leading to significant natural capital losses (Gasparatos *et al.*, 2018). This raises questions as to the sustainability of biofuel production as a renewable energy source. Whilst biofuel production using algae is being tested, it is assumed that the main production activities funded under this subarchetype relate to land-based production systems. As such, spending directed towards production of biofuels is considered to have a significant negative impact on natural capital (-1).

Some hydrogen energy production can have adverse environmental impacts, particularly if hydrogen is produced from coal without carbon capture and storage (Herzog and Tatsutani, 2005). Distribution infrastructure for hydrogen power also has varying impacts with respect to land-use change. Pipelines, trucks, and high-pressure gas tubes for hydrogen distribution create demand for materials and put pressure on natural capital. However, hydrogen power will generally use less fossil fuels than existing fuel sources, pose a much lower risk of pollution incidents compared to oil or petrol, and hydrogen distribution systems may substitute for other fuel transmission infrastructure. As such, there is no net overall natural capital impact (0) expected for spending on this subarchetype.

Impacts on air pollution—Since clean energy is a direct substitute for fossil fuels based energy, which itself produces significant air pollution (Shindell & Smith, 2019), we expect a decrease in air pollution (+1) to result from these policies.

Direct impacts on environmental adaptation and resilience—Typically, the green conditions associated with support for the energy sector relate to energy transition and GHG reduction initiatives, as opposed to climate change adaptation and resilience measures (UK Government, 2021a; BNDES, 2020). Moreover, short-term programs in particular are unlikely to impact the long-term trajectory of adaptation and resilience. These policies are therefore expected to have a neutral (0) long-term impact on indirect climate change adaptation and resilience.

On the other hand, measures to improve the resilience of traditional energy infrastructure have a positive effect. These range from management and technical solutions to technological and structural measures. Management and technical measures can include load forecasting and improved early warning systems (IEA, 2015). Technological and structural measures can include designing wind turbines for higher wind speeds or maintaining flood-prone and offshore infrastructure (IEA, 2015). Policies that address these measures are expected to have a positive (+1) direct impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Clean energy spending provides sustainable jobs, increasing livelihood opportunities and thus adaptive capacity, i.e. the ability of individuals or households to be resilient in the face of a climate change induced shock (Mimura *et al.*, 2014; Colting-Pulumbarit *et al.*, 2018). Clean energy spending also enhances access to energy, and energy is a crucial determinant of development and of adaptive capacity (Maller and Strengers, 2011; Scott *et al.*, 2015).

However, this archetype includes investment in clean energy infrastructure without consideration for climate change resilience. Renewable generation facilities are vulnerable to climate change impacts, particularly the increased incidence and strength of extreme weather events and rising sea levels, which threaten physical facilities, as well as through changes in water availability, which impacts hydropower, as well as thermal power plants' cooling facilities (IEA, 2015; OECD, 2018). Therefore, the positive impacts of energy access are somewhat outweighed by the vulnerability of these facilities to future climate impacts (Urban and Mitchell, 2011; IEA, 2021). On balance, clean energy policies with no consideration for resilience are thus expected to have a neutral (0) impact on indirect adaptation and resilience. On the other hand, policies that enhance the resilience of energy infrastructure have a positive (+1) indirect impact on adaptation and resilience by enhancing adaptive capacity of individuals and systems.

Impacts on wealth inequality—There is mixed evidence surrounding the impact of renewable energy on wealth inequality. Whilst some studies have found that renewable energy adoption reduces income inequality (Topcu & Tugcu, 2020), others have found that the shift towards clean energy may exacerbate energy inequality and therefore increase income inequality (McGee & Greiner, 2019). As a result of this mixed evidence, we expect, on average, little net change (0) as a result of these policies.

Impacts on rural livelihoods—There are mixed impacts of clean energy infrastructure in rural communities. Rural areas are often chosen as locations for renewable energy projects (Lombard & Ferreira, 2015), and impacts range from land use changes which may not be beneficial to rural communities, to increased availability of high-quality jobs in those areas (Bergmann *et al.*, 2008; Poggi *et al.*, 2018). We therefore expect, on average, little net change (0) as a result of these policies.

G. Traditional transportation (operational)

Impacts on short- and long-term GHG emissions—Support for airlines and other traditional transport is likely to lead to large increases in GHG emissions (-2) relative to a scenario in which these policies were not implemented, as these are emissions-intensive sectors (IEA, 2018). In the short and long term, traditional transport spending and particularly funding for aviation sites and road maintenance, increases the general utility of transportation vehicles, including planes and ICEV, thus delivering heightened use of those assets and increased GHG emissions in the long run. However, the effects of operational spending are very small relative to the effects of new construction, covered by the corresponding discretionary archetype.

Port and ship construction supports freight, which tends to be a carbon-intensive mode of transportation, but not as intensive as other options (Bouman, 2017; Cristea, 2013; Lindstad *et al.*, 2012).

Overall, this archetype attracts the score of (-2) in the long run.

Impacts on natural capital—There is evidence to suggest that traditional transport spending has a negative impact on natural capital, with adverse impacts on land, biodiversity and natural capital stocks (Liang & Ye, 2021).

Roads in particular can have significant indirect impacts on natural capital, in particular increased exploitation of natural capital due to enhanced access, including agricultural takeover of surrounding natural vegetation, timber harvesting, and hunting. This leads to diminished ecosystem services, including water quality, flood regulation, coastal protection, and climate regulation (Mandle *et al.*, 2016). Bridges impact rivers, aggravates soil erosion, and put essential hydrological services provided by rivers at risk (Xiaofeng *et al.*, 2021). Roads can also potentially impact fisheries through changes to peak storm flow, rising sedimentation in stream water, and loss of streamside vegetation, culverts and other barriers and landslides (Mandle *et al.*, 2016).

Moreover, traditional combustion vehicles, in order to function, require a number of environmentally destructive processes, including oil extraction, refining, and transportation. This generates pollution and puts stress on raw materials (Samsara, 2021) as well as on the environments in which they are extracted.

Airports and associated roads may disturb ecosystems through noise pollution and by constituting disruptive physical barriers and divisions (Forman & Deblinger, 2000). Overall, the main natural capital impacts of aviation operations are from emissions, waste and energy consumption (Sameh & Scavuzzi, 2016).

Ports and ships produce noise which disturbs wildlife, discharges of ballast water which spread invasive species, sewage, sludge, oil and anti-fouling treatments from ships which contaminate port waters; certain hazardous cargos also pose wider environmental risks (OECD, 2011). Port operations themselves can also cause water pollution, resulting in degradation to marine habitats and loss of aquatic species (US EPA, 2021). All of these factors indicate additional stress on natural ecosystems and marine life.

Thus, a significantly negative long-term natural capital impact (-1) is associated with spending on this archetype.

Impacts on air pollution—The air pollution effects of transportation methods that involve the combustion of fossil fuels have been well documented. A large body of evidence shows that this kind of transport causes large amounts of air pollution including nitrogen oxides and sulphur oxides (Lozhkina & Lozhkin, 2016). We therefore expect air pollution to worsen (-1) as a result of these policies.

Direct impacts on environmental adaptation and resilience—Continued support without green conditions will enable transportation providers to continue emitting greenhouse gases. In the long-term, emitting greenhouse gases will contribute to climate change, which will have adverse physical impacts. Long-term operational support to this industry can be expected to have a negative effect on direct adaptation and resilience (-1).

Indirect impacts on environmental adaptation and resilience—Again, support for greenhouse gas-emitting transportation systems will enable continued emissions, as well as indirectly preventing accelerated transition towards greener forms of transportation. This will have a negative effect on indirect adaptation and resilience in the long term (-1).

Impacts on wealth inequality—There is little evidence to suggest that traditional transport infrastructure has significant impacts in wealth inequality. We therefore expect little net change (0) as a result of these policies.

Impacts on rural livelihoods—Rural communities are physically isolated from essential goods and services that may not exist in their location, therefore operations to ensure access to transportation disproportionately benefit rural communities (Arcury *et al.*, 2005). It is therefore expected that these policies will improve rural livelihoods (+1).

H. Clean and/or resilient transportation (operational)

Impacts on short- and long-term GHG emissions—In the short term, little change in emissions is expected from operational policies, although they may encourage consumption with a small negative effect. Long term, clean transport spending plays a vital role in reducing GHG emissions, as it directly disincentivizes the use of high-emission traditional transport modes such as personal ICEVs (Dominković, 2018; Hardman *et al.*, 2017; Rudolph, 2016). It is therefore expected that clean transport spending brings a small negative short-term change in GHG (-1), but large improvements in GHG emissions long-term (+2). Public transport digitalisation efforts are an exception, with no short-term impacts on GHG emissions (0).

Efforts to increase the physical resilience of transportation infrastructure to climate change are varied, including conducting more frequent maintenance (Markolf *et al.*, 2019). While transportation infrastructure in general contributes to greenhouse gas emissions by facilitating the use of combustion vehicles (Lozhkina & Lozhkin, 2016), those impacts are attributed to BAU use of existing infrastructure, not to additional resilience measures specifically. The long-term impacts of more resilient transportation infrastructure are expected to be positive (+1).

Electric vehicle (EV) spending in particular spurs heightened demand, especially in countries with sufficient infrastructure supporting easy utilisation (Hardman *et al.*, 2017; Rudolph, 2016). EV production brings a moderate increase in GHG emissions, in some cases even more than conventional vehicles due to the resources and energy consumed during battery production (Hawkins *et al.*, 2013). That said, the difference can be relatively small (Hawkins *et al.*, 2012). Further, there is substantial scope for recycling and repurposing of batteries, driving down the yearly average of GHG emissions associated with the production phase of EVs (Ahmadi *et al.*, 2015; Bobba *et al.*, 2018; Casals *et al.*, 2015). The strongest driver of EV emissions is the energy-mix used for powering the car (Faria *et al.*, 2013; Jochem *et al.*, 2015). EVs powered with a coal-heavy energy mix, assuming an extreme case, may have a higher carbon footprint than highly efficient ICEVs (Hawkins *et al.*, 2012; Huo *et al.*, 2010; Woo *et al.*, 2017; Wu *et al.*, 2012). Regional case studies, performed in coal-powered regions in China, Poland, and the US corroborate this (Burchart-Korol *et al.*, 2018; Huo *et al.*, 2010). Nevertheless, assuming a moderately clean energy mix, higher utilisation of EVs is associated with substantial reductions in GHG emissions over the vehicle's full lifecycle (Hawkins *et al.*, 2013). Further, in the case of a sustainable energy mix, like that in Scandinavia, lifecycle emissions are lower than that of traditional internal combustion vehicles by a significant margin (Faria *et al.*, 2013; Jochem *et al.*, 2015). Hence, incentivising EV purchases, in conjunction with a clean energy mix, is a crucial component of the transition towards a clean economy (Buekers *et al.*, 2014; Jochem *et al.*, 2015). Considering the above, we assume an increase in GHG emissions in the short term (-1) for EV spending due to the carbon footprint of the manufacturing process. In the long run, this spending is expected to lower GHG emissions, with the size of the benefit determined by the domestic energy-mix. The countries under assessment vary significantly with respect to said factor (IEA, 2020c). For the long term, an average of (+1) is assigned.

Rail spending increases the ease of public transportation and the efficiency of rail shipment, which lowers national GHG emissions associated with transportation in the long term (+1).

Impacts on natural capital—Green transportation spending may have a somewhat positive impact on natural capital by supplanting more damaging traditional transportation, but transportation systems in general tend to have negative impacts on natural capital. On balance, there is little evidence to suggest that these policies will have significant natural capital impacts. We therefore expect little net change (0) as a result of these policies.

Spending on electric vehicles (EVs) tends to increase the proportion of electric vehicles in the fleet, thus replacing more of the demand for combustion engine vehicles with demand for electric vehicles. The main unique component of EVs is lithium-ion cells, which rely on extraction of raw materials including cobalt, lithium and rare earth minerals. This is linked to environmental concerns including sulphur dioxide emissions and other pollution (Tabuchi & Plumer, 2021). During lithium extraction, leakages into water courses can result in pollution, which has been observed to led to fish and yak poisoning in parts of China (Hineman, 2020). Electric vehicles have additionally been estimated to have a greater resource footprint than combustion engine vehicles over their lifecycle, including in the operation and maintenance phases of their use. The resource extraction and pollution effects associated with increasing the number of EVs constructed and used imply a significant negative impact on natural capital (Kosai *et al.*, 2021). Though after the manufacturing stage the natural capital impacts of electric vehicles are negligible, there are some significant impacts involved in the manufacturing process, particularly for batteries. There are high environmental costs to the mining of lithium for these batteries, though there is high potential for recycling these and other materials used in EV construction (Van Mierlo *et al.*, 2017). If we consider these impacts as part of the result of EV spending, these policies are expected to have negative natural capital impacts (-1).

Impacts on air pollution—Green transportation spending facilitates the transition away from traditional transportation methods which cause significant air pollution (Lozhkina & Lozhkin, 2016). We therefore expect the policies, in general, to result in an improvement in air pollution (+1). We note, however, this is dependent to some degree on the electricity generation mix in the country (Buekers *et al.*, 2014). Unfortunately, we are unable to capture this effect with this archetype assessment.

Though electric vehicles are not usually free of air pollution impacts over their lifespan, they produce substantially fewer pollutants than their conventional counterparts, and this is somewhat variable by the electricity generation mix in the country (Ke *et al.*, 2017). Therefore, electric vehicle spending is expected to cause a net improvement (+1) in air quality.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that indiscriminate spending on clean transport infrastructure has any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience. In particular, policies with green conditions usually compel airlines and other transportation companies to reduce their greenhouse gas emissions by switching to less carbon-intensive fuel or undertaking alternative actions (Abate *et al.*, 2020), without significantly changing their production models. Consequently, these policies will likely have little (0) impact on direct climate change adaptation and resilience.

Electric vehicles (EVs) also have mixed effects for resilience. EVs can contribute to the resilience of the electricity grid by absorbing renewable energy and provided a power source during outages (Hussain & Musilek, 2022); however, lack of access to electricity during an outage can also prevent the use of EVs for evacuation purposes (Adderly *et al.*, 2018). Relevant policies are therefore expected to have a neutral (0) impact for both direct and indirect climate change adaptation and resilience.

However, longer-term, non-EV policies with more direct relevance to the resilience of transportation provision are predicted to have a positive impact. Supporting high levels of efficiency in dirty transport, for instance, should reduce GHG emissions (Jacyna *et al.*, 2017) and is therefore expected to have a positive (+1) impact on direct climate change adaptation and resilience. Moreover, policies specifically aiming to maintain the adaptability and resilience of transport systems also have a positive effect. Physical transportation infrastructure is expected to be adversely and directly impacted by climate change, particularly as a result of temperature change, changes in precipitation, extreme weather events, and flooding (Markolf *et al.*, 2019). Efforts to sustain the physical resilience of transportation infrastructure to climate change include conducting more frequent maintenance among other measures (Markolf *et al.*, 2019). These policies are expected to have a positive (+1) direct impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Transportation infrastructure is a key determinant of adaptive capacity, i.e. the ability of individuals and systems to adapt and respond to climate change impacts (UNEP, 2021; Keskitalo *et al.*, 2011; Mimura *et al.*, 2014). Transportation infrastructure is expected to be highly adversely impacted by climate change, particularly as a result of temperature change, changes in precipitation, extreme weather events, and flooding (Markolf *et al.*, 2019). Policies that maintain existing green or resilient transportation infrastructure, and therefore sustain adaptive capacity, are thus expected to have a positive (+1) indirect impact on adaptation and resilience.

Impacts on wealth inequality—Though many clean transport options such as public transport and cycling are low-cost relative to other transport methods and therefore theoretically more likely to benefit low-income individuals, there is little evidence to suggest that this translates to tangible wealth inequality effects. We therefore expect little net change in wealth inequality (0) as a result of these policies.

The impacts of electric vehicle incentives on wealth inequality depend in large part on how well they are targeted, but it is often the case that, because of the prohibitively high costs of electric vehicles at present, the vast majority of electric vehicle incentives go to very wealthy consumers despite subsidies (Borenstein and Davis, 2016). Therefore, unless policymakers learn from mistakes of the past, on average, electric vehicle incentives are likely to worsen wealth inequality (-1).

Impacts on rural livelihoods—Rural communities are physically isolated from essential goods and services that may not exist in their location, therefore spending on transportation operations disproportionately benefits rural communities (Arcury *et al.*, 2005). It is therefore expected that these policies will improve rural livelihoods (+1).

Uptake of electric vehicles is much higher in metropolitan areas than in rural areas, due to economic factors as well as lack of charging infrastructure (Chen *et al.*, 2020; Westin *et al.*, 2018). These policies are therefore unlikely to impact rural populations significantly (0).

I. Communications (operational)

Impacts on short- and long-term GHG emissions—Little short-run change in emissions is expected from operational policies. In the long run, mixed effects will follow. First, considering the complementary nature of infrastructure and ICT devices, we assume an increase in demand for such goods will be seen as soon as the investments are completed. The manufacturing of ICT devices, mobiles, laptops, and the like for operational communications policies carries a substantial carbon footprint (Lange *et al.*, 2020). Further, the utilisation phase of such appliances entails energy usage, which in a setting with a carbon-heavy energy mix can mean heightened GHG emissions (Van Heddeghem *et al.*, 2014; Webb, 2008). Infrastructure maintenance and operations contribute somewhat to the national carbon footprint through electricity used for power and cooling (Gombiner, 2011). Nevertheless, the ICT sector has been at the forefront of efficiency increases in terms of energy usage, which is tracked by its substantial global carbon footprint (Van Heddeghem *et al.*, 2014; Malmodin and Lundén, 2018).

In the long term, improved communication network coverage will presumably alter the day-to-day behaviours of individuals and firms (see Coroama *et al.*, 2012; Danish *et al.*, 2018; Esselaar *et al.*, 2007; Um *et al.*, 2002; Gilwald and Stork, 2008; Gutierrez *et al.*, 2009). Digitalisation could lead to some positive effects on national GHG emissions. As just one practical example, electronic invoicing can substantially reduce energy consumption compared to traditional invoicing (Moberg *et al.*, 2010). Similar arguments regarding the possible environmental benefits resulting from digitalisation are shown by Weber *et al.* (2010) for downloading music and by Amasawa *et al.* (2018) for the adoption of e-readers.

ICT development has been widely associated with decreased vehicle use and reduced traffic, which has a double emissions benefit (Esselaar *et al.*, 2007; Um *et al.*, 2002; Gilwald and Stork, 2008; Gutierrez *et al.*, 2009). Practices like remote working and internet conferencing are among the drivers of this relationship (Coroama, *et al.* 2012; Gutierrez *et al.*, 2009). Nevertheless, general positive impacts on GHG emissions from efficiency gains may not be realised if rebound effects are included in the evaluation (Jevons, 1906; Khazzoom 1980). Increases in efficiency may spur lower savings rates and substitution effects. The ICT sector is arguably especially prone to substantial rebound effects, as it greatly decreases the costs of service delivery (Lange *et al.*, 2020). Per sale, internet retail reduces the GHG emissions of distribution, but if the ease of purchase leads to increased demand, the net effects on emissions are mixed (Al-Mulali *et al.*, 2015; Horner *et al.* 2016; Mangiaracina *et al.*, 2015).

Further, rebound effects might include accelerated economic growth, associated with increased productivity and production (Lange *et al.*, 2019). This has been supported by regional studies in OECD countries, US, Finland, and several South Asian countries (Erumban and Das, 2016; Jalava and Pohjola, 2008; Jorgenson *et al.*, 2016; Lange *et al.*, 2020; Lee and Brahmasrene, 2014; Salahuddin and Alam, 2016; Wang, 1999). Nevertheless, the causal relationship between ICT development and economic growth remains controversial (Lange *et al.*, 2020). Civil cybersecurity programmes and implementation of digital programmes do not come with significant short-term impacts on GHG emissions.

In general, as the archetype in question facilitates the long-term development of ICT technologies on the national scale, we assume mixed and ambiguous effects, and therefore a score of (0).

Resilience spending for existing communications infrastructure may include spatial and environmental planning (Fu *et al.*, 2016; Sansavini, 2017). Other improvements may include new technologies, such as the use of cloud computing to shift computational loads away from regions experiencing extreme weather conditions, and improved contingency planning and use of early warning systems (Fu *et al.*, 2016). Many of these solutions involve enhanced planning and use of existing systems, thus limiting short-term GHG emissions. We therefore expect little net change (0) in short-term and long-term greenhouse gas emissions from these policies.

Impacts on natural capital—There are expected to be some natural capital impacts resulting from the expansion of communications infrastructure (Maeng & Nedovic-Budic, 2004), as well as impacts from hazardous materials use and often improper recycling (Williams, 2011). Investment in ICT hardware at any scale also has the potential to generate significant streams of electronic waste. However, technological improvements and general spending on communications provide vital tools for facilitating the protection of natural capital. Moreover, although communications spending may generate electronic waste and require natural capital inputs for construction, it may also reduce demands for hard infrastructure such as transport, for instance through teleworking. Considering these opposing natural capital impacts, we expect that, in general, policies under this archetype are likely to result in little net change (0) in natural capital. We recognise that there is variation at the policy level that is unable to be captured using this assessment method.

Impacts on air pollution—For most communications spending, there are likely to be negative impacts on air pollution resulting from materials and energy use. We therefore expect worsened air pollution (-1) as a result of these policies. In the case of civil cybersecurity programs and implementation of digital programs, there is little evidence of significant air pollution effects, as they are primarily software measures. We therefore expect little net change in air pollution (0) as a result of these subarchetypes.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that operational communications spending in general has any direct impacts for climate change adaptation and resilience. These policies are therefore generally expected to have a neutral (0) impact on direct climate change adaptation and resilience. However, climate change is expected to have adverse direct impacts on physical communications infrastructure, in particular through the increased prevalence of heatwaves and flooding (Fu *et al.*, 2016). Spending specifically intended to maintain the physical resilience of communications infrastructure may include maintenance of physical structures and networks, including diversity of systems as well as network nodes for at-risk regions that do not have diversified network coverage (Fu *et al.*, 2016; Sansavini, 2017). These policies are expected to have a positive (+1) direct impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Resilient communications infrastructure has been shown to improve the ability of economies and communities to adapt to climate change (Fu *et al.*, 2016). There are numerous potential indirect impacts of communications investment on adaptation and resilience. For instance, communications infrastructure may facilitate emergency communications, which indirectly contributes to environmental adaptation and resilience. Communications spending may also facilitate other adaptability- or resilience-enhancing initiatives, such as education or worker retraining. Additionally, as a tentative hypothesis, spending on infrastructure relevant to remote working in particular, as a subset of communications infrastructure, is expected to induce long-lasting behavioural change in individuals and organisations (Lund *et al.*, 2021; Mark *et al.*, 2022). Remote working options may enable greater flexibility and adaptation in the face of disruptions caused by climate change, such as future natural disasters. Efforts to maintain the resilience of communications infrastructure are thus expected to positively (+1) impact indirect adaptation and resilience.

Impacts on wealth inequality—Digital connectivity has been shown to have mixed effects on income inequality, depending on surrounding economic, political and technological factors (Bauer, 2018). We therefore, on average, expect little change (0) resulting from these policies.

Impacts on rural livelihoods—There exists a significant disparity between connectivity and access to broadband and digital technologies between rural and non-rural communities. Rural communities benefit substantially from these policies as they help avoid problems of unequal access to information, services and social opportunities among other things (Townsend *et al.*, 2013). We therefore expect that these policies will likely have a positive impact (+1) on rural livelihood.

J. Other utilities (operational)

Impacts on short- and long-term GHG emissions—Short-term impacts of all spending on this archetype are expected to be neutral or slightly negative due to requiring or facilitating resource use. For clean and resilient utilities specifically, long-term impacts could be moderately to significantly positive, depending on the scale of the investment. As a baseline, most clean and resilient utilities are expected to see reductions in greenhouse gas emissions (+1), due to improved energy efficiency (Stephens *et al.*, 2013).

Impacts on natural capital—Utilities have a physical footprint and can adversely affect natural capital. However, maintaining utilities is important for efficient use of natural capital (e.g., addressing water leakages) and avoiding pollution incidents (e.g., stormwater and sewage discharge to aquatic ecosystems). Utilities providers can even act with explicit natural capital objectives in mind (National Grid, 2022) and using green infrastructure, for instance in managing stormwater flows (Chini *et al.*, 2017). There is a risk that spending on utilities may prolong the use of fossil fuels, particularly gas. However, overall, we expect a significant and positive natural capital impact associated with spending on this subarchetype (+1).

Impacts on air pollution—There is little evidence of significant air pollution effects from utilities spending. We therefore expect little net change in air pollution (0) as a result of this archetype.

Direct impacts on environmental adaptation and resilience—Climate change is expected to have adverse direct impacts on local utilities, with disruptions expected to water and energy supply, as well as sanitation systems (OECD, 2018; OECD, 2013). Extreme weather events and flooding are projected to damage physical infrastructure and impact water quality, while changes in temperature and precipitation will place additional pressure on water resources (OECD, 2018; OECD, 2013). Measures to maintain the resilience of local utilities may include management initiatives, such as load forecasting, vegetation management, promotion of behavioural change, and disaster mitigation planning (OECD, 2018). Structural measures may include retrofitting, reinforcing or relocating existing infrastructure or using more resilient materials (OECD, 2018; Huang *et al.*, 2017). Policies that focus on 'clean' or 'green' investments in local utilities, such as smart grid technology or the use of natural infrastructure, typically also enhance resilience. These policies are therefore expected to have a positive (+1) direct impact on adaptation and resilience.

There is little evidence to suggest that spending on utilities in general, without particular regard for resilience or greenness, has any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—The services that are provided by local utilities (water supply, waste and sanitation, energy provision) are crucial to the functioning and adaptive capacity of individuals, communities, and systems (Mimura *et al.*, 2014). As such, investing in resilient local utilities indirectly enhances adaptation and resilience of communities and economies more generally. Moreover, the adverse physical impacts of climate change on local utilities have cascading effects for local communities and economies. For example, in many sectors of the economy, disruptions and economic losses during or after an extreme weather event are primarily caused by disruptions to basic services such as energy supply, rather than due to direct physical damages from the weather event (OECD, 2018). Therefore, policies that enhance the resilience of local utilities are expected to have a positive indirect (+1) impact on adaptation and resilience. Policies that focus on 'clean' or 'green' investments in local utilities, such as smart grid technology or the use of natural infrastructure, typically also enhance resilience.

However, general investment in utilities without regard for resilience may see its usefulness outweighed by its vulnerability to the effects of climate change. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Impacts on wealth inequality—Utilities are crucial to collective life regardless of wealth. Although more impoverished communities tend to be more affected by lacking or dysfunctional utilities services, there is little evidence that non-targeted utilities spending in general has any significant effect on wealth inequality. We therefore expect little net change in wealth inequality (0) as a result of this archetype.

Impacts on rural livelihoods—Again, although rural communities may tend to be more affected by lacking or dysfunctional utilities services, there is little evidence that general utilities spending not targeted at rural communities has any significant specific effect on rural livelihoods. We therefore expect little net change in rural livelihoods (0) as a result of this archetype.

K. Military (operational)

Impacts on short- and long-term GHG emissions— Spending on the armed forces is likely to cause significant increases in GHG emissions, both in the short and long term. Short term impacts are likely to be coupled to the purchase of equipment and enhancement of capabilities, while long term effects will result from continued use of hydrocarbon fuels (Belcher *et al.*, 2019; Clark *et al.* 2010). We, therefore, expect large increases in GHG emissions (-2) in both the short and long term for this archetype.

In the case of administration funding, GHG effects are likely to be smaller (-1) in the short term for administrative investments, but in the long term, this subarchetype still directly facilitates carbon-intensive operations, thus the long-term score (-2) remains.

Researchers should note that some governments mobilise their military personnel for environmental initiatives that might indirectly support lower GHG emissions. For instance, the Seychelles Coast Guard is a branch of the defense force that actively engages in environmental protection. In the case that military support is clearly divided into those programs which do and don't serve environmental objectives, we consider that the relevant environmentally positive designations might be better categorized to another archetype (with the most appropriate archetype determined by the sector that is supported). As always, the researcher should use their discretion.

Impacts on natural capital—Beyond the devastating and long-lasting environmental consequences of military conflict (UNEP, 2019), land use by the armed forces even in peacetime is significant and can have large negative consequences for natural capital. In particular, military land use has been shown to decrease biodiversity and has sizable impacts on ecosystem structures (Lawrence *et al.*, 2015). The impact of military equipment production and transportation on natural capital is also expected to be substantial. In some cases, military spending may be associated with peacekeeping or conflict deterrence, and some armed forces even participate in nature protection activities (Defence Infrastructure Organisation, 2021). However, the relevance of these factors is limited, and their effect is small compared to other impacts of military spending. We therefore expect overall negative natural capital consequences (-1) as a result of these policies.

Impacts on air pollution—It is likely that armed forces investment will have a negative impact (-1) on air pollution, especially through construction and use of vehicles and aircraft, in addition to other military operations (Hamilton, 2016).

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that armed forces spending will have any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—There is little evidence to suggest that armed forces spending will have any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—There is a significant body of evidence suggesting that spending on armed forces and the military has negative impacts for income inequality. The reasons for this include differences in pay between civilian and military work, gender inequality in the military compounding existing gender-based pay disparities, and increasing capital intensity (Abell, 1994; Kentor *et al.*, 2012; Biscione & Caruso, 2019). We therefore expect income inequality to worsen (-1) as a result of these policies.

Impacts on rural livelihoods –There is little evidence to suggest that there are significant impacts on rural livelihood resulting from armed forces spending. Though in some countries, individuals from rural communities are more likely to join the armed forces, this is not the case across the board. We therefore expect little net change (0) as a result of these policies, noting that there is country-level variation that we are unable to capture with this assessment.

L. Emergency response services (operational)

Impacts on short- and long-term GHG emissions—Support for emergency services is vital, but in the short term, often involves manufacturing to ensure that sufficient resources for crisis management are available. This manufacturing is likely to bring a short-term increase in GHG emissions, driven by energy and materials usage (Behrens, 2016). In the long term, however, there is little evidence to suggest significant GHG impacts. We therefore expect a moderate increase in emissions short-term (-1), but little net change in the long term (0).

Administrative support for emergency response is not likely to involve significant marginal manufacturing, and therefore we expect little net change (0) for both short and long-term GHG impacts for this subarchetype.

Impacts on natural capital—There is little evidence of significant natural capital effects resulting directly from emergency services support, especially because it is non-infrastructural in nature. Procurement of emergency response equipment may generate significant waste streams in the short to medium term; however, particularly in the long term, it is unlikely to have significant impacts on the exploitation of natural capital for materials or as waste sinks. Emergency services support may create localised short-term pressures on the environment, but the scale of cumulative natural capital impacts is likely to be small, and may be compensated for through mitigation of negative natural capital impacts which may arise from a lack of organised emergency response systems. Therefore, we expect little net change (0) as a result of these policies.

Impacts on air pollution—There is little evidence of significant air pollution effects resulting directly from emergency services support. Though manufacturing may be involved, it is often at a smaller scale than most other manufacturing projects, and few of the goods required for emergency response are particularly air pollution-intensive to produce. Therefore, we expect little net change (0) as a result of these policies.

Direct impacts on environmental adaptation and resilience—Operational support for emergency services and disaster management is crucial for ensuring physical resilience to the effects of climate change. For example, granting tax exemptions for investment in disaster resilience has been shown to have positive effects on resilience (Mavrodieva *et al.*, 2019). These policies are therefore expected to have a positive (+1) direct impact on climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Emergency response systems encompass the personnel, information technology, and social communication systems involved in the coordination and distribution of information and resources to respond to a climate, health, or other emergency event (Shen and Shaw, 2004; Uhr *et al.*, 2008). When implemented effectively, emergency response systems enhance the resilience of communities and economies by ensuring the necessary materials and equipment are in place to prepare for and respond to an emergency event, thus reducing loss of lives and property (Bissell *et al.*, 2004; Huang *et al.*, 2011). The pathway of impact is indirect (+1), as the emergency management system does not itself enhance physical resilience; rather, it enables the provision of materials and equipment which, themselves, enhance physical resilience.

Having timely access to sufficient quality and quantity of emergency response equipment and materials is crucial to ensuring the effectiveness of disaster response (Huang *et al.*, 2011; Hale and Moberg, 2005). Equipment and materials for emergency response may include medical equipment, PPE, water storage and treatment equipment, emergency response and excavation vehicles, construction equipment, power and lighting equipment, and basic food, water, and shelter materials (Okeagu *et al.*, 2021; WHO, 2009; Chen *et al.*, 2011). The procurement of emergency response equipment has an indirect, positive (+1) impact on the ability of individuals, communities, and economies to adapt and recover in the wake of a disaster.

Impacts on wealth inequality—There is little evidence of significant wealth distribution effects resulting directly from emergency services support. Therefore, we expect little net change (0) as a result of these policies.

Impacts on rural livelihoods—Though rural communities are likely to benefit from emergency services support, there is little evidence to suggest that they will benefit to a higher degree than the general population, unless the policies are targeted specifically at rural communities. We therefore expect little net change in rural livelihoods (0) as a direct result of these policies.

M. Natural capital, parks, and forestry and other environmental (operational)

Impacts on short- and long-term GHG emissions—There is evidence that the expansion of green spaces results in decreased emissions in both the short and long term (Pan *et al.*, 2011). We, therefore, expect moderate improvements in GHG emissions (+1) in both cases.

For environmental re(building) initiatives including afforestation, reforestation, and environmental rehabilitation, and environmental protection initiatives including conservation and natural infrastructure resilience, we expect large long-term GHG benefits (+2) as they likely support carbon sequestration (Kumar and Nair, 2011; Lal and Singh, 2000; Lal *et al.* 2018).

Impacts on natural capital—By their nature (with the exception of unsustainable forestry practices), these projects tend to be designed to improve and protect natural capital, and they have been shown to be effective in this in the past (Chenoweth *et al.*, 2018).

Parks, sustainable forestry operations, and other environmental initiatives support wildlife, regulate climate by reducing the urban heat island effect, decrease air and noise pollution, and reduce contaminants, among other benefits. Green infrastructure additionally helps reduce local flood risk and enhances hydrological services in terms of groundwater recharge and environmental flows (Fairbrass *et al.*, 2018). Investments in parks and green spaces enhance tree cover, and preserve or improve biodiversity (Rakhshandehroo *et al.*, 2017).

Environmental restoration and rehabilitation activities such as afforestation directly enhance tree cover and vegetation, generating habitats for wildlife and other ecosystem benefits including improved water filtration, carbon sequestration, and flood regulation (Natural Capital Committee, 2020). Reforestation also improves adaptive capacity as well as soil quality and water supply (IUCN, 2011).

Conservation measures can protect and increase natural capital, including forests, water, minerals, biodiversity, and fish stocks (World Bank, 2022). Conserving ecosystems also enhances ecosystem- and species-level diversity, pollination, and food security (US EPA, 2022).

Therefore, these policies are expected to have a positive impact on natural capital (+1).

Impacts on air pollution—Green spaces and natural infrastructure have been shown to improve air pollution, as porous greenery can assist with the removal of pollutants (Abhijith *et al.*, 2017; Brack, 2002). We therefore expect an improvement in air pollution as a result of these policies (+1).

Direct impacts on environmental adaptation and resilience—Public parks and green spaces, particularly in urban areas, can reduce the adverse physical impacts of climate change, for example by reducing flooding from storm water (Alexander *et al.*, 2019; Ahiablame *et al.*, 2012; Seddon *et al.*, 2020).

Environmental protection and (re)building initiatives, including conservation, natural infrastructure resilience, afforestation, reforestation, and environmental rehabilitation, can enhance the physical resilience of ecosystems and urban spaces. In particular, these initiatives help to protect natural and human capital from erosion, flooding, and drought (Seddon *et al.*, 2020).

Payments for ecosystem services (PES) contributes to direct adaptation and resilience by strengthening the physical resilience of ecosystems to adverse climate impacts. For example, regulatory ecosystem services, such as water and erosion regulation, can enhance the resilience of ecosystems to climate shocks, thus improving (+1) direct or physical climate change adaptation and resilience outcomes (Van de Sand, 2012).

Other non-agricultural examples of sustainable land management include planting vegetation in desert or dryland areas for carbon sequestration in vegetation and soil (Bai *et al.*, 2021; Yang *et al.*, 2014). Sustainable land management increases the resilience of ecological systems to climate change, for example by enhancing soil health and moisture retention and by increasing biodiversity (Branca *et al.*, 2013; Cowie *et al.*, 2011). These policies are therefore expected to result in a positive (+1) impact on direct climate change adaptation and resilience.

Overall, spending on natural infrastructure and green spaces is expected to have positive impacts for direct climate change adaptation and resilience, by enhancing the physical resilience of natural and human capital to adverse climate impacts (Seddon *et al.*, 2020). All of these policies are therefore expected to have positive (+1) impacts on direct adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Extreme heat from climate change has adverse health impacts, including increased heat stress and heat-related morbidity (Mathey *et al.*, 2011). Public parks and green spaces, particularly in urban areas, can reduce heat stress and morbidity by mitigating urban heat island effects (Braubach *et al.*, 2017; Mathey *et al.*, 2011; Seddon *et al.*, 2020).

Environmental (re)building initiatives, including afforestation, reforestation, and environmental rehabilitation, can increase socio-economic resilience and enable local community adaptation to the adverse impacts of climate change (Kim *et al.*, 2021; Rahman *et al.*, 2018; Seddon *et al.*, 2020). In particular, these projects can provide a buffer for communities against climate shocks by enhancing and diversifying ecosystem services and protecting natural resources (Seddon *et al.*, 2020).

Payments for ecosystem services (PES) contributes to indirect adaptation and resilience by strengthening ecosystem services that contribute to the adaptive capacity of communities, such as the provision of food and income. For example, provisioning ecosystem services such as the provision of food and fodder can strengthen community resilience by providing a source of sustenance and income, which helps to increase communities' ability to withstand climate-induced shocks (Van de Sand, 2012).

The enhanced ecological resilience of sustainably managed land has positive outcomes for neighbouring communities, including more resilient livelihoods and food security (Branca *et al.*, 2013; Cowie *et al.*, 2011). These policies are therefore expected to result in a positive (+1) impact on indirect climate change adaptation and resilience.

General spending on natural infrastructure and green spaces is expected to have positive impacts for indirect climate change adaptation and resilience, by enhancing socio-economic resilience and adaptation of local or adjacent communities (Seddon *et al.*, 2020). All of these policies are therefore expected to have positive (+1) impacts on indirect adaptation and resilience.

Impacts on wealth inequality—There is little evidence that natural infrastructure and green space investment have significant first-order impacts on wealth inequality. Therefore, little net change (0) is expected as a result of these policies.

Impacts on rural livelihoods—There is little evidence that natural infrastructure projects that are not directly targeted at rural communities will have significant impacts on that demographic beyond what is expected for the general population. We therefore expect little net change (0) as a result of these policies.

N. Worker retraining and job creation (operational)

Impacts on short- and long-term GHG emissions—In the short term, while training programs are ongoing, there is little evidence that spending will induce significant GHG impacts. In the long term, there is naturally variation in GHG impacts dependent on the industry for which individuals are trained. In general, determining what employment a worker is likely to secure because of their training is not straightforward. Further, it is difficult to attribute GHG emissions from the employing industries to the original worker retraining programs. We therefore expect little net change in both short-term and long-term GHG emissions (0) because of such policies.

For subarchetypes relating to green worker retraining and job creation, it is well documented that for emissions to be reduced in accordance with current targets, there will need to be a significant shift in worker skills to meet the needs of a decarbonized economy (Pearce & Stilwell, 2008; Bird & Lawton, 2009; ILO, 2008). In the short-term, we expect these policies to have little impact on GHG emissions (0), as the emissions benefits from relevant adaptation projects are a step removed from the training itself. In the longer term, however, green worker retraining programs (of which adaptation and resilience training is a subset) are expected to have positive impacts on greenhouse gas emissions as they begin to redirect economic activity towards decarbonisation initiatives (Herren *et al.*, 2012). Green worker retraining and job creation policies are therefore expected to have a significant positive (+2) impact on GHG emissions in the long-term.

Impacts on natural capital—We can assume that, without this spending, unemployment would be higher, and green transition prospects may be impeded by skills shortages as well as economic prospects among workers in declining industries remaining more uncertain.

There is little evidence to suggest that worker retraining and job creation have significant first order effects on natural capital. We therefore expect little net change (0) as a result of general worker retraining and job creation policies.

Some green worker retraining and job creation policies, on the other hand, may also help reduce pressure on, restore, or improve the resilience of natural capital. Sustainability and employment often go hand in hand (ILO, 2018), especially as green sectors are often labour-intensive (ILO & WWF, 2020). Green jobs may also improve energy and raw materials efficiency, and reduce waste and pollution (ILO, 2018). However, some relevant jobs and technologies, such as sea wall construction or other hard infrastructure, are likely to increase demands for non-renewable natural resources, and therefore deplete the natural capital stock. In this context, as the types of skills being developed and the resulting impact on any sector development is not known, the net impact on natural capital cannot be readily estimated. Since effects could go either way, we estimate a neutral effect (0).

Impacts on air pollution—There is little evidence to suggest that general worker retraining and job creation policies are likely to have first-order impacts on air pollution. In general, we expect little net change (0) as a result of these policies. We recognise that there is some variation by industry that we are unable to capture with this assessment.

For green worker retraining and job creation, the air pollution co-benefits of green industries (McCollum *et al.*, 2013) mean that workers impacted by these policies will likely facilitate reductions in air pollution. We therefore expect an improvement in air pollution (+1) as a result of these policies.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that worker retraining and job creation in general have significant effects on environmental adaptation and resilience. In fact, evidence suggests that green worker retraining and job creation do not have significant first order effects on physical adaptation and resilience. Rather, job training and creation *indirectly* enhances adaptive capacity (Colting-Pulumbarit *et al.*, 2018; Mimura *et al.*, 2014; Van de Sand, 2012). As such, investment in green jobs in the adaptation and resilience sector is expected to have little net impact (0) on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience –Spending on worker retraining and job creation in general, as well as on green jobs specifically, increases livelihood opportunities and thus adaptive capacity, i.e. the ability of individuals or households to be resilient in the face of a climate change induced shock (Mimura *et al.*, 2014; Colting-Pulumbarit *et al.*, 2018), as well as increasing the pool of skills and knowledge in a society. As such, this type of investment in general is expected to have a positive (+1) impact on indirect adaptation and resilience. More specifically, training and new employment in green jobs, particularly in the adaptation and resilience sector, has two pathways of indirect positive impacts. First, the creation of more jobs and income opportunities increases adaptive capacity, i.e., the ability of individuals or households to be resilient in the face of a climate change induced shock (Mimura *et al.*, 2014). Second, green job investment indirectly enhances physical resilience, by contributing to projects that, for example, bolster ecosystems and infrastructure against the adverse impacts of climate change (Sand, 2012). As such, investment in green jobs in the adaptation and resilience sector in particular is expected to have a positive (+1) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—There is evidence to suggest that when workers are displaced, income losses are significant and persistent (Jacobson *et al.*, 1993), which naturally contribute to increased wealth inequality. Since these policies are designed to reduce the effects of worker displacement, it follows that they will likely improve wealth inequality (+1) relative to no policy intervention.

Impacts on rural livelihoods—There is little evidence to suggest that worker retraining and job creation policies are likely to have disproportionately large impacts on rural livelihoods relative to the rest of the population, unless the policies directly target rural communities. We therefore expect little net change (0) as a result of these policies.

O. Social welfare / social security (operational)

Impacts on short- and long-term GHG emissions—There is little evidence to suggest that support for social care has any first-order impacts for GHG emissions. This policy is therefore expected to have a neutral (0) impact.

Impacts on natural capital—There is little evidence to suggest that support for social care has any first-order impacts on natural capital. This policy is therefore expected to have a neutral (0) impact.

Impacts on air pollution—There is little evidence to suggest that support for social care has any first-order impacts for air pollution. This policy is therefore expected to have a neutral (0) impact.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that support for social care has any direct impacts for climate change adaptation and resilience. This policy is therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Investing in social services will strengthen them and enable them to effectively assist more people. Doing so is crucial given the range of impacts that climate change is expected to have on healthcare and other social-care oriented industries (UK Health Security Agency and National Health Service, 2021). This policy is therefore expected to have a positive (+1) indirect impact on climate change adaptation and resilience.

Impacts on wealth inequality—Social welfare and social security is directed at economically vulnerable populations, and particularly at points in life when support is most needed by those populations. This support can help reduce abject poverty as well as enable vulnerable populations to integrate more successfully into economic activity. By targeting support towards the disadvantaged within the economic system, these policies are expected to reduce wealth inequality (+1).

Impacts on rural livelihoods—Rural populations are often among the most economically vulnerable within a country and can be expected to benefit significantly from social welfare and social security policies. However, in some cases, when it is not directly targeted at rural populations, this support will be less readily available to rural populations for structural or logistical reasons, limiting their access to support. Nevertheless, we expect a positive effect (+1) on rural livelihoods on average. There is significant country-level variation which we cannot account for in this assessment; policymakers are encouraged to use their discretion.

P. Other traditional operations

Impacts on short- and long-term GHG emissions—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on GHG emissions. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Impacts on natural capital—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on natural capital. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Impacts on air pollution—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on air pollution. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Direct impacts on environmental adaptation and resilience—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on direct climate change adaptation and resilience. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Indirect impacts on environmental adaptation and resilience—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on indirect climate change adaptation and resilience. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Impacts on wealth inequality—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on wealth inequality. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Impacts on rural livelihoods—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on rural livelihoods. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Q. Other clean and/or resilient operations

Impacts on short- and long-term GHG emissions—Due to the broad range of policies in this archetype, mixed effects are expected. Relative to traditional operations, however, clean and/or resilient operations can be expected to prioritise reduction of GHG emissions (+1). Policymakers are encouraged to use their own discretion on a case-by-case basis.

Impacts on natural capital—Due to the broad range of policies in this archetype, mixed effects are expected. Relative to traditional operations, however, clean and/or resilient operations can be expected to prioritise protection of natural capital (+1). Policymakers are encouraged to use their own discretion on a case-by-case basis.

Impacts on air pollution—Due to the broad range of policies in this archetype, mixed effects are expected. Relative to traditional operations, however, clean and/or resilient operations can be expected to prioritise reduction of air pollution (+1). Policymakers are encouraged to use their own discretion on a case-by-case basis.

Direct impacts on environmental adaptation and resilience—Clean and/or resilient operations can be expected to have positive direct impacts on environmental adaptation and resilience (see other sections of this document for examples). These policies are expected to directly facilitate physical resilience initiatives, resulting in positive (+1) impacts for direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—In addition to increasing direct, physical resilience, clean and/or resilient operations are also expected to have positive indirect climate change adaptation impacts, boosting economic opportunities and enhancing the adaptive capacity of recipient communities (IEA, 2020a). These policies are therefore expected to result in positive (+1) impacts for indirect climate change adaptation and resilience.

Impacts on wealth inequality—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on wealth inequality. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Impacts on rural livelihoods—Due to the broad range of policies in this archetype, it is expected to have a neutral (0) impact on rural livelihoods. Policymakers are encouraged to use their own discretion on a case-by-case basis.

Discretionary-type archetypes

α. Core government service expansion (discretionary)

Impacts on short- and long-term GHG emissions—There is wide variation in practices that may be supported by spending in this category; it is therefore difficult to assign GHG emissions scores. However, in general, considering that spending in this archetype is likely to mostly address labour costs and basic services (e.g., electricity) that would be associated with any workplace, it seems unlikely that there would be an associated increase in emissions (either short or long term) compared to the situation in which the increased spending did not occur. This is, however, a broad generalisation and we encourage the SBA user to consider manual assessment of GHG impact for policy items that might be spurring new emissions. This might be the case, for example, for indiscriminate support of some subnational entities, which could spur increased consumption, in turn moderately increasing short-term GHG emissions (Dubois *et al.*, 2019). Overall, for this policy, we suggest that the user consider a starting point of little change in GHG emissions in both the short and long term (0).

Impacts on natural capital—There is little evidence of significant natural capital effects resulting from these policies, especially given that they are non-infrastructural. We therefore expect little net change in natural capital (0) because of these policies.

Impacts on air pollution—There is little evidence of significant air pollution effects resulting from these policies, given that they concern core support of government operations and not production or resource exploitation. We therefore expect little net change (0) because of these policies.

Direct impacts on environmental adaptation and resilience—Core support of government operations does not directly enhance adaptation or resilience unless funds are specifically earmarked for environmental activities (Schröter-Schlaack *et al.*, 2014). These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Increased support of core government services is unlikely to have a meaningful down-the-line impact on environmental resilience, although impacts on general forms of resilience could be supported with baseline adaptive capacity that comes from having centrally-coordinated policy staff available to respond to a changing external environment. For the case where funds are directed to subnational public entities, there might be an argument that spending indirectly strengthens adaptive capacity since local officials have more information on the conditions in the regions in which they live than national officials. Consequently, they can be better able to deliver public services that offer environmental benefits. Nzau (2014) concludes that "one dollar spent at the sub-national level would result in more welfare to the people and greater impact than the same amount of money spent at the national level". However, given the breadth of this archetype, the SBA users are advised to begin with the assumption that indirect impacts on A&R are low (0).

Impacts on wealth inequality—There is little evidence of significant wealth inequality impacts resulting from these policies. Perhaps, in the instance of subnational disbursements, states and localities might choose to target received funds towards low-income individuals more than is done at the national level, but this would be an edge case compared to most policies recorded in this category. We therefore expect, as a baseline, little net change (0) in wealth inequality because of the average policy in this category.

Impacts on rural livelihoods—There is little evidence to suggest that support for general government operations, or indeed subnational public entities, has significant impacts on rural communities beyond what is expected for the general population, unless the policies are specifically targeted to those communities. We therefore expect little net change (0) because of these policies.

Notes relevant to potential impacts on economic criteria—According to research on 31 European countries, public investment seems to be particularly effective in fostering economic growth when it supports the creation of human capital and the functioning of economic affairs and public services, including basic R&D and the operability of public institutions (Saccone *et al.*, 2022).

β. Health (discretionary)

Impacts on short- and long-term GHG emissions—Healthcare contributes substantially to global GHG emission levels, although the impact varies based on differing domestic characteristics. The US healthcare sector assessment for 2013 notes an increase in sectoral emissions from 8% to 10% of total national emissions (Eckelman and Sherman, 2016; Chung and Melzer, 2009). The biggest contributors were hospital care (36%), physician and clinical services (12%), and the prescription drugs sector (10%). While the US is an outlier, it is not the case that the emissions from the healthcare sector are of a negligible magnitude. In Australia, the sector contributes 7% of the general GHG emissions (Malik *et al.*, 2018). In Japan, healthcare contributed 5.2% of the country's carbon footprint (Nansai *et al.*, 2020). In Canada, the negative impact of the sector is smaller but still significant (Eckelman *et al.*, 2018). Pichler *et al.* (2019) found in a cross-national study that in a group of 35 countries including both HICs and developing nations like India, Mexico, and Turkey, the mean share of healthcare related GHG emissions was 5.4%, with the highest levels occurring in the Netherlands, the US, and Belgium. Although there is variability on the domestic level, the linkage between the healthcare sector and GHG emissions is well-established. That said, it is difficult to directly associate new public investment with higher long-term emissions—indeed, stronger public health systems might lead to more efficient healthcare in some contexts. Additionally, earlier detection of health complications can often reduce the magnitude and frequency of later interventions (Etzioni *et al.*, 2003). Finally, in many countries public health investments are more likely to support essential health interventions over elective and cosmetic interventions, which have increased significantly in popularity (e.g. Deng *et al.*, 2019; Liu and Miller, 2008); the consequences of this public health focus on GHGs is unknown.

Subarchetype β2 (mental health investment) is likely to have a smaller emissions role than other subarchetypes as it is not reliant on physical infrastructure in the same way. Many recent mental health investments also support efficient telemedicine, which can decrease the GHG emissions associated with commuting to healthcare facilities.

All considered, there is likely to be a large detrimental change (-2) in short-term and minor changes in long-term (-1) GHG emissions resulting from these varied health investment policies, except for subarchetype β2 which has only a medium-sized detrimental change in the short-term (-1) and neutral in the long-term (0). Of course, as with many other archetypes, there is substantial heterogeneity in emissions from country-to-country that this assessment is not able to capture. In some nations, particularly developing countries, health investment could increase GHG emissions substantially in the long-term.

Impacts on natural capital—Some healthcare activities, including both materials production and service provision, can generate significant waste streams that can impact natural capital. Additionally, new construction of healthcare infrastructure (e.g., hospitals) can have a detrimental impact on local natural capital. Whilst animal testing is used widely in drug testing and development, there are international efforts to reduce this as much as possible (Akkermans *et al.*, 2020). This is also expected to make up a relatively small proportion of healthcare investment spending. In total, Lenzen *et al.*, (2020) estimate that the health care sector is responsible for between 1 and 5% of global environmental impacts (depending on the indicator used) and this may exceed 5% in some countries. This is corroborated by many case study analyses (e.g. Hasan and Rahman, 2018; Kwikiriza *et al.*, 2019). On net, we expect a negative impact of discretionary health spending on natural capital compared to other spending (-1), except for mental health investments (0). Of course, the impacts are likely to be highly context specific.

Impacts on air pollution—There is mixed evidence regarding the air pollution impacts of healthcare investment. Whilst there are some air pollution effects resulting from healthcare capital and practices (Sherman *et al.*, 2019), several national and sub-national healthcare providers have introduced sustainability units to consider the environmental impacts of new and existing service provision (NHS England, 2018). However, these programs are relatively nascent and impact so far unclear. Given these competing effects, we expect that overall, these policies will likely result in little net change in air pollution (0), recognising that there may be country level discrepancies that we are unable to capture here.

Direct impacts on environmental adaptation and resilience—Climate change is expected to have an adverse direct impact on physical healthcare infrastructure, with natural disasters, for example, predicted to have damaging impacts on hospital and other facilities (Smith *et al.*, 2014; Loosemore *et al.*, 2011). Policies in this archetype do not specify resilient infrastructure and thus do not have a positive score for direct adaptation and resilience; however, physical healthcare infrastructure investment does not directly worsen adaptation and resilience outcomes. As such, these policies are expected to have a neutral (0) direct physical impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—The availability of good quality physical healthcare infrastructure is crucial to ensuring the ability of populations to adapt and be resilient in the face of climate change (Smith *et al.*, 2014). These policies are thus expected to have an indirect, positive (+1) impact on climate change adaptation and resilience.

Impacts on wealth inequality—As described in the archetype B (operational health support) entry, wealth inequality is generally associated with poorer health outcomes (Nowatzki, 2012). The impact of ongoing health spending on inequality is likely to depend principally on the beneficiaries of the spending. Generally, health spending might disproportionately boost health outcomes for less wealthy individuals as they are more likely to rely on public healthcare systems and not receive adequate healthcare in the absence of those systems. Of course, there will be significant variation in these outcomes depending on the policy. In the general case, we asses that ongoing health spending is likely to reduce wealth inequality (+1).

Impacts on rural livelihoods—As described in the archetype B (operational health support) entry, rural communities are less likely to have access to good quality health care in comparison to urban communities (Merwin *et al.*, 2006), thus they are likely to face a higher marginal benefit from healthcare investment. We therefore expect an improvement in rural livelihoods (+1) because of these policies.

Notes relevant to potential impacts on economic criteria—Examining health sector spending compared to other budget sectors, Reeves *et al.* (2013) suggest that healthcare spending can have one of the biggest fiscal multipliers, estimated around 4.3 over the period 1995-2010 in the US (95% confidence interval of 2.5 to 6.1). While this multiplier appeared to drop during measured recessionary periods, it remained a statistically significant growth factor. According to research on 31 European countries, in the post-2008 period, significant multiplicative effects are found for investment by governments in the promotion of health (Saccone *et al.*, 2022). Research in Portugal includes investment in health among the types of infrastructure investment with the highest economic multipliers (Pereira and Pereira, 2018).

γ. Education (discretionary)

Impacts on short- and long-term GHG emissions—In the short-term, investment in physical infrastructure and equipment in the education sector is expected to cause significant increases in GHG emissions (-2), due to the emissions intensity of the construction process (Huang *et al.*, 2018; Nässén *et al.*, 2007). Investments in equipment are likely to have a smaller immediate impact, but still increase emissions (-1).

Staff and scholarships are unlikely to have a significant impact beyond the status quo (0). In the longer term, the majority of new GHG emissions is likely to be from electricity consumption and manufacturing of educational materials, which is only indirectly linked to the presence of educational infrastructure. Therefore, we expect little net change long-term (0) from educational infrastructure investments.

For funding to support understanding of climate change mitigation, adaptation, and/or resilience, funding could conceivably reduce GHG emissions in the long term. Educational programs can mitigate climate change by instilling behavioural change towards lower-emissions lifestyles, social structures, and economies (Anderson, 2012). However, the pathways through which educational programs impact GHG emissions are indirect, and there has been limited evidence demonstrating tangible outcomes of educational programs on emissions reductions so far (Anderson, 2012). In the absence of greater evidence, it is difficult to decisively assess the impact of these policies; we suggest a low direct impact (0) on GHG emissions in the short-term and a hopefully positive impact in the longer-term (+1).

Impacts on natural capital—There may be some long-term natural capital benefits resulting from higher education attainment and therefore ecological literacy (Howell, 1992) This effect is likely small for non-targeted educational investment, and significantly variable by country and education system. Therefore, little net change (0) is likely to result from these policies in general.

For targeted climate change education, there is evidence that this will have significant effects on developing capacity for climate change mitigation and adaptation, amplified by multiplier effects as people share what they learn, resulting in increased public demand for climate, conservation, and natural capital enhancement measures (Stevenson *et al.*, 2017). Thus, targeted climate change education is expected to have a positive impact (+1).

Impacts on air pollution—There have been few significant links found between the education sector and air pollution, thus there is little net change (0) expected as a result of these policies.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that general investment in support for education (with no specified climate change adaptation and resilience measures) has any direct, physical impacts for climate change adaptation and resilience. Climate change is expected to have a direct, physical impact on educational infrastructure, with natural disasters, for example, predicted to have damaging impacts on school facilities (Anderson, 2012). Policies in this archetype do not specify resilient infrastructure and thus do not have a positive score for direct adaptation and resilience; however, physical educational infrastructure investment does not directly worsen adaptation and resilience outcomes. As such, these policies are expected to have a neutral (0) impact on direct adaptation and resilience.

Indirect impacts on environmental adaptation and resilience –Educational programs to support understanding of climate change mitigation, adaptation and resilience are crucial to improving peoples' adaptive capacity by providing knowledge and skills needed for making informed decisions related to climate change (Anderson, 2012; Wamsler *et al.*, 2012). In fact, education, even that which is not climate-specific, has been found to increase adaptive capacity. Wamsler *et al.* (2012) determine that education, particularly formal education, increased the adaptive capacity of rural communities in El Salvador and Brazil by enhancing their understanding of risk, access to information, ability to utilize information and development of coping strategies. Similarly, Muttarak and Lutz (2014) conclude that education increases adaptive capacity by improving cognition, problem-solving, knowledge and risk perception. These policies are therefore expected to have a positive (+1) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—Education has been shown to have significant positive impacts on wealth inequality through increasing capacity of children, even from lower income backgrounds, to attain higher paying jobs (Abdullah *et al.*, 2015). We therefore expect these policies to result in improvements in wealth inequality (+1)

Impacts on rural livelihoods—There exists significant disparities in educational access between rural and non-rural communities (Byun *et al.*, 2012), and education has been shown to be a vital component of combating rural poverty (Schafft, 2016). We therefore expect these policies to result in improvements in rural livelihoods (+1).

Notes relevant to potential impacts on economic criteria—Education spending was found to have the highest fiscal multiplier out of different budget sectors in a 2013 study by Reeves *et al.* The multiplier is 8.24 (95% confidence interval of 3.94 to 12.54), which has been observed to drop during recessions, but nevertheless remain significant. Some literature (Judson, 1998) finds that for education investment to correlate to GDP growth, a country could do well to focus on primary education but ensure investment across education levels. The study finds that universal primary education is optimal for all but very poor countries, for whom budget constraints might complicate matters. Research in Portugal includes investment in education-related infrastructure among the types of infrastructure investment with the highest economic multipliers (Pereira and Pereira, 2018).

δ. Socio-cultural programs (discretionary)

Impacts on short- and long-term GHG emissions—There is little evidence to suggest that social and cultural initiatives, in general, have any significant impact on greenhouse house emissions. We, therefore, expect little net change (0) because of general socio-cultural policies.

Overall, the tourism and leisure industries contribute significantly to global GHG emissions (Gössling and Peeters, 2015; Lenzen *et al.*, 2018; Peeters and Dubois, 2010). Depending on the scope of emissions included and assessment methodology used, these industries generate between 4.4% - 8% of worldwide CO2e emissions (Lenzen *et al.*, 2018; Peeters and Dubois, 2010). The sector is growing due to heightened demand, entailing upward trends in GHG emissions (Gössling and Peeters, 2015; Lenzen *et al.*, 2018). Further, there seems to be limited scope to reduce emissions through technological or processual improvements (ibid). Recent assessments have placed tourism and leisure behind manufacturing and construction in terms of the carbon multiplier, which is a ratio of CO2e emissions per US$ generated in economic value, demonstrating the high carbon intensity of the industry (Lenzen *et al.*, 2018). The high carbon intensity of tourism and leisure is driven primarily by its extensive transportation needs, entailing a strong correlation between the level of emissions per tourist and distance traveled (Dubois and Ceron, 2006; Filimonau *et al.* 2014; Gössling *et al.* 2005; Lenzen *et al.* 2018).

General hospitality infrastructure also contributes significantly to sectoral GHG emissions (Rahman *et al.* 2012). Hospitality sites, and in particular large hotels, are among the least sustainable building types in terms of energy consumption (Beccali *et al.*, 2009; Rahman *et al.*, 2012). Further, the active tourism and leisure industries require the support of manufacturing (to meet often high shopping demands of tourists) and agriculture (to provide the necessary quantity of food and beverages). The above general evidence is supported by a wide array of national case studies, showcasing substantial increases in CO2e emissions due to the growth of the tourism and leisure industries (Katircioğlu, 2014; Katircioglu *et al.*, 2014; Tang *et al.*, 2014). Domestic practices, most importantly sourcing energy from renewable sources, decrease the carbon footprint associated with providing for tourists (Lenzen *et al.*, 2018).

Support for general tourism and hospitality services could allow a swifter return to carbon-heavy BAU practices in the leisure and tourism sector in the short term. We expect these policies to have substantial emission-increasing effects in long run (-2).

Specific support for greener and/or more resilient tourism including ecotourism is likely to reduce long-term emissions compared to the status quo scenario of no green investment. Green or sustainable tourism initiatives can be categorised as either: i) making existing tourism more sustainable, such as through energy efficiency improvements, switching to renewable energy sources and encouraging shorter travel distances; or ii) investing in new eco-tourism initiatives, such as sustainable safaris and lodging. Efforts to make existing tourism more sustainable have typically been outweighed by simultaneous growth in the industry in general, resulting on net in higher GHG emissions in the short-term, despite ongoing efforts to reduce the industry's GHG impact (Lenzen *et al.*, 2018). In the case of new investment in eco-tourism, Higham (2007) finds that eco-tourism has a high transportation component and, in some cases, can outweigh conventional tourism in terms of its carbon footprint, due to the high material costs of infrastructure construction, the fossil fuel intensive profile of current transportation options, and the reluctance of consumers to voluntarily reduce their personal tourism carbon footprints (Khanra *et al.*, 2021). However, many other green tourism initiatives, like improving energy efficiency in hotels, can demonstrably reduce carbon emissions. Overall, compared to a scenario in which these policies were not implemented, we therefore expect them to have little net impact on GHG emissions in the short-term (0) and a small positive impact in the long-term (+1).

Incentives for arts and cultural activities are expected to bring limited impact to GHG emissions in both the short and long run (0) as these policies do not target the biggest factors contributing to the tourism and leisure industries' carbon footprint.

Measures to promote leisure participation are expected to bring some emission-increasing effects on GHG emission levels in the short run (-1) and little impact in the long run (0). While it depends very much on the initiative in question, incentives to promote leisure participation usually occur at the domestic level, thus incentivizing shorter distances for travel, with corresponding reductions in GHG emissions.

Impacts on natural capital—There is little evidence to suggest that general socio-cultural programs have significant impacts on natural capital. We therefore expect little net change (0) as a result of these policies.

Incentives for the tourism industry are expected to have negative impacts on natural capital (-1), particularly marine life and coastal environments (Burak *et al.*, 2004). Tourism can severely impact natural capital through excessive energy use, transportation, waste generation and water consumption (Zahedi, 2008).

Tourism's three principal environmental impacts include the depletion of natural resources, pollution and land degradation (Lemma, 2014). Support for tourism with no green conditions can result in general infrastructure development in ecologically rich areas, resulting in water degradation, biodiversity loss, soil erosion, and waste generation (GreenTumble, 2022). It can also exert great pressure on the local resources such as energy, food, and minerals, including pressure towards deforestation for fuelwood (Sunlu, 2003). Thus, we expect subarchetypes related to support for general tourism to have a negative impact on natural capital.

Eco-tourism, on the other hand, generates greater environmental awareness and scientific knowledge among tourists, informing attitudes towards conservation. Some eco-tourism initiatives also correspond to conservation efforts, including afforestation and repopulation of endangered species (Swanston, 2018). Eco-tourism initiatives are also likely to shift activities in the sector away from negative natural capital impacts. Thus, green and resilient tourism spending in particular is expected to have a significant positive impact on natural capital over the long term (+1).

We note that there are country-level differences that we are unable to capture with this assessment.

Impacts on air pollution—There is little evidence to suggest that there are significant air pollution consequences of general socio-cultural programs. Therefore, little net change (0) is expected as a result of these policies.

Incentives for the tourism industry are expected to have impacts on air pollution through inducing long distance travel, which is pollution intensive (Harrison *et al.*, 2015). We therefore expect air pollution to worsen (-1) as a result of these policies.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that general investment in support for arts and culture organisations has substantial direct impacts for climate change adaptation and resilience, unless it is specifically earmarked for resilience or adaptation purposes, which is rare. These policies are therefore expected to have a neutral (0) impact on direct adaptation and resilience.

The holiday and leisure sector also falls into this archetype. Without substantial investments in adaptation and resilience, climate change is expected to have direct, physical impacts on the holiday and leisure sector (Dogru *et al.*, 2019; Walmsley, 2011). Policies which invest in support to holiday and leisure businesses with no green conditions will not improve this situation. Policies which include green conditions, such as, for example, requirements for energy efficiency, cannot necessarily be expected to instigate longer-term changes for climate change adaptation and resilience either. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience overall. On the other hand, efforts to specifically adapt and increase the physical resilience of the sector, such as preventing beach erosion, stocking water bodies with adapted species for angling, and setbacks of tourist infrastructure, will have positive direct (+1) outcomes on the adaptation and resilience of the tourism sector (Scott, Hall and Gossling, 2012).

Indirect impacts on environmental adaptation and resilience—As above, whether the policies in question carry green conditions or not, they are unlikely to instigate long-term changes for adaptation and resilience. The expected indirect effect is neutral (0) unless spending is specifically earmarked for adaptation and resilience (particularly in the holiday and leisure sector), in which case it is positive (+1).

Impacts on wealth inequality—Whilst low-income people are likely to benefit significantly from investment in social and cultural programs, as is captured in the quality-of-life measure (Gilmore, 2014), there is little evidence to suggest that there will be and direct impacts on wealth inequality. We therefore expect little net change (0) as a result of these policies.

On tourism-specific archetypes, whilst in some countries, low-income workers may be protected by these programs, there are others in which the exploitation of workers is rife in the tourism and leisure industry. Given these opposing factors, we expect little net change (0) as a result of these policies, noting that there is significant country-level variation that we are unable to capture with this assessment.

Impacts on rural livelihoods—Though increased access to social and cultural programs is beneficial for rural livelihoods and development (Duxbury & Campbell, 2011), it is unlikely that policies in this category will have an outsized impact on rural communities as they are not specifically targeted there. We expect these policies to have little impact (0) on average that is specific to rural communities.

There is little evidence to suggest that leisure industry incentives that are not specifically targeted towards rural communities will have significant effects on rural livelihoods beyond what is expected in the general population. We therefore expect little net change (0) to result from these policies. We note that there is significant country-level variation in this archetype, particularly for tourism incentives which can contribute to poverty reduction in rural areas, but also cause climate related damage to rural areas. We are unfortunately unable to capture this variation in our policy assessment.

Notes relevant to potential impacts on economic criteria—Studies on the economic returns to socio-cultural investment are generally highly localised. In Pilsen, Czech Republic, which was chosen to be the European Capital of Culture in 2015, the gross value-added multiplier of arts, entertainment, and recreation was 0.49 (Nosková, 2016). The contribution of arts and culture to the national economy in the UK was modelled, and the gross value added multiplier was found to be 1.43 (CEBR, 2013).

A global study by the World Travel and Tourism Council suggested that the multiplier effect of investment in tourism is higher than in sectors like communications, education, or financial services (WTTC, 2012). Yet, of course, there are many factors that could influence the size of relevant fiscal multipliers, and depending on the time period considered, they can be directly linked to tourism multipliers (i.e., those that come from tourist expenditure). Quite obviously, the level of economic development has a major impact; interestingly, studies suggest that tourism output multipliers and employment multipliers increase with economic development (Yang, Fik and Altschuler, 2018; Zhang, Madsen and Jensen-Butler, 2007). Another factor is the level of national or regional economic diversification, which also increases multipliers by involving more sectors of the economy (Muchapondwa and Stage, 2013). The typology of tourist attractions is another obvious factor. Richer regions with mostly 3+ stars hotels have higher tourism multipliers than regions with 2-star hotels or camping (Hansen and Jensen, 1996). Also, there is evidence that suggests coastal destinations with the sun as the main resource have a higher tourism multiplier effect, whereas regions with mainly cultural resources have the lowest tourism multiplier values (van Leeuwen, Nijkamp and Rietveld, 2009). Ntibanyurwa (2006) suggests that regions with small businesses enjoy higher multiplier effects. Hence, the multiplier effect of tourism is dependent on regional conditions and tourism policies (Huse, Gustavsen and Almedal, 1998).

When it comes to the green tourism subarchetype, a World Bank study (World Bank, 2021b) finds that sustainable tourism in protected areas can bring high benefit to local economies, with high tourism multipliers (similar to other types of tourism). Furthermore, in most cases, multiplier shares favour the poor.

ε. Traditional energy (discretionary)

Impacts on short- and long-term GHG emissions—Traditional energy is an emissions-intensive sector, and it is expected that many traditional energy assets will become stranded under business-as-usual conditions with no intervention (IRENA, 2017). We therefore expect support for these businesses to result in increased long-term GHG emissions for an economy (-1).

As with almost all construction projects, traditional energy infrastructure projects are expected to have negative GHG impacts in the short term, mainly derived from material use (Behrens, 2016). As these policies directly perpetuate fossil fuel production and consumption, they are likely to cause large increases in GHG emissions long term. Therefore, these policies are expected to result in significant increases in GHG emissions (-2) both short and long term.

Measures to improve the resilience of existing energy infrastructure range from management and technical solutions to technological and structural solutions. Management and technical measures can include vegetation management, underground transmission and distribution networks, load forecasting, and improved early warning systems (IEA and OECD, 2015). Technological and structural measures can include fortifying flood-prone and offshore infrastructure, relocating infrastructure away from high-risk zones, and the implementation of smart grids and micro grids to better manage generation and distribution (IEA and OECD, 2015). Some of these solutions require construction and materials use, which is an emissions intensive (Huang *et al.*, 2018; Nässén *et al.*, 2007), thus resulting in a moderate increase (-1) in short-term GHG emissions. The long-term emissions implications of increased resilience of traditional energy infrastructure are complex. On the one hand, improving the resilience of traditional energy infrastructure, which emits high volumes of greenhouse gases (IEA, 2021), will prolong its usage, thus increasing the overall emissions from each of these facilities. On the other hand, prolonging the usage of existing facilities may slow the installation of new traditional energy facilities. The latter hypothesis has however been at least somewhat overstated in political discourse. While new installations of traditional energy facilities, such as coal power plants, have slowed in recent years, the primary reasons are lower-cost renewable alternatives, greater awareness of environmental risk, and scarce financing options, rather than the lifetime of existing facilities (IEA, 2021). As such, increasing resilience of existing traditional energy infrastructure is expected to have a moderate but negative (-1) net long-term impact on GHG emissions.

Impacts on natural capital—Traditional energy projects, especially those involved with the extraction of fossil fuels, can have significant negative impacts on natural capital. Spending on traditional fossil-fuel driven power generation poses concerns for natural capital and the environment (El-Sharkawi, 2021). Its effects can include, among others, soil erosion, vegetation destruction, aquatic ecosystem disturbance and toxic pollution (Lin *et al.*, 2005; Meng, 2017).

Fossil fuel power plant construction and operations have both short- and long-term impacts on water availability and quality, wetlands, vegetation, wildlife, protected species, land and soil quality (El-Sharkawi, 2021). Associated drilling, extraction, transportation, burning and consumption of fossil fuels is land-intensive, significantly affects wildlife, pollutes streams and rivers, and contributes to soil erosion (MET Group, 2020). Large power plants may require land clearing; construction of roads, railroads and pipelines; and electricity transmission lines which alter landscapes, produce waste, and negatively impact soil, water resources, native plant populations and wildlife (US EIA, 2021).

Oil, coal and gas refineries are a major source of water and soil pollution (Hazardous Substance Research Center, 2003), including through harmful waste streams and accidental spills which contaminate surface and ground waters (Groundwork, 2020). Effluents from oil refineries such as ammonia, sulphides, phenol, and hydrocarbons can also have adverse impacts for the aquatic environments (Wake, 2005).

Coal mines case destruction of landscapes and habitats, disturbing wildlife and ecosystems (TheWorldCounts, 2021) and resulting in loss of forest cover and biodiversity. They are also associated with soil pollution and deterioration linked to disposal of solid waste, contaminated water and acid mine drainage (Paltasingh & Satapathy, 2021). Mine construction also entails land-use changes which can cause flooding and adversely impact aquatic life downstream (Trucost, 2013). Coal mines also contribute to groundwater contamination through acidic water leakages and chemical and dust pollution (TheWorldCounts, 2021). Transportation of fossil fuels from mines or wells also poses a serious risk of accidents and spillage. Natural gas transmission is prone to methane leakages, while oil spills have adverse impacts on land, biodiversity, and water resources (UCS, 2016). Land use for construction of pipelines and transmission channels for fossil fuels can also have negative impacts on natural capital.

Spending on efficiency or resilience of fossil fuel energy systems is not the exception in this assessment. Energy efficiency projects may include insulation, weather stripping around windows and doors, and efficient appliances (Huxley-Reicher, 2022). Climate-resilient fossil fuel energy systems, if they exist, require generation diversity, grid automation, distributed resources, and interagency planning (Marcacci, 2019), as well as potentially involving underground distribution networks, improved early warning systems, flood regulating infrastructure, and implementation of smart grids (IEA and OECD, 2015). While these measures can lead to increased energy efficiency and environmental performance, they will also prevent the phasing-out of environmentally destructive traditional energy systems, with overall negative impacts for natural capital.

Therefore, all policies in this archetype are expected to have a negative impact (-1) on natural capital.

Impacts on air pollution—The fossil fuels involved in traditional energy in traditional energy infrastructure are also sources of a number of air pollutants, including sulphur dioxide (Shindell & Smith, 2019). We therefore expect these policies to worsen (-1) air pollution.

Direct impacts on environmental adaptation and resilience—Investment to support energy systems without green conditions enables energy companies to continue acting in a business-as-usual manner and even to expand traditional operations which are incompatible with the realities of climate change. In the long-term, this will reduce the adaptive capacity and resilience of energy companies since they will become more vulnerable to climate change (IEA and OECD, 2015; OECD, 2018). If support policies are short-term and focused on sector expansion, we expect them to have a neutral (0) long-term impact on direct adaptation and resilience, while longer-term expansion policies may have a negative impact overall (-1).

Measures to improve the resilience of traditional energy infrastructure range from management and technical solutions to technological and structural measures. Management and technical measures can include vegetation management, underground transmission and distribution networks, load forecasting, and improved early warning systems (IEA and OECD, 2015). Technological and structural measures can include fortifying flood-prone and offshore infrastructure, relocating infrastructure away from high-risk zones, and the implementation of smart grids and micro grids to better manage generation and distribution (IEA and OECD, 2015). Policies that address these measures specifically are expected to have a positive (+1) direct impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—As above, support which enables energy companies to continue business as usual reduces adaptive capacity and resilience. Short-term support will likely have a neutral impact, while long-term support may have a negative impact on indirect adaptation and resilience.

Investment in new or refurbished power plants, for example, has complex impacts on indirect adaptation and resilience. Access to energy is a crucial determinant of development and of adaptive capacity, thus investment in energy generation has positive impacts for indirect adaptation (Maller and Strengers, 2011; Scott *et al.*, 2015). Energy can include locally available sources, such as biomass, as well as more infrastructural solutions, such as electricity grids (Scott *et al.*, 2015). However, this archetype captures investment in new or refurbished power plants without consideration for climate change resilience; therefore, the positive impacts of additional generation capacity might be outweighed by their vulnerability to future climate impacts (Urban and Mitchell, 2011; IEA, 2021). The construction of new or refurbished power plants also provides jobs (a positive for adaptive capacity); however, these jobs are not in a sustainable sector (Pai *et al.*, 2020; Evans & Phelan, 2016). Moreover, in the long-run, traditional power plants will contribute to GHG emissions, thus worsening climate change and, therefore, adaptation outcomes for communities and systems. As such, these policies are expected to have an overall negative (-1) impact on indirect adaptation and resilience.

In terms of specific adaptation and resilience investment, it is true that in the long-term, GHG impacts from traditional energy facilities may instigate further climate change, thus worsening indirect adaptation outcomes; however, the bulk of GHG emissions from traditional energy will likely be from business-as-usual usage of existing or new facilities, rather than from the extended use of existing facilities due to resilience initiatives. Policies that enhance the resilience of energy infrastructure thus have a positive (+1) indirect impact on adaptation and resilience by enhancing adaptive capacity of individuals and systems.

Impacts on wealth inequality—There is little evidence to suggest that there are significant first order impacts on wealth inequality resulting from traditional energy infrastructure investment. We therefore expect little net change (0) to result from these policies.

Impacts on rural livelihoods—Traditional energy projects are often sited in rural areas and despite some short-term financial gains (Mishra, 2009), rural communities face a number of negative consequences from these policies, including negative health impacts These policies are therefore expected to generate negative impacts (-1) for rural livelihoods.

Notes relevant to potential impacts on economic criteria—Traditional fuel energy investment has a lower multiplier compared to renewable energy investment, estimated by the IMF to be around 0.5-0.6 whilst renewable energy investment multipliers are 1.1-1.5, depending on horizon and specification. This traditional fuel energy multiplier is based on the investment data for oil, gas and coal for the total amount of investment costs incurred in any given year (Batini *et al.*, 2021). Hasna (2021) also finds lower multipliers for traditional energy compared to green energy investments. O'Callaghan *et al.*'s (2022) review explains that based on existing literature, job creation and fiscal multipliers can be higher with clean energy compared to traditional energy.

ζ. Clean energy (discretionary)

Impacts on short- and long-term GHG emissions—For this policy archetype, we expect improvements in GHG emissions in the long term with clean energy policies mitigating the GHG emissions inherent in fossil fuel energy use. We therefore expect some decrease in long-term GHG emissions because of these policies.

As with almost all construction projects, clean energy infrastructure is expected to have negative GHG impacts in the short term, mainly due to material use (Behrens, 2016). Long term, however, clean energy projects facilitate the transition away from fossil fuels and therefore significantly reduce GHG emissions (Shafiei and Salim, 2014). Hence, these policies are expected to result in a significant increase in GHG emissions short term (-2), but a significant decrease long term (+2).

Impacts on natural capital—Clean energy infrastructure programs, whilst they may have some natural capital impacts in their own right, offset the need for continued fossil fuel use, thereby mitigating further negative natural capital effects that result from traditional energy (Lin *et al.*, 2005; Meng, 2017). Thus, clean energy use reduces the environmental impacts associated with drilling, extraction, transportation, burning and consumption of fossil fuels (MET Group, 2020). As well as reducing GHGs, this will also reduce other environmental effects of traditional energy generation, such as acid rain from coal burning (Rahman and Castro, 1995) or dissemination of heavy metals from coal ash (Ruhl *et al.*, 2010). Many renewable energies also reduce demand for water as electricity is not generated using steam turbines (Saidur *et al.*, 2011).

However, clean energy also has impacts on natural capital. Solar energy, particularly solar farms, have impacts on natural capital through land use and local reduction of ground temperatures, which may affect ecosystems (Gunerhan *et al.*, 2008). The literature on wind farms is somewhat mixed. Saidur *et al.*, (2011) notes a relatively low impact on natural habitats compared to other energy generation activities. However, wind turbines are linked to avian and bat mortality. Bailey *et al.*, (2014) find that offshore wind farms disturb marine habitats by creating noise and collision risks to marine species, but may also provide shelter and act as artificial reefs.

Energy transmission systems have a physical footprint that requires land, and their development can adversely affect natural habitats through disturbance and fragmentation. Transmission lines also present electrocution and collision risks to birds and bats; however, if suitably planned, transmission infrastructure does not usually pose a major threat to biodiversity (European Commission, 2018). With adequate planning, energy transmission authorities can make choices to improve the quality of nature (National Grid, 2022).

Battery and storage infrastructure solves the issue of cycling between oversupply and shortages in the renewable energy sector, and thus contributes to replacing fossil fuel energy. However, batteries require significant natural capital inputs including lead and lithium-ion (Stoppato *et al.*, 2021). Lithium extraction may lead to leakages into water courses, which can result in pollution and has led to fish and yak poisoning in parts of China (Hineman, 2020). Pumped hydro energy storage (PHES) systems are extremely water-intensive, and may also have significant local environmental impacts associated with impounding water.

As a result of these mixed impacts, we expect, on average, little net change (0) because of these policies.

Increasing resilience in energy infrastructure may include building coastal barriers and storm-harden energy infrastructure to address high water levels, adding peak generation and power storage capacity, expanding the use of non-water-intensive energy technologies, implementing air-cooled or low-water-use cooling systems for thermoelectric power plants, and improving reliability of grid systems through back-up power supply, intelligent controls, smart grid, micro-grids, and distributed generation (Zamuda *et al.*, 2018). These measures can reduce pressures on water supply but may increase demand for specific raw materials. Overall, the net estimated natural capital impact is neutral (0).

Some specific forms of renewable energy have more particular natural capital impacts.

Hydropower dams are well known to disrupt river ecosystems, restrict fish migration and cause sediment transfers (Pringle, 2003). Impoundments associated with hydropower also cause massive flooding of natural habitats and change temperature gradients in rivers. On average, hydropower may be predicted to have negative (-1) impacts on natural capital.

Nuclear power is the subject of ongoing debate concerning its environmental benefits and downsides. Nuclear power generation has the smallest land transformation requirement in m2/GWh of the main electricity producing processes (Rusu *et al.*, 2018). However, with present technology, the risk of serious negative environmental impacts resulting from nuclear waste and from accidents remains non-negligible (Prăvălie and Bandoc, 2018). When accidents happen, the impact on natural capital can be dramatic, resulting in massive and long-lasting contamination of land and water; contamination and resulting biodiversity loss is also associated with uranium mining and milling processes (Rusu *et al.*, 2018). Nuclear waste disposal also remains a long-term challenge; though it is long-lived, however, it should be noted that this waste is relatively small in volume when compared to waste produced, for example, when using coal to generate electricity (Vujić *et al.*, 2012). Moreover, new generations of nuclear power plants constructed using present spending will be built with enhanced safety features and closed fuel cycles, which would largely mitigate waste issues. Given these trade-offs in potential environmental risk and reduced environmental pressure, there is no overall net natural capital impact (0) associated with spending on nuclear energy generation.

Biofuels similarly have mixed impacts. Like other renewable energy sources, they have positive effects by replacing fossil fuels. However, biofuel feedstocks require land (Jeswani *et al.*, 2020), which can directly or indirectly lead to ecosystem destruction. Biofuel production is extremely land-intensive, with estimates indicating that 8% to 36% of current cropland would be required to meet 10% of global transport fuel demand in 2030 (Bringezu *et al.*, 2009). It is also associated with deforestation, land degradation, increased water use, fertiliser and pesticide application. Evidence indicates that the use of biofuels has caused great harm to biodiversity and ecosystems in South America and South-East Asia (NERC, 2014). For instance, based on national production targets, it was predicted that direct and indirect land-use change associated with biofuels would lead to loss of 121,970 square kilometres of forest by 2020 (Lapola *et al.*, 2010). The link between forest destruction and biofuel production holds true across 112 countries (Keles *et al.*, 2018). Biofuel production is also a major driver of landscape modification, with links to habitat loss, pollution and invasive species, leading to significant natural capital losses (Gasparatos *et al.*, 2018). This raises questions as to the sustainability of biofuel production as a renewable energy source. Whilst biofuel production using algae is being tested, it is assumed that the main production activities funded under this subarchetype relate to land-based production systems. As such, spending directed towards production of biofuels is considered to have a significant negative impact on natural capital (-1).

Some hydrogen energy production can have adverse environmental impacts, particularly if hydrogen is produced from coal without carbon capture and storage (Herzog and Tatsutani, 2005). Distribution infrastructure for hydrogen power also has varying impacts with respect to land-use change. Pipelines, trucks, and high-pressure gas tubes for hydrogen distribution create demand for materials and put pressure on natural capital. However, hydrogen power will generally use less fossil fuels than existing fuel sources, pose a much lower risk of pollution incidents compared to oil or petrol, and hydrogen distribution systems may substitute for other fuel transmission infrastructure. As such, there is no net overall natural capital impact (0) expected for spending on this subarchetype.

Impacts on air pollution—Since clean energy is a direct substitute for fossil fuels based energy, which itself produces significant air pollution (Shindell & Smith, 2019), we expect a decrease in air pollution (+1) to result from these policies.

Direct impacts on environmental adaptation and resilience—Typically, the green conditions associated with support for the energy sector relate to energy transition and GHG reduction initiatives, as opposed to climate change adaptation and resilience measures (UK Government, 2021a; BNDES, 2020). Moreover, short-term programs in particular are unlikely to impact the long-term trajectory of adaptation and resilience. These policies are therefore expected to have a neutral (0) long-term impact on indirect climate change adaptation and resilience.

On the other hand, measures to improve the resilience of traditional energy infrastructure have a positive effect. These range from management and technical solutions to technological and structural measures. Management and technical measures can include load forecasting and improved early warning systems (IEA, 2015). Technological and structural measures can include designing wind turbines for higher wind speeds, fortifying flood-prone and offshore infrastructure, relocating infrastructure away from high-risk zones, and the implementation of smart grids and micro grids to better manage generation and distribution (IEA, 2015). Policies that address these measures are expected to have a positive (+1) direct impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Clean energy investment provides sustainable jobs, increasing livelihood opportunities and thus adaptive capacity, i.e. the ability of individuals or households to be resilient in the face of a climate change induced shock (Mimura *et al.*, 2014; Colting-Pulumbarit *et al.*, 2018). Clean energy infrastructure also enhances access to energy, and energy is a crucial determinant of development and of adaptive capacity (Maller and Strengers, 2011; Scott *et al.*, 2015).

However, this archetype includes investment in clean energy infrastructure without consideration for climate change resilience. Renewable generation facilities are vulnerable to climate change impacts, particularly the increased incidence and strength of extreme weather events and rising sea levels, which threaten physical facilities, as well as through changes in water availability, which impacts hydropower, as well as thermal power plants' cooling facilities (IEA, 2015; OECD, 2018). Therefore, the positive impacts of energy access are somewhat outweighed by the vulnerability of these facilities to future climate impacts (Urban and Mitchell, 2011; IEA, 2021). On balance, clean energy policies with no consideration for resilience are thus expected to have a neutral (0) impact on indirect adaptation and resilience. On the other hand, policies that enhance the resilience of energy infrastructure have a positive (+1) indirect impact on adaptation and resilience by enhancing adaptive capacity of individuals and systems.

Impacts on wealth inequality—There is mixed evidence surrounding the impact of renewable energy on wealth inequality. Whilst some studies have found that renewable energy adoption reduces income inequality (Topcu & Tugcu, 2020), others have found that the shift towards clean energy may exacerbate energy inequality and therefore exacerbate income inequality (McGee & Greiner, 2019). As a result of this mixed evidence, we expect, on average, little net change (0) because of these policies.

Impacts on rural livelihoods—There are mixed impacts of clean energy infrastructure in rural communities. Rural areas are often chosen as locations for renewable energy projects (Lombard & Ferreira, 2015), and impacts range from land use changes which may not be beneficial to rural communities, to increased availability of high-quality jobs in those areas (Bergmann *et al.*, 2008; Poggi *et al.*, 2018). We therefore expect, on average, little net change (0) because of these policies.

Notes relevant to potential impacts on economic criteria—Renewable energy investment yields a much higher multiplier effect than traditional energy investment, found to be between 1.1-1.5, compared to the fossil fuel energy investment multiplier of 0.5-0.6 (Batini *et al.*, 2021). This multiplier includes the construction of facilities, transmission and distribution networks, and smart meters. It is also found that the cumulative multiplier for renewable energy spending falls only marginally over the years, whilst traditional energy spending that is not eco-friendly seems to have a smaller multiplier year after year. Additionally, examining the impulse response of GDP to a 1% shock to spending in renewable energy as well as a similar shock in traditional energy shows that whilst the renewable energy multiplier is statistically significant up until 4 years after the shock, traditional energy multiplier is not significant after 3 years.

Further studies show that solar microgrids have a high employment multiplier (Parag and Ainspan, 2019), and wind and geothermal investments sometimes yield higher multipliers than both solar and traditional investments (Hartono *et al.*, 2020).

Based on studies conducted in Australia (Vivid Economics, 2021), Brazil (Vivid Economics, 2021), China (Vivid Economics, 2021), Greece (Stamopoulos *et al.*, 2021), India (Vivid Economics, 2021), Indonesia (Hartono *et al.*, 2020; Vivid Economics, 2021), Israel (Parag and Ainspan, 2019), Japan (Vivid Economics, 2021), South Africa (Vivid Economics, 2021), the UK (Vivid Economics, 2021), and across 13 developed and emerging economies (JISEA, 2021), fiscal investment in clean energy tends to bring higher economic multipliers than traditional energy investment. Research in the USA also indicates higher multipliers on clean energy in comparison to findings on general public infrastructure multipliers or the multipliers on non-green energy, with significant effects on sectoral output, employment, and investment; this may be explained by the initial stock of public capital in this sector being further away from its steady state, leading to higher short-run marginal productivity (Hasna, 2021).

In comparative international research, clean energy multipliers are again positive and very likely to be larger than those on fossil fuels (Batini *et al.*, 2021), and clean energy investments and energy efficiency retrofits can outperform traditional energy sources on direct and indirect job creation and labour intensity (O'Callaghan *et al.*, 2022). The high labour intensity of renewable energy-related jobs in particular results in positive multipliers, and there is a significantly smaller risk of off-shoring for investment in renewable energy construction and energy efficiency improvements relative to traditional fiscal stimulus methods (Hoang *et al.*, 2021). Research on G7 countries suggests that clean energy investment may have a strong positive impact on human development (Hashemizadeh *et al.*, 2022). In countries with high levels of pollution, clean energy investment may also have additional long-term effects by preventing illness and premature deaths (Vivid Economics, 2021). Surveying leading global economists Hepburn *et al.* (2020) also find that clean energy investments have a high economic multiplier.

The user of the SBA taxonomy should take caution when considering economies that rely heavily on imported materials for clean energy, and for that matter for all other infrastructure. A reliance on imports could reduce the fiscal multiplier of investment.

η. Traditional transportation (discretionary)

Impacts on short- and long-term GHG emissions—Support for airlines and other traditional transport is likely to lead to large increases in GHG emissions (-2) relative to a scenario in which these policies were not implemented, as these are emissions-intensive sectors (IEA, 2018). In the short term, traditional transport infrastructure projects are highly carbon intensive in construction (-2), driven by material and energy use (Chen *et al.* 2017; Hong *et al.*, 2014; Huang *et al.*, 2018). In the long term, traditional transport infrastructure investment, in particular, funding for aviation sites and road construction, increases the general utility of transportation vehicles, including planes and ICEV, thus delivering heightened use of those assets and increased GHG emissions in the long run. However, in the case of road construction, increasing electric vehicle sales complicate the assessment of long-term emissions impact. In most major geographies, and particularly in the advanced economies that are making major road investments, higher road investment is not guaranteed to increase long-term emissions because new roads might decrease travel length and could disproportionately advantage EVs. Therefore, adopting a conservative interpretation, traditional transport infrastructure investments falling under the road construction subarchetype brings an unclear (0) impact on long-term GHG emissions. For aviation infrastructure, no near-term shift towards non-fossil airplanes means that increased investment is likely to significantly increase GHG emissions (-2) in the long term. ICE automobile support will impact demand for fossil-fuel-burning vehicles, which carries a long-term negative impact on GHG emissions (-2). Port and ship construction supports freight, which tends to be a carbon-intensive mode of transportation, but not as intensive as other options (Bouman, 2017; Cristea, 2013; Lindstad *et al.*, 2012).

Overall, this archetype attracts the score of (-2) in the long run.

Impacts on natural capital—There is evidence to suggest that traditional transport infrastructure has a negative impact on natural capital through the extensive land use required for many of these projects (Moretti *et al.*, 2018), with adverse impacts on land, biodiversity and natural capital stocks (Liang & Ye, 2021).

Road construction, including excavation, disrupts ecosystems, resulting in reduced biodiversity and soil erosion (Xiaofeng *et al.*, 2021). It can also have significant indirect impacts, in particular increased exploitation of natural capital due to increased access, including agricultural takeover of surrounding natural vegetation, timber harvesting, and hunting. This leads to diminished ecosystem services, including water quality, flood regulation, coastal protection, and climate regulation (Mandle *et al.*, 2016). Bridge projects impact rivers, aggravates soil erosion, and put essential hydrological services provided by rivers at risk (Xiaofeng *et al.*, 2021). Roads can also potentially impact fisheries through changes to peak storm flow, rising sedimentation in stream water, and loss of streamside vegetation, culverts and other barriers and landslides (Mandle *et al.*, 2016).

Traditional combustion vehicles, in order to function, require a number of environmentally destructive processes, including oil extraction, refining, and transportation. This generates pollution and puts stress on raw materials (Samsara, 2021) as well as on the environments in which they are extracted.

Airports and associated roads may disturb ecosystems through noise pollution and by creating disruptive physical barriers and divisions (Forman & Deblinger, 2000). Aviation infrastructure also demands land and increases pressure to convert natural ecosystems. Moreover, the construction of new airports can lead to emissions above and beyond general infrastructure projects from large-scale asphalt paving operations, as well as dust emissions from staging, demolition, and clearing earthworks activities (Kenney *et al.*, 2015). Overall, the main natural capital impacts of aviation infrastructure are from land-use changes, emissions, waste and energy consumption (Sameh & Scavuzzi, 2016).

Ports and ships produce noise which disturbs wildlife, discharges of ballast water which spread invasive species, sewage, sludge, oil and anti-fouling treatments from ships which contaminate port waters; certain hazardous cargos also pose wider environmental risks (OECD, 2011). Port operations themselves can also cause water pollution, resulting in degradation to marine habitats and loss of aquatic species (US EPA, 2021). All of these factors indicate additional stress on natural ecosystems and marine life.

Thus, a significantly negative long-term natural capital impact (-1) is associated with spending on this archetype.

Impacts on air pollution—The air pollution effects of transportation methods that involve the combustion of fossil fuels have been well documented. A large body of evidence shows that this kind of transport causes large amounts of air pollution including nitrogen oxides and sulphur oxides (Lozhkina & Lozhkin, 2016). We therefore expect air pollution to worsen (-1) as a result of these policies.

Direct impacts on environmental adaptation and resilience—Investment without green conditions will enable transportation providers to continue emitting greenhouse gases. In the long-term, emitting greenhouse gases will contribute to climate change, which will have adverse physical impacts. Short-term investments of this type are expected to have a neutral (0) long-term impact on direct adaptation and resilience, while long-term support can be expected to have a negative effect (-1).

Indirect impacts on environmental adaptation and resilience—Again, investment in greenhouse gas-emitting transportation systems will enable continued emissions, as well as preventing accelerated transition towards greener forms of transportation. Short-term policies may be expected to have a neutral effect (0), while long-term support for this industry will have a negative effect on indirect adaptation and resilience (-1).

Impacts on wealth inequality—There is little evidence to suggest that traditional transport infrastructure has significant impacts in wealth inequality. We therefore expect little net change (0) as a result of these policies.

Impacts on rural livelihoods—Rural communities are physically isolated from essential goods and services that may not exist in their location, therefore increased access to transportation disproportionately benefits rural communities (Arcury *et al.*, 2005). It is therefore expected that these policies will improve rural livelihoods (+1).

Notes relevant to potential impacts on economic criteria—Leduc and Wilson (2012) find that highway spending shocks positively affect local GDP, both in the short and long-term, although the effect is not permanent. Considering the US, Bonakdarpour *et al.* (2021) find that additional highway and bridge spending has an output multiplier similar to that of investments in public transit (3.4 and 3.3 respectively).

Research in Egypt suggests that higher public air transport investment leads to modest growth in GDP, employment, income, consumption, private investment, and trade (Njoya and Ragab, 2022). Research in Portugal includes investment in ports and airports among the types of infrastructure investment with the highest economic multipliers, while national road and highway investment has a positive effect which is nonetheless too weak to improve the public budget, and the economic effect of investment in municipal roads is insignificant (Pereira and Pereira, 2018).

θ. Clean and/or resilient transportation (discretionary)

Impacts on short- and long-term GHG emissions—In the short term, clean transport infrastructure projects are carbon intensive during the implementation phase due to the materials and energy used (Huang *et al.*, 2018). Long term, clean transport infrastructure plays a vital role in reducing GHG emissions, as it directly disincentivizes the use of high-emission traditional transport modes such as personal ICEVs (Dominković, 2018; Hardman *et al.*, 2017; Rudolph, 2016). It is therefore expected that clean transport investment brings significant short-term increases in GHG (-2) but large improvements in GHG emissions long-term (+2). Public transport digitalisation efforts are an exception, with no short-term impacts on GHG emissions (0).

Efforts to increase the physical resilience of transportation infrastructure to climate change are varied, including: switching paving materials, conducting more frequent maintenance, upgrading drainage systems, increasing shading, elevation, relocation and fortification of roads, tunnels, and bridges, and adding additional infrastructure such as levees and seawalls (Markolf *et al.*, 2019).

While transportation infrastructure in general contributes to greenhouse gas emissions by facilitating the use of combustion vehicles (Lozhkina & Lozhkin, 2016), those impacts are attributed to BAU use of existing infrastructure, not to additional resilience measures, specifically. Some of these policy options involve construction and materials use, which is a greenhouse gas emissions intensive process (Huang *et al.*, 2018; Nässén *et al.*, 2007). However, the extent of construction required is smaller in scope than the construction of new transportation infrastructure. These policies are thus expected to increase greenhouse gas emissions by a modest amount (-1) in the short term. The long-term impacts of more resilient transportation infrastructure are expected to be neutral (0), due to the short-term nature of construction required.

Electric vehicle (EV) incentives in particular spur heightened demand, especially in countries with sufficient infrastructure supporting easy utilisation (Hardman *et al.*, 2017; Rudolph, 2016). EV production brings a moderate increase in GHG emissions, in some cases even more than conventional vehicles due to the resources and energy consumed during battery production (Hawkins *et al.*, 2013). That said, the difference can be relatively small (Hawkins *et al.*, 2012). Further, there is substantial scope for recycling and repurposing of batteries, driving down the yearly average of GHG emissions associated with the production phase of EVs (Ahmadi *et al.*, 2015; Bobba *et al.*, 2018; Casals *et al.*, 2015). The strongest driver of EV emissions is the energy-mix used for powering the car (Faria *et al.*, 2013; Jochem *et al.*, 2015). EVs powered with a coal-heavy energy mix, assuming an extreme case, may have a higher carbon footprint than highly efficient ICEVs (Hawkins *et al.*, 2012; Huo *et al.*, 2010; Woo *et al.*, 2017; Wu *et al.*, 2012). Regional case studies, performed in coal-powered regions in China, Poland, and the US corroborate this (Burchart-Korol *et al.*, 2018; Huo *et al.*, 2010). Nevertheless, assuming a moderately clean energy mix, higher utilisation of EVs is associated with substantial reductions in GHG emissions over the vehicle's full lifecycle (Hawkins *et al.*, 2013). Further, in the case of a sustainable energy mix, like that in Scandinavia, lifecycle emissions are lower than that of traditional internal combustion vehicles by a significant margin (Faria *et al.*, 2013; Jochem *et al.*, 2015). Hence, incentivising EV purchases, in conjunction with a clean energy mix, is a crucial component of the transition towards a clean economy (Buekers *et al.*, 2014; Jochem *et al.*, 2015). Considering the above, we assume an increase in GHG emissions in the short term (-1) for both EV transfer programs and EV subsidies due to the carbon footprint of the manufacturing process. In the long run, investment in both is expected to lower GHG emissions, with the size of the benefit determined by the domestic energy-mix. The countries under assessment vary significantly with respect to said factor (IEA, 2020c). For the long term, an average of (+1) is assigned.

Rail construction and capacity increases the ease of public transportation and the efficiency of rail shipment, which lowers national GHG emissions associated with transportation in the long term (+1).

Impacts on natural capital—Clean transport infrastructure is usually smaller in scale than traditional transport projects and do not in themselves involve additional land use. While it has some of the same impacts, it also tends to achieve reduced emissions, improved air quality, and demand shifts away from emissions-intensive traditional transport. There is little evidence to suggest that these policies will have significant natural capital impacts. We therefore expect little net change (0) as a result of these policies.

New public transport systems or line expansions are larger scale infrastructure projects that could be expected to involve negative natural capital impacts through land use. Particularly if managed poorly, infrastructure projects can have significant impacts on the air quality, water quality, noise pollution, and GHG emissions (National Infrastructure Commission, 2021). Public transport expansion may also have adverse effects in terms of eutrophication, ozone depletion and carcinogenic effect (Koroneos, 2011). Ill-planned infrastructure can result in water pollution, soil erosion, and noise pollution, with adverse effects on biodiversity (Barrientos *et al.*, 2017). In some cases, public transport may replace existing traditional transport, complicated our assessment. Overall, however, we expect policies in this subarchetype to have a negative impact on natural capital (-1).

Rail network expansion is associated with soil and water pollution, affecting vegetation and aquatic life, as well as noise which may disturb wildlife. Fuel spills, de-icing chemicals and waste generation are also sources of air and water pollution associated with rail operations (Barrientos *et al.*, 2017). Light, noise and vibrations of added trains and tracks can adversely affect biodiversity including insects, birds, and amphibians (Barrientos *et al.*, 2017). Railways also have significant impacts on natural habitats and biodiversity through land-intensive infrastructure, including yards, stations and the rail tracks themselves (Gent, 2005), which disrupts habitats and ecosystems. Teo *et al.*, (2019) find similar fragmentation, barrier, and pollution effects for both rail and roads. However, impacts of rail may be less severe than those of roads a result of lower pollution from electric trains, impacts being plausibly limited to approximately 250m either side of the track (compared to 500m for roads), and limited train stops which reduce the human footprint on the biosphere. In many cases, there is a strong likelihood that this spending would be directed to road construction if not spent on rail, complicating our assessment. Overall, still, the direct impact of rail construction is negative (-1).

Spending on electric vehicles (EVs) aims to increase the proportion of electric vehicles in the fleet, thus replacing more of the demand for combustion engine vehicles with demand for electric vehicles. The main unique component of EVs is lithium-ion cells, which rely on extraction of raw materials including cobalt, lithium and rare earth minerals. This is linked to environmental concerns including sulphur dioxide emissions and other pollution (Tabuchi & Plumer, 2021). During lithium extraction, leakages into water courses can result in pollution, which has been observed to led to fish and yak poisoning in parts of China (Hineman, 2020). Electric vehicles have additionally been estimated to have a greater resource footprint than combustion engine vehicles over their lifecycle, including in the operation and maintenance phases of their use. The resource extraction and pollution effects associated with increasing the number of EVs constructed and used imply a significant negative impact on natural capital (Kosai *et al.*, 2021).

Though after the manufacturing stage the natural capital impacts of electric vehicles are negligible, there are some significant impacts involved in the manufacturing process, particularly for batteries. There are high environmental costs to the mining of lithium for these batteries, though there is high potential for recycling these and other materials used in EV construction (Van Mierlo *et al.*, 2017). These impacts considered, these policies are expected to have negative natural capital impacts (-1).

EV charging infrastructure initiatives will involve construction at various scales: charging stations, street chargers, workplace chargers, and private home chargers (Nour *et al.*, 2020). However, EV charging infrastructure is anticipated to be a feature of existing road infrastructure, and therefore produce no significant additional effects on natural capital (0).

Impacts on air pollution—Though there are some limited air pollution effects of the construction phase of these projects, they ultimately facilitate the transition away from traditional transportation methods which cause significant air pollution (Lozhkina & Lozhkin, 2016). We therefore expect the policies, in general, to result in an improvement in air pollution (+1). We note, however, this is dependent to some degree on the electricity generation mix in the country (Buekers *et al.*, 2014). Unfortunately, we are unable to capture this effect with this archetype assessment.

Though electric vehicles are not usually free of air pollution impacts over their lifespan, they produce substantially fewer pollutants than their conventional counterparts, and this is somewhat variable by the electricity generation mix in the country (Ke *et al.*, 2017). Therefore, electric vehicle incentives are expected to cause a net improvement (+1) in air quality.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that indiscriminate investment in clean transport infrastructure has any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience. Investment policies with green conditions usually compel airlines and other transportation companies to reduce their greenhouse gas emissions by switching to less carbon-intensive fuel or undertaking alternative actions (Abate *et al.*, 2020), without significantly changing their production models. Consequently, these policies will likely have little (0) impact on direct climate change adaptation and resilience.

Electric vehicles (EVs) also have mixed effects for resilience. EVs can contribute to the resilience of the electricity grid by absorbing renewable energy and provided a power source during outages (Hussain & Musilek, 2022); however, lack of access to electricity during an outage can also prevent the use of EVs for evacuation purposes (Adderly *et al.*, 2018). Relevant policies are therefore expected to have a neutral (0) impact for both direct and indirect climate change adaptation and resilience.

However, longer-term, non-EV policies requiring more radical changes to transportation provision are predicted to have a positive impact by encouraging more meaningful shifts in resource usage. Improving efficiency in dirty transport, for instance, should reduce GHG emissions (Jacyna *et al.*, 2017) and is therefore expected to have a positive (+1) impact on direct climate change adaptation and resilience. Moreover, policies specifically aiming to improve the adaptability and resilience of transport systems also have a positive effect. Physical transportation infrastructure is expected to be adversely and directly impacted by climate change, particularly as a result of temperature change, changes in precipitation, extreme weather events, and flooding (Markolf *et al.*, 2019). Efforts to increase the physical resilience of transportation infrastructure to climate change are varied, including: switching paving materials; conducting more frequent maintenance; upgrading drainage systems; increasing shading; elevation, relocation and fortification of roads, tunnels, and bridges; and adding additional infrastructure such as levees and seawalls (Markolf *et al.*, 2019). These policies are expected to have a positive (+1) direct impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Transportation infrastructure is a key determinant of adaptive capacity, i.e. the ability of individuals and systems to adapt and respond to climate change impacts (UNEP, 2021; Keskitalo *et al.*, 2011; Mimura *et al.*, 2014). Transportation infrastructure is expected to be highly adversely impacted by climate change, particularly as a result of temperature change, changes in precipitation, extreme weather events, and flooding (Markolf *et al.*, 2019). Policies that increase the overall greenness or resilience of transportation infrastructure, and therefore improve adaptive capacity, are thus expected to have a positive (+1) indirect impact on adaptation and resilience.

Impacts on wealth inequality—Though many clean transport options such as public transport and cycling are low-cost relative to other transport methods and therefore theoretically more likely to benefit low-income individuals, there is little evidence to suggest that this translates to tangible wealth inequality effects. We therefore expect little net change in wealth inequality (0) as a result of these policies.

The impacts of electric vehicle incentives on wealth inequality depend in large part on how well they are targeted, but it is often the case that, because of the prohibitively high costs of electric vehicles at present, the vast majority of electric vehicle incentives go to very wealthy consumers despite subsidies (Borenstein and Davis, 2016). Therefore, unless policymakers learn from mistakes of the past, on average, electric vehicle incentives are likely to worsen wealth inequality (-1).

Impacts on rural livelihoods—Rural communities are physically isolated from essential goods and services that may not exist in their location, therefore increased access to transportation disproportionately benefits rural communities (Arcury *et al.*, 2005). It is therefore expected that these policies will improve rural livelihoods (+1).

Uptake of electric vehicles is much higher in metropolitan areas than in rural areas, due to economic factors as well as lack of charging infrastructure (Chen *et al.*, 2020; Westin *et al.*, 2018). These policies are therefore unlikely to impact rural populations significantly (0).

Notes relevant to potential impacts on economic criteria—Green transport investment has a higher economic multiplier (by potential for job creation) than traditional transport investment, according to research conducted on Australia (Vivid Economics, 2021), France (Vivid Economics, 2021), Japan (Vivid Economics, 2021), and South Africa (Vivid Economics, 2021). In the USA, research also indicates a higher multiplier for green rather than traditional transport investment, with an emphasis on electric vehicle charging infrastructure (Vivid Economics, 2021). Advantages have also been noted for the UK (Vivid Economics, 2021). These advantages are not limited to high-income countries: for example, research on Indonesia (Vivid Economics, 2021) and India (Vivid Economics, 2021) indicates similar conclusions, with higher job creation and GVA from clean compared to traditional transport programs, especially public transport and supporting infrastructure. Research on China also points to significant economic advantages from clean transport investment (Vivid Economics, 2021), and contributes to sustainable long-term growth through impacts on both production and consumption (Wu *et al.*, 2021). Research in Portugal includes investment in rail transport among the types of infrastructure investment with the highest economic multipliers (Pereira and Pereira, 2018).

ι. Communications (discretionary)

Impacts on short- and long-term GHG emissions—Infrastructural investments are, in general, high emissions initiatives, thus short-term increases in GHG emissions are expected. In the long run, mixed effects will follow. First, considering the complementary nature of infrastructure and ICT devices, we assume an increase in demand for such goods will be seen as soon as the investments are completed. The manufacturing of ICT devices, mobiles, laptops, and the like carries a substantial carbon footprint (Lange *et al.*, 2020). Further, the utilisation phase of such appliances entails energy usage, which in a setting with a carbon-heavy energy mix can mean heightened GHG emissions (Van Heddeghem *et al.*, 2014; Webb, 2008). Infrastructure maintenance and operations contribute somewhat to the national carbon footprint through electricity used for power and cooling (Gombiner, 2011). Nevertheless, the ICT sector has been at the forefront of efficiency increases in terms of energy usage, which is tracked by its substantial lobal carbon footprint (Van Heddeghem *et al.*, 2014; Malmodin and Lundén, 2018).

In the long term, improved communication network coverage will presumably alter the day-to-day behaviours of individuals and firms (see Coroama *et al.*, 2012; Danish *et al.*, 2018; Esselaar *et al.*, 2007; Um *et al.*, 2002; Gilwald and Stork, 2008; Gutierrez *et al.*, 2009). Digitalisation could lead to some positive effects on national GHG emissions. As just one practical example, electronic invoicing can substantially reduce energy consumption compared to traditional invoicing (Moberg *et al.*, 2010). Similar arguments regarding the possible environmental benefits spurring from digitalisation are shown by Weber *et al.* (2010) for downloading music and by Amasawa *et al.* (2018) for the adoption of e-readers.

ICT development has been widely associated with decreased vehicle use and reduced traffic, which has a double emissions benefit (Esselaar *et al.*, 2007; Um *et al.*, 2002; Gilwald and Stork, 2008; Gutierrez *et al.*, 2009). Practices like remote working and internet conferencing are among the drivers of this relationship (Coroama, *et al.* 2012; Gutierrez *et al.*, 2009). Nevertheless, general positive impacts on GHG emissions from efficiency gains may not be realised if rebound effects are included in the evaluation (Jevons, 1906; Khazzoom 1980). Increases in efficiency may spur lower savings rates and substitution effects. The ICT sector is arguably especially prone to substantial rebound effects, as it greatly decreases the costs of service delivery (Lange *et al.*, 2020). Per sale, internet retail reduces the GHG emissions of distribution, but if the ease of purchase leads to increased demand, the net effects on emissions are mixed (Al-Mulali *et al.*, 2015; Horner *et al.* 2016; Mangiaracina *et al.*, 2015).

Further, rebound effects might include accelerated economic growth, associated with increased productivity and production (Lange *et al.*, 2019). This has been supported by regional studies in OECD countries, US, Finland, and several South Asian countries (Erumban and Das, 2016; Jalava and Pohjola, 2008; Jorgenson *et al.*, 2016; Lange *et al.*, 2020; Lee and Brahmasrene, 2014; Salahuddin and Alam, 2016; Wang, 1999). Nevertheless, the causal relationship between ICT development and economic growth remains controversial (Lange *et al.*, 2020).

For broadband investment, we expect substantial increases in GHG emissions in the short term (-2) due to the manufacturing and production phase of investment. Remote working infrastructure investment attracts the score of (-1) in the short term. Civil cybersecurity programmes and implementation of digital programmes do not come with significant short-term impacts on GHG emissions due to the lack of a construction phase. In general, as the archetype in question facilitates the long-term development of ICT technologies on the national scale, we assume mixed and ambiguous effects, and therefore a score of (0).

Improving the resilience of existing communications infrastructure may include upgrades to physical structures and networks, such as enhanced diversity of systems, improved spatial and environmental planning, and the introduction of additional network nodes for at-risk regions that do not have diversified network coverage (Fu *et al.*, 2016; Sansavini, 2017). Other improvements may include new technologies, such as the use of cloud computing to shift computational loads away from regions experiencing extreme weather conditions, and improved contingency planning and use of early warning systems (Fu *et al.*, 2016). Many of these solutions involve enhanced planning and use of existing systems, thus limiting short-term GHG emissions. While some new construction may be required (such as the installation of additional nodes to diversity network coverage), this is anticipated to be limited in scope compared to other sectors and infrastructural projects. We therefore expect little net change (0) in short-term and long-term greenhouse gas emissions from these policies.

Impacts on natural capital—There are expected to be some natural capital impacts resulting from the expansion of communications infrastructure (Maeng & Nedovic-Budic, 2004), as well as impacts from hazardous materials use and often improper recycling (Williams, 2011). Investment in ICT hardware at any scale also has the potential to generate significant streams of electronic waste. However, technological improvements and general investment in communications provide vital tools for facilitating the protection of natural capital. Moreover, although communications spending may generate electronic waste and require natural capital inputs for construction, it may also reduce demands for hard infrastructure such as transport, for instance through teleworking. Considering these opposing natural capital impacts, we expect that, in general, policies under this archetype are likely to result in little net change (0) in natural capital. We recognise that there is variation at the policy level that is unable to be captured using this assessment method.

Impacts on air pollution—As with any manufacturing or construction process, there are likely to be a negative impact on air pollution resulting from materials and energy use. We therefore expect worsened air pollution (-1) as a result of these policies. In the case of civil cybersecurity programs and implementation of digital programs, there is little evidence of significant air pollution effects, as they are primarily software measures. We therefore expect little net change in air pollution (0) as a result of these subarchetypes.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that communications investment in general has any direct impacts for climate change adaptation and resilience. These policies are therefore generally expected to have a neutral (0) impact on direct climate change adaptation and resilience. However, climate change is expected to have adverse direct impacts on physical communications infrastructure, in particular through the increased prevalence of heatwaves and flooding (Fu *et al.*, 2016). Improvements specifically intended to enhance the physical resilience of communications infrastructure may include upgrades to physical structures and networks, such as enhanced diversity of systems, improved spatial and environmental planning, and the introduction of additional network nodes for at-risk regions that do not have diversified network coverage (Fu *et al.*, 2016; Sansavini, 2017). These policies are expected to have a positive (+1) direct impact on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Enhanced and resilient communications infrastructure has been shown to improve the ability of economies and communities to adapt to climate change (Fu *et al.*, 2016). There are numerous potential indirect impacts of communications investment on adaptation and resilience. For instance, communications infrastructure may facilitate emergency communications, which indirectly contributes to environmental adaptation and resilience. Communications investment may also facilitate other adaptability- or resilience-enhancing initiatives, such as education or worker retraining. Additionally, as a tentative hypothesis, investment in remote working infrastructure in particular, as a subset of communications infrastructure, is expected to induce long-lasting behavioural change in individuals and organisations (Lund *et al.*, 2021; Mark *et al.*, 2022). Remote working options may enable greater flexibility and adaptation in the face of disruptions caused by climate change, such as future natural disasters. Efforts to improve the resilience of communications infrastructure are thus expected to positively (+1) impact indirect adaptation and resilience.

Impacts on wealth inequality—Digital connectivity has been shown to have mixed effects on income inequality, depending on surrounding economic, political and technological factors (Bauer, 2018). We therefore, on average, expect little change (0) resulting from these policies.

Impacts on rural livelihoods—There exists a significant disparity between connectivity and access to broadband and digital technologies between rural and non-rural communities. Rural communities benefit substantially from these policies as they help avoid problems of unequal access to information, services and social opportunities among other things (Townsend *et al.*, 2013). We therefore expect that these policies will likely have a positive impact (+1) on rural livelihoods.

Notes relevant to potential impacts on economic criteria—Many studies find communications investment to positively affect GDP growth and find the effect to be more pronounced in developing countries. One study finds that in a sample of both developed and developing countries, a 10% increase in telecom penetration rate yielded a 2.8% increase in GDP (Röller and Waverman, 1996). In a later paper, they found that about one third of economic growth of 21 OECD countries was associated with expanded telecommunication infrastructure. A threshold level of telecom density is needed for network effects to kick. This study finds a minimum threshold of telecom density of around 24 percent growth. Adding mobile phones empirically lowers this threshold: the critical mass for telecom penetration, the threshold for network effects to kick in, is between 5 to 15% with mobile phones (Torero, Choudhary and Bedi, 2006). Including mobile phones to this model supports the positive causal link from telecommunications and GDP across 113 countries over a 20-year period. Waverman, Meschi and Fuss (2005) find that mobile telephony had a positive and significant impact on economic growth, and that this effect could be twice as large in developing countries compared to developed countries. Wired telecommunication investment also provides stronger multiplier effects, in part due to its low leakages and local economic boosts. (Reynolds, 2009)

Examining investments in different communication technologies show that broadband infrastructure investments might have the highest impact, and fixed technologies the lowest (World Bank, 2009). Figures from a World Bank study of 120 predominantly developing countries suggests that, for both low- and high-income countries, multiplier effects were highest for broadband, followed by internet, mobile, and finally, fixed communication. The study also finds that multipliers in communications are, on whole, larger in developing countries. This aligns with Kathuria *et al.*, (2018), who suggest that 'communication technologies compensate for other forms of inadequate infrastructure in developing countries thus generating bigger impacts'. Research in Portugal includes investment in telecommunications among the types of infrastructure investment with the highest economic multipliers (Pereira and Pereira, 2018).

κ. Other utilities (discretionary)

Impacts on short- and long-term GHG emissions—For clean and/or resilient investment in utilities, impacts are likely to be similar to those of traditional investments in utilities. However, as in the case of clean housing and public buildings, the long-term impacts could be moderately to significantly positive, depending on the scale of the investment. As a baseline, most clean and resilient utilities are expected to see reductions in greenhouse gas emissions (+1), due to improved energy efficiency (Stephens *et al.*, 2013).

Impacts on natural capital—Utilities have a physical footprint, and their construction can adversely affect natural capital. However, improving utilities is important for efficient use of natural capital (e.g., addressing water leakages) and avoiding pollution incidents (e.g., stormwater and sewage discharge to aquatic ecosystems). Utilities providers can even act with explicit natural capital objectives in mind (National Grid, 2022) and using green infrastructure, for instance in managing stormwater flows (Chini *et al.*, 2017). There is a risk that investment in utilities may prolong the use of fossil fuels, particularly gas. However, overall, we expect a significant and positive natural capital impact associated with spending on this archetype (+1).

Impacts on air pollution—There is little evidence of significant air pollution effects from utilities spending. We therefore expect little net change in air pollution (0) as a result of this archetype.

Direct impacts on environmental adaptation and resilience—Climate change is expected to have adverse direct impacts on local utilities, with disruptions expected to water and energy supply, as well as sanitation systems (OECD, 2018; OECD, 2013). Extreme weather events and flooding are projected to damage physical infrastructure and impact water quality, while changes in temperature and precipitation will place additional pressure on water resources (OECD, 2018; OECD, 2013). Measures to enhance the resilience of local utilities may include management initiatives, such as load forecasting, vegetation management, promotion of behavioural change, and disaster mitigation planning (OECD, 2018). Structural measures may include retrofitting, reinforcing or relocating existing infrastructure, implementing smart grid technology, improving energy efficiency, using more resilient materials, and constructing additional infrastructure—both traditional hard infrastructure, as well as natural infrastructure, such as wetland or watershed restoration (OECD, 2018; Huang *et al.*, 2017). Policies that focus on 'clean' or 'green' investments in local utilities, such as smart grid technology or the use of natural infrastructure, typically also enhance resilience. These policies are therefore expected to have a positive (+1) direct impact on adaptation and resilience.

There is little evidence to suggest that spending on utilities in general, without particular regard for resilience or greenness, has any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—The services that are provided by local utilities (water supply, waste and sanitation, energy provision) are crucial to the functioning and adaptive capacity of individuals, communities, and systems (Mimura *et al.*, 2014). As such, investing in resilient local utilities indirectly enhances adaptation and resilience of communities and economies more generally. Moreover, the adverse physical impacts of climate change on local utilities have cascading effects for local communities and economies. For example, in many sectors of the economy, disruptions and economic losses during or after an extreme weather event are primarily caused by disruptions to basic services such as energy supply, rather than due to direct physical damages from the weather event (OECD, 2018). Therefore, policies that enhance the resilience of local utilities are expected to have a positive indirect (+1) impact on adaptation and resilience. Policies that focus on 'clean' or 'green' investments in local utilities, such as smart grid technology or the use of natural infrastructure, typically also enhance resilience.

However, general investment in utilities without regard for resilience may see its usefulness outweighed by its vulnerability to the effects of climate change. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Impacts on wealth inequality—Utilities are crucial to collective life regardless of wealth. Although more impoverished communities tend to be more affected by lacking or dysfunctional utilities services, there is little evidence that non-targeted utilities spending in general has any significant effect on wealth inequality. We therefore expect little net change in wealth inequality (0) as a result of this archetype.

Impacts on rural livelihoods—Again, although rural communities may tend to be more affected by lacking or dysfunctional utilities services, there is little evidence that general utilities spending not targeted at rural communities has any significant specific effect on rural livelihoods. We therefore expect little net change in rural livelihoods (0) as a result of this archetype.

Notes relevant to potential impacts on economic criteria—In developing countries, investment in water, waste and other utilities can have a very high economic multiplier. In Sub-Saharan Africa, water investment is found to increase agricultural production and improve access to markets, with significant impacts on economic growth and poverty reduction (Hanjra *et al.*, 2009). In Malaysia, the value-added multiplier of the recycling sector seems to be high and reinforced by high spillover effects (Utit *et al.*, 2021).

Multipliers in advanced economies are also positive, but according to the literature, seem to be smaller. Research in Portugal shows that investments in electricity and gas can have insignificant economic effects, and that investments in waste and waste water have positive economic effects, but too small to improve the public budget (Pereira and Pereira, 2018) — although recycling is ranked amongst the upper third of economic activities by multiplier effect (Ferrao *et al.*, 2014). In the USA, modelling suggests that an additional $10 million spent on water systems infrastructure generates $5.38 million in additional employee compensation and has a total employment effect of 177 jobs (Heintz *et al.*, 2009).

λ. Military (discretionary)

Impacts on short- and long-term GHG emissions—Investment in the capacity and arsenals of armed forces is likely to cause significant increases in GHG emissions, both in the short and long term. Short term impacts are likely to be coupled to the construction of new military equipment and enhancement of capabilities, while long term effects will result from continued use of hydrocarbon fuels (Belcher *et al.*, 2019; Clark *et al.* 2010). We, therefore, expect large increases in GHG emissions (-2) in both the short and long term for this archetype.

In the case of administration funding, GHG effects are likely to be smaller (-1) in the short term for administrative investments, but in the long term, this subarchetype still directly facilitates carbon-intensive operations, thus the long-term score (-2) remains.

Researchers should note that some governments mobilise their military personnel for environmental initiatives that might indirectly support lower GHG emissions. For instance, the Seychelles Coast Guard is a branch of the defense force that actively engages in environmental protection. In the case that military support is clearly divided into those programs which do and don’t serve environmental objectives, we consider that the relevant environmentally positive designations might be better categorized to another archetype (with the most appropriate archetype determined by the sector that is supported). As always, the researcher should use their discretion.

Impacts on natural capital—Beyond the devastating and long-lasting environmental consequences of military conflict (UNEP, 2019), land use by the armed forces even in peacetime is significant and can have large negative consequences for natural capital. In particular, military land use has been shown to decrease biodiversity and has sizable impacts on ecosystem structures (Lawrence *et al.*, 2015). The impact of military equipment production and transportation on natural capital is also expected to be substantial. In some cases, military spending may be associated with peacekeeping or conflict deterrence, and some armed forces even participate in nature protection activities (Defence Infrastructure Organisation, 2021). However, the relevance of these factors is limited, and their effect is small compared to other impacts of military spending. We therefore expect overall negative natural capital consequences (-1) as a result of these policies.

Impacts on air pollution—It is likely that armed forces investment will have a negative impact (-1) on air pollution, especially through construction and use of vehicles and aircraft, in addition to other military operations (Hamilton, 2016).

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that armed forces investment will have any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—There is little evidence to suggest that armed forces investment will have any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—There is a significant body of evidence suggesting that spending on armed forces and the military has negative impacts for income inequality. The reasons for this include differences in pay between civilian and military work, gender inequality in the military compounding existing gender-based pay disparities, and increasing capital intensity (Abell, 1994; Kentor *et al.*, 2012; Biscione & Caruso, 2019). We therefore expect income inequality to worsen (-1) as a result of these policies.

Impacts on rural livelihoods –There is little evidence to suggest that there are significant impacts on rural livelihood resulting from armed forces investment. Though in some countries, individuals from rural communities are more likely to join the armed forces, this is not the case across the board. We therefore expect little net change (0) as a result of these policies, noting that there is country-level variation that we are unable to capture with this assessment.

Notes relevant to potential impacts on economic criteria—Research on the USA indicates that the multiplier on military spending is higher than the non-defense government spending multiplier estimated in the literature using military build-ups, but it is worth noting that this generalises poorly outside of the USA, as few other countries have been involved in mainly extraterritorial conflicts (Yang, 2012).

Sheremirov and Spirovska (2022 find a multiplier just below 1 for developing economies and well above 1 in advanced economies; the multiplier is also higher in recessions, for negative shocks, under a fixed exchange rate, and in closed economies.

Older research on less developed countries finds negative multipliers on military spending, indicating a depressive effect on growth, in contrast to non-military government spending (Aschauer, 1990; Deger and Smith, 1983).

µ. Emergency response services (discretionary)

Impacts on short- and long-term GHG emissions—Support for emergency services is vital, but in the short term, often involves manufacturing to ensure that sufficient resources for crisis management are available. This manufacturing is likely to bring a short-term increase in GHG emissions, driven by energy and materials usage (Behrens, 2016). In the long term, however, there is little evidence to suggest significant GHG impacts. We therefore expect a moderate increase in emissions short-term (-1), but little net change in the long term (0).

Administrative support for emergency response is not likely to involve significant marginal manufacturing, and therefore we expect little net change (0) for both short and long-term GHG impacts for this subarchetype.

Impacts on natural capital—There is little evidence of significant natural capital effects resulting directly from emergency services support, especially because they are non-infrastructural in nature. Procurement of emergency response equipment may generate significant waste streams in the short to medium term; however, particularly in the long term, it is unlikely to have significant impacts on the exploitation of natural capital for materials or as waste sinks. Emergency services support may create localised short-term pressures on the environment, but the scale of cumulative natural capital impacts is likely to be small, and may be compensated for through mitigation of negative natural capital impacts which may arise from a lack of organised emergency response systems. Therefore, we expect little net change (0) as a result of these policies.

Impacts on air pollution—There is little evidence of significant air pollution effects resulting directly from emergency services support. Though manufacturing may be involved, it is often at a smaller scale than most other manufacturing projects, and few of the goods required for emergency response are particularly air pollution-intensive to produce. Therefore, we expect little net change (0) as a result of these policies.

Direct impacts on environmental adaptation and resilience—Investment in emergency services and disaster management is crucial for ensuring physical resilience to the effects of climate change. For example, granting tax exemptions for investment in disaster resilience has been shown to have positive effects on resilience (Mavrodieva *et al.*, 2019). These policies are therefore expected to have a positive (+1) direct impact on climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Emergency response systems encompass the personnel, information technology, and social communication systems involved in the coordination and distribution of information and resources to respond to a climate, health, or other emergency event (Shen and Shaw, 2004; Uhr *et al.*, 2008). When implemented effectively, emergency response systems enhance the resilience of communities and economies by ensuring the necessary materials and equipment are in place to prepare for and respond to an emergency event, thus reducing loss of lives and property (Bissell *et al.*, 2004; Huang *et al.*, 2011). The pathway of impact is indirect (+1), as the emergency management system does not itself enhance physical resilience; rather, it enables the provision of materials and equipment which, themselves, enhance physical resilience.

Having timely access to sufficient quality and quantity of emergency response equipment and materials is crucial to ensuring the effectiveness of disaster response (Huang *et al.*, 2011; Hale and Moberg, 2005). Equipment and materials for emergency response may include medical equipment, PPE, water storage and treatment equipment, emergency response and excavation vehicles, construction equipment, power and lighting equipment, and basic food, water, and shelter materials (Okeagu *et al.*, 2021; WHO, 2009; Chen *et al.*, 2011). The procurement of emergency response equipment has an indirect, positive (+1) impact on the ability of individuals, communities, and economies to adapt and recover in the wake of a disaster.

Impacts on wealth inequality—There is little evidence of significant wealth distribution effects resulting directly from emergency services support. Therefore, we expect little net change (0) as a result of these policies.

Impacts on rural livelihoods—Though rural communities are likely to benefit from emergency services support, there is little evidence to suggest that they will benefit to a higher degree than the general population, unless the policies are targeted specifically at rural communities. We therefore expect little net change in rural livelihoods (0) as a direct result of these policies.

Notes relevant to potential impacts on economic criteria—According to research on 31 European countries, in the post-2008 period, significant multiplicative effects are found for investment by governments in public order and safety (Saccone *et al.*, 2022).

Studies in the USA find that government spending in the wake of natural disasters have a powerful stimulating effect on local economies, with a high fiscal multiplier (Fidrmuc *et al.*, 2015), particularly through job-creation channels (Zhou, 2017).

It is unclear how well these conclusions might generalise as research specific to, or even incorporating, developing countries is lacking.

v. Natural capital, parks, and forestry and other environmental (discretionary)

Impacts on short- and long-term GHG emissions—Though there may be some negative GHG impacts resulting from short-term construction efforts through some of these policies, for the vast majority, there is evidence that the expansion of green spaces results in decreased emissions in both the short and long term (Pan *et al.*, 2011). We, therefore, expect moderate improvements in GHG emissions (+1) in both cases.

For environmental re(building) initiatives including afforestation, reforestation, and environmental rehabilitation, and environmental protection initiatives including conservation and natural infrastructure resilience, we expect large long-term GHG benefits (+2) as they likely support carbon sequestration (Kumar and Nair, 2011; Lal and Singh, 2000; Lal *et al.* 2018).

Impacts on natural capital—By their nature (with the exception of unsustainable forestry practices), these projects tend to be designed to improve and protect natural capital, and they have been shown to be effective in this in the past (Chenoweth *et al.*, 2018).

Parks, sustainable forestry operations, and other environmental initiatives support wildlife, regulate climate by reducing the urban heat island effect, decrease air and noise pollution, and reduce contaminants, among other benefits. Green infrastructure additionally helps reduce local flood risk, and enhances hydrological services in terms of groundwater recharge and environmental flows (Fairbrass *et al.*, 2018). Investments in parks and green spaces enhance tree cover, and preserve or improve biodiversity (Rakhshandehroo *et al.*, 2017).

Environmental restoration and rehabilitation activities such as afforestation directly enhance tree cover and vegetation, generating habitats for wildlife and other ecosystem benefits including improved water filtration, carbon sequestration, and flood regulation (Natural Capital Committee, 2020). Reforestation also improves adaptive capacity as well as soil quality and water supply (IUCN, 2011).

Conservation measures can protect and increase natural capital, including forests, water, minerals, biodiversity, and fish stocks (World Bank, 2022). Conserving ecosystems also enhances ecosystem- and species-level diversity, pollination, and food security (US EPA, 2022).

Therefore, these policies are expected to have a positive impact on natural capital (+1).

Impacts on air pollution—Green spaces and natural infrastructure have been shown to improve air pollution, as porous greenery can assist with the removal of pollutants (Abhijith *et al.*, 2017; Brack, 2002). We therefore expect an improvement in air pollution as a result of these policies (+1).

Direct impacts on environmental adaptation and resilience—Public parks and green spaces, particularly in urban areas, can reduce the adverse physical impacts of climate change, for example by reducing flooding from storm water (Alexander *et al.*, 2019; Ahiablame *et al.*, 2012; Seddon *et al.*, 2020).

Environmental protection and (re)building initiatives, including conservation, natural infrastructure resilience, afforestation, reforestation, and environmental rehabilitation, can enhance the physical resilience of ecosystems and urban spaces. In particular, these initiatives help to protect natural and human capital from erosion, flooding, and drought (Seddon *et al.*, 2020).

Payments for ecosystem services (PES) contributes to direct adaptation and resilience by strengthening the physical resilience of ecosystems to adverse climate impacts. For example, regulatory ecosystem services, such as water and erosion regulation, can enhance the resilience of ecosystems to climate shocks, thus improving (+1) direct or physical climate change adaptation and resilience outcomes (Van de Sand, 2012).

Other non-agricultural examples of sustainable land management include planting vegetation in desert or dryland areas for carbon sequestration in vegetation and soil (Bai *et al.*, 2021; Yang *et al.*, 2014). Sustainable land management increases the resilience of ecological systems to climate change, for example by enhancing soil health and moisture retention and by increasing biodiversity (Branca *et al.*, 2013; Cowie *et al.*, 2011). These policies are therefore expected to result in a positive (+1) impact on direct climate change adaptation and resilience.

Overall, spending on natural infrastructure and green spaces is expected to have positive impacts for direct climate change adaptation and resilience, by enhancing the physical resilience of natural and human capital to adverse climate impacts (Seddon *et al.*, 2020). All of these policies are therefore expected to have positive (+1) impacts on direct adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Extreme heat from climate change has adverse health impacts, including increased heat stress and heat-related morbidity (Mathey *et al.*, 2011). Public parks and green spaces, particularly in urban areas, can reduce heat stress and morbidity by mitigating urban heat island effects (Braubach *et al.*, 2017; Mathey *et al.*, 2011; Seddon *et al.*, 2020).

Environmental (re)building initiatives, including afforestation, reforestation, and environmental rehabilitation, can increase socio-economic resilience and enable local community adaptation to the adverse impacts of climate change (Kim *et al.*, 2021; Rahman *et al.*, 2018; Seddon *et al.*, 2020). In particular, these projects can provide a buffer for communities against climate shocks by enhancing and diversifying ecosystem services and protecting natural resources (Seddon *et al.*, 2020).

Payments for ecosystem services (PES) contributes to indirect adaptation and resilience by strengthening ecosystem services that contribute to the adaptive capacity of communities, such as the provision of food and income. For example, provisioning ecosystem services such as the provision of food and fodder can strengthen community resilience by providing a source of sustenance and income, which helps to increase communities' ability to withstand climate-induced shocks (Van de Sand, 2012).

The enhanced ecological resilience of sustainably managed land has positive outcomes for neighbouring communities, including more resilient livelihoods and food security (Branca *et al.*, 2013; Cowie *et al.*, 2011). These policies are therefore expected to result in a positive (+1) impact on indirect climate change adaptation and resilience.

General spending on natural infrastructure and green spaces is expected to have positive impacts for indirect climate change adaptation and resilience, by enhancing socio-economic resilience and adaptation of local or adjacent communities (Seddon *et al.*, 2020). All of these policies are therefore expected to have positive (+1) impacts on indirect adaptation and resilience.

Impacts on wealth inequality—There is little evidence that natural infrastructure and green space investment have significant first-order impacts on wealth inequality. Therefore, little net change (0) is expected as a result of these policies.

Impacts on rural livelihoods—There is little evidence that natural infrastructure projects that are not directly targeted at rural communities will have significant impacts on that demographic beyond what is expected for the general population. We therefore expect little net change (0) as a result of these policies.

Notes relevant to potential impacts on economic criteria—In Brazil, for countries with (a) rich biodiversity resources, (b) reforestation, or (c) investment in parks, restoration and other nature-based solutions can have a positive economic multiplier. In China, India, Indonesia, Japan, South Africa, the UK, and the USA, they can perform much better than traditional water investments, driven in part by tourism and labour-intensive job creation channels. Investing in natural capital also boosts resilience to climate change and has long-term economic benefits. In the USA in particular, habitat restoration projects, parks and land conservation have created, on average, 17 jobs per million dollars spent in studied cases, which is much higher than traditional industries including coal, gas, and nuclear energy generation (Edwards *et al.*, 2013).

ξ. Agriculture and fisheries (discretionary)

Impacts on short- and long-term GHG emissions—While agriculture is a high GHG-emitting sector (Balsalobre-Lorente *et al.*, 2019; Dury *et al.*, 2019; Vermeulen *et al.*, 2012), additional investments in general agricultural projects are not expected to substantially alter the BAU trajectory. Population growth and demographic change drive increases in calorific demand and therein facilitate growth in private investment. New public investment generally acts to either (i) shift current growing/rearing patterns rather than total calorific content, wherein the GHG impact of those shifts depend entirely on which patterns are being supported and which are being put aside, or (ii) promote more efficient practices of agricultural production, which might reduce energy use but possibly simultaneously boost total production—again, it depends entirely on the policy.

Therefore, in the absence of more specific policy-level details, this subarchetype is expected to bring little net change (0) to GHG emissions, both in the short-term and long-term.

By contrast, clean and/or resilient agricultural practices have a positive impact on short-term (+1) and long-term (+2) GHG emissions, via two key pathways. First, by encouraging carbon sequestration in soils and vegetation at significant magnitudes, both in the short-term and long-term (while soil carbon sequestration potential is not indefinite, it is nonetheless maintained over longer time horizons of decades under certain environmental conditions) (Horrigan, Lawrence, and Walker, 2002; Lal, 2004; Paustian *et al.*, 1997; Pretty *et al.*, 2002; Post and Kwon, 2000). Second, by avoiding GHG emissions that would have been released under conventional agricultural practices, such as reducing the use of synthetic chemicals (which produce GHG emissions, such as nitrous oxide and carbon dioxide), with both short-term and long-term positive impacts (Horrigan, Lawrence, and Walker, 2002; Pretty *et al.*, 2002).

Fisheries represent a notable source of GHG emissions (Farmery *et al.*, 2014; Parker *et al.*, 2018; MacLeod *et al.*, 2020; Yuan *et al.*, 2019) and additional public investments in general fisheries projects without environmental controls can significantly change local marine environments, reducing GHG sequestration and/or increasing GHG release (Trebilco *et al.*, 2020). However, the GHG impact per dollar will vary by project, with many projects likely having little to no impact or even shifting demand away from farmed or overfished regions. As such, we provide a low negative score (-1) for GHG impact in both the short and long term.

Clean and/or resilient fishery practices have been shown to reduce GHG emissions from fishing through two main pathways. First, practices such as switching to sustainable harvesting equipment (such as substituting passive fisheries, trap fisheries, or gillnets for conventional dredging, bottom-trawling, and beam-trawling equipment) have co-benefits for emissions, as they are less energy-intensive, resulting in a lower GHG emissions output (Seas at Risk, 2008). Second, sustainable aquaculture practices, such as improved feed and nutrition management and integrated aquaculture, result in lower GHG emissions (Boyd *et al.*, 2020). Clean and/or resilient fishery practices thus have a positive (+1) impact on short and long term GHG emissions.

Impacts on natural capital—Though some agricultural practices can improve natural capital if implemented sustainably, many current practices can cause significant soil degradation and other environmental issues (Kopittke et. al., 2019). Business-as-usual agricultural investment is associated with increasing agricultural land use, land use intensity, degradation, pollution, and fragmentation (Ascui and Cojoianu, 2019). Evidence shows that government support to agriculture can be harmful to biodiversity (OECD, 2020b); in particular, support based on prices and output levels encourages intensification of production, which incentivises higher levels of fertiliser and pesticide use. The environmental externalities of crop production may even exceed the market value of the crops themselves in some countries (FAO, 2015). In many countries, a majority of agricultural support funding has been estimated as environmentally harmful (OECD, 2020b), with only very limited support carrying explicit environmental constraints or objectives. Investment in agriculture also increases efficiency and yields, and may in this way relieve some of the demand for agricultural land; however, in the absence of targeted clean agriculture spending, this effect is small compared to the negative impacts outlined here. We thus estimate an overall negative (-1) effect on natural capital for general agricultural spending, on the assumption that it does not have environmental objectives.

Similarly, general investments in fisheries are anticipated to increase fishing activities, which may maintain unsustainable fishing practices or incentivise overfishing, habitat destruction, bycatch, and use of derelict and destructive fishing gear (Hill, 2022). These have highly destructive effects even over short time spans. As well as depleting coastal fish stocks and degrading coastal environments and habitats, fishing without adequate environmental precautions can increase marine pollution (Sumaila *et al.*, 2011). We thus estimate an overall negative (-1) effect on natural capital for general fisheries spending.

Clean, sustainable or resilient agriculture and fisheries policy is linked with more sustainable use of natural capital assets including land, soil and fish stocks, and with mitigating negative externalities of production and harvesting. Governments may choose to provide targeted support aimed at improved biodiversity outcomes and the use of more environmentally sustainable inputs (OECD, 2020b). Adaptive cropping and crop diversification, for example, ensures soil and water conservation, efficient water management, and improved soil carbon storage (Climate-ADAPT, 2019). This practice leads to improvement in soil fertility, increased resource efficiency, and improved climate resilience (FAO, 2018). Agroecological processes also enhance soil health and pollinator populations, improving the state of natural capital. Sustainable land management strategies can improve water and biodiversity, ensure natural flood management, and mitigate coastal erosion risk (DEFRA, 2022). They can significantly reduce negative externalities from agriculture, prevent land degradation, maintain land productivity, and facilitate climate adaptation (Angelo and Du Plessis, 2017). Sustainable land-use options which reduce vulnerability to nutrient loss and soil erosion include growing green manure and cover crops, reducing tillage, improving grazing management, and retaining crop residue, which reduce pressures on natural capital. Overall, sustainable agricultural practices improve conservation of biodiversity, increase water and nutrient buffer capacities, and reverse land degradation trends (IFAD, 2019). Hence, we estimate a significant positive natural capital impact (+1) as a result of spending on green agriculture and fisheries policy.

Impacts on air pollution—The air pollution impacts of agriculture practices are heterogeneous among regions, and it is therefore not possible to assign a score that is appropriate for all policies that may fall under this archetype. Given the heterogeneity, we expect that on average, agricultural uplift policies will have little net impact on air pollution (0).

Direct impacts on environmental adaptation and resilience—Support for agriculture, forestry and fisheries without green conditions aims to enable businesses in this sector to continue their business-as-usual practices. Unless there are substantial investments in adaptation and resilience, climate change is expected to have adverse indirect impacts on the agricultural sector, including increased prevalence of natural disasters (which destroy agricultural assets and infrastructure), the proliferation of pests and diseases, detrimental yield impacts from changing temperatures and precipitation, disruption to trade, price instability, and loss of livelihoods, with the negative impacts disproportionately borne by smallholder food producers and farmers in lower- and middle- income countries (Dury *et al.*, 2019; FAO, 2021). The distributions of these adverse impacts will be uneven, with some areas standing to temporarily gain from the rising temperatures; in general, however, the sector as a whole will be negatively impacted by climate change, with negative impacts disproportionately borne by lower- and middle- income countries (Dury *et al.*, 2019). Thus, in the long-run, business-as-usual modes of agriculture, forestry and fishing will result in these businesses being vulnerable to adverse climate impacts. Therefore, spending on long-term business-as-usual modes of agriculture that are vulnerable to adverse climate impacts is expected to have a negative (-1) score for direct adaptation and resilience. For policies without green conditions targeted towards short-term relief, we expect little overall impact (0) on direct climate change adaptation and resilience.

However, Pineiro *et al.* (2020) find that farmers have the highest adoption rates for liquidity-support-based environmental programs that provide short-term economic benefits. Many of these programs encourage sustainable agricultural practices that have the potential to enhance climate change adaptation and resilience outcomes, for example by strengthening ecosystems and food systems (Pineiro *et al.*, 2020). Clean and/or resilient agricultural practices directly enhance the physical resilience of agricultural systems to adverse climate change impacts. Practices such as crop diversification, inter-cropping, integrated livestock and cropping systems, and soil management result in positive ecological outcomes, such as improved soil health (including better water retention and reduced soil erosion) and increased biodiversity, which enhances the direct physical resilience of agricultural systems to adverse climate impacts (El Chami, Daccache, and El Moujabber, 2020). Clean and/or resilient agricultural practices are thus given a positive (+1) score for direct A&R.

Similarly, unless there are substantial investments in adaptation and resilience, climate change is expected to have direct, adverse impacts on the fisheries and aquaculture sector, including increased water temperatures, ocean acidification from rising GHG concentration, rising sea levels, and increased storm activity (De Young *et al.* 2012). Unless these anticipated changes are incorporated into management systems, these changes could have profound long-term detrimental impacts on fisheries and aquaculture (De Young *et al.* 2012). Business-as-usual practices are vulnerable to adverse climate impacts, thus resulting in a negative (-1) score for direct adaptation and resilience. For policies without green conditions targeted towards short-term relief, we expect little overall impact (0) on direct climate change adaptation and resilience.

Enhancing the resilience and adaptive capacity of the fisheries and aquaculture industry requires increasing the biodiversity of fish stocks, reducing overfishing and other strains on fish populations, as well as embracing adaptive management strategies (De Young *et al.* 2012). Clean and/or resilient fishery and aquaculture practices that promote these objectives include responsible and sustainable management of wild fisheries and aquaculture facilities, the replacement of conventional harvesting infrastructure (such as dredging, bottom-trawling, and beam-trawling equipment) with more sustainable alternatives (such as passive fisheries, trap fisheries, and gillnets), introduction of polyculture methods, rehabilitation of degraded habitats, and better integration of aquaculture with natural habitats, such as mangrove habitats (Seas at Risk, 2008; Primavera, 2006). Policies that support clean and/or resilient fisheries thus have a positive, direct impact (+1) on adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—In the long-run, business-as-usual modes of agriculture, forestry and fishing will be vulnerable to adverse indirect climate change impacts, such as disruption to trade, price instability, and loss of livelihood (Dury *et al.*, 2019). For long-term business-as-usual policies, we expect a negative (-1) impact, while for policies without green conditions targeted towards short-term relief, we expect little overall impact (0) on indirect climate change adaptation and resilience.

Again, however, policies with green conditions might have a significant impact by encouraging sustainable agricultural practices (Pineiro *et al.*, 2020). Clean and/or resilient agricultural practices have a positive indirect impact on climate change adaptation and resilience. Practices such as adaptive cropping and agroecology improve the physical resilience of agricultural systems, which indirectly enhances the adaptive capacity of agricultural workers by protecting their livelihoods from adverse climate impacts, as well as providing more diversified sources of income (Colting-Pulumbarit *et al.* 2018). Moreover, organic farming has been shown to enhance farmers' human and social capital, thus increasing their adaptive capacity, by entrenching them in strong social networks and organisations (Colting-Pulumbarit *et al.* 2018). Clean and/or resilient agricultural practices are thus given a positive (+1) score for indirect A&R.

For fisheries, again, we expect a negative (-1) impact for long-term business-as-usual policies, while for policies without green conditions targeted towards short-term relief, we expect little overall impact (0) on indirect climate change adaptation and resilience.

Clean and/or resilient fishery and aquaculture practices include the responsible and sustainable management of fish populations, the use of sustainable harvesting equipment (such as passive fisheries, trap fisheries, and gillnets, in lieu of dredging, bottom-trawling, and beam-trawling equipment), the restoration of degraded habitats, introduction of polyculture methods, rehabilitation of degraded habitats, and better integration of aquaculture with natural habitats (Seas at Risk, 2008; Primavera, 2006). These practices preserve fishery livelihoods by ensuring the resilience of fish populations. Additional, more indirect, resilience measures include the promotion of integrated and collective monitoring and information systems, embracing collaboration, as well as implementing community-based adaptation measures, all of which also indirectly enhance the resilience of the sector (Primavera, 2006). These clean and/or resilient fishery policies are expected to have a positive (+1) effect on indirect climate change adaptation and resilience.

Impacts on wealth inequality—Agriculture and fisheries are rural and usually low-earning sectors, so improvements and support to these sectors is likely to primarily affect economically vulnerable populations. We therefore expect improvements to wealth inequality (+1) from these policies.

Impacts on rural livelihoods—By nature, agricultural policies are directed towards benefitting rural communities, therefore they are expected to improve rural livelihoods (+1).

Notes relevant to potential impacts on economic criteria—Investment in green agriculture is particularly important in economies with a large agriculture sector. Sustainable agriculture has a positive economic multiplier according to research conducted in Brazil (Vivid Economics, 2021), and research on France indicates that its multiplier is higher than comparable traditional agriculture investment even in the relatively short term (Vivid Economics, 2021). Improving agricultural processes may also generate new revenue schemes for farmers, for instance by making better use of agricultural waste in countries where its management is currently inefficient (see e.g. Vivid Economics, 2021 on India).

o. Disaster preparedness investment (discretionary)

Impacts on short- and long-term GHG emissions—Most policies with a procurement or construction requirement are likely to rely on manufacturing and construction processes, bringing a short term increase in GHG emissions (Behrens, 2016; Rizan *et al.*, 2021). In the long term, however, there is little evidence to suggest significant GHG impacts will be major. We therefore expect a moderate increase in emissions in the short term (-1), but little net change in the long term (0).

Most investments in risk assessment and early warning systems will primarily entail administrative activities and the use of existing computational and communications equipment, thus requiring little additional GHG emissions. In some contexts, additional communications and computational infrastructure may be required, thus necessitating construction and material use, both of which bring GHG emissions (Behrens, 2016; Huang *et al.*, 2018; Nässén *et al.*, 2007). However, the additional construction and materials requirements are expected to be limited in scope compared to other sectors and to large-scale infrastructural projects. We therefore expect little net change (0) in short term and long term GHG emissions from these policies.

For indirect climate change adaptation and resilience measures, GHG impacts are likely to be subdued. These policies typically centre around socioeconomic, political, administrative, and planning activities (Smit and Wandel, 2006), which have a limited first order impacts on GHG emissions. As such, we expect little net impact (0) on GHG emissions in both the short and long term from these policies.

Impacts on natural capital—Disaster preparedness spending has mixed effects on natural capital. There is potential for ecosystem-based solutions for disaster risk reduction but resource intensive grey (built) infrastructure schemes still dominate thinking and spending on climate (and other disaster) preparedness globally (UNDRR, 2020).

Physical interventions for disaster preparedness can include ecosystem-based or natural capital enhancing measures, such as improved efficiency in irrigation and fertilisation methods, plant breeding for drought resilience, floating gardens, green infrastructure (green roofs, porous pavements, urban parks), adaptive forest management, agroecosystems in farming systems, improved land and water management, and enhancement of mangroves and salt marshes. These approaches can improve storm water management, reduce floods in cities, and moderate the heat-island effect, among other climate resilience improvements (Noble *et al.*, 2015). In the case of disaster mitigation and preparedness related to floods, fires and earthquakes, projects often enhance natural capital as a protective measure, though others may involve the destruction of natural environments to protect urban centres (Heikkila & Huang, 2014). Overall, in many economies, climate proofing and adaptation spending is dominated by investments in grey infrastructure, such as storm and wastewater flow management, flood levees, seawalls, wind and flooding resilience upgrades, and retrofitting, which tend to have negative impacts on natural capital. We therefore maintain our assessment of little net change (0) for this subarchetype, since changes may be either positive or negative.

Impacts on air pollution—There is little evidence of significant air pollution effects resulting from these policies (0). Though manufacturing is involved, it is often at a smaller scale than most other manufacturing projects, and few of the goods required for disaster preparedness are particularly air pollution-intensive to produce.

Direct impacts on environmental adaptation and resilience—Disaster preparedness investment is a crucial part of environmental adaptation and resilience. Spending on disaster preparedness is expected to have positive impacts for climate change adaptation and resilience, although the extent to which these policies have first-order, direct physical impacts for climate change adaptation and resilience will vary by measure. We expect that typically, general disaster preparedness measures will involve some physical, direct dimensions; therefore, these policies are scored as having a positive (+1) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Two crucial components of climate change disaster preparedness are risk assessments and early warning systems (UN-Habitat, 2011). Climate change risk assessment entails formally evaluating the likelihood of climate-related hazards and their expected impacts on communities and economies, as well as identifying avenues for addressing these risks (Adger *et al.*, 2018). Early warning systems entail the integrated use of meteorological, hydrological, or other risk detection systems alongside communications platforms, to ensure the timely and effective dissemination of information about hazardous climate-related events, to enable individuals and communities to take proactive actions to reduce their risk (Basher, 2006). In many contexts, these policies will primarily involve administrative investments and the use of existing communications and computational infrastructure (e.g., sending mass SMS alerts, preparing national and municipal climate risk plans). In some contexts, particularly in lower-income countries and rural areas, more robust measures may be required to strengthen underlying communications and computing infrastructure (Senaratna *et al.*, 2014; Cuevas, 2012; GERES, 2015). Both risk assessment and early warning systems provide individuals and communities with the information required to then take action to reduce their physical risk, as well as to mitigate socioeconomic impacts; as such, these systems have a positive, indirect (+1) impact on climate change adaptation and resilience.

Climate change is expected to increase the emergence of zoonotic disease epidemics, with adverse impacts for human and animal health (IPCC, 2022). Investment in future epidemic reaction capabilities will enhance the ability of local, national, and global communities to be resilient in the face of future epidemics. These policies are therefore expected to positively (+1) impact indirect climate change adaptation and resilience.

Emergency response systems encompass the personnel, information technology, and social communication systems involved in the coordination and distribution of information and resources to respond to a climate, health, or other emergency event (Shen and Shaw, 2004; Uhr *et al.*, 2008). When implemented effectively, emergency response systems enhance the resilience of communities and economies by ensuring the necessary materials and equipment are in place to prepare for and respond to an emergency event, thus reducing loss of lives and property (Bissell *et al.*, 2004; Huang *et al.*, 2011). The pathway of impact is indirect (+1), as the emergency management system does not itself enhance physical resilience; rather, it enables the provision of materials and equipment which, themselves, enhance physical resilience.

Having timely access to sufficient quality and quantity of emergency response equipment and materials is crucial to ensuring the effectiveness of disaster response (Huang *et al.*, 2011; Hale and Moberg, 2005). Equipment and materials for emergency response may include medical equipment, PPE, water storage and treatment equipment, emergency response and excavation vehicles, construction equipment, power and lighting equipment, and basic food, water, and shelter materials (Okeagu *et al.*, 2021; WHO, 2009; Chen *et al.*, 2011). The procurement of emergency response equipment has an indirect, positive (+1) impact on the ability of individuals, communities, and economies to adapt and recover in the wake of a disaster.

In general, spending on disaster preparedness is expected to have positive impacts for climate change adaptation and resilience, although the extent to which these policies have greater impacts for direct versus indirect adaptation and resilience will vary by measure. Nonetheless, even measures that emphasise physical disaster preparedness will have positive socio-economic and adaptive capacity impacts for communities in the area (Smit and Pilifosova, 2003). These policies are therefore expected to have a positive (+1) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—It has been well documented that disasters exacerbate wealth inequality, as low-income communities are less likely to have the resources to manage the effects of a disaster and are more likely to live in disaster-prone areas. This has been shown to be the case for both natural disasters (Howell and Elliott, 2019) and epidemics, including the present COVID-19 pandemic (Elgar *et al.*, 2020). Therefore, policies designed to mitigate and manage disasters are expected to improve wealth inequality (+1)

Impacts on rural livelihoods—Rural communities are often more vulnerable to natural disasters and epidemics than urban communities, as they usually have less access to healthcare and other services that make recovery possible. Furthermore, their income streams are heavily reliant on natural capital and are therefore extremely vulnerable in the case of natural disasters (Jerolleman, 2020). Therefore, policies designed to mitigate and manage disasters are expected to improve rural livelihood (+1).

Notes relevant to potential impacts on economic criteria—Studies in the USA find a large economic multiplier from government spending in the wake of natural disasters (Fidrmuc *et al.*, 2016, Zhou, 2017), indicating that preparedness programs in the category of disaster contingency funds may have significant economic development potential. Research beyond the USA, and specific to disaster preparedness rather than disaster response, is lacking.

π. Green housing and real estate (discretionary)

Impacts on short- and long-term GHG emissions—Clean and/or resilient investments in housing and public buildings are generally expected to be similar to the equivalent general investments in terms of short-term GHG emissions due to the construction process (-2), but in the long term, these buildings are expected to be more energy efficient than others and often use clean energy through rooftop solar power or other means (Tienhaara, 2018). Therefore, it is expected that these investments will reduce GHG emissions in the long term (+2).

In the short term, these programs involve construction and manufacturing, which have been shown to cause significant GHG emissions through the use of materials and energy (Behrens, 2016). Long term, however, energy efficiency improvements associated with building upgrades are expected to bring large decreases in GHG emissions (Ungar and Nadel, 2019). We, therefore, expect these policies to cause a large increase in GHG emissions short-term (-2) and a large decrease in emissions long-term (+2).

Impacts on natural capital—Green housing and real estate is often associated with the use of low-carbon construction materials as well as high energy efficiency and low water use post-construction, thus reducing natural capital impacts. Some green housing and real estate is also mindful of ecology, in which native habitats and species are integrated into the development landscape (DCLG, 2010), with a significant positive impact on natural capital, particularly in the case of redevelopment of existing sites. There is increasing integration of blue green infrastructure, such as sustainable urban drainage systems, into clean housing developments (Williams *et al.*, 2019), which also supports natural capital protection. However, given the trade-offs induced by increased demand for land associated with housing development, we estimate overall neutral (0) net impact on natural capital.

Building upgrades are an exception, as they are unlikely to involve any additional land use. Investment in clean and resilient housing and real estate should result in buildings which use fewer resources and create less pollution (Nilashi *et al.*, 2015), for instance through efforts to retrofit building with green infrastructure such as green roofs and walls (Liberalesso *et al.*, 2020). As such there is anticipated to be a significant positive impact (+1) associated with spending on this subarchetype.

Impacts on air pollution—Though a small amount of pollution may result from green housing and real estate in the short-term, it is low relative to large-scale infrastructure projects and is likely to terminate once the building is complete. There is little evidence to suggest significant long-term air pollution impacts from green housing or real estate. We therefore expect, in general, little net change (0) as a result of these policies.

Direct impacts on environmental adaptation and resilience—Investment in green housing and real estate can be expected to have positive direct impacts on environmental adaptation and resilience (+1). For instance, tax deductions or deferral of tax obligations for investment in building energy efficiency have been shown to have positive direct impacts on adaptation and resilience (Li, 2009; Bertone *et al.*, 2018). Clean and/or resilient new housing investment will increase the physical resilience of ecosystems, and is therefore expected to have a positive (+1) impact on direct climate change adaptation and resilience.

Climate change is expected to have adverse direct impacts on buildings, in particular due to increased prevalence of extreme weather events, greater incidence of flooding, wildfires and high winds, as well as strains on thermal comfort from extreme and rising temperatures (Chalmers, 2014). Investments in creating clean and resilient public buildings (and, by association, investments in clean or green measures, which often have synergies with resilience) are expected to positively impact direct adaptation and resilience (+1). Measures may include replacement or enhancement of heating, ventilation and cooling (HVAC) equipment, enhancements to the building envelope (e.g. insulation, sealing windows), enhancing the efficiency of hot water usage (e.g. heat traps, aerators) and lighting (e.g. daylighting, replacing lightbulbs and fixtures), introducing shading measures (e.g. shading devices, green roofs and other vegetation), and using more resilient materials (Chalmers, 2014; IEA, 2020b).

Indirect impacts on environmental adaptation and resilience—Public buildings, such as educational facilities and government buildings, are essential to the functioning of communities and economies, and thus to their adaptive capacity (Berger *et al.*, 2014; Wamsler *et al.*, 2012). Policies that create new resilient and clean public buildings in particular (or policies that improve the clean or green nature of buildings, such as through energy-efficiency measures, which often have synergies with resilience) are thus expected to positively (+1) enhance indirect adaptation and resilience.

For investments that do not concern public buildings, there is little evidence to suggest that clean and/or resilient new housing investment has any indirect impacts for climate change adaptation and resilience. This policy is therefore expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—Green housing investments increase access to stable, high-quality housing for a population and often focuses on affordable housing for low-income individuals. Housing instability has been shown to be a significant barrier to employment opportunities and therefore a barrier to economic mobility (Mavromaras *et al.*, 2011). It is therefore expected that these policies will improve wealth inequality (+1).

Green building upgrades and energy efficiency upgrades are designed to reduce the amount of energy used. Lower income households spend, on average, a much higher proportion of their income on energy (Ofgem, 2018). The decrease in energy expenditures associated with these policies are likely to disproportionately benefit lower income households, therefore we expect an improvement in wealth inequality (+1) as a result of these policies.

Impacts on rural livelihoods—There is little evidence to suggest that green housing and real estate policies have an outsized impact on rural livelihood unless they are specifically targeted towards rural communities. We therefore expect little net change (0) as a result of these policies.

Notes relevant to potential impacts on economic criteria—Green building investment has a higher economic multiplier (by potential for job creation) than traditional residential investment, according to research conducted on China (Vivid Economics, 2021), France (Vivid Economics, 2021), the UK (Vivid Economics, 2021), and the USA (Vivid Economics, 2021). In Australia, Vivid Economics (2021) note that there is potential for benefits to consumers in terms of reduced costs and potential revenue from selling electricity back to the grid, as well as potential for job creation. Almost certainly, these conclusions may generalise in some form to less developed and less urbanised economies, however the exact characteristics are unclear and will depend on energy market systems and infrastructural capacity. These are of course just some of many of the economic benefits that might come from green housing investment (for instance, the energy security benefits that come from reducing energy demand can be enormous).

ρ. Traditional housing and real estate (discretionary)

Impacts on short- and long-term GHG emissions—The construction of new housing and real estate implies increased short-term GHG emissions (-2). However, there is little evidence to suggest that construction, building upgrades and support policies will cause significant changes in long-term GHG emissions. Therefore, these are expected to result in little net change (0) in long-term GHG emissions.

Impacts on natural capital—Older data indicates that the construction of new housing is responsible for the loss of more rural land than any other type of built development (Parliament, 1998). This has impacts on soil and biodiversity, as well as requiring large amounts of construction materials and water. These impacts may be mitigated by focusing on redeveloping existing sites. It is true that funding for existing housing and real estate can increase its lifespan, increase the efficiency of water and energy use, and reduce its environmental impact. However, in 2012, it was estimated that 60% of the area projected to be urban in 2030 had yet to be built (CBD, 2012). This spending is thus very likely to involve new construction, with adverse impacts on natural capital (-1).

Impacts on air pollution—The construction of new housing and real estate may imply localised short-term increases in air pollution. Increased residential density may also indirectly increase air pollution through increased traffic and other associated phenomena. However, there is little evidence to suggest that construction, building upgrades and support policies will cause significant direct changes in air pollution generally. Therefore, these are expected to result in little net change (0) in air pollution.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that general new housing investment has any direct impacts for climate change adaptation and resilience. This policy is therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Public buildings, such as educational facilities and government buildings, are essential to the functioning of communities and economies, and thus to their adaptive capacity (Berger *et al.*, 2014; Wamsler *et al.*, 2012). Policies that create or improve public buildings in particular might have a slight positive (+1) impact on adaptation and resilience. However, this may be outweighed by the vulnerability of these public buildings to the effects of climate change, so that, when investment in buildings is not concerned with adaptation or resilience, we expect a neutral (0) impact on indirect climate change adaptation and resilience.

For investments that do not concern public buildings, there is little evidence to suggest that general new housing investment has any indirect impacts for climate change adaptation and resilience. This policy is therefore expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—General housing investments increase access to stable, high-quality housing for a population and often focuses on affordable housing for low-income individuals. Housing instability has been shown to be a significant barrier to employment opportunities and therefore a barrier to economic mobility (Mavromaras *et al.*, 2011). It is therefore expected that these policies will improve wealth inequality (+1).

Impacts on rural livelihoods—Unless specifically targeted at rural communities, there is little evidence to suggest that housing and real estate spending has significant particular impacts on rural livelihoods. We estimate a neutral (0) impact.

Notes relevant to potential impacts on economic criteria—housing construction contributes to economic output, creates employment, and generates a demand for materials and related services. It can generates large multiplier effects in terms of output and employment for both skilled and unskilled workers; there may also be a symbiotic relationship between housing finance and financial sector development (Doling *et al.*, 2013). Localised studies support these overarching conclusions. Data from Tomsk, Russia predicts four rubles of added value for each ruble of housing investment in the city economy (Ovsiannikova *et al.*, 2017). Data from Glasgow, UK finds a significant positive local employment multiplier for housing renovation (Zhang *et al.*, 2021).

σ. Materials (discretionary)

Impacts on short- and long-term GHG emissions—Increased material use, manufacturing and consumption have broadly been shown to increase GHG emissions short-term (Behrens, 2016; Dubois *et al.*, 2019; World Bank, 2014). We therefore expect, in general, a moderate increase (-1) in short term GHG emissions because of these policies.

Impacts on natural capital—Mining has negative impacts on natural capital, notably through land use change and pollution (Haddaway *et al.*, 2019). The same is true for other materials extraction, while manufacturing also has significant resource use and pollution effects. We estimate a negative (-1) effect on natural capital from this archetype.

Impacts on air pollution—Mining and other materials extraction activities can have negative impacts on air pollution (Haddaway *et al.*, 2019), while manufacturing is known to be harmful to air quality as a rule. We estimate a negative (-1) effect on air pollution from this archetype.

Direct impacts on environmental adaptation and resilience—Coal mines and oil/gas fields are at high risk of climate change impacts, particularly from natural disasters and flooding (IEA, 2021; ICMM, 2019). Any increased resilience from greater and more diverse availability of materials of these kinds may be outweighed by their vulnerability to adverse climate impacts. Moreover, investments in this category are so diverse as to make the assignment of a general score for adaptation and resilience difficult. Policymakers are advised to assign scores to individual policies within this archetype at their own discretion. Overall, we expect a neutral (0) impact on direct climate change adaptation and resilience for this policy archetype.

Indirect impacts on environmental adaptation and resilience—There is little evidence to suggest that general materials investment has any indirect impacts for climate change adaptation and resilience. If such investments do create jobs, they may not be in sustainable sectors. Again, investments in this category are so diverse as to make the assignment of a general score for adaptation and resilience difficult. Policymakers are advised to assign scores to individual policies within this archetype at their own discretion. Overall, policies in this archetype are expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—There is little evidence to suggest that general materials investment has any significant impacts on wealth inequality. We estimate a neutral (0) impact on wealth inequality for this archetype.

Impacts on rural livelihoods—There is little evidence to suggest that general materials investment has any significant impacts on rural livelihoods. We estimate a neutral (0) impact on rural livelihoods for this archetype.

Notes relevant to potential impacts on economic criteria—Little information is available about the economic multipliers of materials investment, especially cross-nationally, and very little is available about relevant sectors other than mining.

Fleming and Measham (2014) note that the mining industry is capital intensive, and generally, direct labour employed is low compared to other industries. As such, there is significant interest in investigating spillover effects on employment in other sectors. Using regional data from Australia, Fleming and Measham (2014) find that local multipliers of mining are important for some local services sectors such as transport and rental and accommodation services, while local job spillovers into tradable goods sectors (manufacturing and agriculture) are statistically not significant. Local multipliers also vary nationwide from those of regions where operating mines are located. Similar studies of Northern Sweden find a positive statistical relationship between increases in the number of employees in the mining sector and changes in the number of employees in other sectors, particularly the private services sector as well as the industrial sector in the specific case of mining municipalities, with high levels of inter-county variability (Moritz *et al.*, 2017); simulations predict an average employment multiplier of about 2–2.5 during the maximum production phase, indicating that for every 100 jobs in mining about 100–150 jobs are supported elsewhere in the local economy (Ejdemo and Söderholm, 2011).

Similar research also exists for developing economies. Regional-level research in Chile suggests that the mining sector is not important in terms of the backward and forward linkages within the relevant region, but is very important in terms of its volume of production; moreover, its main linkages are with the three sectors with the highest backward and forward linkages, which if taken into account make mining by far the most important sector of the Chilean II region (Aroca, 2001). Overall, national-level data from Chile indicates that every dollar invested in public geoscience information in Chile during the past three decades could have generated 11.5 dollars of government tax revenues from the mining industry, a finding which is consistent with comparable studies in other countries (Gildemeister *et al.*, 2018). Regional research on Tatarstan, Russia also suggests that mining and manufacturing are among the top three growth sectors by investment multiplier (Goridko and Nizhegorodtsev, 2018).

Evidently, this is dependent on the resources present in any given region, and research naturally tends to focus on regions where mining and manufacturing are already important sectors.

τ. Other large-scale infrastructure (discretionary)

Impacts on short- and long-term GHG emissions—As with most physical infrastructure projects, there are significant GHG emissions associated with the construction process of this archetype, impacting short term emissions (Nässén *et al.*, 2007; Arıoğlu Akan *et al.*, 2017; Cass and Mukherjee, 2011). Long term, there is little evidence to suggest GHG emissions are significantly impacted by these general policies. Therefore, we expect a large increase in GHG emissions in the short term (-1) and little net change in the long term (0).

Large-scale space infrastructure may have long-term GHG emissions consequences resulting from ongoing fuel and servicing costs, though this is small relative to other GHG sources (Larson *et al.*, 2017). We, therefore, expect some increase in long term GHG emissions because of these policies (-1). Of course, some space initiatives might involve satellite monitoring of the earth for environmental purposes (for instance, the space agencies of New Zealand and Gabon); in these cases, we suggest that the relevant policies might be better archetyped as other sectoral R&D programmes, but the researcher should use their discretion.

Impacts on natural capital—Large scale infrastructure projects have been shown to negatively impact ecosystems and natural capital, through land clearing among other mechanisms (Sabdo *et al.*, 2019). Infrastructure construction can be indicative of planned urban development, which may include strategies for sustainability and resilience (UNEP, 2021), including nature-based solutions as well as intelligent use of communications technologies, clean urban transport, and sanitation. However, these are only implied, and not actually included, under this archetype. Moreover, though funding for existing infrastructure can increase its lifespan and reduce its environmental impact, expansion or construction of new infrastructure comes at the expense of ecosystems.

Urbanisation and urban infrastructure, in particular, are instrumental in driving land-use change, and therefore the loss of ecosystems and urban green and blue spaces (Brondízio *et al.*, 2019). This includes infrastructure dedicated to climate resilience. Integrating green and grey infrastructure is crucial for climate resilience (Browder, 2019), and natural capital can play important roles in addressing urban challenges (UNEP, 2021). Indeed, nature-based and green infrastructure solutions are increasingly popular ways to address urban development challenges, but infrastructure policy is still dominated by spending on grey infrastructure (WEF, 2022). These grey infrastructure projects, including resilient infrastructure such as levees, dams, and seawalls to protect against increased storm surges and flooding, have negative impacts on natural capital. It is true that some grey infrastructure, such as cool surface treatments, flood and storm resilient buildings, early warning systems and efficiency improvements, has low natural capital impacts (Boland *et al.*, 2021). A significant proportion of spending on urban grey infrastructure will also very likely be associated with previously developed land (or brownfield land) and buildings, significantly reducing its natural capital impact. Overall, however, this policy category is dominated by environmentally harmful activities, so we estimate a negative effect (-1) on natural capital on average.

Large-scale regional infrastructure such as dams, non-coal mines and land reclamation activities also have negative effects on natural capital: dams have destructive effects on ecosystems (Pringle, 2003); mining generates land use change and pollution (Haddaway *et al.*, 2019); and reclamation in marine areas usually leads to biodiversity loss, for instance through disruption of wetland habitats (Ge and Jun-yan, 2011). This is, again, also true of infrastructure specifically intended for climate resilience. The fact that this infrastructure should be able to withstand, respond to, and recover rapidly from disruptions caused by changing climate conditions may somewhat, but not significantly, reduce their natural capital impact (OECD, 2018).

Space infrastructure is likely to include launch sites, access routes, communications and operations centres, and data storage centres. These will likely require some land use change and loss of natural capital. Though space infrastructure may be less land-intensive in terms of land use per unit of investment compared to less technologically intensive infrastructure like roads, mines, or dams, it is still a net negative for natural capital.

Thus, across all subarchetypes, we estimate a negative effect (-1) on natural capital on average from large-scale infrastructure investments.

Impacts on air pollution—Especially with reference to building materials, large-scale infrastructure projects usually result in significant amounts of air pollution (Gong and Zhang, 2004). Therefore, air pollution is likely to worsen (-1) as a result of these policies.

Direct impacts on environmental adaptation and resilience—Climate change is expected to have adverse impacts on the physical infrastructure of urban areas, in particular due to an increase in the incidence and intensity of extreme weather events, heavy precipitation, hotter temperatures, flooding, landslides, and, in coastal areas, sea-level rise and storm surges (IBRD & World Bank, 2011; Revi *et al.*, 2014). Investment in general large-scale urban infrastructure without incorporating climate change adaptation and resilience measures will result in vulnerability to climate change in the future. However, due to the varied nature of general spending on large-scale urban infrastructure, the specific impacts on climate change adaptation and resilience cannot be approximated without more granular data. These policies are therefore generally expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Large-scale infrastructure projects to enhance the resilience of cities to climate change may include new construction, such as building seawalls or levees, or improving the resilience of existing infrastructure, such as increasing capacity for storm and surface water drainage systems (Kirshen *et al.*, 2015; Revi *et al.*, 2014). These policies are expected to have a direct, positive (+1) impact on adaptation and resilience of urban areas.

Climate change is also expected to have adverse impacts on regional communities and economies, in particular due to increased incidence and intensity of extreme weather events, flooding, extreme temperatures, and, in coastal areas, sea level rise and storm surges (Dasgupta *et al.*, 2014). These impacts will be felt particularly through stresses on water resources, food supply, and agriculture, as well as through damage to physical assets and infrastructure (Dasgupta *et al.*, 2014). Investment in general large-scale regional infrastructure without incorporating climate change adaptation and resilience measures will result in vulnerability to climate change in the future. However, due to the varied nature of general spending on large-scale regional infrastructure, the specific impacts on climate change adaptation and resilience cannot be approximated without more granular data. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Large-scale infrastructure projects to enhance the resilience of regional areas to climate change may include the construction of drainage and flood management infrastructure, such as dams, levees, and canals, as well as the implementation of embankments and other protective engineering structures (ADB, n.d.; Mimura *et al.*, 2014). These policies are expected to have a direct, positive (+1) impact on adaptation and resilience of regional areas.

There is little evidence to suggest that investment in large-scale space infrastructure will have any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—Again, due to the varied nature of general spending on large-scale urban infrastructure, the specific impacts on climate change adaptation and resilience cannot be approximated without more granular data. These policies are therefore generally expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Resilience-oriented infrastructure investments, such as seawalls and levees, are critical for increasing the resilience and adaptive capacity of individuals, communities and economic systems to climate and weather related events (Mimura *et al.*, 2014; Herrero *et al.*, 2018). Moreover, investments in large-scale infrastructure for climate resilience can bolster the economic performance of cities by increasing their competitiveness and attractiveness for investors and the private sector, thus enhancing their socioeconomic resilience (IBRD & World Bank, 2011). These policies are therefore expected to have an indirect, positive (+1) impact on climate change adaptation and resilience.

Similarly, due to the varied nature of general spending on large-scale regional infrastructure, the specific impacts on climate change adaptation and resilience cannot be approximated without more granular data. These policies are therefore generally expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

However, infrastructure investments specifically aimed at increasing the resilience and adaptive capacity of individuals, communities and economic systems to climate and weather related events, particularly in rural areas that have historically received less infrastructural investment than urban centres (Mimura *et al.*, 2014; Herrero *et al.*, 2018; Dasgupta *et al.*, 2014), are expected to have an indirect, positive (+1) impact on climate change adaptation and resilience.

There is little evidence to suggest that investment in large-scale space infrastructure will have any specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—There is little evidence that, in general, large-scale infrastructure projects have significant first order impacts on wealth inequality. Therefore, little net change (0) is expected from these policies.

Impacts on rural livelihoods—Though some large-scale infrastructure projects may negatively affect rural communities though poor siting choices and other factors, these policies usually take place outside of rural areas. We therefore expect little net change (0) as a result of these policies.

Notes relevant to potential impacts on economic criteria—Research in South Africa finds that infrastructure investment, particularly in the context of COVID-19 recovery, can have high potential for job creation and thus a relatively high implicit economic multiplier, although authors note that types of infrastructure that shift the production technology could change the long-term growth trajectory, while focusing on employment-intensive investment may only generate temporary effects (Habiyaremye *et al.*, 2022). In the USA, large-scale public infrastructure spending generates growth and employment on a similarly large scale (Hockett and Frank, 2012); modelling finds that each $100 billion in infrastructure spending could boost job growth by roughly 1 million full-time equivalents (FTEs), and that each $100 spent on infrastructure could boost private-sector output by $13 (median) and $17 (average) in the long run (Bivens, 2017). The output multiplier on public infrastructure investment is substantially higher than other forms of fiscal intervention. Research in the UK indicates that sustained investment stimulus in infrastructure by one percentage point of GDP would lead to higher percentage increases relative to GDP (Office of the Chief Economic Advisor in the Scottish Government, 2018), and modelling estimates a positive multiplier effect around 1.33 (Seidu *et al.*, 2020).

Cross-national research indicates that a one-percentage-point increase in infrastructure investment relative to GDP will lead to average long-term output gains of 1% to 5% (Abiad *et al.*, 2014). This result is corroborated by research from the European Union (Coenen *et al.*, 2018). While most of this research is done in highly developed countries, the mechanisms behind these positive multipliers are likely to generalise to less developed economies, perhaps even more strongly, however with high deviation between project types.

υ. General R&D (discretionary)

Impacts on short- and long-term GHG emissions—Research projects, in general, have little short-term impact on GHG emissions as they do not usually involve large-scale manufacturing or other high-emission activities. Of course, there is wide variation between projects, with some having quite high emissions impacts per dollar of investment. However, even research projects that are not explicitly 'clean' often aim to reduce costs in existing processes and bring some energy efficiency improvements through innovation (Arnold and Barth, 2012). Therefore, for the general case, we expect little net change in short term GHG emissions (0). In the long term, for health and science programs as well as digitization and AI programs, we expect moderate improvements (+1). For space programmes, the GHG impact will depend on the nature of the funded initiatives; overwhelmingly, initiatives are likely to increase long-term GHGs by enabling more emissions-heavy space operations (-1), but climate change satellite monitoring initiatives could clearly have a positive impact. For general and other programs, given high variability in initiatives, we assume a negligible long-term baseline impact (0). We advise that the researcher use their personal discretion in making related impact assessments.

Impacts on natural capital—There is little evidence of significant natural capital effects that are direct results of these policies. We therefore expect little net change (0) as a result of these policies.

Impacts on air pollution—There is little evidence to suggest that research and development, in general, has any significant impact on air pollution. We therefore expect little net change (0) as a result of these policies.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that general research and development has any specific climate change adaptation and resilience outcomes. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—There is little evidence to suggest that general research and development has any specific climate change adaptation and resilience outcomes. These policies are therefore expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality –There is evidence to suggest that wealth inequality is, in general, exacerbated by R&D. This is likely the result of changes in the distribution of labour income versus capital income, in addition to high income households being more likely to consume R&D intensive products (Kim *et al.*, 2013). Other studies have found that a cause of this exacerbation is the inherently asymmetric nature of the resultant economic growth (Awaworyi Churchill *et al.*, 2020). We therefore expect wealth inequality to worsen (-1) on average as a result of these policies. We recognise that there is policy and country level variation that we are not able to capture with this assessment. We also note in supplement that there are approaches for directing R&D benefits towards lower-income individuals.

Impacts on rural livelihoods—There is little evidence to suggest that there are significant impacts on rural livelihood resulting directly from R&D that is not specifically targeted at rural communities. We therefore expect little net change (0) as a result of these policies.

Notes relevant to potential impacts on economic criteria—According to data from 31 European countries, basic R&D is one of the key categories in which public investment is effective in fostering economic growth, particularly through the creation of human capital and the functioning of economic affairs and public services (Saccone *et al.*, 2022). The multiplier effect of business-financed R&D investment and its impact on economic growth depend on the economic development and level of industrialisation of the country in question. Higher impacts tend to come in more highly developed and industrialised countries, but research hypotheses indicate that less-developed countries can particularly benefit from enhancing the quality of industry by introducing appropriate incentives, with a particular focus on the best practices of well-developed countries (Banelienė, 2021). In the case of "dirty" R&D in particular, however, some research indicates that this may have a negative economic effect, as well as long-run consequences on health, security, and economic development (Kostakis *et al.*, 2022). Research in Portugal shows that investments in refineries have insignificant economic effects (Pereira and Pereira, 2018).

ф. Clean R&D (discretionary)

Impacts on short- and long-term GHG emissions—Research projects, in general, have little short-term impact on GHG emissions as they do not usually involve large-scale manufacturing or other high-emission activities. Of course, there is wide variation between projects, with some having quite high emissions impacts per dollar of investment. By their nature, clean research and development projects are designed to assist in reducing GHG emissions in the long term, and this is often effective (Guo *et al.*, 2018; Lee & Min, 2015; Orlando *et al.*, 2020). Therefore, we expect little net change in short term GHG emissions (0), but large improvements in the long term (+2).

For R&D programs targeted to the areas of adaptation and resilience, GHG impacts are likely to vary between initiatives, in large part due to differing spillover effects. Measures for climate resilience often have synergies with, or co-benefits for, climate change mitigation objectives, specifically GHG emissions reduction (Locatelli *et al.*, 2016). This is particularly true for land-related initiatives in agriculture and forestry (e.g., agroecology reduces GHG emissions and enhances climate resilience), as well as green infrastructure and urban greening initiatives (Locatelli *et al.*, 2016; Sharifi, 2021). Given the synergies and co-benefits between climate change resilience and mitigation initiatives, green R&D programmes that focus on climate resilience are therefore expected to have positive GHG outcomes in the long-term (+1).

Impacts on natural capital—Green R&D is expected to lower the costs of green interventions, including renewable energy production and decarbonisation, which will aid in the transition away from fossil fuels and toward sustainable and clean production (UK Government, 2021b). It will accelerate the commercialisation of cleaner technologies, buildings, systems and processes, and provide solutions to improve efficiency, sustainability, and circularity (European Commission, 2021), reducing pressures on natural capital. We expect an improvement in natural capital (+1) resulting from these policies.

Green R&D also includes climate resilience: identifying climate-related risks, developing risk-informed resilience, planning transition opportunities, and producing climate services (UKRI, 2018), as well as research on the biophysical components of the earth, the drivers of climate and land-use change, and the adaptive capacities of humans and ecosystems (USGS, 2021). It can support physical interventions, such as ecosystem-based adaptation or climate resilience infrastructure (dykes, seawalls, tidal barriers). It can also include technological interventions, such as early warning systems, new building codes and desalination systems (Stalker, 2006). This is a broad category with mixed impacts, so we anticipate a neutral (0) effect on natural capital from climate resilience R&D on average.

Green agricultural R&D includes biotechnology, agricultural big data, smart monitoring, drones and robotics in farming, vertical farming, crop disease management, and smart floating farms towards climate-smart agriculture (Smith, 2016). This type of R&D is expected to have generally positive effects on natural capital, often by increasing the productivity of land and developing more sustainable and efficient land use strategies, thereby minimising land area and resources required for agricultural operations. It is expected to improve food security, reduce energy use and pressures on natural capital, and improve resource management, soil management and irrigation methods. This will help protect against environmental threats and prevent waste in harvest and storage, with positive natural capital effects. Agricultural productivity, environmental sustainability, and nutrition will all benefit from green agriculture R&D (Rawat, 2020). We therefore expect an improvement in natural capital (+1) resulting from these policies.

Impacts on air pollution—Though their aim is often to reduce GHG emission, clean R&D projects frequently have the side effect of reducing other air pollutants, including those that result from fossil fuel combustion (Perera Frederica P., 2017). Therefore, these policies are expected to improve air pollution (+1).

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that general (non-climate change specific) clean research and development in the agriculture sector has any specific climate change adaptation and resilience outcomes. Non-climate change specific policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

However, R&D programmes that focus on climate resilience can include both direct (physical) and indirect (social, political, economic) resilience measures. R&D programmes for direct (physical) resilience may include, for example, exploration of resilient sea and flood defences and the development of drought-resilient crops and water-saving technologies (UKRI, 2018; European

Commission, 2022a). In the long-term, these policies are expected to have a positive (+1) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—There is little evidence to suggest that general (non-climate change specific) clean research and development in the agriculture sector has any specific climate change adaptation and resilience outcomes. Non-climate change specific policies are therefore expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

However, R&D programmes that focus on climate resilience include both direct (physical) and indirect (social, political, economic) resilience measures. R&D programmes for indirect resilience may include, for example, research into building organisational and sector capacity and strengthening institutions and governance (UKRI, 2018). In the long-term, these policies are expected to have a positive (+1) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—Though clean R&D policies can be expected to have many of the same effects as general R&D projects, assessed as worsening wealth inequality above, there are additional factors at play. Since there is vast evidence to suggest that low-income communities are likely to be disproportionately impacted by the effects of climate change (Islam and Winkel, 2017), it follows that R&D designed to mitigate the effects of climate change will result in improvements in wealth inequality. Therefore, with these two competing impacts considered, we expect little net change (0) as a result of these policies in general.

Impacts on rural livelihoods—There is little evidence to suggest that there are significant impacts on rural livelihood resulting directly from R&D that is not specifically targeted at rural communities. We therefore expect little net change (0) as a result of these policies.

Agricultural R&D, however, is expected to result in improvements in rural livelihood, since it is targeted specifically at that community and may help to stabilise their production and income. We therefore expect improvements in rural livelihood resulting from these policies (+1).

Notes relevant to potential impacts on economic criteria—Clean R&D investment is likely to boost the effects of clean investment more generally (see relevant clean investment subarchetypes). For instance, the positive multiplier on clean energy investment may be significantly reduced if the home economy does not have local production of materials. Clean energy R&D takes advantage of this high-return area and provides the home economy with the ability to benefit from intellectual property and production of materials, potentially shifting the balance towards exports rather than imports. Empirical findings based on 18 European countries document that clean entrepreneurship and innovation have a significant positive effect on the circularity rate, whereas "polluting" entrepreneurship seems to have a negative association with circularity (Kostakis *et al.*, 2022). In the UK, research has identified export and growth opportunities in clean R&D, particularly in alternative process technologies and efficiency improvements, and potentially also in decarbonisation (BEIS and Vivid Economics, 2019). In developing countries, research has identified important ecosystem gaps preventing the development of sustainable R&D, which, if bridged, may unlock significant economic potential (see e.g. Shkabatur *et al.*, 2021 on Ethiopia).

χ. Other traditional investment

Impacts on short- and long-term GHG emissions—Due to the broad nature of this policy archetype, we expect mixed effects on GHG emissions and therefore assign a neutral score (0). Policymakers are encouraged to use their discretion.

Impacts on natural capital—Due to the broad nature of this policy archetype, we expect mixed effects on natural capital and therefore assign a neutral score (0). Policymakers are encouraged to use their discretion.

Impacts on air pollution—Due to the broad nature of this policy archetype, we expect mixed effects on air pollution and therefore assign a neutral score (0). Policymakers are encouraged to use their discretion.

Direct impacts on environmental adaptation and resilience—There is little evidence to suggest that general traditional spending will have specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—There is little evidence to suggest that general traditional spending will have specific impacts for climate change adaptation and resilience. These policies are therefore expected to have a neutral (0) impact on indirect climate change adaptation and resilience.

Impacts on wealth inequality—Due to the broad nature of this policy archetype, we expect mixed effects on wealth inequality and therefore assign a neutral score (0). Policymakers are encouraged to use their discretion.

Impacts on rural livelihoods—Due to the broad nature of this policy archetype, we expect mixed effects on rural livelihoods and therefore assign a neutral score (0). Policymakers are encouraged to use their discretion.

Notes relevant to potential impacts on economic criteria—Investment generally has a positive multiplier. However, research (e.g. O'Callaghan *et al.*, 2021 on South Africa; see also other sections of this review) indicates that traditional investment tends to have lower multipliers than comparable clean and/or resilient investment in many scenarios, although there is some ambiguity (see e.g. Lehr *et al.*, 2012 on Germany). It is also necessary to consider the long term, in which clean and/or resilient investment are likely to present even greater advantages.

ψ. Other clean and/or resilient investment

Impacts on short- and long-term GHG emissions—Due to the broad nature of this policy archetype, we expect mixed effects on GHG emissions. However, relative to traditional investment, clean and/or resilient investment is likely to prioritise reduction of GHG emissions on average. We therefore expect a positive effect (+1) overall. Policymakers are encouraged to use their discretion.

Impacts on natural capital—Due to the broad nature of this policy archetype, we expect mixed effects on natural capital. However, relative to traditional investment, clean and/or resilient investment is likely to prioritise protection of natural capital on average. We therefore expect a positive effect (+1) overall. Policymakers are encouraged to use their discretion.

Impacts on air pollution—Due to the broad nature of this policy archetype, we expect mixed effects on air pollution. However, relative to traditional investment, clean and/or resilient investment is likely to prioritise reduction of air pollution on average. We therefore expect a positive effect (+1) overall. Policymakers are encouraged to use their discretion.

Direct impacts on environmental adaptation and resilience—Clean and/or resilient investments can be expected to have positive direct impacts on environmental adaptation and resilience (see other sections of this document for examples). These policies are expected to directly facilitate as well as spur business investments in physical resilience initiatives, resulting in positive (+1) impacts for direct climate change adaptation and resilience.

However, this does depend to some extent on the type of policy involved. Indirect (economic, political) climate change adaptation and resilience measures, such as investing in community-based adaptation planning or managerial capacity (Smit and Wandel, 2006), may have impacts on direct adaptation measures, for example by encouraging increased investment in enhancing the physical resilience of human and natural resources. But these impacts are indirect, and, as such, we expect limited first order impacts (0) on physical adaptation and resilience as a result of these policies. On the other hand, direct (physical) climate change adaptation and resilience measures may include those directed at natural resources, such as localised anti-flood measures (Driessen *et al.*, 2018), or directed at man-made resources, such as improving the resilience of retail or mining facilities (Ling and Chiang, 2018; Meinel and Schüle, 2018). These policies focus on enhancing the physical resilience of natural and human resources and thus are expected to have a positive (+1) impact on direct climate change adaptation and resilience.

Indirect impacts on environmental adaptation and resilience—In addition to increasing direct, physical resilience, clean and/or resilient investments are also expected to have positive indirect climate change adaptation impacts, boosting economic opportunities and enhancing the adaptive capacity of recipient communities (IEA, 2020a). These policies are therefore expected to result in positive (+1) impacts for indirect climate change adaptation and resilience.

While policies aimed at resilience primarily have a positive direct impact on climate change adaptation and resilience, most direct adaptation and resilience projects will also have positive indirect outcomes, as the physical resilience of infrastructure and other assets also indirectly protects livelihoods and increases adaptive capacity (Smit and Pilifosova, 2003). Moreover, physical resilience projects typically result in positive job creation and livelihood outcomes, which increases adaptive capacity of the individuals employed (Mimura *et al.*, 2014; Colting-Pulumbarit *et al.*, 2018). These direct adaptation and resilience projects are thus also expected to have a positive (+1) indirect impact on climate change adaptation and resilience.

Other indirect (economic, political) climate change adaptation and resilience measures may include, for example, supply chain resilience initiatives, community-based adaptation planning, increasing social and political inclusion, enhancing managerial capacity, or providing access to institutions and information (Smit and Wandel, 2006). These measures focus on the social, economic and political dimensions of adaptive capacity (Smit and Wandel, 2006), thus indirectly enhancing (+1) the adaptation and resilience of communities and economies.

Impacts on wealth inequality—Due to the broad nature of this policy archetype, we expect mixed effects on wealth inequality and therefore assign a neutral score (0). Policymakers are encouraged to use their discretion.

Impacts on rural livelihoods—Due to the broad nature of this policy archetype, we expect mixed effects on rural livelihoods and therefore assign a neutral score (0). Policymakers are encouraged to use their discretion.

Notes relevant to potential impacts on economic criteria—Clean and/or resilient investments in general (see clean R&D archetype) tend to have positive multipliers and these generally tend to be higher than corresponding traditional investments. Green stimulus has a strong capacity to create jobs, to boost economic growth, and to do so in a timely manner (O'Callaghan *et al.*, 2022).

Some investment types not covered in the categories above may be of particular importance depending on country-level variables. For example, in the UK, alternative process technologies and efficiency improvements have been identified as having the highest potential for export and growth among green investment (BEIS and Vivid Economics, 2019). This effect may be even stronger in more manufacturing-heavy economies. As another example, in countries where biomass cooking is widely used, investments in clean cooking may have significant economic as well as environmental and health effects (see e.g. Vivid Economics, 2021 on India).

APPENDIX C. FUTURE TAXONOMY STRUCTURES

TABLE C1. Example of a potential five-level taxonomy structure applied to the operational fiscal subarchetype for health.

Level 1: archetype	Level 2: subarchetype	Level 3: recipient	Level 4: cost type	Level 5: mechanism
Health (operational)				
	Physical health support			
		Direct support to citizens		
			Direct support	
				Grant/allowance
				Subsidy
				Other non-tax incentive
				Tax rebate/credit
				Delayed tax arrangement
				Other tax incentive
		Support to public entity		
			General liquidity support	
			Personnel	
			Systems	
		Support to large business entity		
			General liquidity support	
			Personnel	
				Grant/allowance
				Subsidy
				Other non-tax incentive
				Tax rebate/credit
				Delayed tax arrangement
				Other tax incentive
			Systems	
				Grant/allowance
				Subsidy

			Other non-tax incentive
			Tax rebate/credit
			Delayed tax arrangement
			Other tax incentive
	Support to SME		
		General liquidity support	
		Personnel	
			Grant/allowance
			Subsidy
			Other non-tax incentive
			Tax rebate/credit
			Delayed tax arrangement
			Other tax incentive
		Systems	
			Grant/allowance
			Subsidy
			Other non-tax incentive
			Tax rebate/credit
			Delayed tax arrangement
			Other tax incentive
Mental health support			
	Direct support to citizens		
		Direct support	
			Grant/allowance
			Subsidy
			Other non-tax incentive
			Tax rebate/credit
			Delayed tax arrangement
			Other tax incentive
	Support to public entity		
		General liquidity support	
		Personnel	

		Systems	
	Support to large business entity		
		General liquidity support	
		Personnel	
			Grant/allowance
			Subsidy
			Other non-tax incentive
			Tax rebate/credit
			Delayed tax arrangement
			Other tax incentive
		Systems	
			Grant/allowance
			Subsidy
			Other non-tax incentive
			Tax rebate/credit
			Delayed tax arrangement
			Other tax incentive
	Support to SME		
		General liquidity support	
		Personnel	
			Grant/allowance
			Subsidy
			Other non-tax incentive
			Tax rebate/credit
			Delayed tax arrangement
			Other tax incentive
		Systems	
			Grant/allowance
			Subsidy
			Other non-tax incentive
			Tax rebate/credit
			Delayed tax arrangement

	Other tax incentive

APPENDIX D. CASE STUDY: GABON

As described in the main text, the Gabon pilot application of the SBA was conducted over 2021-2022 with support from UNDP. The application included both consideration of the 2021 budget as a whole and of individual policy options and their environmental characteristics. While the sustainable budgeting taxonomy is best applied in consideration of specific environmental impacts (e.g., short-term GHG emissions or natural capital impacts), it can also be applied based on aggregate "green" impacts, using whatever definition for "green" is preferred by the user. For simplicity, here the impacts of Gabon's 2021 budget are presented in aggregate form using a definition for green that is any policy with a positive impact on net GHG, natural capital, OR air pollution.

Excerpt from Gabon report on the characteristics of the budget excluding PPP

Excluding public-private partnerships, the SBA suggests that approximately 1.7% of 2021 planned expenditure might have green impact, 52.8% of the budget might have neutral impact, 8.5% might have direct negative impacts, and 37.1% is unclear (driven primarily by insufficient granularity in policy descriptions). Considering only investment spending (i.e., capital budget), 4.2% of 2021 planned expenditure can be considered green, 69.3% is neutral, 9.3% might have direct negative impacts, and 17.2% is unclear. The overall, sectoral, and archetype-level distribution of spending is included in figures D1, D2, and D3. A comparison to COVID-19 spending totals for green archetypes is available in figure D4. The reader will note with interest that the largest component of negative spending in Gabon is that spent on the military, followed by that spent on unsustainable or flawed transportation initiatives. Most of the green spending comes from sustainable spending on industrials. As a proportion of total sectoral spending, the greenest sector appears to be materials, however, this reflects a very minor portion of total spending (i.e., not very much in public funds is spent on materials in the first place). Importantly, the sectoral characteristics would likely change significantly if taxation-side subsidies were included in the analysis. Unfortunately, a lack of data on the use of debt financing in Gabon means that the environmental characteristics of debt is unclear. However, the average environmental characteristics of budgets over the past decade (or perhaps two decades) could stand as a proxy for debt, perhaps with annual weightings adjusted by their relative net present value (which would account for both inflation and GDP growth).

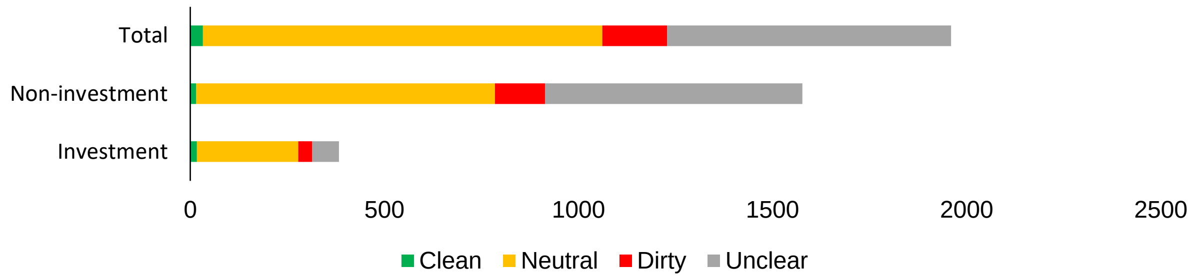


FIGURE D1. Core public expenditure categorized for environmental impact in Gabon (excluding PPP).

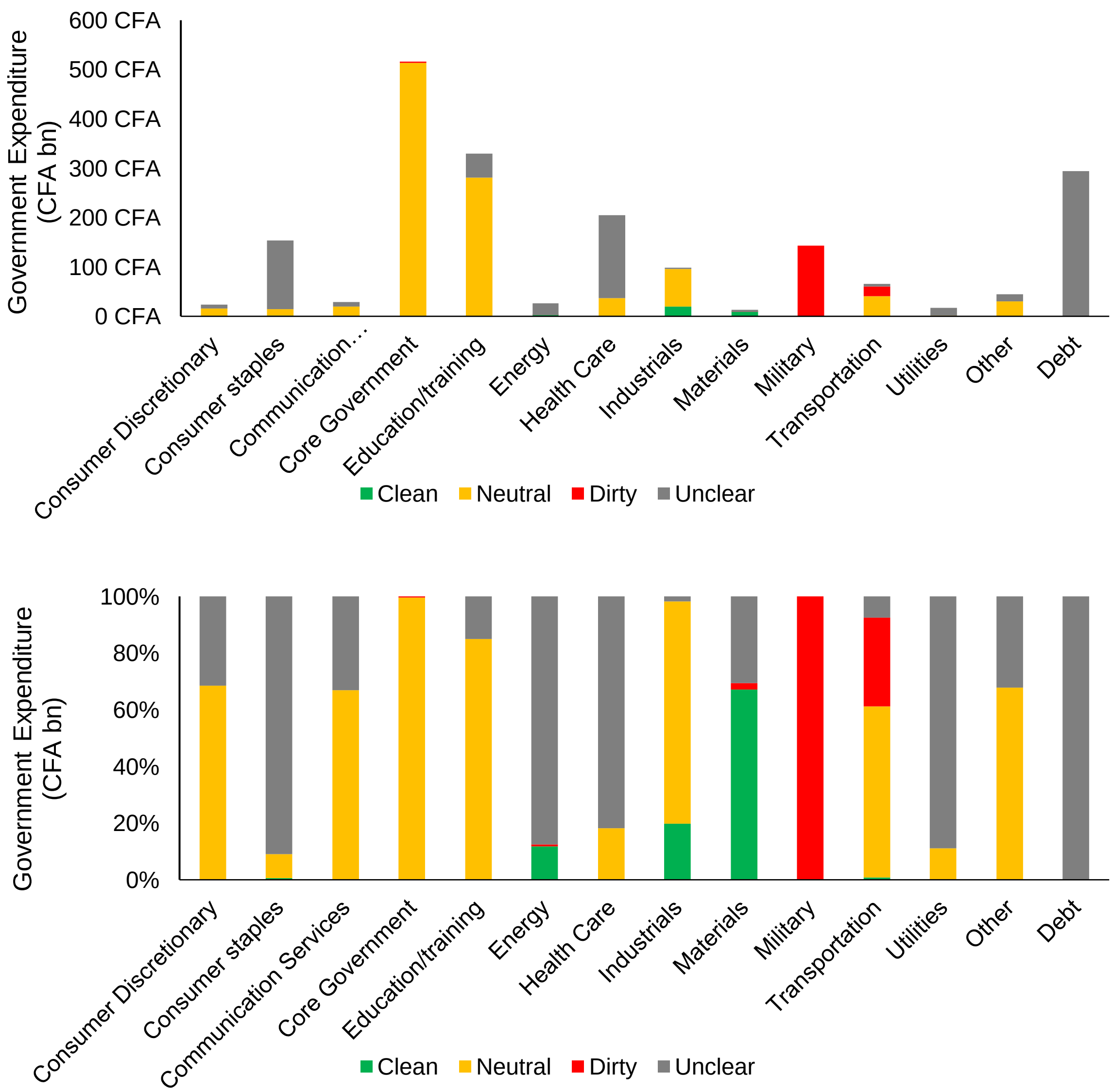


FIGURE D2. Core public expenditure categorized for environmental impact in Gabon by sector (excluding PPP). Top panel: aggregate spending. Bottom: proportional spending.

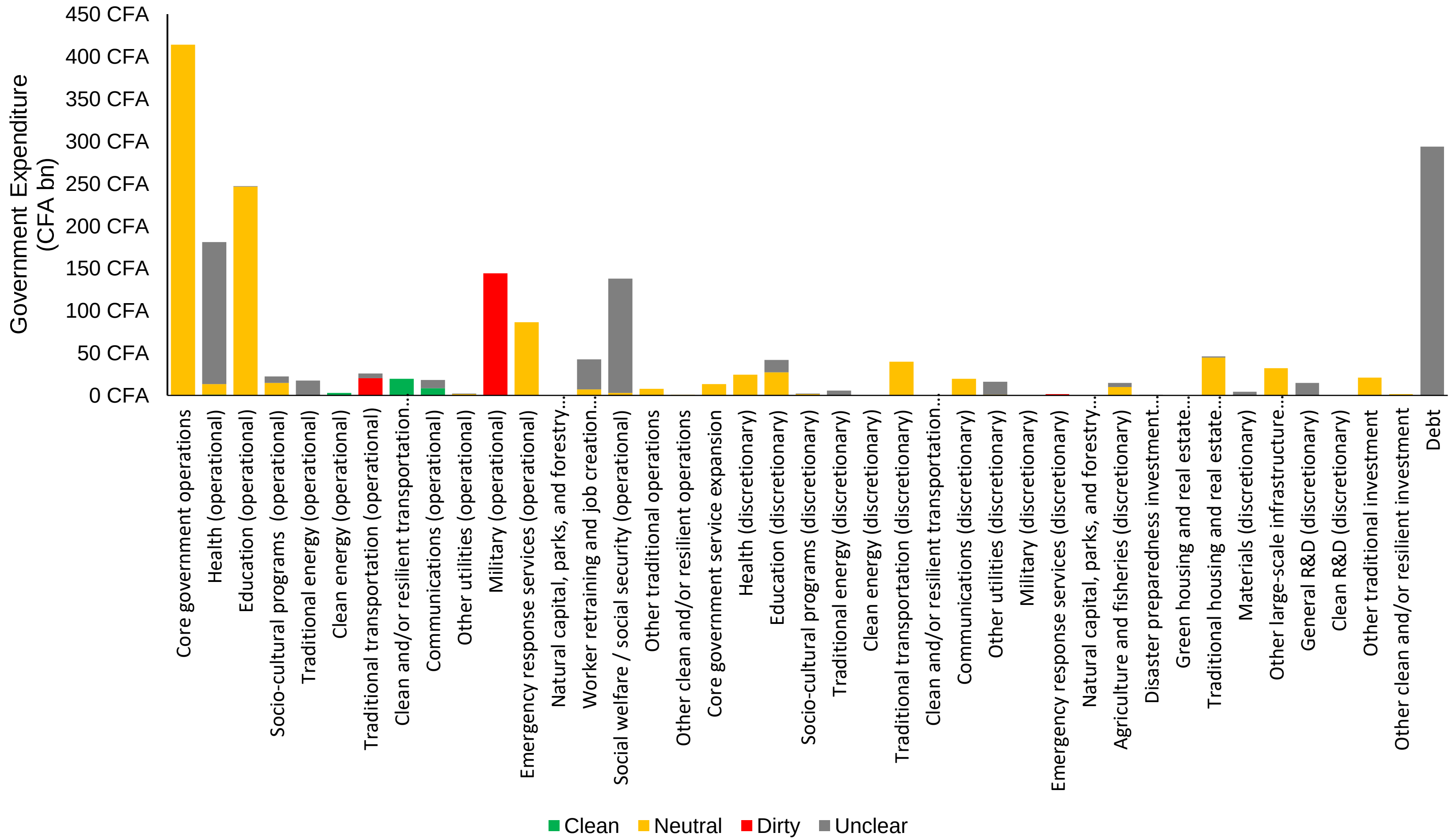
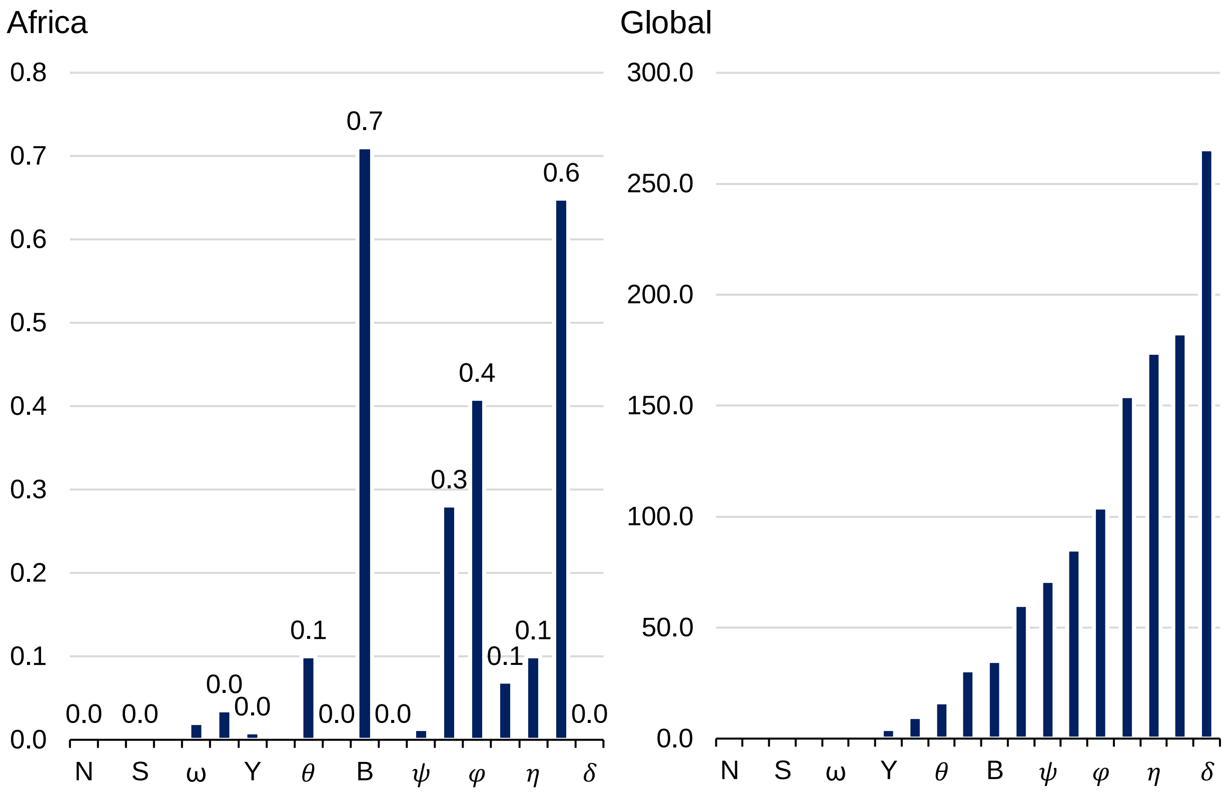


FIGURE D3. Core public expenditure categorized for environmental impact in Gabon by archetype (excluding PPP).



N	Business tax cuts
β	Communications infrastructure investment
S	Tourism and leisure industry incentives
U	Electronic appliance and efficiency incentives
ω	Agriculture and fisheries
X	Worker retraining and job creation
Y	Education investment
π	Other large-scale infrastructure investments
θ	Local (project-based) infrastructure investment
T	Electric vehicle incentives
B	Liquidity support for large businesses
λ	Buildings upgrades and energy efficiency infrastructure investment
ψ	Clean research and development investment
τ	Disaster preparedness
φ	General research and development investment
μ	Natural infrastructure and green spaces investment
η	Clean energy infrastructure investment
V	Green market creation
δ	Clean transport infrastructure investment

FIGURE D4. COVID-19 spending in 'green' categories as defined by the GRO.

Excerpt from Gabon report on the characteristics of the budget including PPP

Including public-private partnerships, approximately 9.0% of 2021 planned expenditure is likely to advance green priorities, 49.1% of the budget might have neutral impact, 7.8% might have direct negative impacts, and 34.2% is unclear (driven primarily by insufficient granularity in policy descriptions). Considering only investment spending (i.e., capital budget), 23.7% of 2021 planned expenditure is green, 49.7% is neutral, 6.8% has direct negative impacts, and 19.7% has unclear impacts. This is a significant increase for green expenditure compared to the ex-PPP scenario, driven by a handful of PPP initiatives in clean energy. The overall, sectoral, and archetype-level distribution of spending is included in figures D5, D6, and D7.

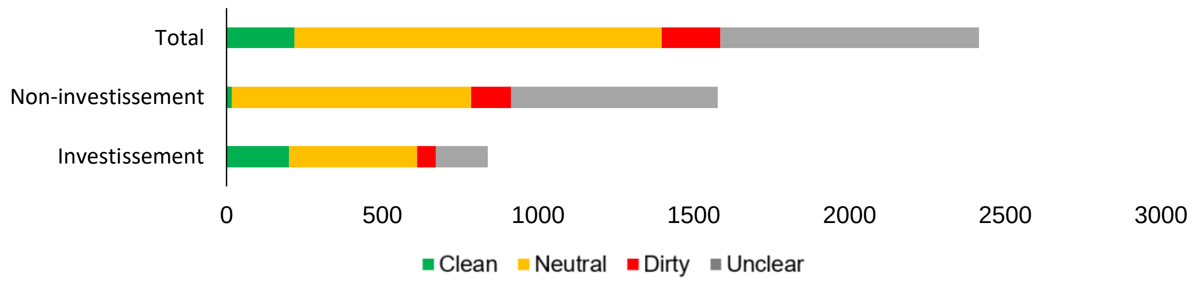


FIGURE D5. Public expenditure including PPP in Gabon, categorized for environmental impact.

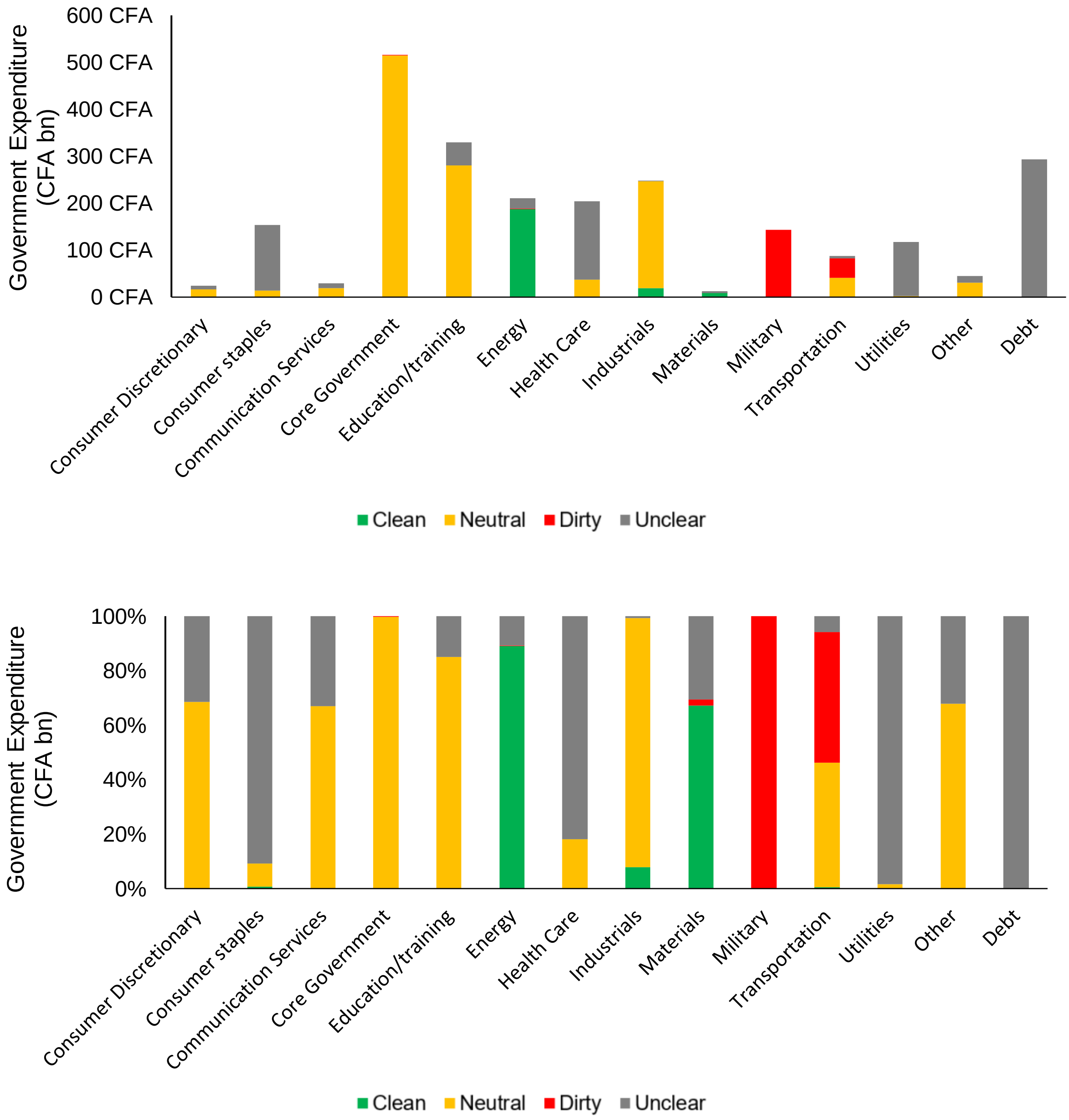


FIGURE D6. Public expenditure including PPP in Gabon, categorized for environmental impact by sector. Top panel: aggregate spending. Bottom: proportional spending.

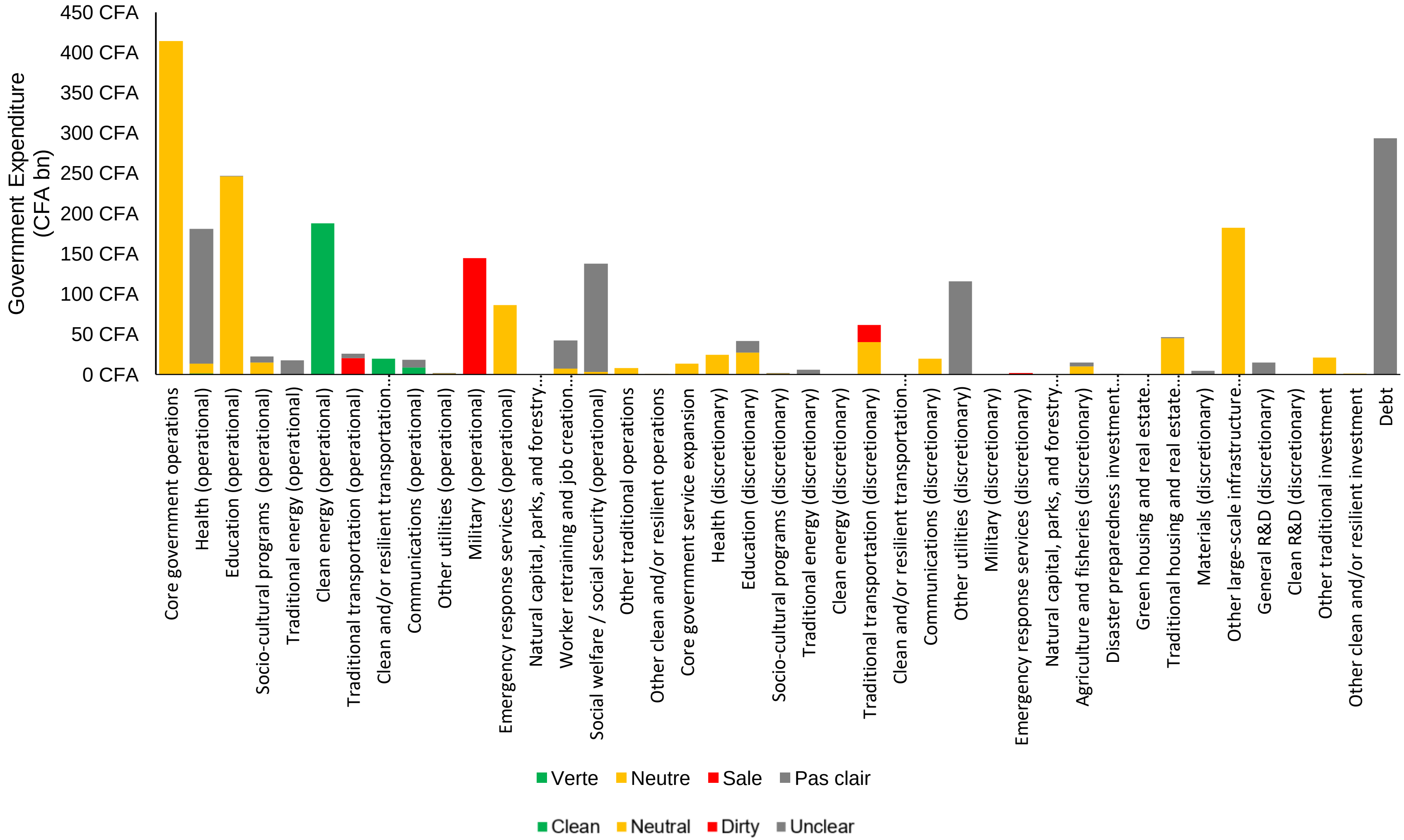


FIGURE D7. Public expenditure including PPP in Gabon, categorized for environmental impact by archetype.

Excerpt from Gabon report on comparing Gabon to other nations

As the first nation to be analysed using the sustainable budgeting taxonomy, it is difficult to meaningfully compare Gabon to others. However, using GRO data, we can make broad considerations in relation to COVID-19 spending patterns analysed globally. These observations are not intended to compare spending, but instead to provide the Gabonese policy maker additional data points in considering their own spending. Figure D8 illustrates green recovery spending in response to COVID-19 around the world and figure D9 provides a perspective on the relative spread of green spending across sectors over the first year of COVID-19.

First, from figure D8, it is apparent that several nations have spent more than 30% of their COVID-19 recovery budgets on green investments. And of those that have spent a significant amount of funds on COVID, most have spent more than 10% on green initiatives. This group includes highly developed countries like Canada and Norway, emerging countries like China, and developing countries like Senegal and Nigeria.

Second, from figure D9, and in consultation of the GRO database, in advanced economies, green investment has been directed to most major sectors. In other words, there are economically strong opportunities to invest in all manner of green programs. The degree to which this is also true in emerging markets and developing countries is not possible to infer from the data, although there remains a wide spread of spending. This is expounded further in many academic publications on the prospects of green recovery across Africa, and further afield (for instance, see report for the Republic of South Africa and report for the Democratic Republic of the Congo).

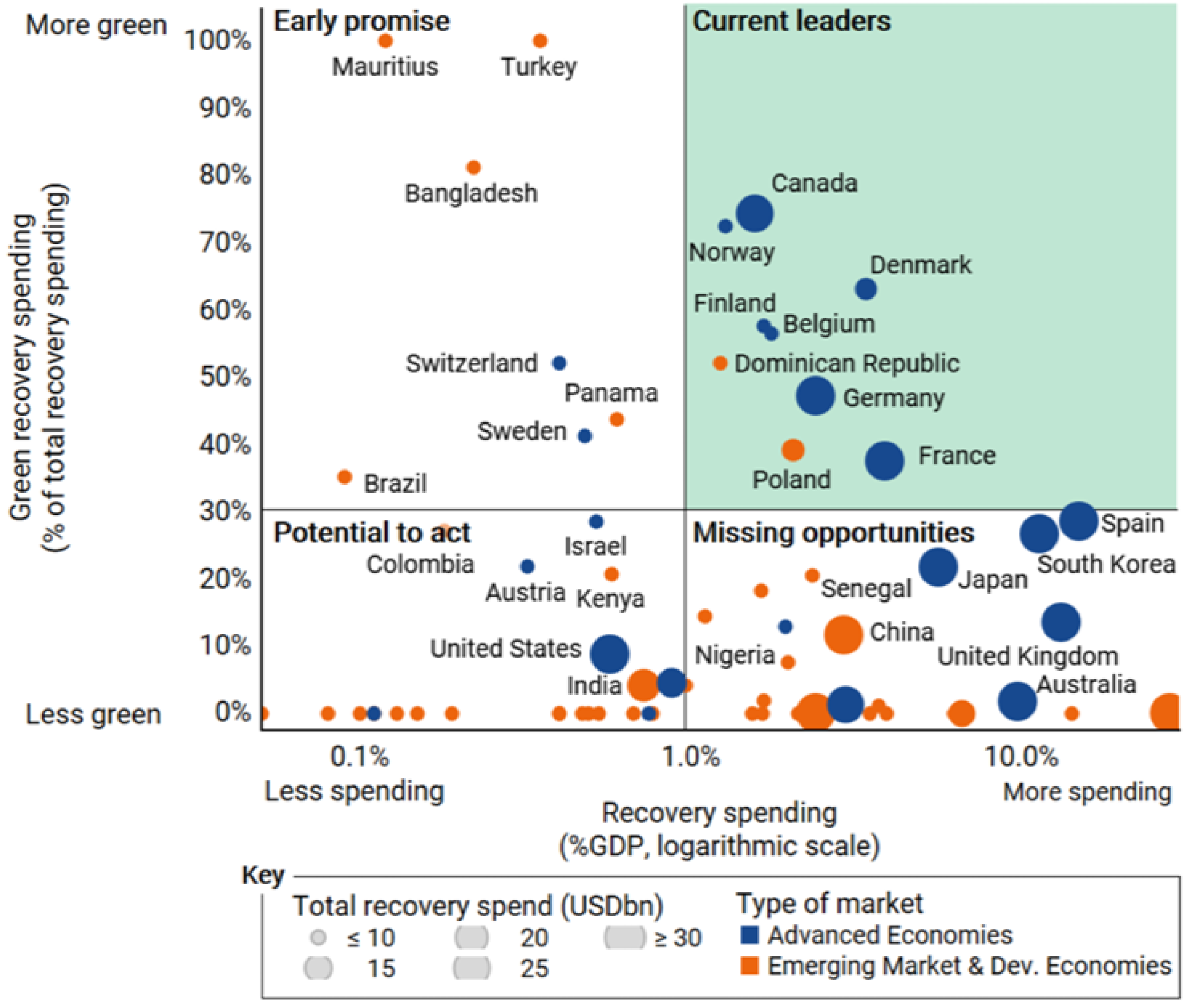


FIGURE D8. Global comparison of COVID-19 green recovery spending as a percentage of total spending versus recovery spending as a percentage of GDP. Source: Are We Building Back Better Update, GRO.

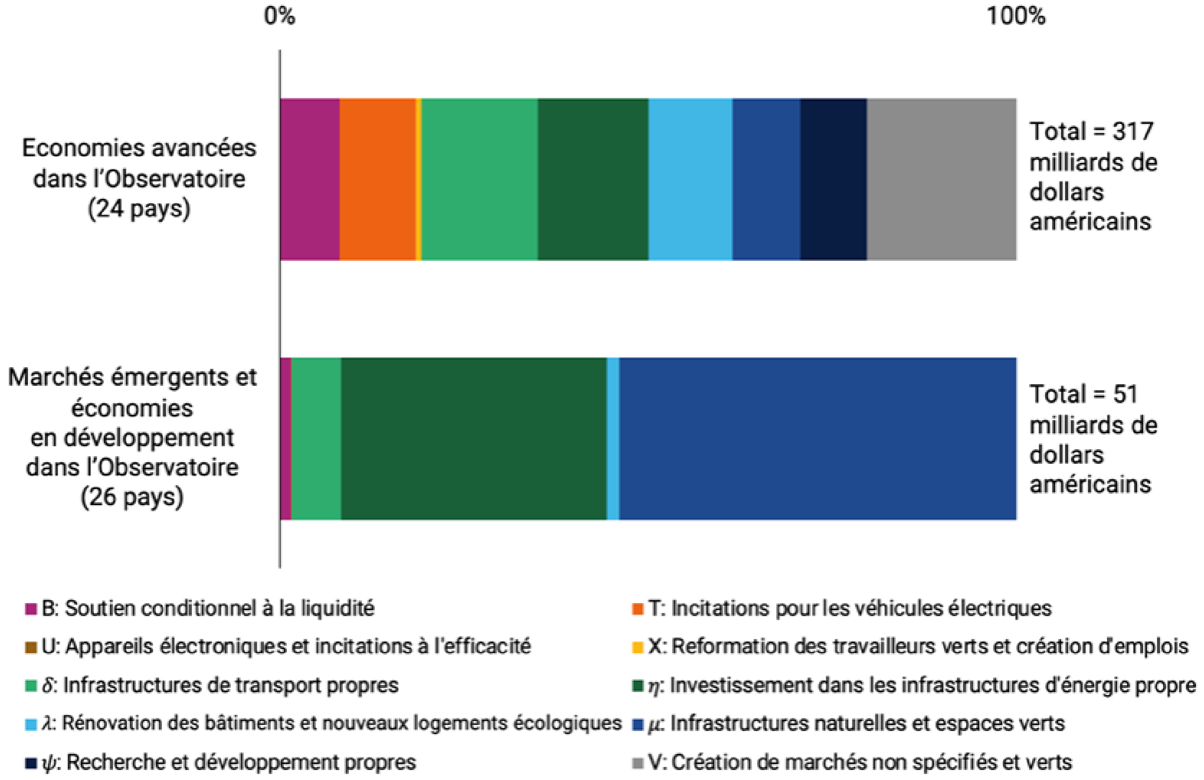


FIGURE D9. Global green recovery spending across sectors in 2020. Source: Are We Building Back Better, GRO.