Policy Research Working Paper 9528

"Building Back Better" in Practice

A Science-Policy Framework for a Green Economic Recovery after COVID-19

Theodoros Zachariadis
Elias Giannakis
Constantinos Taliotis
Marios Karmellos
Nestor Fylaktos
Mark Howells
Will Blyth
Stephane Hallegatte

WORLD BANK GROUP
Climate Change Group
January 2021

Policy Research Working Paper 9528

Abstract

As humanity's current production and consumption patterns exceed planetary boundaries, many opinion leaders have stressed the need to adopt green economic stimulus policies in the aftermath of the COVID-19 pandemic, in line with the United Nations Sustainable Development Goals and the Paris Agreement on Climate Change. This paper provides an integrated framework to design an economic recovery strategy aligned with sustainability objectives through a multi-criterion, multi-stakeholder lens. The aim is to enable decisions by policy makers with the aid of transparent workflows that include expert evidence that is based on quantitative open-source modeling, and qualitative input by diverse social actors in a participatory approach. The paper employs an energy systems model and an economic input-output model to provide quantitative evidence and design a multi-criteria decision process that engages stakeholders from government, enterprises, and civil society. As a case study, the paper studies 13 green recovery measures that are relevant for Cyprus and assesses their appropriateness for criteria related to environmental sustainability, socioeconomic and job impact, and climate resilience. The results highlight trade-offs between immediate and long-run effects, between economic and environmental objectives, and between expert evidence and societal priorities. Importantly, the paper finds that a "return-to-normal" economic stimulus is not only environmentally unsustainable, but also economically inferior to most green recovery schemes.

This paper is a product of the Climate Change Group. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at t.zachariadis@cyi.ac.cy and shallegatte@worldbank.org.

"Building Back Better" in Practice: A Science-Policy Framework for a Green Economic Recovery after COVID-19

Theodoros Zachariadis*, Elias Giannakis, Constantinos Taliotis,
Marios Karmellos and Nestor Fylaktos
Energy, Environment and Water Research Centre, The Cyprus Institute, Cyprus

Mark Howells
Loughborough University and Imperial College London, UK

Will Blyth
Department for International Development, UK

Stephane Hallegatte
The World Bank

Keywords: Energy systems model; Input-output model; Multi-criteria decision analysis; Policy formulation; Stakeholder engagement

JEL: E61, H50, Q54

* Corresponding author. Address: The Cyprus Institute, Konstantinou Kavafi 20, 2121 Aglantzia, Nicosia, Cyprus. Email: t.zachariadis@cyi.ac.cy

1. Introduction

Since mid-2020, despite the persistence of the COVID-19 pandemic, the response of governments around the world has partly moved from the provision of immediate relief to the design and implementation of economic recovery measures for the short and medium term. Leaders of international organizations have stressed the importance of adopting green economic stimulus policies in line with the United Nations Sustainable Development Goals and the Paris Agreement on Climate Change, as greener economies are more resilient to climate change, social unrest, and epidemics (IEA, 2020; IRENA, 2020; UN, 2020; World Bank, 2020). Moving from generic declarations to specific national policies, however, requires a lot of groundwork to be done because each country has to identify those interventions which fit with its special conditions, resources, and needs. Global economic support for relief and recovery from the pandemic has risen to significant levels since spring 2020 – but as regards the conformity of such stimulus measures with climate compatible growth (CCG) and broader sustainability objectives, the picture is mixed.[1]

In the European Union, the 'Next Generation EU' program and the Multiannual Financial Framework, i.e. the EU budget for 2021-2027, which were agreed by EU leaders in July 2020, offer significant opportunities for financing projects with the potential to contribute to sustainable long-term economic development and CCG (European Council, 2020). Still, each country has to prioritize recovery measures that address its specific challenges and fit with its own national capacity. For example, attaching environmental pre-conditions in the financial aid provided to vehicle manufacturers is broadly accepted as a positive measure – but it only applies to countries with automotive industry, whereas it is much less relevant for most countries of the world that are just vehicle importers. Therefore, nationally-owned economic recovery strategies have to be designed and implemented in each country.

In view of these developments, this paper presents an attempt to identify, propose and evaluate interventions that could have promising economic, employment and environmental effects. Although the focus is on the case of Cyprus, an EU member state of about one million inhabitants in the Eastern Mediterranean, the proposed framework has general application, and the underlying tools and processes are selected in such a way as to allow adoption of the approach in other national or regional contexts. We consider short- and long-term impacts of these interventions using a variety of sustainability criteria. This work started in March 2020, a few weeks after the World Health Organization officially declared COVID-19 a pandemic and most countries introduced strong coronavirus-containment measures including widespread lockdowns. To enable a fruitful science-policy interaction that can lead to meaningful recommendations to decision makers (DMs), our main purpose was twofold:

- To enrich the public debate with model-based evidence about the short- and long-term impacts of specific interventions as regards economic output, employment, energy savings and emission reductions; the models used are open-source and available to stakeholders, which increases the transparency of our approach.
- To encourage ownership of the measures by national decision makers in two ways: by extensively receiving feedback from them at different stages of this study; and by building on policies and measures that are largely based on existing national plans so that stakeholders are familiar with

[1] See webpages of 'Energy Policy Tracker' and 'Greenness of Stimulus Index'.

such interventions. This increases the likelihood for adoption of these measures in the national recovery strategy.

For this purpose, we developed a novel integrated assessment framework for the appraisal of economic recovery measures with the aid of multi-criteria decision analysis, which incorporates both quantitative data derived from models and qualitative input provided by several stakeholders. The use of qualitative input is not only necessary because models cannot adequately simulate all possible interventions and all possible impacts; it is also essential for increasing the likelihood of social acceptance of the recovery interventions to be proposed, by avoiding relying solely on knowledge silos of academic experts or governmental policy makers. This is in line with the need for broader mobilization of society for the transition to sustainability (EEA, 2020), and the model is easily applicable in other countries or regions.

A crucial aspect of our contribution is to highlight the importance of thinking beyond purely short-term recovery measures and consider investments and reforms that may take time to materialize but are essential for meeting medium- and long-term environmental objectives. The trade-offs between short- and long-term effectiveness are stressed, among others, by Strand and Toman (2010), who reviewed the green stimulus programs applied worldwide after the 2008-2009 global economic recession and found that most programs with large short-term employment and environmental effects were likely to have weaker effects for long-run growth; and that measures yielding larger employment effects tended to lead to more employment gains for lower-skilled workers, so that the long-term effects on economic growth were relatively small.

A short-term recovery plan, no matter how green it is, cannot deliver the low-carbon transition by itself; it has to be complemented by structural reforms that can deliver environmental and economic benefits over the longer term. As Barbier (2020) underlined, transitioning away from fossil fuels to sustainable low-carbon economies requires commitments to public spending and pricing reforms over a period of at least 5-10 years. Such considerations had to be made clear to national DMs, some of whom were understandably interested in mitigating the immediate impacts of the pandemic and paid less attention to long-term economic reforms.

Another contribution of our paper is that we highlight the mediocre performance of a ‘return-to-normal’ economic stimulus, not only in environmental but also in economic terms. Providing horizontal support in order to increase economy-wide consumer demand indiscriminately is less effective for inducing job creation and economic growth in comparison to most green alternatives. Up to now, this finding has been documented in very few studies in the economic literature (IMF, 2020; Pollitt, 2020), while most other studies merely compared the job creation potential of green measures against a no-stimulus case. Such a finding is especially important to demonstrate to national DMs with country-specific data and models.

Section 2 of the paper describes the main stages of this approach, the recovery measures that were considered, and the sustainability criteria used for assessing these measures; without providing details of the technical work on models or simulations, it lays out the science-policy framework in which subsequent technical analyses can turn out to be useful to DMs. Section 3 presents the results of the energy and economic models employed in this assessment and their policy implications. In Section 4 a multi-criteria assessment is presented, considering the quantitative and qualitative criteria, making use of input from a targeted group of stakeholders. Finally, Section 5 outlines the lessons learned from this study and their relevance for science-policy interactions in other national contexts.

2. Methodology

The lockdown measures to contain the spread of the pandemic led to a serious economic downturn in Cyprus, with GDP contracting by 12.2% in the second quarter of 2020 (Cystat, 2020a). As in most other world regions, economic stimulus packages had to be designed so as to be implemented quickly and to contribute to positive growth and employment impacts in the short term, keeping in mind long-term development and decarbonization objectives. Stern et al. (2020; p. 7) emphasized that “The right investments will need to be fast, labour-intensive in the short run, and have high multipliers and co-benefits, including for air pollution, climate and resilience”. Based on input of experts from Central Banks, think tanks and Ministries of Finance worldwide, Hepburn et al. (2020) identified priorities for a green post-pandemic stimulus such as clean physical infrastructure (e.g. renewable energy and modernized electricity grids), building efficiency retrofits, investment in education and training, clean energy R&D and natural climate solutions. Such findings were taken into account when identifying candidate measures for the case of Cyprus, where the EU-wide goal towards net zero greenhouse gas emissions in 2050 had to be kept in mind, as foreseen in the ‘European Green Deal’ and endorsed by EU leaders by the end of 2019 (European Council, 2019), along with the legally binding obligation for ambitious emission reductions already in 2030.

To address these multiple requirements, it was necessary to identify green economic recovery measures that had already been identified in the public discourse which might be promising in economic and environmental terms. Therefore, we started from existing plans announced by the Finance Minister of Cyprus in May 2020 as well as from measures included in the National Energy and Climate Plan that was submitted to the European Commission in January 2020 (Republic of Cyprus, 2020). Similarly, if the framework is applied in a non-EU country, the approach might begin with a breakdown of the measures included in a country’s Nationally Determined Contribution (NDC) to the UN Framework Convention on Climate Change. Our approach is summarized in Figure 1 and explained in the next paragraphs.

In summary, the approach involves:

a) proposing interventions which expand measures already announced by the national Finance Ministry as well as policies identified in the existing national energy and climate strategy;

b) receiving feedback from stakeholders to obtain a first reality check;

c) assessing measures with proper criteria that account for multiple sustainability objectives in the short and long term;

d) prioritizing measures on the basis of this assessment and considering the available budget.

Above all, it was important to ensure active participation of DMs by using quantitative models that are open-source and available to national authorities as well as transparent workflows. This enables officers from ministries to provide input at various stages of this work, and overall accountability of the process (DFID, 2019).[2]

[2] In so doing we tend towards U4RIA guidelines. U4RIA is an acronym for Ubuntu, Retrievability, Reusability, Repeatability, Re-constructability, Interoperability and Auditability. It aims to further good governance and sound scientific principles to energy modeling for policy support (DFID, 2019).

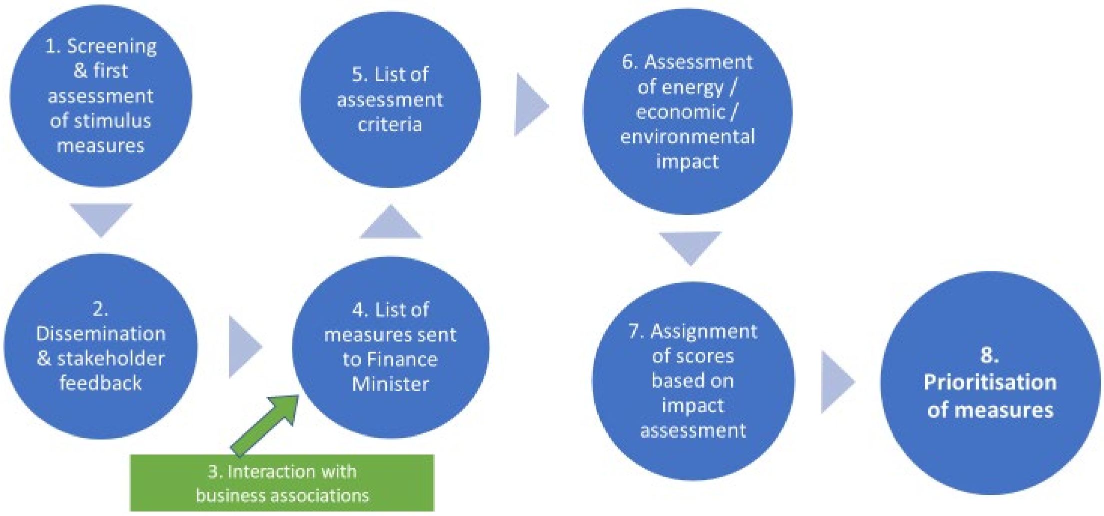


Figure 1: A depiction of the organisational workflow to ensure effective science-policy interaction for green recovery.

In more detail, the workflow consisted of the following stages:

1. Screening and preliminary assessment of potential green stimulus measures. In April 2020 we published a policy brief, alerting policy makers on the need to ensure that economic stimulus measures would enable the green transition (Zachariadis, 2020). We identified a first list of measures that could be implemented within a short period and could positively affect both employment and the environment. The list contained a qualitative evaluation of their impact; most of these estimates came from the Impact Assessment of the National Energy and Climate Plan of Cyprus, which had been finalized in January 2020.

2. Dissemination of the list of measures and stakeholders' feedback. The initial list of green recovery measures was circulated to Ministries of Finance, Environment, Energy and Transport, European Commission officials, NGO representatives and academics. Stakeholders welcomed the proposed measures and focused on the need to ensure low administrative burden to allow fast implementation, and the importance of aligning the proposals with early measures announced by the national government, in order to increase the relevance of the intervention.

3. Interaction with national business associations. In mid-May 2020, after the first wave of the pandemic had been contained and public discussions started focusing on the 'return to normality', the national Federation of Employers and Industrialists (OEB) set up a working group on the green restart of the economy, in which we participated. OEB used our proposals as a starting point and supplemented them with additional measures targeted to enterprises.

4. Enriched list of stimulus measures sent to the Finance Minister. Based on the discussions in OEB's working group, a revised list of green stimulus measures was prepared and sent by the Federation to the Finance Minister of Cyprus in mid-June 2020. Three types of measures were included:

    - Those which complemented general stimulus measures that had been announced by the Finance Minister some days before
    - Measures that had already been foreseen in the National Energy and Climate Plan of Cyprus

- New measures that could be implemented quickly, including institutional reforms that could have a long-lasting impact on the way to climate neutrality in 2050.

Thirteen interventions were identified in this way, which are listed in Table 1. More details about each measure are provided in Table A.1 in Appendix A.

5. Preparing a list of criteria for the assessment of recovery measures. A list of sustainability criteria was created, using as a starting point a comprehensive checklist developed by the World Bank (Hammer and Hallegatte 2020) especially for post-COVID-19 economic stimulus interventions. As some of those criteria were less relevant for the green measures considered here or would lead to the same score for all measures, these were omitted. Two more criteria were added: the technical and/or financial viability of each measure, and its anticipated social acceptance, related to its affordability. The list of criteria used in this paper is presented in Table 2. As the EU decided in 2019 to explicitly include the 17 United Nations Sustainable Development Goals (SDGs) in its regular macroeconomic monitoring procedure, and due to the universality of the SDGs,[3] Table 2 includes also an indication of the SDGs addressed by each sustainability criterion used in this analysis.

6. Identifying the appropriate methodology to assess impacts. For each measure, it had to be determined whether the energy, climate, and employment impact could be assessed through simple calculations or with the aid of models available for Cyprus; the outcome of these considerations is displayed in Table 3. For some measures, such as energy renovations in buildings, models are not available (there is no detailed model of the current building stock), so that the analysis had to rely on simple calculations. For other measures, such as those related to promotion of public transport or low-emission vehicles, the existing OSeMOSYS model of the Cypriot energy system can calculate short- and long-term effects on energy consumption and emissions of greenhouse gases and air pollutants. Similarly, economic impacts can sometimes be modeled through the available input-output model of the Cypriot economy, but others require a qualitative assessment based e.g. on the percentage of domestic capital and labor inputs for the considered activity. Taliotis et al. (2020a) describe the energy and economic models in more detail. Since these models are open-source, available to national authorities, and have already been used for preparing the National Energy and Climate Plan, national ministries have full access to them so that they can conduct any follow-up analysis if needed.

7. Assignment of scores and weights for each sustainability criterion. After the model-based energy and economic assessment of the measures was completed, qualitative assessments followed for the rest of the criteria (those shown in light-blue-shaded cells in Table 3). Stakeholder input was sought, and a specific workshop was organized with representatives of different governmental departments, the private sector, and NGOs. Each stakeholder provided a score of each recovery measure by criterion and a weight for all criteria as will be described in Section 4.

8. Prioritization of measures. Stakeholder data were processed and, along with model-based results, provided a final ranking of the proposed interventions. These were communicated to all DMs. Governmental authorities are able to use them for prioritizing measures in their recovery strategy.

[3] See https://www.un.org/sustainabledevelopment/ for a description of each SDG.

Table 1: List of the green recovery measures that were considered in this paper. The investment costs column for 2020-2030 includes the costs of the column on its left.

Name of measure	*Sector*	*Investment cost 2020-2022 (M€)*	*Investment cost 2020-2030 (M€)*	*of which from public funds*
M1. Immediate launch of grants for energy renovations of buildings from unused budget of 2020-21	Buildings	30	30	50%
M2. New grant scheme for energy renovations of existing buildings, 2021-27	Buildings	70	140	50%
M3. Grants for energy renovations of buildings under construction for upgrade to Near-Zero Energy Buildings	Buildings	70	70	50%
M4. Installation of smart electricity meters	Electricity	35	55	100%
M5. Virtual net billing for encouragement of photovoltaic installations by enterprises	Electricity	29	136	0%
M6. Subsidy to loans of businesses certified with an environmental management system	Industry	2	2	100
M7. Business4Climate scheme - grants to enterprises with a verified low-carbon action plan up to 2030	Industry	5	10	30%
M8. Implementation of existing Sustainable Urban Mobility Plans (SUMP)	Transport	80	100	100%
M9. Construction of tram in the capital city of Nicosia	Transport	0	225	100%
M10. Scrappage scheme for old cars to be replaced with battery electric vehicles	Transport	12	12	30%
M11. Replacement of streetlights in municipalities and villages with energy efficient lighting	Electricity	45	45	100%
M12. Tree planting along urban and intercity roads	Nature	17	85	100%
M13. Fiscally neutral carbon taxation for economic sectors out of the EU Emissions Trading System	Horizontal	0.5	0.5	100
Total		**395**	**911**	

Note: Costs are expressed in million euros at constant prices of year 2020.

Table 2: Criteria used for the evaluation of green economic recovery measures and their relation to UN Sustainable Development Goals (SDGs).

i) Performance criteria for the short term (for the next 2 years):

	Short name	*Explanation*	*Related SDGs*
Environmental impact	**Energy**	Energy savings (ktoe) per million euros invested	7
	CO2	CO_2 emission savings (tn) per million euros invested	13
	Other Environmental Impact	Other short-term environmental impact (on air quality, nature, water resources, land productivity, biodiversity, etc.)	3, 6, 11
Economic / social impact	**Economic multiplier**	Economic output generation (million €) per million euros invested	8
	Jobs	Net employment generation (persons) per million euros invested	8
	Demand in affected sectors	Does the initiative generate demand in the most affected sectors? Or does this initiative target new or different sectors? If in a different sector, can the workforce easily shift to this new sector? Does the initiative include measures to facilitate the transition of workers and the required investments?	4, 8
	Time to Implement	How long will it take to fully implement this initiative and to create jobs and activity (including project design, consultation processes, budget mobilization, procurement, etc.)?	8
	Infrastructure & Productivity	Does the measure improve existing infrastructure? Does this affect productivity in the short term?	9
	Technical feasibility	Is the intervention technically feasible with the country's capacity and know-how?	
	Affordability	Is there a risk that vulnerable households or firms will incur high costs due to the measure?	1, 10
	Social acceptance	Is the measure socially acceptable? Can it contribute to social objectives like reducing poverty and precarity?	1, 10

Table 2 (continued).

ii) Performance criteria for the longer term (mostly for 2030):

	Short name	*Explanation*	*Related SDGs*
Environmental impact	**Energy**	Energy savings (ktoe) per million euros invested	7
	CO2	CO_2 emission savings (tn) per million euros invested	13
	Low-carbon technologies / strategies	Does the intervention provide the technical means to better integrate or employ low-carbon technologies or strategies (for instance, through improvements to transmission and distribution infrastructure, public transit infrastructure, sidewalks or bike lanes, or by promoting denser urban development) that may yield benefits **beyond the year 2030**? Does it contribute to a deep decarbonization objective **by 2050**?	13, 15
	Other Environmental Impact	Other short-term environmental impact (on air quality, nature, water resources, land productivity, biodiversity, etc.)	3, 6, 11, 15
Economic / social impact	**Economic multiplier**	Economic output generation (million €) per million euros invested	8
	Jobs	Net employment generation (persons) per million euros invested	8
	Energy security	Does the intervention increase local/national energy security?	7
	Infrastructure & Productivity	Will the intervention improve local economic productivity through access to better, more reliable infrastructure services?	9
	R&D and innovation	Can the intervention spur R&D or innovation in the specific technologies?	9
	Market Failures	Will the intervention address market failures, such as market distorting subsidies, pricing that fails to account for externalities, etc.?	8
	Economic / Climate Resilience	Does the intervention improve socio-economic resilience, that is, the ability of the population to cope with and recover from shocks? Does it improve their adaptive capacity, that is their ability to reduce negative impacts (such as adapting buildings to improve resilience to extreme temperature)?	1, 8, 10, 11
	Decarbonization / Effect on NDC	Does the measure contribute substantially to decarbonization of the economy by 2030? Does it significantly affect the country's NDC to be submitted to UNFCCC?	12, 13

Table 3: An outline of the methods used to evaluate the thirteen green recovery measures. The list of criteria is a condensed form of the detailed list appearing in Table 2.

Measure	Criteria for assessment of short-term and long-term impacts						
	Energy use	Carbon emissions	Air pollutant emissions	Other environmental impact	Economic multiplier	Net employment effect per million euros invested	Effect on skills, resilience, productivity etc.
1. Immediate launch of grant scheme for energy renovations of buildings from unused budget of 2020-21							
2. New grant scheme for energy renovations of buildings, 2021-27							
3. Grants for energy renovations of buildings under construction for upgrade to Near-Zero Energy Buildings							
4. Installation of smart electricity meters							
5. Virtual net billing for encouragement of photovoltaic installations by enterprises							
6. Subsidy to loans of businesses which have been certified with an environmental management system							
7. Business4Climate scheme - grants to enterprises with a verified low-carbon action plan up to 2030							
8. Implementation of existing Sustainable Urban Mobility Plans (SUMP)							
9. Construction of tram in the capital city of Nicosia							
10. Scrappage scheme for old cars to be replaced with battery electric vehicles							
11. Replacement of streetlights in municipalities and villages with energy efficient lighting							
12. Tree planting along urban and intercity roads							
13. Fiscally neutral carbon taxation for economic sectors out of the EU Emissions Trading System							

- Calculations with computational energy/environment/economy models
- Simple bottom-up calculations based on data from National Energy and Climate Plan of January 2020
- Qualitative assessment based on stakeholder input

3. Simulations with energy and economic models

Of the measures listed in Table 1, the economic, energy and environmental impact of those related to specific technological or behavioral interventions could partly be simulated with models available in Cyprus, which were also employed for assessing the impacts of the National Energy and Climate Plan. Taliotis et al. (2020a) explain how these models were linked to provide policy-relevant results. This section presents the assumptions and results from application of these models.

3.1. Energy and environmental simulations

The assessment of the effect of green interventions on energy use and air emissions was carried out with OSeMOSYS, a long-term bottom-up energy systems model, whose objective function is the minimization of the discounted system cost, satisfying all exogenously defined demands for energy services within a set of context-specific constraints (Howells et al., 2011). Some of the input to OSeMOSYS is provided by a separate energy forecast model (Zachariadis and Taibi, 2015) which projects final energy consumption across the economy as well as the related energy expenditures of households and businesses that will be used in the economic modeling described in Section 3.2.

The application of OSeMOSYS for the energy system of Cyprus is described in detail in previous studies (Taliotis et al., 2017, 2020b). This section provides a description of the techno-economic assumptions relevant to the aforementioned list of measures. As indicated in Table 3, the OSeMOSYS model was used to quantify impacts related to measures 8, 9, 10 and 13: the implementation of existing Sustainable Urban Mobility Plans (SUMPs), the construction of the tram line in Nicosia, the scrappage scheme for old cars to be replaced with battery electric vehicles, and the gradual implementation of a fiscally neutral carbon taxation system for sectors that do not fall within the EU Emissions Trading System (ETS). The first two of these measures are included in the country's National Energy and Climate Plan (Republic of Cyprus, 2020), while the latter two interventions have already been under consideration by the government. The model output focused only on benefits related to energy savings and carbon emission reductions; improvements in air quality and congestion, which are essential benefits of sustainable mobility measures, were not considered explicitly but were included in a qualitative manner in the criterion 'other environmental impacts' in Table 2.

Implementation of SUMPs entails an effort to achieve a considerable shift away from private vehicles to sustainable modes of transport (i.e. public transport, cycling and walking). Based on estimations provided by the competent national authority of Cyprus (Public Works Department), Table 4 provides a brief overview of the impact of this measure on the projected demand for each mode of transport. The techno-economic characteristics for each technology option in these modes is available in the existing base literature (Taliotis et al., 2020a). With estimated costs of €180 million for the development of the necessary infrastructure, the partial implementation of SUMP can offer short-term final energy savings of 57 thousand tons of oil equivalent (ktoe) and a cumulative GHG emission reduction of 159 ktons carbon dioxide equivalent (CO_2 eq) in the period up to 2023. Until the end of the decade, it is projected that consumption of 394 ktoe of automotive fuel can be avoided, leading to a cumulative GHG emission reduction of 1,092 ktons CO_2 eq; in 2030 alone, fuel savings will amount to 54 ktoe and GHG emissions will be reduced by 151 ktons CO_2 eq.

Table 4: Projected road transport activity (million vehicle-kilometers) for each mode of transport in scenarios with and without SUMP implementation.

	2020	2025			2030		
		Reference	SUMP	SUMP & Tram	Reference	SUMP	SUMP & Tram
Buses	68	73	102	102	78	136	136
Light commercial vehicles	1,917	2,057	2,031	2,031	2,197	2,144	2,144
Motorcycles	208	223	198	198	238	204	188
Passenger cars	6,753	7,245	6,423	6,423	7,737	6,633	6,093
Heavy duty vehicles	317	340	346	346	364	374	374

The development of the tram line in Nicosia, which is planned to come into operation in 2028, is closely related to the SUMP implementation. This project will further enable the adoption of sustainable modes of passenger transport, contributing to a greater modal shift (Table 4). It is estimated that it can reduce the annual mileage of private passenger cars and motorcycles by 540 million and 16 million vehicle-kilometers respectively. According to the feasibility study conducted by national authorities, the tram line will have an upfront cost of approximately €225 million and annual operation and maintenance costs of €12 million (Ministry of Communication and Works, Public Works Department, 2015). It is estimated that it will serve up to 17.9 million passengers in year 2030, while it will have an annual electricity demand of about 9,130 MWh. According to these assumptions and based on results extracted from OSeMOSYS, in the first three years of its operation (i.e. 2028-2030), the added modal shift enabled by the tram line will result in final energy savings of 87 ktoe (mainly gasoline) and a reduction in GHG emissions of 249 ktons CO_2 eq.

The third measure that relates to the transport sector is the scrappage of vehicles, which have a first registration date older than 15 years, and their replacement with battery electric vehicles. For a maximum replacement rate of 200 vehicles per year with a grant of €5,000 per vehicle, this measure will require public funds of €1 million annually. Overall, it is assumed that 400 vehicles will be replaced through this scheme. This will allow short-term annual energy savings amounting to 0.2 ktoe in 2023, leading to a GHG emission reduction of 0.5 ktons CO_2 eq in the same year. Given that OSeMOSYS projections about the power generation mix indicate that the carbon intensity of electricity will decrease over time, it is estimated that the annual GHG emission reduction will increase to 0.6 ktons CO_2 eq by 2025.

Implementation of a carbon tax on fuels for sectors that do not fall within the EU ETS can be considered as an ambitious but useful measure to promote early action towards an energy transition aligned with the Paris Agreement goals. This envisioned tax is assumed to be implemented gradually and reach €120 per ton of CO_2 by 2025. This will encourage the adoption of energy efficiency measures and increasing the attractiveness of low-carbon energy technologies, such as heat pumps in the heating and cooling sector and electric vehicles in the transport sector. In the period up to 2023, this measure is projected to lead to final energy savings of 78 ktoe and a GHG emission reduction of 302 ktons CO_2 eq. By 2030, this measure can lead to cumulative energy savings of 766 ktoe, while it will reduce GHG emissions by 4,356 ktons CO_2 eq over the same period. Most of the savings are achieved towards the end of the period; final energy demand is reduced by 121 ktoe and GHG emissions are lower by 700 ktons CO_2 eq in 2030.

Since the 13 examined measures are of different scales, their effectiveness should be compared against each one's initial cost of implementation. With regard to energy savings and GHG emission reduction, as indicated in Table 5, the best-performing measures in the short-term (i.e. 2021-2023) are the fiscally neutral carbon taxation (which is a regulatory measure and hence has very low implementation costs), the virtual net billing scheme (which is also regulatory and will enable a faster deployment of decentralized solar power generation), the implementation of SUMPs and the subsidized loans to businesses with certificates of environmental management systems. The same measures are among the best performers in the long-term (i.e. up to 2030). Additional to these, the grant scheme utilizing unused budget of 2020-21 for energy renovations in buildings, as well as the energy efficiency upgrade of street lighting indicate the highest energy savings and GHG emission mitigation potential per unit of investment. However, some measures, such as the construction of the tram line and the tree plantation can have considerable positive effects in the longer term, which are not captured by the present analysis.

3.2. Economic analysis

3.2.1. Input-output modeling and assumptions

Input-Output (IO) analysis is a quantitative technique for studying the interdependence of production sectors in an economy over a stated time period (Miller and Blair, 2009; Giannakis and Bruggeman, 2017). In this paper, a continuous demand-driven IO model with disequilibrium adjustment processes was applied to assess the economy-wide effects of the selected energy-related economic recovery measures. The assumptions and the application of the model for the evaluation of energy policies in Cyprus are described in detail in Taliotis et al. (2020a).

Projected annual expenditures, including capital investments and operation and maintenance costs, from the OSeMOSYS model are introduced to the IO model to reflect changes in the investment demand of economic sectors as a result of each one of the 13 measures listed in Table 1. Expenditures are classified in seven categories: industrial equipment, power generation technologies, electricity storage technologies, gas infrastructure, public transport, private transport, and buildings (including energy efficiency measures, heat pumps, solar water heaters etc.). In addition, the projected annual energy consumption expenditure of households obtained from the energy forecast model mentioned in Section 3.1 is introduced to the IO model to estimate the multiplier effect of changes in private consumption. Tables in Appendix B present the distribution of annual spending associated with investments and private consumption by sector of economic activity under the alternative energy-related recovery measures.

The initial static equilibrium conditions of the IO model, which serve as the reference case, are based on the latest available national symmetric IO table of Cyprus for the year 2016. The national table, which includes 65 sectors of economic activity, was aggregated into 20 economic sectors, which is presented in Appendix B (Table B. 11). The demand growth rates for the economic sectors are defined based on the GDP projections for the period up to 2030, including the impact of the COVID-19 pandemic, and were obtained from the Ministry of Finance. Specifically, for 2020 we assumed a decline in the growth of the Cypriot economy (-7.4%) across all economic sectors, and for 2021 a strong economy-wide recovery (+6.1%). From 2023 onwards, growth rates return to usual levels following the official national macroeconomic outlook.

Some of the recovery measures listed in Table 1 involve energy savings and hence induce a decrease in private consumption for energy, traded products, and services. We assumed that this reduction of spending, after accounting for household savings,[4] will return to the economy and induce a rise in

[4] We assumed that the household saving rate is 2.4% of disposable income in Cyprus, in line with Eurostat (2020).

consumer demand for goods and services in line with the current consumption expenditure of Cypriot households (Cystat, 2020b).

Finally, apart from the 13 selected green recovery measures, we explore the macroeconomic effects of a counterfactual scenario, which would be to provide uniform economy-wide demand stimulus ('helicopter money') to Cypriot consumers. In this scenario, we aggregate the capital investments of all measures, amounting to 395 million euros in 2020 up to 2022 as shown in Table 1, and reallocate them in the economy according to the current sectoral shares of final demand.

3.2.2. Results

According to the IO model specification, the impact of a policy on economic growth and employment depends on how much investments in a sector affect demand for intermediate goods/services in other sectors, what part of intermediate inputs of a sector takes place in the country, which production activities are displaced by the new investments, and how labor-intensive are the sectors affected by new investments, compared to the labor intensity of displaced activities in other sectors. Keeping these considerations in mind, one can interpret the results of the IO simulations which are presented in Table 6. In essence these are the economy-wide effects (in terms of generated economic output and employment) of the investments and changes in private consumption induced by each of the 13 measures. Figure 2 illustrates these results by displaying graphically the economic effects versus the employment and environmental effects of the modeled interventions. Effects seem to be relatively higher in the short run due to the allocation of investment expenditures mainly in 2021-22 and because a strong economy-wide rebound is assumed in Cyprus for these two years.

Table 6 confirms once more the conclusion that Barbier (2020), Popp et al. (2020), and Strand and Toman (2010) have drawn on the basis of ex-post assessments around the world: measures performing best in the short-run are partly different from those with the largest positive effect in the longer term. With regard to economic output generation, in the short-run measures M4 and M5 (installation of smart electricity meters and virtual net billing) create the highest economy-wide effects relative to the reference scenario; for every million euros (M€) invested for these interventions, the total output of the economy increases by 1.45 M€ and 1.44M€ respectively in 2022/23. Two measures that could boost short-term output, M9 and M12, are not included – M9 because the construction of the tram line is expected to start after 2023, and M12 because tree planting has not been simulated with the IO model due to lack of data.

As regards long-run impacts, virtual net billing creates the highest economy-wide effects relative to the reference scenario. Conversely, some interventions yield negative economic effects, with the more pronounced being those of the tram line (M9) and energy renovations (M2). The negative multiplier effect of the former measure is attributed to the reduction of household spending for new and used cars especially in 2028-30, which reduces the economic output of the trade sector.[5] As regards the latter intervention, renovations improve the energy efficiency performance of buildings and lead to lower energy consumption; although this is beneficial for households and businesses, it adversely affects the economic output of fuel importers and electric utilities which have strong backward linkages in the economy and therefore considerably affect aggregate national economic activity.

[5] It has to be kept in mind that side-benefits due to avoided external costs of congestion and air pollution are not accounted for in these calculations; implementation of SUMP and tram (measures M8 and M9) would benefit the most from the inclusion of externalities in the cost assessment.

The impact of green recovery interventions on employment is similar but not identical to the effect on economic output. In the short run, virtual net billing and smart meters create the highest positive effects on national employment relative to the reference scenario; for every million euros (M€) invested in either measure, about 14 new jobs are created throughout the economy. In the long-run (2030), the virtual net billing measure still creates the highest economy-wide employment effects. On the contrary, sustainable mobility interventions M8 and M9 create the largest negative effects in terms of employment generation. Their negative employment multipliers are due to their success in shifting mobility from private cars to public transport, which causes household spending for fuel and car purchases as well as for car maintenance to drop considerably; these economic activities (belonging to the trade sector) are labor-intensive so that overall employment falls.

These 'negative' effects of energy efficiency measures have to be treated with caution and should not be interpreted as suggesting to avoid energy efficiency investments that improve the economy-wide productivity of energy use. A feature of the IO model is the assumption of fixed technical coefficients: the combinations of inputs are employed in fixed proportions. This assumption implies that there is no substitution among the inputs and no technological progress, which becomes less plausible when the impacts over a longer time horizon are modeled. To the extent that the reduced economic output and employment in sectors such as trade of vehicles and fuels is compensated through re-training of workers and re-orientation of business activities, negative economic impacts of sustainable mobility can be overcome. More broadly, the ability of an economy to transform itself and use the resources saved to grow new sectors, or to divert saved resources to export-oriented activities as a result of increased business competitiveness, will depend on factors like people's skills, availability of financing and policy decisions – aspects that are insufficiently accounted for by IO models.

It should also be noted that the model does not distinguish between employment categories, so that our approach cannot include the impact on low-skilled and high-skilled workers, which would be important for evaluating the effect of each intervention on long-term growth prospects. Such considerations are important in view of the findings of studies that examined stimulus measures applied after the 2008-2009 economic downturn, which highlight the importance of observing differences in skills in order to properly compare alternative policies (Chen et al., 2020; Strand and Toman, 2010). Moreover, job calculations do not account for the possibility that supply of skills in some sectors may not suffice to meet growing demand. For example, a construction boom due to energy renovations may be limited by a lack of skilled technicians in the country, at a time where a 'renovation wave' in buildings is foreseen across the entire Europe. Therefore, before deciding on the extent of implementation of a recovery measure, a skill mismatch analysis would be needed to ensure that human resources are available for realizing this intervention.

It is particularly interesting to observe the results of the counterfactual scenario, which assumes a 'return-to-normal' economic stimulus, where all recovery funds are allocated uniformly to households and businesses, and consumption continues as before. As shown in the last row of Table 6 and indicated by a red dot in Figure 2, a business-as-usual economic recovery is clearly not the preferable option; with an economic multiplier of just 0.83, it performs better than only two of all the green measures. It also has a mediocre effect in terms of employment generation, with 6.3 new jobs per M€, whereas four green measures have more than double the job benefits. This clearly indicates that a uniform demand stimulus is far from the most effective strategy for increasing employment in the short term. Such a finding, which has been explored in very few studies so far, is confirmed by Pollitt (2020) for major EU economies (through a macroeconometric model) and by IMF (2020) for the global economy (through a computable general equilibrium model).

Table 5: Energy and emission savings by measure, based partly on simulations made with the OSeMOSYS energy model of Cyprus and partly on simpler calculation methods.

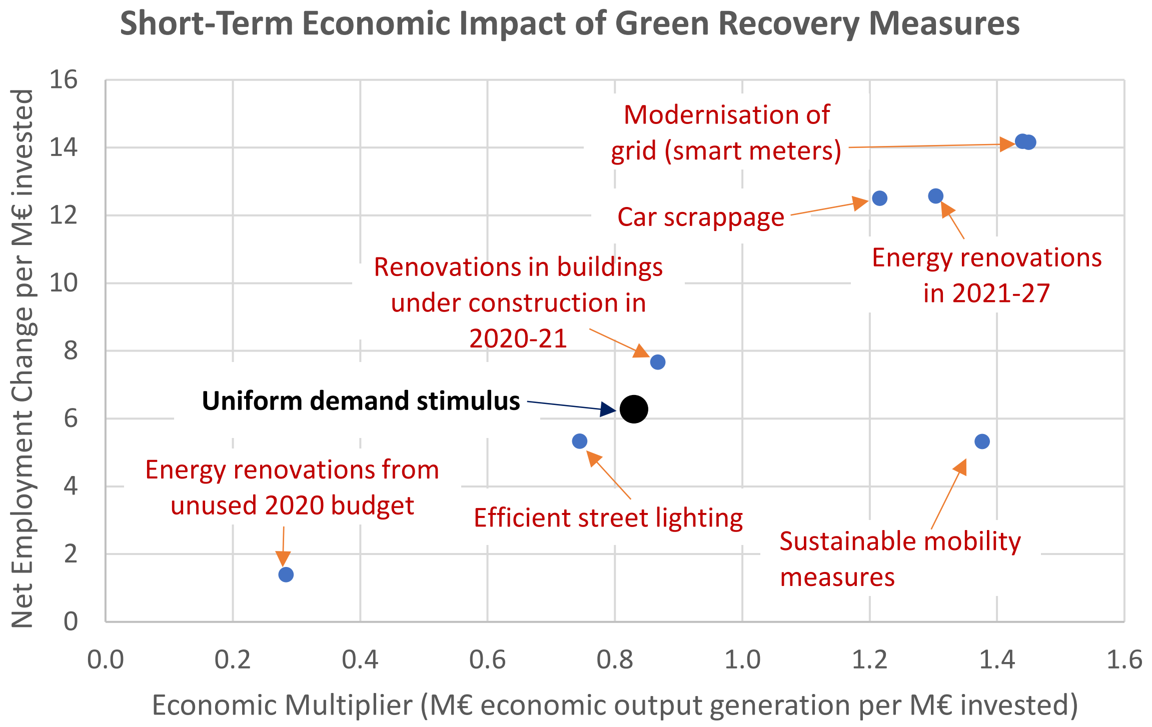
Effect of measures on energy use and carbon emissions (per million euros invested) compared to a business-as-usual evolution	Short-term savings (2022/23)		Long-term cumulative savings (up to 2030)	
Measure	Energy use (ktoe/M€)	CO_2 (tn/M€)	Energy use (total ktoe / M€)	CO_2 (total tn / M€)
1. Immediate launch of grants for energy renovations of buildings from unused budget of 2020-21	0.02	0.20	0.80	6.91
2. New grant scheme for energy renovations of existing buildings, 2021-27	0.01	0.09	0.35	3.02
3. Grants for energy renovations of buildings under construction for upgrade to Near-Zero Energy Buildings	0.01	0.09	0.09	0.57
4. Installation of smart electricity meters	0.01	0.12	0.19	1.62
5. Virtual net billing for encouragement of photovoltaic installations by enterprises	1.00	6.00	6.00	40.00
6. Subsidy to loans of businesses certified with an environmental management system	0.25	1.50	1.50	10.00
7. Business4Climate scheme - grants to enterprises with a verified low-carbon action plan up to 2030	0.03	0.15	0.15	1.00
8. Implementation of existing Sustainable Urban Mobility Plans (SUMP)	0.28	0.79	3.50	9.00
9. Construction of tram in the capital city of Nicosia			0.39	1.11
10. Scrappage scheme for old cars to be replaced with battery electric vehicles	0.02	0.05	0.15	0.40
11. Replacement of streetlights in municipalities and villages with energy efficient lighting	0.07	0.61	0.67	6.14
12. Tree planting along urban and intercity roads		0.06	0.00	2.35
13. Fiscally neutral carbon taxation for economic sectors out of the EU Emissions Trading System	92.00	136.00	1800.00	2500.00
Business as Usual case (economy-wide demand stimulus)	*0.00*	*0.00*	*0.00*	*0.00*

Notes: ktoe: thousand tons of oil equivalent; M€: million euros at constant prices of year 2016.

Table 6: Economic and employment impacts by measure according to simulations with the Cyprus input-output model relative to a reference scenario without measures.

Effect of measures on growth and jobs (per million euros invested) compared to a business-as-usual evolution	*Short-term impact (2022/23)*		*Long-term impact (up to 2030)*	
Measure	*Economic multiplier*	*Net employment per M€ invested*	*Economic multiplier*	*Net employment per M€ invested*
1. Immediate launch of grants for energy renovations of buildings from unused budget of 2020-21	0.28	1.40	0.01	0.66
2. New grant scheme for energy renovations of existing buildings, 2021-27	1.30	12.57	-0.05	-0.07
3. Grants for energy renovations of buildings under construction for upgrade to Near-Zero Energy Buildings	0.87	7.67	0.01	0.11
4. Installation of smart electricity meters	1.45	14.16	0.01	0.23
5. Virtual net billing for encouragement of photovoltaic installations by enterprises	1.44	14.19	0.20	1.85
6. Subsidy to loans of businesses certified with an environmental management system				
7. Business4Climate scheme - grants to enterprises with a verified low-carbon action plan up to 2030				
8. Implementation of existing Sustainable Urban Mobility Plans (SUMP)	1.38	5.33	-0.01	-13.66
9. Construction of tram in the capital city of Nicosia			-0.07	-3.28
10. Scrappage scheme for old cars to be replaced with battery electric vehicles	1.22	12.51	-0.01	-1.27
11. Replacement of streetlights in municipalities and villages with energy efficient lighting	0.74	5.34	0.01	0.32
12. Tree planting along urban and intercity roads				
13. Fiscally neutral carbon taxation for economic sectors out of the EU Emissions Trading System				
Business as Usual case (economy-wide demand stimulus)	*0.83*	*6.27*	*0.01*	*0.04*

Note: Some cells are blank because some measures were not simulated with the IO model. M€: million euros at constant prices of year 2016.



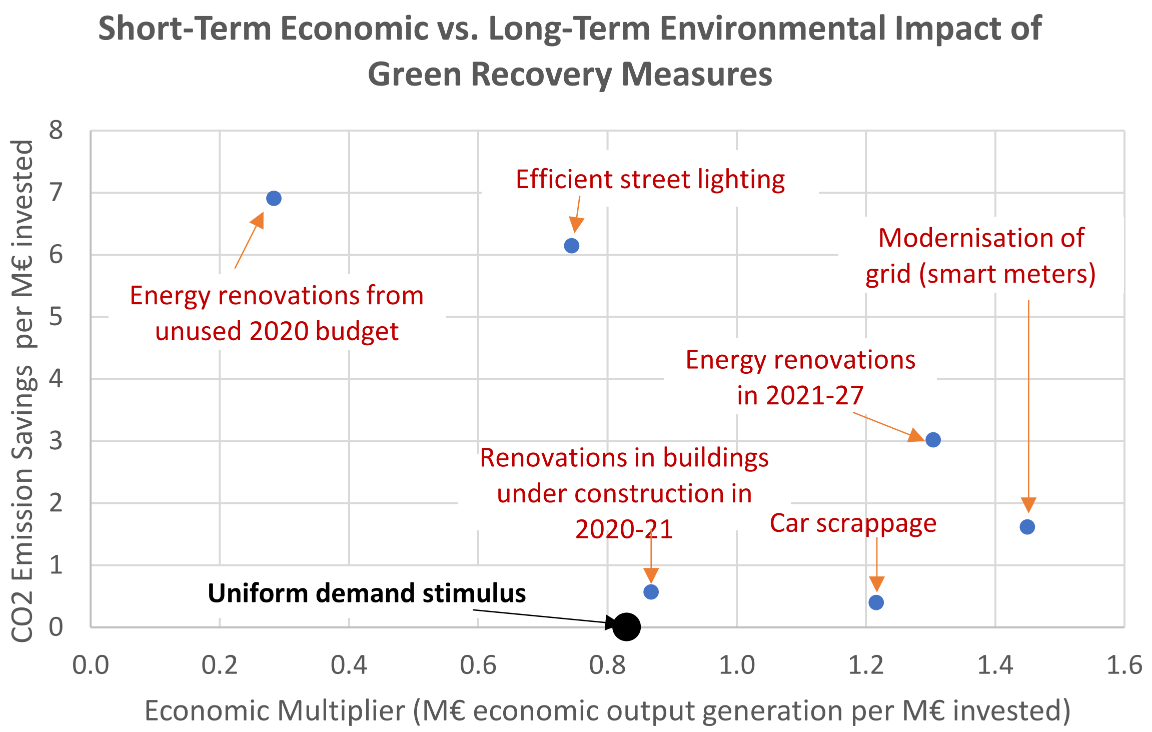


Figure 2: Relationship between short-term impact of measures on economic output and employment (top) and between short-term effect on economic output vs. long-term effect on carbon emission savings (bottom).

4. Multi-criteria assessment

Following the simulations of energy and economic impacts, step 7 (as shown in Figure 1) involved the multi-criteria assessment of recovery measures. This section presents the methods used and their results.

4.1. Overview of the assessment framework

Multi-criteria decision analysis (MCDA) has been developed to support DMs, especially when facing decisions involving multiple and potentially competing objectives (Jordan and Turnpenny, 2015). In the last decades, several methods have been developed for many types of decision problems. MCDA techniques have been widely applied in a variety of fields, including energy and environment (Ahmed et al., 2020; Ali et al., 2019; Baumann et al., 2019; Kumar et al., 2017; Liu and Du, 2020). Two of the most common methods used in MCDA problems are the Analytical Hierarchy Process (AHP) method and the Preference Ranking Organisation Method for Enriching Evaluation (PROMETHEE) (Greco et al., 2016; Papathanasiou and Ploskas, 2018). There are several examples of applications of AHP and PROMETHEE in the fields of energy planning, selection of energy projects, and sustainable supply chains (Abdullah et al., 2019; Mastrocinque et al., 2020; Zelt et al., 2019). PROMETHEE has also been used in the development and evaluation of scenarios for energy planning (Simoes et al., 2019; Witt et al., 2020) and for evaluating market opportunities for renewables (Andreopoulou et al., 2018).

AHP and PROMETHEE can be combined, as shown by several studies so far (Abdel-Basset et al., 2021; Neofytou et al., 2020; Seddiki and Bennadji, 2019). AHP can be used to produce the weights of each criterion for each DM, which would be used as an input for applying PROMETHEE to produce the ranking of the actions. A similar framework has been developed in Matlab® for this paper, using a PROMETHEE Group Decision Support System (GDSS) approach. Figure 3 presents a flowchart for the application of AHP/PROMETHEE in this study.

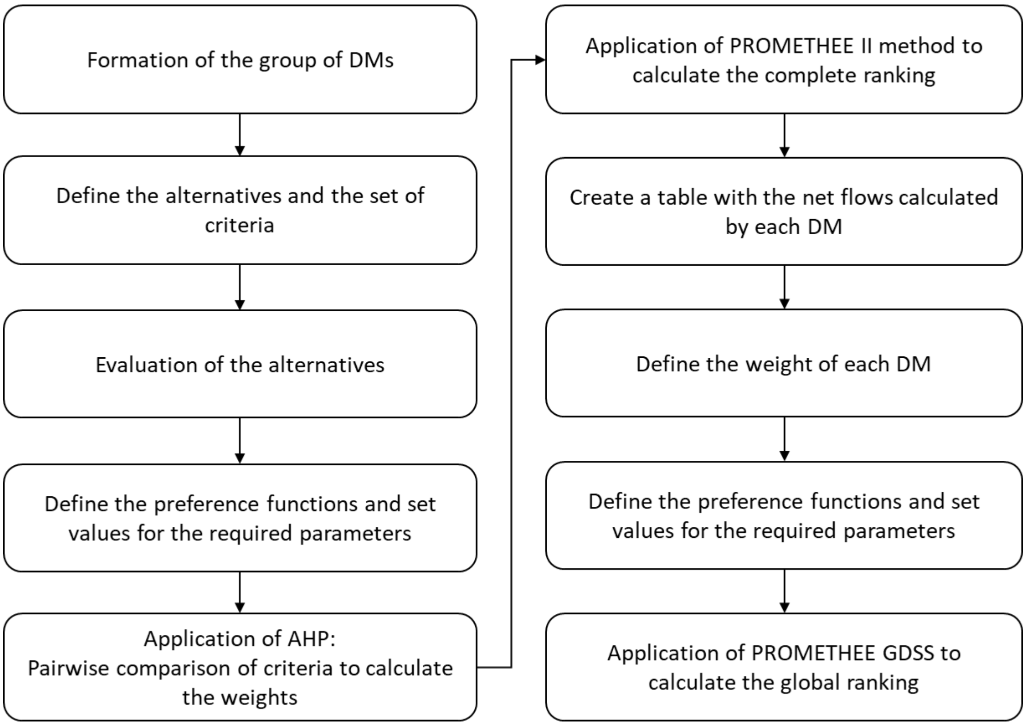


Figure 3. The AHP/PROMETHEE framework workflow

Appendix C provides technical information about the application of these methods. In summary, AHP is a pairwise comparison method which uses a ratio scale that does not require any units. DMs express their preferences for one alternative over another one, using a 1-9 scale as shown in Table 7, which is assumed to offer the appropriate flexibility. In the framework of this study the 23 criteria shown in Table 2 have been divided into two broad categories of short- and long-term impacts and further subdivided into two subcategories, namely: (i) environmental criteria, and (ii) economic/social criteria, as shown in Figures C.1 to C.3 in Appendix C.

For the evaluation and ranking of the alternatives, the PROMETHEE method has been applied. The independent experts were asked to provide a score of each alternative recovery measure (or action as it is called in PROMETHEE terminology) for each criterion in a typical 1-5 scale ranging from 'very low' to 'very high' impact. As several DMs provided input, the PROMETHEE GDSS was then implemented to combine the scores of individual DMs and produce a global evaluation that leads to the final ranking of measures.

Table 7. The 1-9 fundamental AHP scale

	AHP Scale for pairwise comparisons
1	Equal Importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong

	AHP Scale for pairwise comparisons
9	Extreme importance

4.2. Stakeholder input

A variety of stakeholders were invited to act as DMs and provide input for this assessment. They were selected in order to be representative of public policy makers both from technical ministries (Ministries of Energy, Environment, and Transport) and from the Finance Ministry. Representatives of non-governmental organizations and of the private sector were also invited. These DMs participated in a dedicated workshop that was held on October 5, 2020. To enable better interaction of the authors with DMs, to provide appropriate explanations about recovery measures and sustainability criteria, and to offer direct assistance to DMs for filling in the required data, the workshop was held with physical presence and therefore the number of DMs had to be limited for social distancing reasons. The group of DMs consisted of 10 stakeholders: three economic planning officers from the Finance Ministry, one tax officer from the Finance Ministry, one officer from the Ministry of Energy, one officer from the Ministry of Transport, one from an energy NGO, one from an environmental NGO, two from the national Federation of Employers representing the private sector, and one group from the co-authors of this paper. At the workshop, participants were informed in detail about the list of recovery measures and the evaluation criteria, and were then provided with the respective tables to fill in, applying elements of the AHP and PROMETHEE methods. The tables that each DM had to fill in are provided in Appendix D.

Weighting of the different criteria according to each DM's preferences, in line with the AHP method, was carried out through a piecewise comparison between each criterion using Tables D.1 to D.7 of Appendix D. All input that was required for the application of the AHP method was checked for consistency. In all cases, the consistency ratio (see eq. (1) in Appendix C) was calculated and was found to lie below the threshold of 10%, so that the input of all DMs was considered to be consistent. A review of the input of each workshop participant revealed that their preferences varied significantly by criterion, highlighting the different priorities of each stakeholder. For example, representatives of private enterprises valued short-term criteria more strongly than long-term ones, in contrast to other stakeholders. On the other hand, some governmental stakeholders provided a higher weight to long-term environmental criteria compared to short-term ones. Overall, most DMs assigned a higher importance to the long term than to the short term, whereas there was no consistent preference to environmental versus economic/social criteria. Figure 4 illustrates the normalized weights assigned on average by DMs to the four different groups of criteria. Some examples of the actual input of stakeholders are provided in Tables E.1 and E.2 in Appendix E.

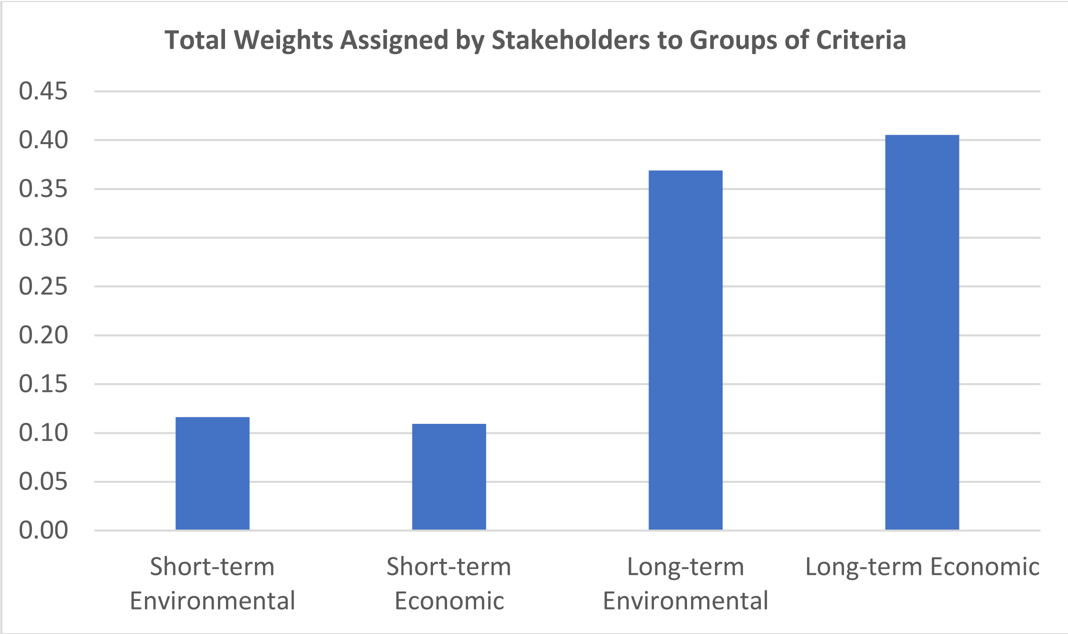


Figure 4. Weights assigned by participating stakeholders to the four groups of sustainability criteria

Next, the PROMETHEE II method was applied in which each DM evaluated the performance of all green interventions with a score in the scale 1-5, indicating an evaluation ranging from 'very low' to 'very high'. Scores for each recovery measure by criterion, in line with this method, were provided by each stakeholder in Tables D.8 and D.9 in Appendix D. It should be noted that the scores for four criteria (energy savings, carbon emission savings, economic multiplier, and new jobs created) have been calculated through simulations with the relevant models described in Section 3, therefore stakeholders could not change these scores. Tables E.3 and E.4 in Appendix E show an example of the evaluation scores provided by one stakeholder.

4.3. Results and discussion

Before arriving at the final results of this analysis, it is necessary to calculate the net flow from the input of each stakeholder using equations (6) and (7). This intermediate result is shown in Table D.6 in Appendix D. Then, the final step is the application of the PROMETHEE GDSS in order to calculate the global ranking of all measures. For this part we assumed that each of the 10 stakeholders has the same weight (i.e. each DM has a weight of 0.1), and – in line with the methodology described in Appendix C – a type 5 preference function was implemented, with the indifference threshold set to 0.05 and the preference threshold to 0.25. Obviously, the ranking of alternatives is affected by both the weights assigned by each DM and their respective scoring by measure and criterion.

Figure 5 displays the results of the evaluation, averaged over all 10 DMs, before weighting the four groups of criteria. The carbon tax reform (measure M13) received a high score for its environmental performance in both the short and the long term, and actions related to sustainable mobility (M8 and M9) also had a good score on long-term environmental performance. Conversely, measures M5, M6 and M7, which mainly target enterprises, were assigned by DMs the highest scores regarding long-term economic effectiveness.

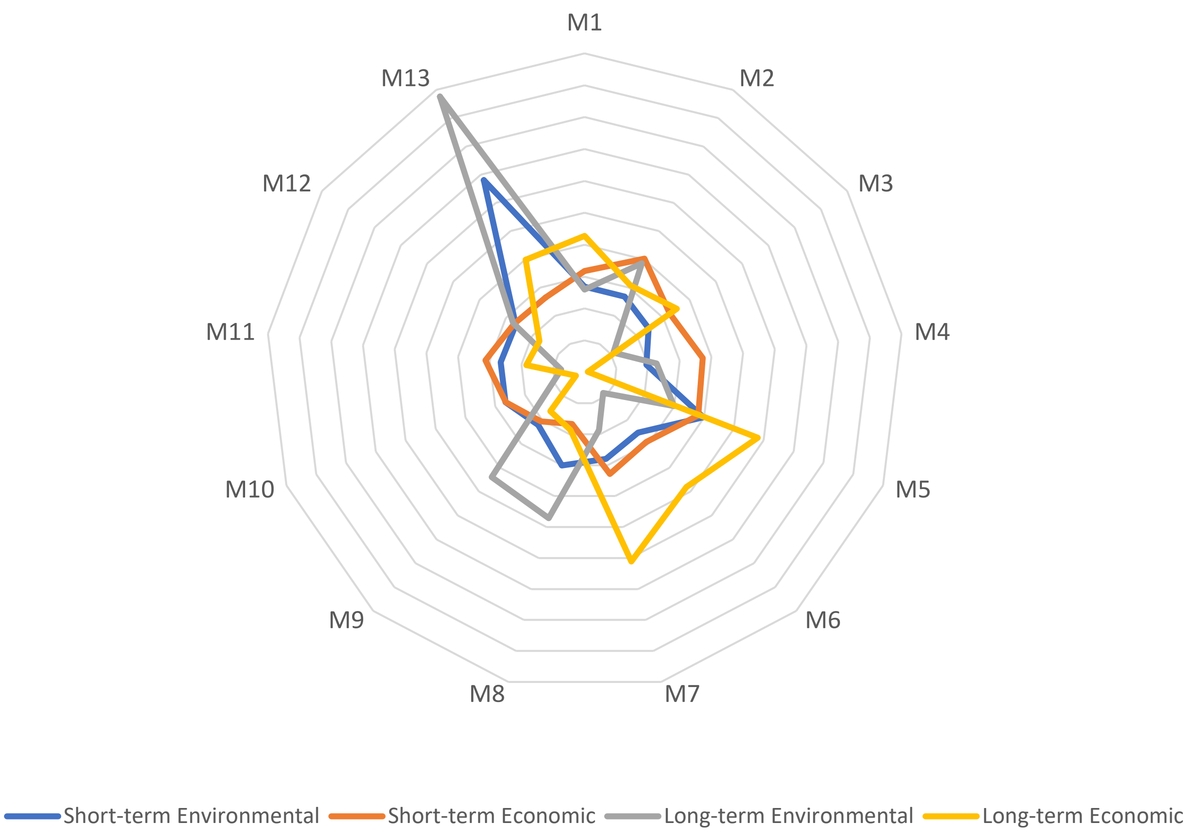


Figure 5. Evaluation of recovery measures M1-M13 based on the average input of all stakeholders.

After weighting the scores for all four groups of criterial, the final ranking is presented in Table 8, which shows that the best green recovery intervention is considered to be the fiscally neutral carbon tax reform (M13). This measure had the best results in terms of energy savings and carbon savings for the short- and long-term, which were calculated using quantitative models, but received also high evaluations from the stakeholders in several criteria – it ranked first in the individual ranking of five of the 10 stakeholders. In addition, the stakeholders valued measures M5, M2 and M7 (implementation of virtual net billing, energy renovations of buildings and grants to reduce the carbon footprint of enterprises) as the next most important for the sustainable development of Cyprus.

Table 8. Global preference net flow and final ranking of alternative measures

Action no.	Action name	Global preference net flow
M13	Fiscally neutral carbon tax reform for sectors out of the EU Emissions Trading System	0.510
M5	Virtual net billing for encouragement of photovoltaic installations	0.320
M2	New grants for energy renovations of existing buildings, 2021-27	0.112
M7	Grants to enterprises with verified low-carbon action plan up to 2030	0.107
M1	Immediate launch of grants for energy renovations of buildings from unused budget of 2020-21	0.061
M8	Sustainable Urban Mobility Plans	-0.002

M6	Subsidy to loans of green businesses	-0.082
M9	Construction of tram in the capital city of Nicosia	-0.097
M12	Tree planting	-0.111
M3	Grants for energy renovations of buildings under construction	-0.115
M4	Installation of smart electricity meters	-0.183
M11	Replacement of streetlights with energy efficient lighting	-0.240
M10	Scrappage of old cars to be replaced with battery electric vehicles	-0.280

These results offer interesting insights when compared to evaluations performed informally by some of the authors, who applied a simple assessment approach to obtain a rapid view of the preferred policies. Although the expert view of some of the authors had considered long-term modernization and decarbonization interventions (even beyond 2030) as important priorities, those were not among the preferred measures of the stakeholders as displayed in Table 8. For example, the only nature-based measure (M12 – tree planting) and the two sustainable mobility measures (M8 and M9) rank average or below-average in stakeholder preferences; this may be attributed to concerns by some stakeholders, which were orally communicated during the workshop, that these measures are unrealistic, too costly, or can only have limited effects. Another reason may be that most stakeholders considered the period to 2030 as 'long-term' and left 2050 out of sight. However, long-term sustainability objectives may require actions that start immediately. For example, it has been shown that to reach an ambitious target in 2050 (such as the net carbon neutrality pledged by the EU), ambitious measures are necessary now in order to allow time for technology penetration and behavioral changes (Sotiriou and Zachariadis 2019).

A second example is the installation of smart electricity meters (M4), which may accelerate penetration of decentralized renewable electricity and allow for flexible electricity tariffs and other high-technology innovations. This was evaluated by the workshop participants among the least preferable options, although the authors' expert judgement considered this a high-ranking measure. It has been recognized in the literature that heterogeneity of stakeholders results in preferences which diverge from those of experts (Zelt et al., 2019). Instead of dismissing stakeholder views as ill-informed or biased, it would be more fruitful for experts to regard these views as a serious warning that some measures may have lower social acceptance than experts believe, and adapt the proposed policies accordingly while at the same time designing proper information and communication campaigns to target audiences and the broader public.

At the same time, it is impressive that a seemingly unpopular measure (carbon taxation, even if framed as fiscally neutral) received the top score among recovery measures. In view of the extensive discussions about the social acceptance of such pricing schemes worldwide (Elliott et al., 2020; Klenert et al., 2018), this seems to be a surprising but also encouraging result, as carbon pricing is widely considered by economists as a necessary ingredient of effective decarbonization policies. In the context of the current pandemic, Engström et al. (2020, p. 805) call this kind of reform "excellent climate policies [which] also help deal with the coronavirus crisis by allowing reductions to labour taxes". A plausible explanation for the high score of this measure among Cypriot stakeholders is that exactly this kind of green tax reform (comprising an increase in environmental taxes to be compensated by reductions in labor taxation) has been promoted in Cyprus by some experts since 2015, with a consistent attempt to inform governmental authorities, NGOs and trade unions about its advantages (Zachariadis, 2016). The resulting top performance in this assessment may be an indication that targeted and well-supported information flows to diverse stakeholders have been effective and may lead to societal acceptance of such a reform in the near future.

5. Conclusions

Despite the persistence of the COVID-19 pandemic, which has led to the greatest peacetime economic disruption in living memory, governments around the world are gradually transitioning from immediate relief to economic recovery plans of huge dimensions. In this paper we have looked at whether a general methodology, tailored for the EU member state of Cyprus, could effectively screen for green recovery measures that respond to immediate needs while also building resilience.

Our science-policy framework starts from existing governmental plans on economic development and climate change mitigation, with the aim to select projects that provide the largest benefits in terms of short-term economic stimulus and job creation while being in line with the country's long-term decarbonization objectives. We have deployed energy and economic models for a quantitative assessment of some criteria, as well as qualitative expert judgement for a series of sustainability and resilience criteria. State-of-the-art multi-criteria decision analysis methods were applied with the aid of input from multiple stakeholders from the public, private and non-governmental sectors. Results from stakeholder input confirm that no single measure is the perfect one, hence a portfolio of measures is necessary – which reinforces the importance for policy makers to consider multiple criteria before arriving at decisions for investments and reforms.

Our analysis illustrates the importance of combining simple methods with more sophisticated models for an assessment of recovery measures that can provide meaningful support to policy makers. Moreover, our findings clearly demonstrate trade-offs between the short term (2022), the long term (2030) and the climate neutrality (2050) targets, as well as the superiority of many green measures in comparison to business-as-usual demand stimulus. More specifically, we find that:

- Some immediate measures with attractive short-term impact have short-lived benefits and turn out to be inferior in both economic and environmental terms by 2030. This is in line with the finding of Barbier (2020) that a different policy mix is required for short-term (1–2 year) interventions as compared to a medium to long-term (5–10 year) strategy for a recovery leading to a green transition.
- Institutional or regulatory changes, such as the gradual implementation of carbon pricing or the reform of electricity rules to enable decentralized power generation, may have long-term impacts with low cost.
- Modernizing the energy infrastructure and nature-based solutions like tree planting are very promising for the longer term but turned out not to be preferable by many of the DMs who provided input, either because stakeholders put more value to short-term benefits or because they do not consider such measures to be feasible or cost-effective.
- Blunt economy-wide demand stimulus measures are not only environmentally unsustainable, but also economically mediocre – they perform worse in promoting economic growth and employment than most of the green measures examined in this paper. This provides evidence against a 'return-to-normal' stimulus which can be found in very few studies in the literature.

The final ranking of appropriate measures benefited from input by diverse societal stakeholders. This contributes to the 'democratization' of the policy formulation process (Jordan and Turnpenny, 2015) and enables ownership of the measures by national decision makers. Linking the sustainability criteria with the UN Sustainable Development Goals facilitates the alignment of national recovery programs with the EU and international policy agenda.

Despite the support to green recovery measures among environmental scientists, environmental economists and think tanks, it is worth keeping in mind that green investments and reforms are not the only growth-enhancing ones. Given the occurrence of the pandemic, many public investments will be directed to health and social care infrastructures as well as information and communication technology. Besides their economic returns, such expenditures may be more aligned with the priorities of an aging population in the industrialized world (Helm, 2020). In this context, green recovery measures are worth promoting strongly – in view of their environmental and economic benefits – but at the same time cautiously – in order not to alienate large parts of the population and the political system. A critical aspect in this regard is to include green considerations into non-green spending in order to reap multiple benefits; for example, modernizing infrastructure through energy renovations in hospitals and schools increases the welfare of the population as well as climate resilience. This reinforces the need for proper science-policy interaction, to be facilitated by the use of open-source models, transparent methods and stakeholder participation; such aspects are crucial for enhancing the legitimacy of arguments of the scientific community towards economic stimulus that accelerates the green transition.

Solid empirical analysis of previous economic stimulus programs can provide valuable evidence and inform policy making; this is especially relevant when distinguishing between the effects of smaller and larger green infrastructure projects (Engström et al., 2020), and investments benefiting high- and low-skilled workers (Popp et al., 2020) – aspects that are not captured by the simpler modeling framework used in this study. However, as the size of the post-pandemic fiscal stimulus is larger than anything similar in the past, and as policy makers need fast guidance to steer between health protection, economic relief and climate resilience, it may not be sufficient to rely on sophisticated analyses based on data from a few large industrialized countries. Therefore, the approach described in this paper may provide meaningful support for any country seeking guidance in designing its own green recovery plan. In any case, the process will need to be adapted to the local context and involve the right actors. This is necessary to ensure the resulting proposal has the right credibility and ownership in the country.

Acknowledgments

This study was partly funded by the Research and Innovation Foundation of Cyprus, under the Funding Scheme "RESTART 2016-2020 Programmes for Research, Technological Development and Innovation", co-funded by the European Regional Development Fund and the Republic of Cyprus, in the frame of the project "Supporting the Economic Recovery of Cyprus with a View to Energy and Climate Policy" (grant no. CONCEPT-COVID/0420/0008). Howells' input was supported by the FCDO Climate Compatible Growth Program. The authors are grateful to stakeholders who participated at a workshop on 5 October 2020 and provided input for the multi-criteria assessment.

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Appendix A: List of Green Recovery Measures

Table A. 1. Description of the proposed green recovery measures

#	Title	Description	Comments
M1	Immediate launch of grant scheme for energy renovations of buildings from unused budget of 2020-21	For energy renovations in existing residential, commercial and public buildings which can become near-zero energy buildings **or** can yield energy savings of at least 40%.	€30 million (national and EU funds) can be used immediately because €15 million are still available from EU Structural Funds of the period 2014-2020. Proposal: Spend this amount by 31/12/2021.
M2	New grant scheme for energy renovations of existing buildings, 2021-27	For energy renovations in existing residential, commercial and public buildings which can become near-zero energy buildings **or** can yield energy savings of at least 40%.	€70 million (national and EU funds) have been requested for the period 2021-27 (50% of the total cost). Proposal: Spend this amount by 31/12/2022, with the prospect to increase it later. The previous similar program was successful. As the proposed scheme is much larger, simpler procedures are needed to ensure fast implementation.
M3	Grants for energy renovations of buildings under construction for upgrade to Near-Zero Energy Buildings (NZEB)	Increased state guarantees and/or grants and/or tax credits to residential & commercial buildings under construction (which have not been connected to the electricity grid yet) and to buildings that have obtained a building permit after 1/1/2018, so that they can immediately be upgraded to NZEB.	Grants of €70 million could be allocated between residential & commercial buildings (maximum: 7000 buildings). If increased state guarantees are adopted there is no immediate cost. This measure will yield immediate improvement in energy efficiency of new buildings beyond mandatory requirements. *New proposal, currently not included in National Energy and Climate Plan.*
M4	Installation of smart electricity meters	Installation of 400.000 smart meters by EAC	Important measure to enable high penetration of renewable electricity, in implementation of Directive 2019/944/EU. The installation is scheduled to be completed by the end of 2027. Proposal: complete this installation by 31/12/2023 in collaboration with private installers.
M5	Virtual net billing for encouragement of photovoltaic installations by enterprises	PV installation by enterprises with virtual net billing (or virtual net-metering for multi-apartment buildings) method and/or from individuals through renting the roofs of their houses	Regulatory change is required with the consent of CERA. It is a low-cost measure with large benefits for the penetration of renewable electricity. *New proposal, currently not included in National Energy and Climate Plan.*

#	Title	Description	Comments
M6	Subsidy to loans of businesses certified with an environmental management system	As an economic stimulus measure, Interest rates of business loans will be subsidized by the government. It is proposed that the interest rate to be subsidized is 0.5% higher for those firms that have adopted or will adopt the EU Eco-Management and Labelling Scheme EMAS by 31/12/2021. The certification process can be subsidized with a small grant of the order of €2000 per firm.	This measure will yield fast improvement in energy efficiency and/or environmental performance of businesses. *New proposal, currently not included in National Energy and Climate Plan.*
M7	Business4Climate scheme – grants to enterprises with a verified low-carbon action plan up to 2030	Continuation of the pilot scheme 'Business4Climate', which provides grants to firms of all sectors which provide a credible Action Plan to reduce their carbon footprint by 2030	This measure will yield fast improvement in energy efficiency and/or environmental performance of businesses.
M8	Implementation of existing Sustainable Urban Mobility Plans	Immediate implementation of the SUMP of Limassol which has been completed. Implementation of SUMPs of Nicosia and Larnaca as soon as the respective plans have been finished. (Does not include cost of additional buses)	SUMPs are extremely important for the elimination of fossil fuel use in transport. Implementation cost of Limassol SUMP: €170 million up to 2032. Proposal: Provide €100 million for fast application of SUMP of Limassol + start of implementation of SUMPs of the cities of Larnaca & Nicosia by 31/12/2022.
M9	Construction of tram in the capital city of Nicosia	Construction of tram lines in Nicosia	This is s a longer-term measure but with potentially significant impact, hence it is added separately from the broader SUMP measure. Also, even though focused on international rail travel, the EU's draft Green Recovery Plan puts an emphasis on shifting passenger transport to rail services.
M10	Scrappage scheme for old cars to be replaced with battery electric vehicles	Grant to scrap an old car and replace it with a fully electric car; scheme to last for two years, 2021 and 2022	5,000 euros grant for each old car that is scrapped and replaced with a fully electric one
M11	Replacement of streetlights in municipalities and villages with energy efficient lighting	Replacement of street lighting in municipalities and communities. In 2018 a financial instrument was established for Municipalities and Communities, through which they can apply for a loan to the	Very cost-effective measure. Target: Change 300,000 lamps by 31/12/2021 - currently about half of these lamps are planned to change by that time.

#	Title	Description	Comments
		Ministry of the Interior for the replacement of street lighting. At the moment, eleven municipalities have been approved. It is expected that more Municipalities will participate in the financial instrument in 2020 and 2021.	
M12	Tree planting along urban and intercity roads	Extensive tree planting of up to 650,000 trees along the urban road network and up to 350,000 trees along the interurban road network.	1. Shading, lowering temperatures and better walking and cycling conditions may cause an additional shift from car to sustainable modes of transport. 2. CO_2 absorption. 3. Aesthetic upgrade and urban landscaping of all cities and rural routes.
M13	Fiscally neutral carbon taxation for economic sectors out of the EU Emissions Trading System	Tax up to €120/ton of carbon dioxide on non-ETS sectors, i.e. on all fossil fuels except those used for power generation and by cement plant and brick factories.	Gradual introduction within 5 years. Expected public revenues in full implementation: €100-150 million/year. Tax revenues could be rebated to all households to increase political acceptance.

Appendix B: Input-Output Model

Table B. 1. Annual spending associated with investments and households' consumption under the Car Scrappage Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manufacturing	0.00	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical and Plastic Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery and Equipment	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Energy	0.00	0.09	0.12	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Construction	0.00	0.35	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trade	0.00	0.42	0.33	-0.19	-0.19	-0.19	-0.19	-0.20	-0.20	-0.20	-0.20
Accommodation and Food Services	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Banking-Financing	0.00	0.12	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real Estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public Administration	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Education	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Health	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other Services	0.00	0.01	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table B. 2. Annual spending associated with investments and households' consumption under the ISUI1 Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical and Plastic Products	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Products	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery and Equipment	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy	0.00	-0.07	-0.34	-0.69	-1.05	-1.05	-1.07	-1.08	-1.09	-1.11	-1.12
Construction	0.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trade	0.00	0.92	0.12	0.25	0.38	0.38	0.39	0.39	0.40	0.40	0.41
Accommodation and Food Services	0.00	0.01	0.04	0.08	0.12	0.12	0.12	0.13	0.13	0.13	0.13
Transportation	0.00	0.01	0.05	0.11	0.16	0.16	0.17	0.17	0.17	0.17	0.17

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Banking-Financing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real Estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public Administration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.02	0.04	0.06	0.06	0.06	0.06	0.06	0.07	0.07
Health	0.00	0.00	0.02	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.08
Other Services	0.00	0.01	0.07	0.14	0.22	0.22	0.22	0.22	0.23	0.23	0.23

Table B. 3. Annual spending associated with investments and households' consumption under the ISUI2 Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical and Plastic Products	0.00	3.50	3.50	1.40	1.40	1.40	1.40	1.40	0.00	0.00	0.00
Metal Products	0.00	1.75	1.75	0.70	0.70	0.70	0.70	0.70	0.00	0.00	0.00
Machinery and Equipment	0.00	1.75	1.75	0.70	0.70	0.70	0.70	0.70	0.00	0.00	0.00
Energy	0.00	-0.10	-0.24	-0.50	-1.22	-1.76	-2.14	-2.89	-2.92	-2.96	-2.98

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Construction	0.00	17.50	17.50	7.00	7.00	7.00	7.00	7.00	0.00	0.00	0.00
Trade	0.00	1.09	1.14	0.60	0.86	1.06	1.20	1.47	1.06	1.07	1.08
Accommodation and Food Services	0.00	0.01	0.03	0.06	0.14	0.20	0.25	0.34	0.34	0.34	0.35
Transportation	0.00	0.02	0.04	0.08	0.19	0.27	0.33	0.45	0.46	0.46	0.47
Banking-Financing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real Estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public Administration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.01	0.01	0.03	0.07	0.10	0.13	0.17	0.17	0.17	0.17
Health	0.00	0.01	0.02	0.03	0.08	0.12	0.14	0.19	0.20	0.20	0.20
Other Services	0.00	0.02	0.05	0.10	0.25	0.36	0.44	0.60	0.60	0.61	0.62

Table B. 4. Annual spending associated with investments and households' consumption under the Nicosia Tram Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical and Plastic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Products											
Metal Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery and Equipment	0.00	0.00	0.00	0.08	0.16	0.16	0.16	0.16	0.41	0.41	0.41
Energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.77	6.80	6.81
Construction	0.00	0.00	0.00	6.25	12.50	12.50	12.50	12.50	1.18	1.18	1.18
Trade	0.00	0.00	0.00	1.31	2.63	2.63	2.63	2.63	-19.66	-19.74	-19.79
Accommodation and Food Services	0.00	0.00	0.00	0.13	0.25	0.25	0.25	0.25	2.37	2.38	2.38
Transportation	0.00	0.00	0.00	2.58	5.15	5.15	5.15	5.15	3.18	3.20	3.21
Banking-Financing	0.00	0.00	0.00	0.50	1.00	1.00	1.00	1.00	0.94	0.94	0.94
Real Estate	0.00	0.00	0.00	0.75	1.50	1.50	1.50	1.50	0.24	0.24	0.24
Public Administration	0.00	0.00	0.00	0.13	0.25	0.25	0.25	0.25	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	1.20	1.20
Health	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	1.38	1.38
Other Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.23	4.25	4.26

Table B. 5. Annual spending associated with investments and households' consumption under the preNZEB Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manuf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
acturing											
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical and Plastic Products	0.00	5.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Products	0.00	2.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery and Equipment	0.00	2.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy	0.00	-0.17	-0.17	-0.17	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.19
Construction	0.00	25.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trade	0.00	1.56	0.66	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
Accommodation and Food Services	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Transportation	0.00	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Banking-Financing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real Estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public Administration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Health	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other Services	0.00	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table B. 6. Annual spending associated with investments and households' consumption under the Public Lighting Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical and Plastic Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery and Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy	0.00	5.67	3.02	0.33	0.33	0.34	0.34	0.34	0.35	0.35	0.35
Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trade	0.00	0.13	0.27	0.36	0.36	0.37	0.37	0.38	0.38	0.38	0.39
Accommodation and Food Services	0.00	0.04	0.09	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Transportation	0.00	0.06	0.12	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17
Banking-Financing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real Estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Public Administration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.02	0.04	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Health	0.00	0.02	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Other Services	0.00	5.16	1.96	-1.09	-1.10	-1.10	-1.12	-1.13	-1.14	-1.15	-1.16

Table B. 7. Annual spending associated with investments and households' consumption under the Smart Meters Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical and Plastic Products	0.00	1.50	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Products	0.00	0.75	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery and Equipment	0.00	0.75	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy	0.00	-0.03	-0.06	-0.09	-0.20	-0.31	-0.42	-0.54	-0.55	-0.55	-0.56
Construction	0.00	7.50	10.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trade	0.00	0.46	0.62	0.63	0.07	0.11	0.15	0.20	0.20	0.20	0.20
Accommodation and Food	0.00	0.00	0.01	0.01	0.02	0.04	0.05	0.06	0.06	0.06	0.06

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Services											
Transportation	0.00	0.00	0.01	0.01	0.03	0.05	0.07	0.08	0.09	0.09	0.09
Banking-Financing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real Estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public Administration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.03
Health	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04
Other Services	0.00	0.01	0.01	0.02	0.04	0.06	0.09	0.11	0.11	0.11	0.12

Table B. 8. Annual spending associated with investments and households' consumption under the SUMP Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical and Plastic Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery and Equipment	0.00	0.12	0.12	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy	0.00	2.13	4.27	6.45	8.61	10.73	12.92	15.06	9.06	11.26	13.39
Construction	0.00	10.00	10.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trade	-0.01	-4.13	-10.36	-17.80	-25.16	-31.35	-37.75	-44.01	-26.47	-32.90	-39.13
Accommodation and Food Services	0.00	0.95	1.69	2.36	3.01	3.75	4.52	5.27	3.17	3.94	4.68
Transportation	0.00	5.12	6.13	5.09	4.05	5.05	6.08	7.09	4.26	5.30	6.30
Banking-Financing	0.00	0.80	0.80	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real Estate	0.00	1.20	1.20	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public Administration	0.00	0.20	0.20	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.38	0.75	1.14	1.52	1.90	2.28	2.66	1.60	1.99	2.37
Health	0.00	0.43	0.86	1.31	1.74	2.17	2.62	3.05	1.84	2.28	2.71
Other Services	0.00	1.33	2.67	4.03	5.38	6.70	8.07	9.41	5.66	7.04	8.37

Table B. 9. Annual spending associated with investments and households' consumption under the Virtual Net Billing Measure relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and Paper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Chemical and Plastic Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery and Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy	0.00	0.04	0.09	0.13	0.17	0.22	0.26	0.30	0.35	0.39	0.43
Construction	0.00	2.93	2.89	2.84	2.80	2.75	2.71	2.66	2.62	2.57	2.53
Trade	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Accommodation and Food Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transportation	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06
Banking-Financing	0.00	0.08	0.08	0.09	0.09	0.10	0.10	0.11	0.12	0.12	0.13
Real Estate	0.00	0.24	0.27	0.29	0.31	0.33	0.35	0.37	0.39	0.42	0.44
Public Administration	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06
Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Health	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B. 10. Annual spending associated with households' consumption under the Counterfactual Scenario (Uniform Economy-Wide Demand Stimulus) relative to the Reference Scenario by sector of economic activity for the period 2020-2030 (in million euros)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.22	3.37	2.29	1.42	1.19	1.18	1.18	1.18	0.20	0.19	0.00
Forestry	0.01	0.18	0.12	0.08	0.06	0.06	0.06	0.06	0.01	0.01	0.00

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Mining	0.01	0.18	0.12	0.08	0.06	0.06	0.06	0.06	0.01	0.01	0.00
Food Manufacturing	0.72	10.88	7.41	4.59	3.84	3.83	3.82	3.81	0.64	0.62	0.00
Textile	0.19	2.92	1.99	1.23	1.03	1.03	1.03	1.02	0.17	0.17	0.00
Wood and Paper	0.04	0.62	0.42	0.26	0.22	0.22	0.22	0.22	0.04	0.04	0.00
Chemical and Plastic Products	0.63	9.48	6.45	4.00	3.35	3.34	3.33	3.32	0.55	0.54	0.00
Metal Products	0.10	1.50	1.02	0.63	0.53	0.53	0.52	0.52	0.09	0.09	0.00
Machinery and Equipment	1.65	24.71	16.83	10.43	8.73	8.70	8.68	8.65	1.44	1.42	0.00
Energy	0.10	1.50	1.02	0.63	0.53	0.53	0.53	0.53	0.09	0.09	0.00
Construction	0.60	9.04	6.16	3.82	3.19	3.18	3.18	3.17	0.53	0.52	0.00
Trade	0.94	14.18	9.66	5.99	5.01	4.99	4.98	4.96	0.83	0.81	0.00
Accommodation and Food Services	1.08	16.21	11.04	6.84	5.72	5.71	5.69	5.67	0.95	0.93	0.00
Transportation	1.51	22.66	15.43	9.57	8.00	7.98	7.96	7.93	1.32	1.30	0.00
Banking-Financing	2.22	33.32	22.69	14.07	11.77	11.73	11.70	11.66	1.95	1.91	0.00
Real Estate	0.79	11.90	8.10	5.02	4.20	4.19	4.18	4.17	0.69	0.68	0.00
Public Administration	0.76	11.42	7.78	4.82	4.03	4.02	4.01	4.00	0.67	0.66	0.00
Education	0.56	8.34	5.68	3.52	2.94	2.94	2.93	2.92	0.49	0.48	0.00
Health	0.51	7.59	5.17	3.21	2.68	2.67	2.66	2.66	0.44	0.44	0.00

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Other Services	2.01	30.23	20.58	12.76	10.67	10.64	10.61	10.58	1.77	1.73	0.00

Table B. 11. NACE (Statistical classification of economic activities in the European Union) codes of the sectors of economic activity that make up the 20 sectors for the

Sector	Description NACE
Agriculture	A01, A03
Forestry	A02
Mining	B
Food Manufacturing	C10, C11, C12
Textile	C13, C15
Wood and Paper	C16, C17, C18
Chemical and Plastic Products	C19--C23
Metal Products	C24, C25
Machinery and Equipment	C26--C33
Energy	D
Construction	F
Trade	G45--G47
Accommodation and Food Services	I
Transportation	H49--H53
Banking-Financing	K64--K66
Real Estate	L68
Public Administration	O
Education	P
Health	Q
Other Services	E, J58-63, M69-75, N, R, S, T, U

Appendix C: Description of the AHP and PROMETHEE Methods

C.1. AHP Method

AHP is a pairwise comparison method which uses a ratio scale that does not require any units. DMs express their preferences for one alternative over another one. The number of comparisons is $\frac{n^2-n}{2}$, expressed in an $n \times n$ pairwise comparison matrix. Typically DMs express their preferences using a 1-9 scale as shown in Table 7, which is assumed to offer the appropriate flexibility.

One important aspect of this method is that the pairwise comparison matrix needs to be consistent, which becomes more difficult for matrices with large dimensions. This can be checked via the consistency ratio as shown in eqs. (1) and (2).

$$CR(X) = \frac{CI(X)}{RI_n} \tag{1}$$

$$CI(X) = \frac{\lambda_{max} - n}{n - 1} \tag{2}$$

Where $CI(X)$ the consistency index, RI_n a real number that estimates the average CI from a large data set of randomly generated matrices of size n and estimations can be found in the literature, and λ_{max} the maximum eigenvector (Saaty and Sodenkamp, 2010). It is suggested that matrices with $CR > 0.1$ are inconsistent.

The priorities can be calculated typically by three methods, namely: (i) the eigenvector method, (ii) the normalized column sum method, and (iii) the geometric mean method. In this paper the geometric mean method has been applied, where the priority vector is calculated as the geometric mean of the elements on a row, over the respective normalization term in order for the sum of the weights to be equal to 1, as shown in eq. (3):

$$w_i = \frac{\left(\prod_{j=1}^{n} x_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} x_{ij}\right)^{1/n}} \tag{3}$$

In the framework of this study the 23 criteria shown in Table 2 have been divided into two broad categories of short- and long-term impacts and further subdivided into two subcategories, namely: (i) environmental criteria, and (ii) economic/social criteria, as shown in Figures C.1 to C.3.

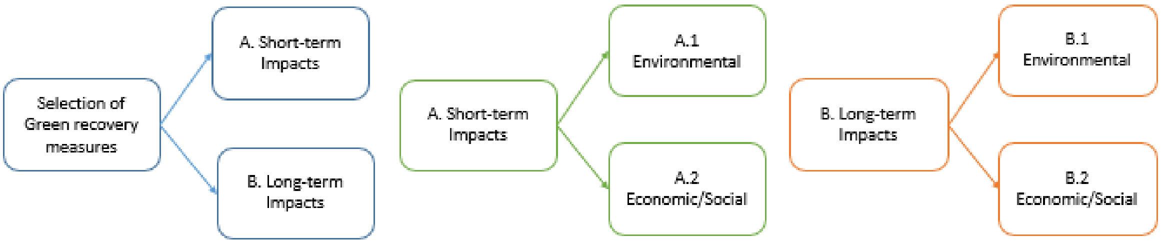


Figure C.1. AHP framework for prioritization of green recovery measures based on short- and long-term impacts

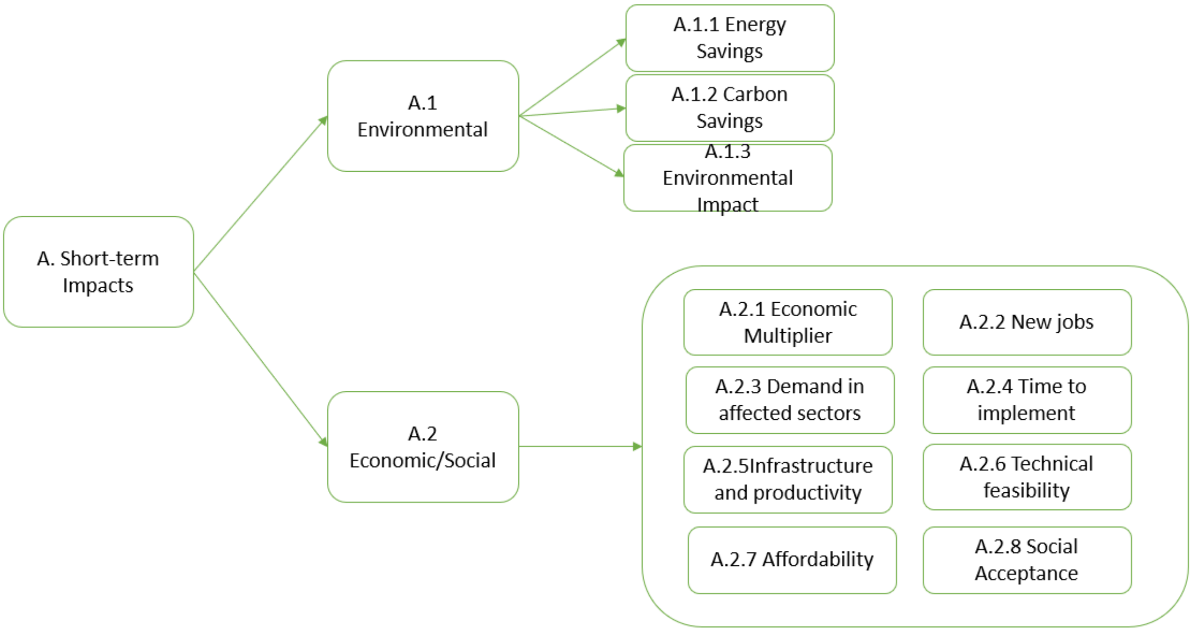


Figure C.2. AHP framework for prioritization of green recovery measures based on short environmental and economic/social impacts

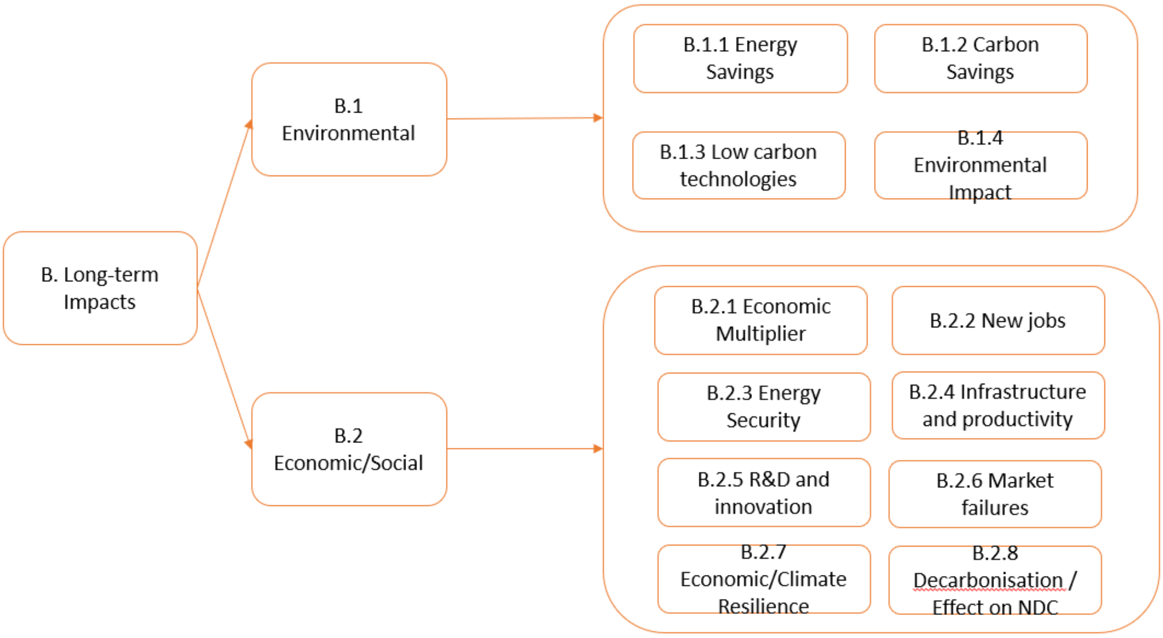


Figure C.3. AHP framework for prioritization of green recovery measures based on long environmental and economic/social impacts

C.2. PROMETHEE Method

For the evaluation and ranking of the alternatives, the PROMETHEE method has been applied. The independent experts were asked to evaluate each alternative (or action as it is called in PROMETHEE terminology) for each criterion. The remaining criteria are qualitative, and the DMs were asked to express their evaluation in a typical 1-5 scale ranging from very low to very high. In PROMETHEE each action is compared to $(m-1)$ other actions in order to calculate the positive and negative outranking flow of each action as a number between 0 and 1. These values express how much this action is preferred over all the other ones as shown in eqs. (4) and (5):

$$\varphi^{+} = \frac{1}{m-1}\sum_{x\in A}\pi(a,x) \tag{4}$$

$$\varphi^{-} = \frac{1}{m-1}\sum_{x\in A}\pi(a,x) \tag{5}$$

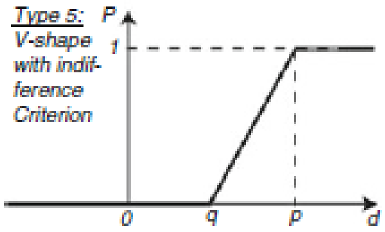
While the PROMETHEE I method offers a partial ranking between the alternatives, the PROMETHEE II method was used, which can offer a complete ranking among all the actions. In PROMETHEE II the net flow needs to be calculated in order to rank the actions, according to eqs. (6) and (7):

$$\varphi(a) = \varphi^{+}(a) - \varphi^{-}(a) = \frac{1}{m-1}\sum_{j=1}^{n}\sum_{x\in A}\left[P_j(a,x) - P_j(x,a)\right] w_j \tag{6}$$

and

$$\varphi(a) = \sum_{j=1}^{n}\varphi_j(a)\, w_j \tag{7}$$

For the pairwise comparison, a Type 5 V-shape preference function has been used, which considers a preference (p) and indifference (q) threshold as shown in FigureC.4.



$$P(d) = \begin{cases} 0 & d \leq q \\ \frac{d-q}{p-q} & q < d \leq p \\ 1 & d > p \end{cases}$$

Figure C.4. The type 5 preference function (Papathanasiou and Ploskas, 2018)

As there are several DMs, the PROMETHEE GDSS is implemented. At the final stage of this method, a global evaluation takes place; after the individual evaluation from each expert, a global matrix is constructed with the rows being the alternatives and the columns the flow values calculated by the DMs. We assumed that the weights of the DMs are equal and that the preference function is of the same type. It is noted that the DMs have agreed to the preference and indifference thresholds. Then the PROMETHEE method is applied which gives the final ranking.

Appendix D: AHP and PROMETHEE Input Tables

Table D. 1. Pairwise comparison between short- and long-term impacts using the AHP scale (please fill only the blank cells)

	Short-term impacts	**Long-term impacts**
Short-term impacts	1	
Long-term impacts		1

Table D. 2. Pairwise comparison between short-term "Energy/Environmental" and "Economic/Social" criteria using the AHP scale (please fill only the blank cells)

	Energy/Environmental	**Economic/Social**
Energy/Environmental	1	
Economic/Social		1

Table D. 3. Pairwise comparison between long-term "Energy/Environmental" and "Economic/Social" criteria using the AHP scale (please fill only the blank cells)

	Energy/Environmental	**Economic/Social**
Energy/Environmental	1	
Economic/Social		1

Table D. 4. Pairwise comparison between short-term "Energy/Environmental" criteria using the AHP scale (please fill only the blank cells)

	Energy savings	CO2 savings	Environmental Impact
Energy savings	1		
CO2 savings		1	
Environmental Impact			1

Table D. 5. Pairwise comparison between short-term "Economic/Social" criteria using the AHP scale (please fill only the blank cells)

	Economic multiplier	Net new jobs	Demand in affected sectors	Time to Implement	Infrastructure & Productivity	Technical feasibility	Affordability	Social acceptance
Economic multiplier	1							
Net new jobs		1						
Demand in affected sectors			1					
Time to Implement				1				
Infrastructure & Productivity					1			
Technical feasibility						1		
Affordability							1	
Social acceptance								1

Table D. 6. Pairwise comparison between long-term "Energy/Environmental" criteria using the AHP scale (please fill only the blank cells)

	Energy savings	**CO2 savings**	**Environmental Impact**	**Low-carbon technologies / strategies**
Energy savings	1			
CO2 savings		1		
Environmental Impact			1	
Low-carbon technologies / strategies				1

Table D. 7. Pairwise comparison between long-term "Economic/Social" criteria using the AHP scale (please fill only the blank cells)

	Economic multiplier	**Net new jobs**	**Energy security**	**Infrastructure & Productivity**	**R&D and innovation**	**Market Failures**	**Economic/Climate Resilience**	**Decarbonization / Effect on NDC**
Economic multiplier	1							
Net new jobs		1						
Energy security			1					
Infrastructure & Productivity				1				
R&D and innovation					1			
Market Failures						1		
Economic / Climate Resilience							1	
Decarbonization / Effect on NDC								1

Table D. 8. Evaluation of measures regarding short-term impacts using the qualitative scale (1-5)

		Short-term Impacts						
		Energy /Environmental	**Economic/Social**					
		Environmental Impact	**Demand in affected sectors**	**Time to Implement**	**Infrastructure & Productivity**	**Technical feasibility**	**Affordability**	**Social acceptance**
M1	Immediate launch of grant scheme for energy renovations of buildings from unused budget of 2020-21							
M2	New grant scheme for energy renovations of existing buildings, 2021-27							
M3	Grants for energy renovations of buildings under construction for upgrade to Near-Zero Energy Buildings (NZEB)							
M4	Installation of smart electricity meters							
M5	Virtual net billing for encouragement of photovoltaic installations by enterprises							
M6	Subsidy to loans of businesses certified with an environmental management system							
M7	Business4Climate scheme – grants to enterprises with a verified low-carbon actin plan up to 2030							
M8	Implementation of existing Sustainable Urban Mobility Plans							
M9	Construction of tram in the capital city of Nicosia							
M10	Scrappage scheme for old cars to be replaced with battery electric vehicles							
M11	Replacement of streetlights in municipalities and villages with energy efficient lighting							
M12	Tree planting along urban and intercity roads							
M13	Fiscally neutral carbon taxation for economic sectors out of the EU Emissions Trading System							

Table D. 9. Evaluation of measures regarding long-term impacts using the qualitative scale (1-5)

		Long-term Impacts							
		Energy/Environmental		**Economic/Social**					
		Low-carbon technologies / strategies	**Environmental Impact**	**Energy security**	**Infrastructure & Productivity**	**R&D and innovation**	**Market Failures**	**Economic / Climate Resilience**	**Decarbonization / Effect on NDC**
M1	Immediate launch of grant scheme for energy renovations of buildings from unused budget of 2020-21								
M2	New grant scheme for energy renovations of existing buildings, 2021-27								
M3	Grants for energy renovations of buildings under construction for upgrade to Near-Zero Energy Buildings (NZEB)								
M4	Installation of smart electricity meters								
M5	Virtual net billing for encouragement of photovoltaic installations by enterprises								
M6	Subsidy to loans of businesses certified with an environmental management system								
M7	Business4Climate scheme – grants to enterprises with a verified low-carbon actin plan up to 2030								
M8	Implementation of existing Sustainable Urban Mobility Plans								
M9	Construction of tram in the capital city of Nicosia								

		Long-term Impacts							
		Energy/Environmental		Economic/Social					
		Low-carbon technologies / strategies	Environmental Impact	Energy security	Infrastructure & Productivity	R&D and innovation	Market Failures	Economic / Climate Resilience	Decarbonization / Effect on NDC
M10	Scrappage scheme for old cars to be replaced with battery electric vehicles								
M11	Replacement of streetlights in municipalities and villages with energy efficient lighting								
M12	Tree planting along urban and intercity roads								
M13	Fiscally neutral carbon taxation for economic sectors out of the EU Emissions Trading System								

Appendix E: Examples of Stakeholder Input

Table E.1. Weights provided by each DM for the short-term criteria of this study

	A.1.1	A.1.2	A.1.3	A2.1	A2.2	A2.3	A2.4	A2.5	A2.6	A2.7	A2.8
DM1	0.016	0.016	0.031	0.007	0.006	0.006	0.008	0.005	0.014	0.004	0.012
DM2	0.006	0.019	0.059	0.003	0.017	0.003	0.004	0.004	0.015	0.012	0.025
DM3	0.005	0.014	0.014	0.007	0.017	0.048	0.048	0.011	0.008	0.002	0.025
DM4	0.007	0.007	0.007	0.003	0.007	0.005	0.016	0.011	0.035	0.035	0.035
DM5	0.006	0.041	0.036	0.004	0.021	0.008	0.007	0.008	0.010	0.012	0.013
DM6	0.254	0.254	0.254	0.019	0.005	0.043	0.014	0.005	0.005	0.002	0.002
DM7	0.005	0.005	0.005	0.005	0.006	0.004	0.055	0.003	0.009	0.015	0.012
DM8	0.002	0.009	0.009	0.004	0.004	0.021	0.006	0.021	0.021	0.021	0.004
DM9	0.001	0.006	0.007	0.005	0.011	0.032	0.032	0.008	0.005	0.002	0.017
DM10	0.008	0.042	0.017	0.009	0.013	0.009	0.021	0.010	0.008	0.031	0.031

Table E.2. Weights provided by each DM for the long-term criteria of this study

	B.1.1	B.1.2	B.1.3	B.1.4	B2.1	B2.2	B2.3	B2.4	B2.5	B2.6	B2.7	B2.8
DM1	0.136	0.136	0.229	0.081	0.033	0.033	0.039	0.023	0.021	0.016	0.055	0.073
DM2	0.019	0.039	0.263	0.096	0.014	0.045	0.047	0.017	0.046	0.013	0.132	0.105
DM3	0.022	0.158	0.158	0.063	0.034	0.077	0.058	0.038	0.030	0.018	0.074	0.071
DM4	0.009	0.009	0.009	0.076	0.027	0.012	0.012	0.119	0.174	0.038	0.174	0.174
DM5	0.017	0.135	0.135	0.130	0.012	0.044	0.047	0.015	0.043	0.020	0.102	0.134
DM6	0.019	0.025	0.029	0.052	0.002	0.002	0.002	0.001	0.002	0.003	0.003	0.001
DM7	0.191	0.191	0.191	0.191	0.004	0.004	0.018	0.018	0.010	0.007	0.023	0.026
DM8	0.006	0.023	0.023	0.073	0.016	0.168	0.168	0.168	0.037	0.106	0.016	0.071
DM9	0.027	0.027	0.027	0.027	0.064	0.064	0.064	0.064	0.064	0.064	0.191	0.191
DM10	0.076	0.185	0.116	0.266	0.019	0.023	0.021	0.020	0.015	0.007	0.019	0.032

Table E.3. Application of PROMETHEE II: Evaluation scores for short-term criteria by DM1

	Environmental			Economic/Social							
	A.1.1	**A.1.2**	**A.1.3**	**A2.1**	**A2.2**	**A2.3**	**A2.4**	**A2.5**	**A2.6**	**A2.7**	**A2.8**
M1	0.025	0.149	4.000	0.000	7.935	4.000	4.000	5.000	4.000	3.000	4.000

	Environmental			Economic/Social							
	A.1.1	**A.1.2**	**A.1.3**	**A2.1**	**A2.2**	**A2.3**	**A2.4**	**A2.5**	**A2.6**	**A2.7**	**A2.8**
M2	0.011	0.065	4.000	24.211	27.645	4.000	2.000	3.000	4.000	3.000	4.000
M3	0.015	0.063	4.000	5.504	9.819	4.000	4.000	5.000	4.000	3.000	4.000
M4	0.014	0.085	3.000	42.417	45.326	3.000	3.000	3.000	3.000	4.000	4.000
M5	1.087	4.412	3.000	42.225	45.326	3.000	3.000	3.000	4.000	4.000	4.000
M6	0.272	1.103	3.000	8.083	14.601	3.000	4.000	3.000	3.000	4.000	3.000
M7	0.027	0.110	2.000	8.083	14.601	3.000	4.000	3.000	3.000	4.000	3.000
M8	0.307	0.581	4.000	29.061	2.065	4.000	2.000	3.000	3.000	5.000	3.000
M9	0.000	0.000	4.000	100.000	100.000	4.000	1.000	4.000	3.000	5.000	3.000
M10	0.022	0.037	3.000	6.967	0.000	2.000	4.000	2.000	5.000	3.000	4.000
M11	0.077	0.451	4.000	2.771	13.007	2.000	3.000	3.000	5.000	4.000	4.000
M12	0.000	0.043	2.000	8.083	14.601	2.000	2.000	3.000	3.000	4.000	5.000
M13	100.000	100.000	3.000	8.083	14.601	3.000	2.000	2.000	3.000	3.000	3.000

Table E.4. Application of PROMETHEE II: Evaluation scores for long-term criteria by DM1

	Environmental				Economic/Social							
	B.1.1	**B.1.2**	**B.1.3**	**B.1.4**	**B2.1**	**B2.2**	**B2.3**	**B2.4**	**B2.5**	**B2.6**	**B2.7**	**B2.8**
M1	0.044	0.260	4.000	4.000	30.072	92.328	4.000	3.000	2.000	3.000	3.000	4.000
M2	0.019	0.105	5.000	5.000	9.420	87.621	5.000	4.000	4.000	4.000	4.000	5.000
M3	0.005	0.007	3.000	3.000	30.072	88.781	3.000	2.000	2.000	2.000	2.000	2.000
M4	0.011	0.049	4.000	4.000	30.072	89.555	3.000	4.000	2.000	2.000	2.000	2.000
M5	0.333	1.584	4.000	4.000	100.000	100.000	3.000	4.000	2.000	2.000	2.000	2.000
M6	0.083	0.384	3.000	3.000	26.812	88.072	2.000	3.000	4.000	3.000	3.000	3.000
M7	0.009	0.024	3.000	3.000	26.812	88.072	2.000	3.000	4.000	3.000	3.000	3.000
M8	0.194	0.344	5.000	5.000	21.739	0.000	4.000	5.000	3.000	3.000	5.000	5.000
M9	0.022	0.028	5.000	5.000	0.000	66.925	4.000	5.000	3.000	3.000	5.000	4.000
M10	0.008	0.000	3.000	3.000	21.739	79.884	2.000	2.000	2.000	2.000	2.000	2.000
M11	0.037	0.230	3.000	3.000	31.159	90.135	2.000	3.000	2.000	2.000	3.000	3.000
M12	0.000	0.078	5.000	5.000	26.812	88.072	4.000	4.000	2.000	2.000	4.000	5.000
M13	100.000	100.000	4.000	4.000	26.812	88.072	4.000	3.000	4.000	2.000	3.000	4.000

Table E.5. Preference function characteristics

	A.1.1	A.1.2	A.1.3	A2.1	A2.2	A2.3	A2.4	A2.5	A2.6	A2.7	A2.8	
q	1	2	1	2	2	1	1	1	1	1	1	
p	5	5	2	5	5	2	2	2	2	2	2	
	B.1.1	**B.1.2**	**B.1.3**	**B.1.4**	**B2.1**	**B2.2**	**B2.3**	**B2.4**	**B2.5**	**B2.6**	**B2.7**	**B2.8**
q	1	1	1	1	2	2	1	1	1	1	1	1
p	5	5	2	2	5	5	2	2	2	2	2	2

Table E.6. Net flows of each alternative using PROMETHEE II for each DM

	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10
M1	0.024	0.128	0.153	-0.027	-0.319	-0.050	0.142	0.044	0.060	-0.008
M2	0.193	0.163	0.105	-0.001	-0.104	-0.055	0.148	-0.047	-0.054	-0.020
M3	-0.185	0.070	0.128	-0.022	-0.125	-0.076	-0.103	0.054	0.019	-0.108
M4	-0.066	-0.181	0.093	-0.318	0.050	-0.122	0.085	-0.431	0.068	0.031
M5	0.011	0.032	0.241	0.174	0.002	0.193	-0.059	-0.090	0.142	0.271
M6	-0.165	-0.180	-0.192	0.216	0.161	-0.059	-0.111	0.348	-0.019	-0.177
M7	-0.182	-0.018	0.054	0.208	0.056	0.022	-0.110	0.388	0.089	-0.096
M8	0.160	0.058	-0.467	0.011	0.104	-0.020	-0.056	0.037	-0.100	0.124
M9	0.147	0.032	-0.110	-0.038	0.015	-0.162	-0.075	-0.042	-0.237	0.126
M10	-0.266	-0.156	0.080	0.127	0.078	-0.074	-0.121	-0.378	-0.120	-0.226
M11	-0.162	-0.125	0.165	-0.143	-0.139	-0.025	-0.143	-0.022	0.018	-0.150
M12	0.156	0.144	0.069	-0.126	-0.160	-0.115	-0.018	-0.309	0.032	-0.124
M13	0.335	0.034	-0.320	-0.061	0.382	0.542	0.421	0.449	0.102	0.357