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Article

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Abstract: Climate change is a critical sustainability challenge for islands and their main economic sectors. Rising sea levels, extreme temperatures, and drier conditions are the impacts with the most significant potential to amplify the economic damage on islands. However, their isolation and natural conditions bring about some leeway to respond to climate impacts on their terms. This paper aims to provide a local-level analysis and ranking of alternative adaptation pathways in an island context through the stakeholders' lens. This study reviews the latest advancements in adaptation science and proposes a catalogue of adaptation and risk management options that feed a participatory assessment and ranking by local stakeholders. The research was conducted on the island of Sicily (Italy) and saw the participation of high-level experts and tourism, energy, and maritime transport representatives. It employs a sequential process of four ordered steps oriented towards adaptation planning and stakeholders' engagement. The process reveals breaches between what stakeholders' would prioritise when designing policy pathways and their opinion about the most beneficial and balanced adaptation programmes across the sustainability criteria. Results indicate that, according to stakeholders, the priorities are to prepare the energy, tourism, and maritime transport sectors to confront future climate-related events more efficiently. Other transformational actions to ensure long-term social-ecological resilience, which requires significant structural changes and substantial investments, are not at the core of the public needs.

Keywords: climate change; island; adaptation; land ecosystems; resilience; sustainability

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1. Introduction

Europe's islands experience greater vulnerability to the risks of climate change (CC) than the mainland, as recognised in the New EU Strategy on Adaptation to Climate Change [1]. On the island of Sicily, the largest island in the Mediterranean Sea [2], the main socio-economic sectors will be heavily affected by rising sea levels, extreme sea and air temperatures, and drier conditions. Although there is a lack of information available at the local level, significant changes are expected in land biodiversity, usable beach surface, forest fire danger, droughts, and heatwaves at one point or another on the island [3–7].

Despite existing efforts, the island of Sicily lacks reliable information and monitoring systems regarding the impact of CC at the island level and limited analysis of appropriate adaptation programmes, hindering the successful implementation of climate actions. No regional adaptation plans exist, and national approaches do not promote intelligent and fast adaptation at the local level. That is, the opportunity to make informed decisions and explore new developments that fully exploit the island's potential [8].

In response, this paper aims to analyse and rank adaptation and risk management programmes for the island of Sicily and define alternative pathways with local stakeholders tailored to the island's context. The study employed a mixed approach; we reviewed the latest scientific advancements in adaptation science and proposed a catalogue of 72 adaptation and risk management options, representing the programmes used in the participatory phase involving 32 stakeholders. A multi-criteria scale and a set of tools and background information were utilised to facilitate the four-stage evaluation and ranking process and reach a collective result.

It was assumed that the cost of adapting to CC could range from minimal to high and require small or incremental changes to the significant transformation from the status quo. Hence, we consider four possible adaptation trajectories: minimum intervention (APT A), economic capacity expansion (APT B), efficiency enhancement (APT C), and system restructuring (APT D). In addition, the proposed policy trajectories cover three time-frames: short-term (up to 2030), mid-century (up to 2050), and end-century (up to 2100). Among the sectors exposed to CC relevant to the Sicilian economy, this study focuses on maritime transport, energy and tourism for several reasons [8]:

(i) Palermo is a strategic Italian port for the Motorways of the Sea system by the Ministry of Transport. In terms of port facilities, the island of Sicily exceeds the national average.
(ii) Renewable sources are hydroelectric, photovoltaics and biomass; the solar potential is recognised with higher productivity levels.
(iii) The island of Sicily's sunny and dry climate, cuisine, and cultural and natural heritage has attracted increasing numbers of visitors worldwide, making tourism a sector of great relevance for local development.

The main contribution of this research is its method and bottom-up approach since top-down processes have been shown to lack the capacity to downscale the information requirements to speed up climate actions on the island of Sicily. Therefore, the final set of adaptation measures is framed by the island's socio-economic context and ranked according to sustainability criteria. At the same time, the involvement of key actors in the policy design exercise may reduce the risk of low sensitiveness and motivation of local decision-makers to lead a behavioural change.

This paper describes the current situation on the island of Sicily and the projections related to climate change impacts, alongside the policy context of adaptation and risk management. The methodology section highlights the workflow, the duration and the tools utilised to guide the participatory process. The subsequent section describes the analysis of the results by sector and discusses the findings and their managerial and policy implications.

2. The Vulnerability of Islands to Climate Change

The effects of global CC are expected to vary in both magnitude and timing as well as by geographic region [9]. The impacts are going to depend on the region. Island communities are among the first and most adversely affected by the impacts of global CC [10] because they share relatively larger coastal zones and feature valuable ecosystems and natural environments, with a high level of species endemism, unique functional traits and evolutionary patterns [11].

The scientific literature on CC provides a comprehensive understanding of the direct impacts of a changing climate on islands, from the tropics to the polar regions [12].

However, the well-known problem is that "climate models often provide coarse spatial resolution for the case of small islands" [13]. These direct impacts include changes in the atmosphere and the ocean's physical and chemical parameters, leading to sea-level rise, ocean warming acidification, and changes in extreme event patterns [13].

Estimates indicate that certain islands may disappear because of sea-level rise, while others will face a considerable reduction in coastal areas, beaches, and land surface [9,14]. Other cascading consequences to which islands are particularly exposed are marine flooding [13], shifts in species ranges due to (ocean and air) temperature, and precipitation changes, leading to drier conditions and an increased frequency of heat waves and forest fires [15].

These physical changes pose a challenge to the sustainability of tourism, energy, fisheries, aquaculture, and maritime transport, which are essential for islands, as sea-related economic activities have always been key to their socioeconomic development [8,16,17]. At the same time, these activities on islands face different and often more significant structural challenges regarding, for example, the cost of products and services than in other coastal regions [18]. Moreover, the public support and generation of funds needed to maintain economic and social development follow different dynamics on islands than on the European mainland.

Islands are also subject to more challenging adaptation processes than the mainland due to their geographic remoteness, low economic diversification, and difficulties enjoying the scale advantages of human and economic agglomerations [19]. At the same time, island communities are deeply connected in ways that facilitate islanders' abilities to respond to CC on their terms. The social homogeneity and cohesion, their condition as living labs, and their openness to explore new development trajectories have proven to be effective in inducing greater flexibility and decision-making efficiency and favouring the implementation of environmentally oriented policies that reduce both the exposure to external economic fluctuations and the vulnerability to climatic disasters and CC [12].

However, with few exceptions, the progress of islands towards decarbonisation and fast and smart adaptation to CC shows poor results [12]. This is so for three main reasons. First, best practices at the island level are not well documented and disseminated to benchmark for the rest of the islands [20]. Second, academics and governments still cannot provide the massive amount of local information each island needs to implement policies more efficiently [16,21,22]. Third, the existing studies fail to explain when and how adaptive capacity at the local level translates into effective adaptation action [21].

In this respect, the consensus clearly emphasises that adaptation is fundamentally a local issue, and local involvement, participation and ownership are a central precondition for successful implementation. Moreover, studies agree that adaptation is implemented more effectively and efficiently when stakeholder perceptions and concerns about climate risks increase [20]. Hence, this work responds to these implementation gaps by providing a methodological framework for building up the basis for the analysis and ranking of adaptation policies that account for the specificities and identify the peculiar challenges and opportunities faced by the island under study in an ineludible step toward this goal. The wide range of quantitative and qualitative information sources and experiences of the local stakeholders' contributed to raising awareness and reaching a collective view. In this vein, the study may be seen as an analysis model that other islands and sectors can easily implement.

3. Climate Change and Adaptation Response on the Island of Sicily

Located in the south of Italy, the island of Sicily is the largest and one of the most densely populated islands in the Mediterranean Sea (see Figure 1). With its surrounding islands, Sicily's island forms an autonomous Italy region [8,22]. The island is primarily mountainous: 61% of the region consists of hills, 25% mountains, and 14% plains [22]. There is seismic and volcanic activity that is quite intense. It hosts Europe's highest active volcano, Mount Etna (3.350 m). The climate is subtropical and Mediterranean.

Underground water and springs are plentiful. The rainfall is generally relatively poor, especially at low altitudes and on the coast, where the landscape is semi-arid. Over 1000 m of altitude, snowfall can be abundant and frequent. For example, the Etna Volcano also has snow in the summer due to the Atlantic currents, affecting the climate, especially between the end of July and August. Over the years, the natural vegetation of the island of Sicily has been dramatically reduced by human influence, and forest land occupies only 4% of the territory nowadays [8,22–24].

Figure 1. The geographic location of the island of Sicily.

The island of Sicily's sunny, dry climate scenery and the rich and unique natural and cultural heritage—tangible, such as arts, architecture, and craftsmanship, and intangible, such as cuisine, music, and literature—represent a relevant tourism resource and attraction for tourist flows to the island all year round, even if the peak season is from May to September. Tourism is considered an important activity of great potential on the island of Sicily. However, it represents a small share of regional GDP [24], mainly due to the limited touristic capacity of the island and overall infrastructure [25]. Tourist infrastructure is the island's main weakness, constraining tourism's economic exploitation [26].

Regarding energy, the island of Sicily is interconnected through high-voltage links with the Italian mainland and Malta. Malta meets an essential share of its total electricity demand via imports from the island of Sicily. More than 65% of electricity is supplied through a high-voltage interconnector established in 2015. The Sicilian power supply system features traditional thermal, hydro, biomass, PV, and wind plants. The island of Sicily has significant solar potential, with high levels of horizontal irradiation. Expanding the interconnection capacity has enabled exports from the island to the mainland and contributed to the fall in electricity prices [23].

Maritime transport is essential for the island of Sicily, particularly for the island's connection to the mainland, with minor routes connecting to small surrounding islands.

Making investments in upgrading and maintaining infrastructure is a priority concern to improve the tourism and transport sector, as the current state hinders the efficient movement of people and goods. As a "convergence" region, the island of Sicily has received EU funding to improve mobility, focusing on railways, ports, and interconnecting parts through highway or road networks [27].

3.1. Future Climate and Macroeconomic Impacts: Reference Scenario

The island of Sicily's CC projections was reviewed by several sources, including MED-CORDEX and CMIP5 Ensemble [6,7,28]. Climate models indicate that the island is mainly affected by sea-level rise, extreme temperatures and drier conditions. Future climate conditions will thus have profound implications in terms of more prolonged droughts and heatwaves, higher energy demand, beach losses, and increased forest fire risk. For example, in the worst scenario (status quo), the sea level is projected to increase by 63 cm by the end of the century (2100), leading to an average beach surface loss of about 60% [6]. In the current climate, days with thermal discomfort on the island occur two months per year. Still, heatwaves could become the norm by the end of the century, with temperatures exceeding 35 °C for more than four months if no actions are implemented [29].

Moreover, the island is expected to be severely affected by meteorological droughts, exceeding the "very dry" conditions and fire danger thresholds [3,30,31]. This could lead to unprecedented increases in water demand by island residents, tourists and agriculture.

Table 1 summarises the essential CC impacts on the island, along with the sources they were extracted from. Considering that these changes are anticipated to be more pronounced during the warm part of the year, the impacts on tourism and energy demand will be more significant [8]. This information was synthesised and utilised as input for the policy design exercise with stakeholders, explained in the following sections. All climate impacts are estimated for two IPCC emissions scenarios: RCP2.6, a scenario that aims to keep global warming likely below 2 °C, above preindustrial levels, and RCP8.5, a baseline scenario without additional efforts to constrain emissions. Two-time horizons are considered: the near (2040–2060) and the distant (2080–2100) future, which reflect changes above the reference period.

Table 1. Projections of climate-related impacts on land ecosystems and sectoral activities on the island of Sicily.

Indicator	Reference (1986–2005)	RCP2.6 (2045–2060)	RCP2.6 (2080–2100)	RCP8.5 (2045–2060)	RCP8.5 (2080–2100)	References
Mean sea level rise		▲11 cm	▲23 cm	▲31 cm	▲63 cm	Leon et al., 2021 [8]; Lionello et al., 2019 [22]; Mariano et al., 2021 [6]; Primo et al., 2019 [28] Lionello, P.; Conte, D.; Reale, M., 2019 [32]
Reduced beach area		▼24%	▼34%	▼47%	▼61%	
Phanerogam surface *(Posidonia)*	966 km²	966 km²	966 km²	966 km²	693 km²	
Fire weather index (FWI) [a]	Low risk	Medium risk	Medium risk	High risk	Very high risk	Bacciu et al., 2021 [3] Conte et al., 2020 [33]; Jorda et al., 2020 [5]
Humidity index Number of days per year with humidex greater than 35 °C	52 d/y	68.5 d/y	70.1 d/y	74.1 d/y	118.7 d/y	
Available water- SPEI [b] Standardised precipitation-evapotranspiration index	0.00 Normal	−0.6 Normal	−0.6 Normal	−1.4 Medium dry	−2.3 Extremely dry	De la Vara et al., 2020 [34]; Soto-Navarro et al., 2020 [7]; Zittis, 2018 [30]; Zittis et al., 2019 [31] and 2021 [29].
Cooling degree days (CDDs) Number of degree-days with air temperature higher than 20 °C	210 DD	326 DD	314 DD	454 DD	746 DD	
Port damages		▼0.04%	▼0.04%	▼0.10%	▼0.12%	

In terms of decreased GDP						Kaján and Saarinen, 2013 [35]; Leon et al., 2021 [8]; Vrontisi et al., 2022 [25]
Electricity consumption Desalination and cooling	1720.19 GWh/year	▲10.5%	▲3.1%	▲25.3%	▲43.5%	
Tourism expenditure % change from reference case	av.p/person (EUR 1180)	▼7.2%	▼10.0%	▼13.8%	▼38.4%	

[a] An FWI system provides numerical non-dimensional ratings of relative fire potential for a generalised fuel type (mature pine stands) based solely on weather observations. The scale ranges from 0 to 1, from the lowest interval of 0–0.2 (very low danger) to the highest of 0.8–1.0 (very high). The categories vary greatly among subareas (NUT3). [b] SPEI is a representative indicator of increased water demand, indicating available water stored in dams or underground resources; it ranges from −2 (extremely dry) to 2 (extremely humid).

In their studies, Leon et al. (2021) [8] and Vrontisi et al. (2022) [25] examined the impact of CC on the Sicilian regional economy for different future climate scenarios. This macroeconomic analysis simulates future changes in GDP, private consumption, investments, exports and imports, sectoral activities, and employment [25]. Looking further into the results for the island of Sicily, the studies reveal an increased energy demand for cooling buildings and for the production of more water, which is necessary to maintain the living conditions of the domestic population and tourists.

This research highlights that the potential increased electricity demand could be partly satisfied by imports, while the domestic electricity network will probably handle the rest. This will require additional cooling equipment and higher utilisation of existing cooling systems. Hence, further investments to increase capacity are needed for the island, and the sectors actively engaged in this process, such as construction and market services, will increase [25].

According to Vrontisi et al. (2022) [25], reducing tourist expenditure will decrease the island's private consumption, investments, and trade deficits. The latter will originate with decreased imports (due to an overall decrease in domestic demand) and increased exports. Reduced demand for labour in tourism-related industries is expected to exert negative pressure on wages, which will benefit other sectors - mainly those that employ labour intensively.

The study concludes that CC hurts the regional economy because the macroeconomic impacts are more sensitive to higher emission patterns (RCP8.5), decreased tourism, and an increased need for electricity. The simulation results indicate that tourism is amongst the sectors that will experience the steepest decline in activity levels. In contrast, the electricity and construction sectors could record increased activity levels [35].

The cumulative reduction of GDP over the period 2040–2100 is estimated to be 0.54% in RCP2.6 and 2.6% in RCP8.5. Increased investment in the energy sector will lead to higher capital prices and result in a loss of competitiveness. In addition, the high investment in energy needed for additional cooling outweighs smaller consumption losses [25].

3.2. Adaptation Policy Context

Adapting to CC can be based on uncoordinated ad hoc choices and the actions of individuals and stakeholders or collective decisions, with numerous efforts coordinated at various levels—local, regional, national, or supranational [36]—that respond to sectoral vulnerabilities [37,38]. Adaptation also requires multidisciplinary knowledge and shared responsibility coordinated between governmental and non-governmental actors in different policy areas [39].

Italy has been dedicated to supporting and providing a robust analytical basis for the National Integrated Energy and Climate Plan (2018). The plan includes a BASE scenario that describes an evolution of the energy system with current policies and measures and a PNEC scenario that quantifies the strategic objectives for 2030. In this vein, using renewables and promoting energy efficiency are the leading measures envisaged to achieve the climate objectives of the country. The latest National Plan of Adaptation to Climate Change (PNACC), launched in July 2017, identifies and discusses the main objectives to be pursued and the necessary steps for each socio-economic sector of interest. From the sector analysis, over 350 actions are proposed in a single database containing detailed analytical information for each step and different selection keys to allow easy search and consultation.

At the regional level, in 2019, the Regional Department of Agriculture defined the guidelines to launch a regional strategy for adapting agriculture to CC. It was realised within the LIFE project "Adaptation to climate change impacts on the Mediterranean islands' agriculture—ADAPT2CLIMA" as an associate beneficiary [40]. In the same year, the Sicilian Region defined a regional action strategy to combat desertification [41], a document developed with the support of the Technical Committee Scientific ex-art. 3 of the l.r. 8 May 2018 n. 8. The overall objective of the strategy is to define a unified governance model based on multi-sectoral and multi-level approaches, ensuring a guidance framework concerning the spatial planning and hydrogeological risks of the priority agricultural, forestry, and resource sectors. The actions to implement the strategy were based on the National Action Plan (NAP) Drought and Desertification Control Programme and the national adaptation strategy for climate change (SNAC).

Moreover, the actions reflect the sustainable development objectives defined by UN Resolution 25 September 2015 in Transforming Our World: Agenda 2030 for Sustainable Development. Agenda 2030 is a programme of action with 17 selected goals to reach sustainable development, further articulated into 169 economic, environmental, social, and institutional sub-objectives. This document stresses the need for an integrated vision of the different dimensions concerning economic development, environmental protection, and human and social rights. The actions aim to arrest biodiversity loss, protect environmental resources and services, and fight and mitigate CC effects to protect and improve terrestrial and aquatic ecosystems.

There is limited information on CC impacts in the island context (i.e., Sicily and Sardinia). No adaptation plans were implemented in the past to identify necessary and specific measures for the local context. Regional governments are characterised by a weak understanding and awareness of the features and dissimilarities of CC impacts on islands compared to the mainland [8]. In addition, some documents highlighted inadequate allocation of funds from the national to the local level, a lack of locally relevant and practical information about potential impacts, limited financial resources for both medium-sized organisations and local governments, and low climate culture of the organisations [40,41].

As previously highlighted, in recent years, thanks to the island of Sicily's participation in the European project ADAPT2CLIMA, the effectiveness of some of the PNACC actions was analysed in a simulated scenario of decreasing climate-related vulnerability of the agriculture sector. The process helped to understand the importance of stressing more specific actions at the island level. Available solutions for the mainland are designed for homogeneous areas, and their implementation may not be efficient in particular contexts. Other limitations and barriers to implementing such measures on the island are related to national organisations and local governments' capacities and different priorities [40].

4. Methodology

The participatory process was conducted in four steps, strictly oriented toward stakeholders' engagement and promoting local adaptation action [42]. Presenting and discussing the background material was step 1. It laid the groundwork for the policy design exercise as it defined the picture of future climate scenarios for the island and their potential impact on the local socio-economic system. An extensive review of the available literature was required before this stage. Additional effort was dedicated to translating scientific results, complex data, and maps into infographics and fact sheets, with images and words to facilitate the comprehension of non-experts' and their interpretation of the information. The information was presented to stakeholders at an introductory event in which we also explained the analysis to be carried out.

Step 2 was devoted to the stakeholders' analysis of a catalogue of adaptation and risk management options, including 72 programmes (24 per sector). The programmes were adapted from the available literature on CC adaptation. At this stage, pre-defined criteria were established to evaluate these programmes' appropriateness and sustainability potential in the study context. This step was conducted at the sector level by organising workshops. Stakeholders were experts from local universities and research centres, public offices and agencies, and local sectoral associations. The sample included the stakeholders who agreed to cooperate on a volunteer basis.

Designing sector adaptation pathways was step 3. This was done through an online tool, similar to a questionnaire, that collected individual preferences for adaptation programmes that represented, according to stakeholders, a priority concern for the island in the short term (until 2030), mid-term (mid-century–until 2050), and long term (end of the century until 2100). Four possible scenarios of policy ambition (APTs) were constructed, aiming to obtain different packages of ranked programmes. Frequency analysis was applied to the stakeholders' responses. Results, aggregated by sector, were presented in a plenary session to identify cross-sector win-win situations (i.e., actions that would yield positive adaptation across some or all sectors) and, when possible, their decarbonisation performance (i.e., how each pathway will address measuring decarbonisation targets for the region).

Step 4 covered the pathway sustainability evaluation, allowing for a comparison between the final APTs and time frames in a radar graph. Figure 2 presents the methodological framework designed for the participatory process, the flow of information, and the sequence of methods performed to support the creation of local pathways.

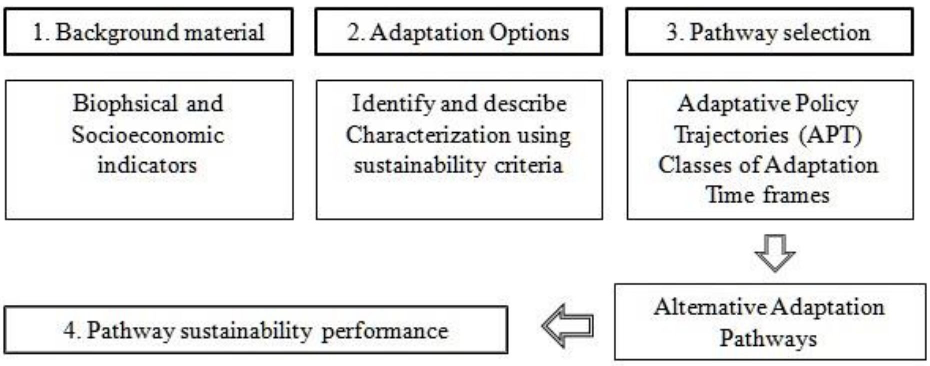

Figure 2. Methodological framework.

In total, 32 stakeholders were involved in this process. The profile involved policy- and decision-makers and practitioners, representing 44% of the sample; non-governmental and civil society organisations (16%); science experts (25%); and private parties, business operators, and sector regulators (15%). This process took two years, from June 2018 to March 2021. This was mainly because the COVID-19 pandemic appeared in the middle and stopped the process, which required a new and different start. The original plan was to hold only physical workshops and face-to-face questionnaires. In reality, a significant part of the process was redone and organised through online sessions, some in plenary with all stakeholders and others as sectoral workshops. This change also required dedicated resources to create a robust online support tool to collect individual views efficiently. The rationale of the COVID-19 contingency plan was to make it as easy as possible for stakeholders to carry out the proposed work without seriously compromising the scientific quality of the outcomes.

4.1. Catalogue of Adaptation and Risk Management Options

As mentioned before, the second step required the catalogue of programmes to be constructed, hence the policy options for the stakeholder analysis. In this vein, the Intergovernmental Panel on Climate Change (IPCC) proposes the use of RCP scenarios, which express starting atmospheric conditions for the CC models; SSPs that compile predefined packages of future socioeconomic contexts; and SPAs that include climate policy goals, policy regimes and measures, and implementation limits and obstacles [43,44].

A review of European adaptation literature and best practices was undertaken to create an outstanding catalogue to guide stakeholders' discussions on local benefits. The first significant source to start building this list was the Climate-ADAPT database (2022) [45], and the second was specific CC policy studies [46–51].

The main challenge in this phase was downscaling the programmes to the local scale. Indeed, several failures remain, as the proposed programmes neither ascertain the specific way in which a policy can be implemented nor the particular technologies nor investments needed (i.e., the beach protection programme through coastal defence infrastructure does not identify which specific structure is the most appropriate, which can vary from one point of the coast to another).

The adaptation and risk options/programmes were classified following Suckall et al. (2018) [52]. They considered three main strategic vectors for climate adaptation and resilience of any sector:

(i) Vulnerability reduction (VR): Programmes to reduce socio-economic vulnerability based on the five capitals of the sustainable livelihoods approach [47].
(ii) Disaster risk reduction (DRR): Programmes developed through the Hyogo and Sendai frameworks [52,53].
(iii) Socio-ecological resilience (SER): Programmes that affect socio-ecological resilience, including millennium ecosystem assessment (MEA) and Common International Classification of Ecosystem Services (CICES) [46,47].

Table 2 presents the distribution of the proposed programmes by sector and strategic vector, with the primary sources they were adapted from. The Supplementary Material includes the final catalogue of the 72 adaptation and risk management options utilised in this study and their characterisations.

Table 2. The number of adaptation programmes under analysis by a strategic vector (columns) and sector (rows).

	Vulnerability Reduction (VR)	Disaster Risk Reduction (DRR)	Socio-Economic Resilience (SER)
Maritime transport	10 programmes	8 programmes	6 programmes
Energy	10 programmes	8 programmes	6 programmes
Tourism	10 programmes	8 programmes	6 programmes
Reference	Bitner-Gregersen et al. (2018) [47]; De Bruin et al. (2009) [53]; De Sisternes et al. (2016) [54]; Lehr et al. (2012) [55]; Scott et al. (2013) [56]; Taneja, et al. (2012) [57]	Alfieri, L. et al. (2012) [58]; Ayoub et al. (2018) [59]; Crainic et al. (2009) [60]; Chhetri. et al. (2015) [61]; Cuce at al. (2016) [62]; Hammett and Mixter (2017) [63]; de Bruin (2009) [53]; Stahlhut et al. (2008) [64];	Apsley et al. (2009) [67]; Arias-Gaviria (2019) [46]; Bitner-Gregersen et al. (2018) [47]; Iglesias and Abanades (2017) [48]; Lund and Chiasson (2007) [68]; McNally and Natanzi

	Erol-Kantarci et al. (2011) [65]; Chen et.al (2015) [66]; Zhang al. (2017) [51]	(2018) [49]; Water Research Laboratory (2022) [69]

With the programmes being pre-defined, the stakeholders in each sector group contributed to their final characterisation. The sectoral groups were thus invited to analyse the pertinence of each programme and its sustainability potential. They could also propose new programmes not initially included in the catalogue at this stage.

Following Haque (2016) [70] and Verkerk et al. (2017) [71], five criteria were defined to evaluate the programmes, as shown in Table 3. The first criterion refers to cost efficiency (1 = low cost-efficiency; 4 = high cost-efficiency). It relates to the programme's ability to address current or future climate hazards/risks in the most economical way. The programme's ability to reduce emissions and minimise trade-offs with mitigation objectives was also considered relevant, together with the analysis of the current capacity on the island to implement the programmes (technical applicability). According to the stakeholders' views, the criterion of social acceptability refers to the potential acceptance of the program by civil society and policymakers. This information was utilised for the sustainability analysis of the final pathways, which is explained in the following sections.

Table 3. Criteria and scale are utilised to evaluate the sustainability potential of programmes.

Criterion	Description	Measurement
Cost-efficiency	Ability of proposed programme to efficiently address current or future climate hazards/risks in most economical way	1 = very low cost-efficiency; 4 = very high cost-efficiency
Environmental protection	Ability to protect environment, now and in the future	1 = very low environmental protection; 4 = very high environmental protection
Mitigation (GHG emissions) win–win and trade-off	Current ability to meet (win–win) or not (trade-off) island's mitigation objectives	1 = very high trade-off with mitigation goals; 4 = very high mitigation win–win and low trade-off
Technical applicability	Current ability to technically implement proposed option/programme	1 = very low technical applicability; 4 = very high technical applicability
Social acceptability	Social acceptability of option/measure	1 = very low social acceptability; 4 = very high social acceptability

4.2. Designing Sector Adaptation Pathways

Adaptation pathways usually capture policy preferences in a given time and context [52]. In this study, four adaptation pathway trajectories (APTs) were delineated as scenarios of policy ambition in terms of investment and commitment [71,52]. Therefore, it was assumed that stakeholders' preferences for programmes could be grouped from minimal to high-cost scenarios and from requiring a small to a significant change above the status quo [52].

Table 4 summarises the four APTs scenarios considered. Each APT has a specific narrative, adapted from Kebede et al. (2018) [72], Suckall et al. (2018) [52], and Hall et al. (2016) [73]. Minimum intervention APT A corresponds to a general approach in which climate actions continue to follow the tendency of historical levels of investment, where policies respond more exclusively to urgent needs protecting citizens and lives at a lower cost. Economic capacity expansion APT B focuses on planning the increasing investment in infrastructure capacity for the long-term resilience of the sector. Efficiency enhancement APT C may include actions to optimise the performance and efficiency of the current system, targeting both supply and demand and the deployment of technological innovations. Finally, system restructuring APT D groups highly transformational actions with a high level of investment and an increased commitment to significant policy change.

Table 4. The APT A,B,C,D, explanation.

APT A **Minimum intervention** (low investment/low commitment)	Assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts. Addresses those areas where maximum impact can be achieved for the lowest cost.
APT B **Economic capacity expansion** (high investment/low commitment)	Focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy. Requires a high level of investment to prepare the economy for future change but does not aim to reorient the economy or create significant change.
APT C **System efficiency enhancement** (medium investment/medium commitment)	Based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system, looking at ways of distributing labour, balancing livelihood choices, and best-utilising ecosystem services to enhance livelihoods and well-being under climate change.
APT D **System restructuring** (high investment/high commitment)	Embraces fundamental pre-emptive change at every level to completely transform the current socio-ecological and economic systems and thus change the social and physical functioning of archipelago/island sectors. Has a guiding belief that significant/radical landscape and societal modifications are justified to create long-term system restructuring despite the short-term costs among some social groups or economic sectors.

In the next phase (step 3), stakeholders were presented with a full explanation of the APTs to encourage thinking about different portfolios of ranked adaptation programmes. If one stakeholder could not analyse one APT scenario, it would be omitted, which was not the case. Hence, stakeholders selected the programmes they considered priority actions in each time frame (short-term, up to 2030; mid-century, 2030–2050; end-century, 2050–2100), as shown in Figure 3. The process was carried out for each APT scenario and sector independently, supported by an online tool that facilitated the exercise. The analysis was carried out by stakeholders individually. If a stakeholder was part of all three sector groups, they made 216 choices. All programmes selected within each time frame/APT were subject to frequency analysis.

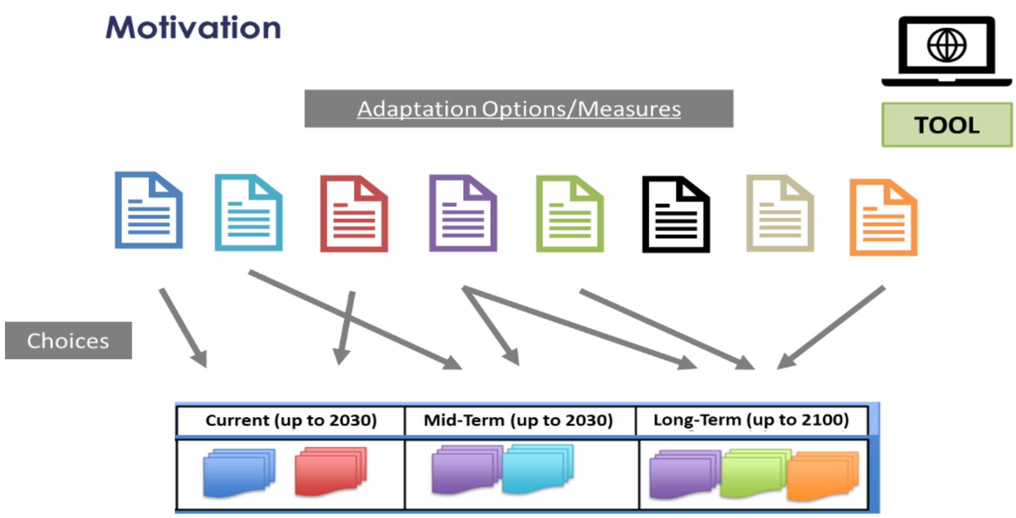

Figure 3. Theoretical representations of stakeholders' choices in the policy design exercise.

Hence, the final APTs obtained for each sector were formed with the most frequently chosen programmes. If a program was selected by at least 50% of the stakeholders in a specific time frame and APT, it was included in the pathway. The results were refined during a meeting with all sector representatives to capture inconsistencies and mutual benefits.

5. Results

The results are presented in two outputs per sector: (i) selected adaptation pathways (APTs) and (ii) sustainability evaluation. The first refers to the composition of the four final pathways per sector (from APT A to APT D) by incorporating the most frequent responses in each time frame. As expected, each APT comprises programmes representing a particular combination of priorities and commitment, which generally leads to a specific involvement level and policy ambition. Secondly, each pathway's sustainability potential is analysed by aggregating the average scores of the five sustainability criteria explained in Section 3.1.

5.1. Maritime Transport

The final adaptation pathways for the maritime transport sector are presented in Table 5. Pathways are significantly heterogeneous across the four APTs. Generally, the programme "Integrate ports in urban tissue" (MT7, socio-ecological resilience) received the highest level of concordance at 83%, followed by "Intelligent transport systems" (MT21, risk reduction) and "Refrigeration, cooling and ventilation systems" (MT13, vulnerability reduction), both at 75%.

APT A (low commitment) is characterised by the presence of programmes related to infrastructure protection (MT6), awareness campaigns (MT9), preparedness for delays and cancellations due to climate events (MT22), re-design of ports (MT18), and service management (MT 23) to confront climate-related impacts and maintain ports' operability in worsening future climate scenarios. Meanwhile, APT C and D add more ambitious programmes and propose more marine-friendly coastal protection infrastructures that can act as a source of wave energy production (MT3,4), thus combining adaptation with emissions reduction.

As expected, programmes to reduce vulnerability (VR) and increase resilience capacity (SER) have a more significant presence in APT C and D. Finally, climate-proof ports and activities (MT17) were the programmes more frequently chosen by stakeholders in all APTs, indicating that this should be considered a priority in all policy scenarios. Creating an intelligent transport system (MT21) only appears in the low investment scenario (APT

A). According to stakeholders, the island has sufficient technical capacity to implement this programme in its current situation.

Table 5. Alternative adaptation pathways for the maritime transport sector.

ID	Programmes	Strategic vector	APT A			APT B			APT C			APT D		
			S	M	L	S	M	L	S	M	L	S	M	L
MT1	Insurance mechanisms for ports	VR					B						D	
MT2	Financial incentives to retreat from high-risk areas						B						D	
MT10	Social dialogue for training in the port sector			A			B			C			D	
MT9	Awareness campaigns for behavioural change			A			B			C			D	
MT11	Diversification of trade using climate resilient commodities									C				
MT12	Climate resilient economy and jobs									C				
MT13	Refrigeration, cooling and ventilation systems									C			D	
MT14	Restrict development and settlement in low-lying areas									C			D	
MT16	Increase operational speed and flexibility in ports						B							
MT15	Sturdiness improvement of vessels						B							
MT17	Climate proof ports and port activities	DRR		A			B			C			D	
MT18	Consider expansion/retreat of ports in urban planning			A			B			C			D	
MT20	Early Warning Systems (EWS) and climate change monitoring									C				
MT19	Reinforcement of inspection, repair and maintenance of infrastructures									C				
MT21	Intelligent Transport Systems (ITS)			A										
MT22	Prepare for service delays or cancellations			A										
MT24	Post-Disaster recovery funds			A									D	
MT23	Backup routes and infrastructures during extreme weather			A									D	
MT4	Combined protection and wave energy infrastructures	SER								C			D	
MT3	Marine life friendly coastal protection structures			A			B			C			D	
MT6	Coastal protection structures			A			B			C				
MT5	Hybrid and full electric ship propulsion						B			C				
MT7	Integrate ports in urban tissue									C				
MT8	Ocean pools									C				

Note: VR, vulnerability reduction; DRR, disaster risk reduction; SER, socio-ecological resilience. Each APT (A, B, C, D) is represented in 3 time-frames: S, short-term (up to 2030); M, medium-term (up to 2050); and L, long-term (until 2100). Coloured boxes show the final programs that formed each APT: blue: APT A; green: AT B; orange: APT C; purple: APT D.

Figure 4 presents the results of the sustainability evaluation. The radar graph utilises the mean scores of the five sustainability criteria for the group of programmes that formed each APT and time frame. Only short- and long-term results are shown in the graphic.

In general, all four APT scenarios exhibit similar rankings; relatively high social acceptability and technical applicability of the programmes selected and low performance in terms of environmental protection. This means that stakeholders tend to choose programmes they consider to generate the maximum impact for the lowest cost in the island's current situation and better prepare the sector to deal with climate events. For example, APT C has the best sustainability performance, considering the five criteria in the longer term. It received the highest average scores in the cost-efficiency, environmental protection, and mitigation potential scales. This is because APT C includes programmes such as MT5 that propose the electrification of vessels. At the same time, APT A and B are more devoted to preparing vessels for sea storms (MT15) or using information systems to alert ships of CC hazards earlier (MT21), in which there is no direct environmental protection but by sector.

The same occurs in the short term, where APT D has the best sustainability performance, as it includes more adaptation programmes with the potential to reduce emissions (i.e., MT4).

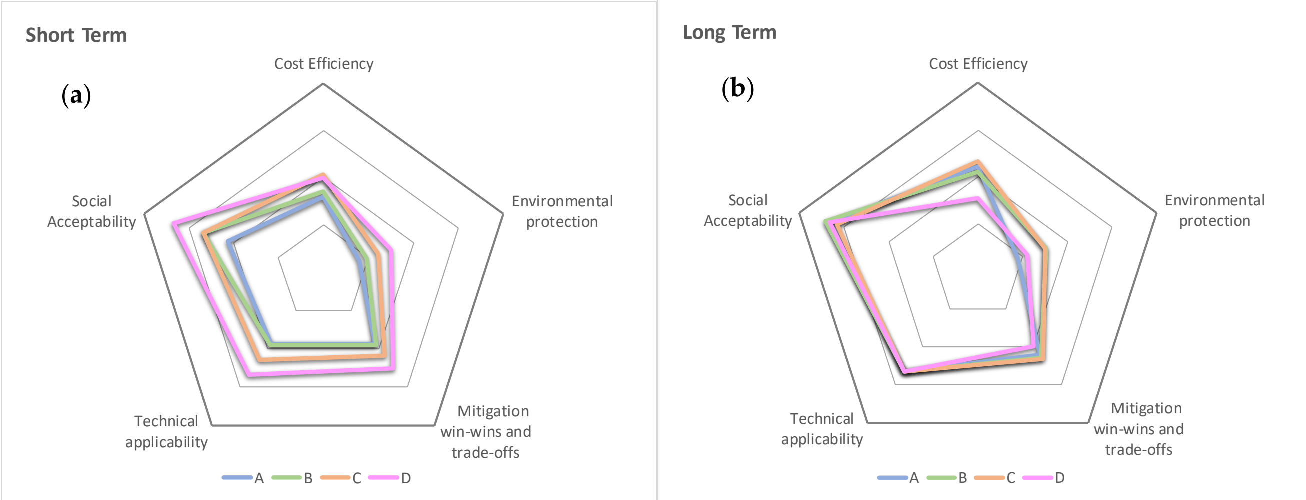

Figure 4. APT sustainability evaluation. (**a**) Sustainability evaluation of APTs in the short term; (**b**) sustainability evaluation of APTs in the long term. Note: The sustainability potential of each programme was measured by a 4-point scale and considering five criteria: cost-efficiency, environmental protection, mitigation (GHG emissions) win-win and trade-off, technical applicability, and social acceptability (see Section 3.1).

5.2. Energy

Table 6 presents the final adaptation pathways for the energy sector on the island of Sicily. Overall, APTs are characterised by heterogeneity concerning programmes and strategic vectors of significant concern. As expected, programmes aiming to increase social-ecological resilience are concentrated in more ambitious policy scenarios (APTC-D). At the same time, APTA is more devoted to preparedness and recovery in extreme events (DRR) cases. Hence, using waste heat from power plants for heating pools (E8) is the programme most frequently chosen within APT C and D, while in APT A, more operational actions were often selected by stakeholders, such as E22 (energy independency, 67%), E23 (energy recovery microgrid, 56%), E21 (study and develop energy grid connections, 56%), and E17 (review building codes of the energy infrastructure, 56%). On its side, APT C is characterised by a broader awareness of the need to reduce vulnerability and increase social-ecological resilience in the medium- and long-term.

All APTs propose the creation of green jobs and businesses (E9) and the review of building codes and generators (E17) for all time frames to reduce the vulnerability of the sector (VR). However, stakeholders consider the commitment to raise public information and knowledge about climate actions in the energy sector as secondary (E10), given the low frequency of responses. The promotion of educational gardens (E7) is not a priority since it was not chosen by any APT.

Table 6. Alternative adaptation pathways for the energy sector.

ID	Programmes	Strategic vector	APT A			APT B			APT C			APT D		
			S	M	L	S	M	L	S	M	L	S	M	L
E2	Financial support for smart control of energy in houses and buildings	VR					B						D	
E1	Financial support for buildings with low energy needs						B						D	
E9	Green jobs and businesses			A			B			C			D	
E10	Public information service on climate action			A			B			C			D	
E11	Small scale production and consumption									C				
E12	Risk reporting platform									C				
E13	Energy storage systems									C			D	
E14	Collection and storage of forest fuel loads									C			D	
E16	Demand Side Management (DSM) of Energy						B							
E15	Seawater Air Conditioning (SWAC).						B							
E17	Review building codes of the energy infrastructure	DRR		A			B			C			D	
E18	Upgrade evaporative cooling systems			A			B			C			D	
E20	Grid reliability									C				
E19	Early Warning Systems (EWS)									C				
E21	Study and develop energy grid connections			A										
E22	Energy-independent facilities (generators)			A										
E23	Energy recovery micro grids			A									D	
E24	Local recovery energy outage capacity			A									D	
E4	Underground tubes and piping in urban planning	SER		A			B			C			D	
E3	Energy efficiency in urban water management			A			B			C			D	
E5	Biomass power from household waste						B			C				
E6	Urban green corridors									C			D	
E8	Heated pools with waste heat from power plants									C				
E7	Educational garden plots									C				

Note: VR, vulnerability reduction; DRR, disaster risk reduction; SER, socio-ecological resilience. Each APT (A, B, C, D) is represented in 3 time-frames: S, short-term (up to 2030); M, medium-term (up to 2050); and L, long-term (until 2100). Coloured boxes show the final programs that formed each APT: blue: APT A; green: APT B; orange: APT C; purple: APT D.

Figure 5 presents the sustainability analysis results by calculating the mean scores of the five sustainability criteria for every group of programmes that formed the APTs. Although stakeholders were aware of the most beneficial and balanced adaptation programmes across the sustainability criteria, the priorities in policy design are dominated more by the aim of public acceptance and the maximum impact for the lowest cost.

For example, when stakeholders evaluated the sustainability potential of the energy programmes, the collection and storage of forest fuel loads (E14) received higher average scores than the operationalisation of energy microgrids (E23), which aim to prepare systems for power outages caused by knock-out events and excess demand (e.g., during heat waves). However, the latter was chosen as a priority measure in APT A by 56% of the stakeholders, while E14 was only by 22% in the APTD. This can be explained by the vast amount of resources and cross-sectoral collaboration required in maintaining woods, increasing the spacing between trees and reusing materials for energy (pellets, biogas).

Although few in number, other programmes such as E8 (heated pools with waste heat from power plants) were considered with excellent sustainability potential and were highly preferred in the policy design, given their potential to increase tourist attraction to the destination. This type of result enriched by the cross-sectoral discussion highlights the relevance of cost efficiency and social acceptance for stakeholders.

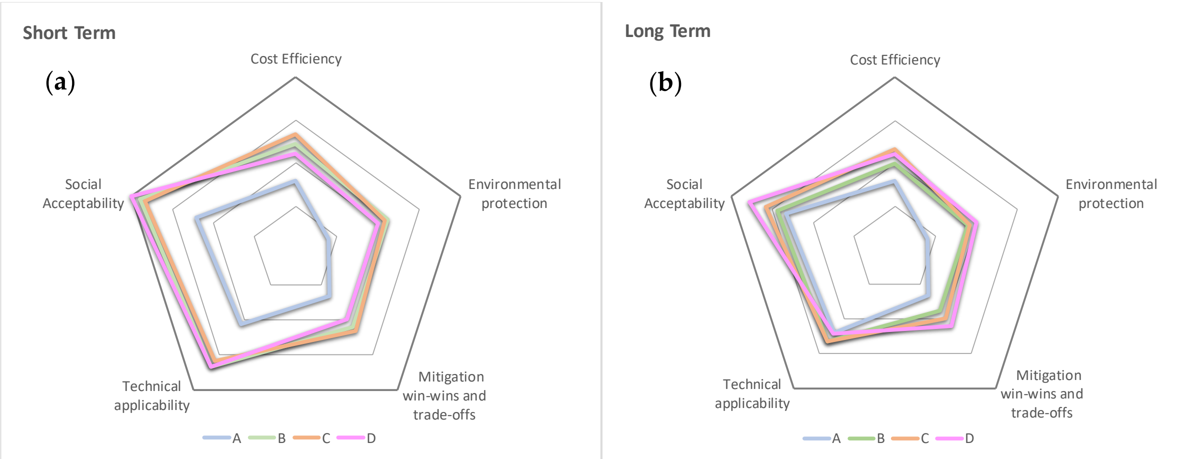

Figure 5. APT sustainability evaluation. (**a**) Sustainability evaluation of APTs in the short term; (**b**) sustainability evaluation of APTs in the long term. Note: Sustainability of proposed programs was measured on a 4-point scale considering five criteria: cost-efficiency, environmental protection, mitigation (GHG emissions), win-win and trade-off, technical applicability, and social acceptability (see Section 3.1).

5.3. Tourism

Table 7 presents the final structure and composition of the APTs for the tourism sector. Moreover, significant attention is drawn in this sector toward a more practical and operational approach to adapting existing processes and management. Programmes related to modelling and forecasting (T4), tourism diversification (T9), and drought management (T18) were chosen in all four APTs by more than half of the stakeholders, which means that they are priority concerns.

Specifically, concerning vulnerability reduction (VR) objectives, the results indicate that stakeholders are centred on natural, social, and physical capital rather than financially related programmes. Especially in APT C, the goal is to address a circular economy system and more sustainable tourist activities.

Table 7. Alternative adaptation pathways for the tourism sector.

ID	Programmes	Strategic Vector	APT A			APT B			APT C			APT D		
			S	M	L	S	M	L	S	M	L	S	M	L
T1	Economic Policy Instruments (EPIs)	VR					B						D	
T2	Financial incentives to retreat from high-risk areas						B						D	
T9	Activity and product diversification			A			B			C			D	
T10	Public awareness programmes			A			B			C			D	
T11	Local circular economy									C				
T12	Tourist awareness campaigns									C				
T13	Local sustainable fishing									C			D	
T14	Water restrictions and grey-water recycling									C			D	
T15	Beach nourishment						B							
T16	Desalination						B							
T18	Drought and water conservation plans	DRR		A			B			C			D	
T17	Coastal protection structures			A			B			C			D	
T19	Mainstreaming Disaster Risk Management (DRM)									C				
T20	Using water to cope with heat waves									C				
T22	Health care delivery systems			A										
T21	Fire management plans			A										
T24	Pre-disaster early recovery planning			A									D	
T23	Post-Disaster recovery funds			A									D	
T4	Monitoring, modelling and forecasting systems	SER		A			B			C			D	

T3	Adaptation of groundwater management			A			B			C			D	
T6	River rehabilitation and restoration						B			C				
T5	Dune restoration and rehabilitation						B			C				
T7	Adaptive management of natural habitats									C				
T8	Ocean pools									C				

Note: VR, vulnerability reduction; DRR, disaster risk reduction; SER, socio-ecological resilience. Each APT (A, B, C, D) is represented in 3 time-frames: S, short term (up to 2030); M, medium-term (up to 2050); and L, long term (until 2100). Coloured boxes show the final programs that formed each APT: blue: APT A; green: APT B; orange: APT C; and purple: APT D.

To manage disaster risks (DRR), the results highlight a significant preference for coastal protection (T17) and water conservation plans (T18). Within the programmes addressing socio-ecological resilience (SER), the adaptive management of natural habitats was considered a priority for most stakeholders in APT C, indicating that this is crucial for promoting efficiency in adaptation investment.

Figure 6 presents the sustainability analysis results by calculating the mean scores of the five sustainability criteria. The four APT scenarios have similar sustainability results from the short to long term, with social acceptability and technical applicability showing the best results for all APTs. In APT A, stakeholders prioritise programmes that provide the sector with security and new directions to maintain its economic performance (e.g., coastal protection structures, diversification of the tourism economy, etc.). Scenarios APT B and APT C show more balanced results for all sustainability criteria. Finally, high investment and commitment to CC (APT D) requires implementing more ambitious programmes in terms of environmental protection and win-win mitigation scenarios without forgetting the social and technical aspects (e.g., greywater recycling, T14).

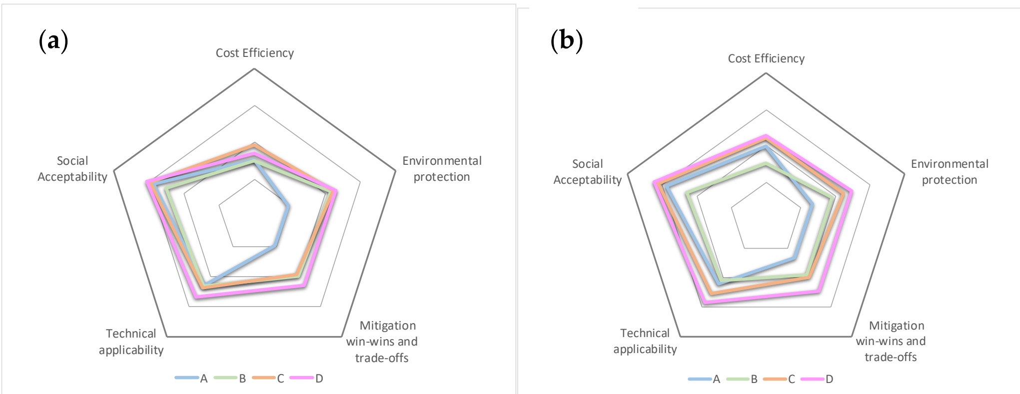

Figure 6. APT sustainability analysis. (**a**) Sustainability evaluation of APTs in the short term; (**b**) sustainability evaluation of APTs in the long term. Note: Sustainability of proposed programs was measured by a 4-point scale considering five criteria: cost-efficiency, environmental protection, mitigation (GHG emissions) win-win and trade-off, technical applicability, and social acceptability (see Section 3.1).

6. Policy Discussion

With policymakers ultimately being the ones who are expected to make correct use of this research, we attempted to maximise its policy orientation by reaching a compromise between simplicity and scientific relevance that proved to be highly appreciated [70,71]. We analysed and ranked CC adaptation programmes for tourism, energy and maritime transport and proposed alternative adaptation pathways for the case of the island of Sicily through the lens of high-level sectoral representatives, academics, and experts. These primary outlines are considered the first and most essential attitudes to be prepared at the local level for future climate scenarios. When top-down governance systems prevail, as with the island of Sicily, there is often a lack of communication-related to climate change impacts and a lack of empowerment of local decision-makers, which increases the risk of adaptation [72–74]. In this vein, the policy implication of the study is twofold. First, the production of precise and adapted information at a local level by enabling cooperation between science and society to raise awareness about the urgent need to deal with climate change issues in more efficient terms; second, the engagement process carried out can be seen as a step towards speeding up the transition from identifying adaptive capacities to designing adaptation policies in terms of long-term sustainability and social-ecological resilience.

The participatory process also provided information about critical areas that need to be addressed at a local level, such as the incomplete understanding of vulnerability dimensions and leeway for adaptation [12,21,42,75]. It also allowed us to discuss priority risks, other islands, and new opportunities for the island of Sicily from a multidisciplinary perspective [24,25,75]. Some climate risks for the island of Sicily are expected to be lower than for other European islands farther from the mainland [76,77]. In addition, although the island of Sicily is significantly exposed to marine habitat degradation, there is more potential to offer viable substitutes for marine and tourist activities, thanks to the island's extraordinary endowment of assets. Indeed, the island of Sicily presents a balanced array of tourist offerings [26], including a wide range of cultural, social, landscape, gastronomic, and historical resources that ensure the tourism activity is not strictly dependent on the marine environment, as well as being more resilient [4,44] to the risk of seawater heating [35].

More details about spatial hotspots were revealed, which allows for an in-depth characterisation of the adaptation programmes (i.e., to which tourism products the island should be diversified). Moreover, some priority measures proposed for the energy sector were considered beneficial for tourism, such as enabling energy microgrids and using waste heat from power plants for heating pools. Hence, considering that transparency and case-specific information is crucial for ensuring a higher commitment to effective adaptation planning [52], this study has significantly contributed to building up the basis for improved climate actions at a local level.

The most challenging task was putting the stakeholders into the context of different scenarios of policy ambition. This task was highly demanding but significantly improved the stakeholders' experience with the process. An excellent understanding was achieved when the APTs' rationale was scaled down with shorter descriptions, images, and real-world examples [52]. The results demonstrate that stakeholders correctly understood the diverse policy directions when making their choices. For instance, they selected more programmes that provide general solutions for protecting citizens and capital needs; highly diversified activities; and responses to potential damage to economic activities in the low-commitment scenario, APT A. In APT B (economic capacity expansion), we see that many resources (investments) are used to deal with climate risks and thus expand the capacity of protection from risk. For example, coastal flooding is dealt with by building ever larger heavy protections that prevent the impact of physical force. In APT C, more efficient solutions are selected, implying fewer resources but requiring more engagement. In APT D (system restructuring), where high investment and engagement are necessary, we frequently find measures with the potential to enhance socio-ecological resilience.

This means that stakeholders recognise the need to protect human and social capital but also the quality of the environmental services that support these activities. With the policy scenarios and measures being understood by almost all, stakeholders' concerns revolved around affordability and the significant costs associated with the required structural changes, which certainly depend on national decisions [78–81]. This may be why stakeholders tend to concentrate on more ambitious adaptation programmes in the longer term.

7. Conclusions

This article used a mixed-method approach through literature review and participatory assessment based on multicriteria analysis [70,73] to identify and rank alternative adaptation pathways [71,72] in an island context. The methodology is framed in the socio-economic context of the island of Sicily, a large island without implemented adaptation plans.

In this regard, this study has been able to crystallise measures that, according to the stakeholders, have the potential to increase the climate-related resiliency capacities of the energy, tourism, and maritime transport sectors. The methodological framework was ambitious and led to valuable results, bearing in mind that this was the first step towards local adaptation solutions. Therefore, the proposed pathways should be considered a focal point for future discussion between researchers, practitioners and the island's citizens. Hence, there is room for future contributions in these subfields of research.

From the methodological perspective, there is a possibility to use this evidence to bridge the gap between academic research and practical policy design beyond the sectors and the island analysed. In this respect, a relevant issue is whether findings reported in the literature can constitute a common groundwork for raising alternative solutions to climate actions locally. Moreover, when the information at a local level is full of subjectivity, experts' participation is crucial, and multi-criteria analyses have proven sufficient robustness in many decision-making fields [42].

The study's results highlight the great importance that local stakeholders attach to programmes for their ability to meet social and capital needs in future climate scenarios with a contained investment. The participatory process also revealed a breach between what stakeholders would prioritise when designing adaptation pathways and their opinion about the policies across the sustainability criteria. Although stakeholders were aware of the most beneficial and balanced adaptation programmes, the priorities when designing climate policies are dominated more by the aim of public acceptance and the maximum impact for the lowest cost.

The study focuses on three sectors, but there was room to discuss adaptation with a multisector perspective. In this regard, common adaptation needs to arise, mainly to confront sea-level rise and increased frequency of extreme temperatures, a major concern of the local stakeholders and a critical risk for the island according to climate projections. This concern was materialised in the stakeholders' choices, with a higher preference for infrastructure protection measures (MT4, MT6), the improvement of cooling (MT13) and energy storage systems (E13), and improved healthcare delivery systems (T22), among others. Surprisingly, the energy sector was the only one where stakeholders considered raising public information and awareness not to be a priority, suggesting that society (consumers) is far from influencing policymaking.

Some study limitations emerged regarding the geographical, sectoral scope and the dimension and composition of the sample of stakeholders involved. Indeed, the number of experts was limited, and the composition was homogeneous. There were not the same numbers of categories, practitioners, academics, public authorities, and sector experts for each sector analysed. At the same time, the number of stakeholders in each industry was not equal. This suggests the need to conduct further analysis to overcome these aspects. Moreover, the consideration of other sectors that are also relevant for the islands (i.e., fisheries, aquaculture, agriculture) could enrich the analysis and expected benefits of climate actions.

Future research could consider a deeper analysis of the structural relations between sectors and the extension of the multicriteria analysis since sectoral changes induced by certain hazards would modify the exposure and vulnerability of other sectors. A solution may be using different hierarchy trees, each defined for a particular combination of climate risks and sectors and adequately treating the systemic loops between them.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land11081206/s1. Catalogue of adaptation options for the island of Sicily (Italy).

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Assessing Climate Change Adaptation and Risk Management Programmes: Stakeholder Participation Process and Policy Implications for Transport, Energy and Tourism Sectors on the Island of Sicily

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Abstract: Climate change is a critical sustainability challenge for islands and their main economic sectors. Rising sea levels, extreme temperatures, and drier conditions are the impacts with the most significant potential to amplify the economic damage on islands. However, their isolation and natural conditions bring about some leeway to respond to climate impacts on their terms. This paper aims to provide a local-level analysis and ranking of alternative adaptation pathways in an island context through the stakeholders' lens. This study reviews the latest advancements in adaptation science and proposes a catalogue of adaptation and risk management options that feed a participatory assessment and ranking by local stakeholders. The research was conducted on the island of Sicily (Italy) and saw the participation of high-level experts and tourism, energy, and maritime transport representatives. It employs a sequential process of four ordered steps oriented towards adaptation planning and stakeholders' engagement. The process reveals breaches between what stakeholders' would prioritise when designing policy pathways and their opinion about the most beneficial and balanced adaptation programmes across the sustainability criteria. Results indicate that, according to stakeholders, the priorities are to prepare the energy, tourism, and maritime transport sectors to confront future climate-related events more efficiently. Other transformational actions to ensure long-term social-ecological resilience, which requires significant structural changes and substantial investments, are not at the core of the public needs.

Keywords: climate change; island; adaptation; land ecosystems; resilience; sustainability

1. Introduction

Europe's islands experience greater vulnerability to the risks of climate change (CC) than the mainland, as recognised in the New EU Strategy on Adaptation to Climate Change [1]. On the island of Sicily, the largest island in the Mediterranean Sea [2], the main socio-economic sectors will be heavily affected by rising sea levels, extreme sea and air temperatures, and drier conditions. Although there is a lack of information available at the local level, significant changes are expected in land biodiversity, usable beach surface, forest fire danger, droughts, and heatwaves at one point or another on the island [3–7].

Despite existing efforts, the island of Sicily lacks reliable information and monitoring systems regarding the impact of CC at the island level and limited analysis of appropriate adaptation programmes, hindering the successful implementation of climate actions. No regional adaptation plans exist, and national approaches do not promote intelligent and fast adaptation at the local level. That is, the opportunity to make informed decisions and explore new developments that fully exploit the island's potential [8].

In response, this paper aims to analyse and rank adaptation and risk management programmes for the island of Sicily and define alternative pathways with local stakeholders tailored to the island's context. The study employed a mixed approach; we reviewed the latest scientific advancements in adaptation science and proposed a catalogue of 72 adaptation and risk management options, representing the programmes used in the participatory phase involving 32 stakeholders. A multi-criteria scale and a set of tools and background information were utilised to facilitate the four-stage evaluation and ranking process and reach a collective result.

It was assumed that the cost of adapting to CC could range from minimal to high and require small or incremental changes to the significant transformation from the status quo. Hence, we consider four possible adaptation trajectories: minimum intervention (APT A), economic capacity expansion (APT B), efficiency enhancement (APT C), and system restructuring (APT D). In addition, the proposed policy trajectories cover three time-frames: short-term (up to 2030), mid-century (up to 2050), and end-century (up to 2100). Among the sectors exposed to CC relevant to the Sicilian economy, this study focuses on maritime transport, energy and tourism for several reasons [8]:

(i) Palermo is a strategic Italian port for the Motorways of the Sea system by the Ministry of Transport. In terms of port facilities, the island of Sicily exceeds the national average.
(ii) Renewable sources are hydroelectric, photovoltaics and biomass; the solar potential is recognised with higher productivity levels.
(iii) The island of Sicily's sunny and dry climate, cuisine, and cultural and natural heritage has attracted increasing numbers of visitors worldwide, making tourism a sector of great relevance for local development.

The main contribution of this research is its method and bottom-up approach since top-down processes have been shown to lack the capacity to downscale the information requirements to speed up climate actions on the island of Sicily. Therefore, the final set of adaptation measures is framed by the island's socio-economic context and ranked according to sustainability criteria. At the same time, the involvement of key actors in the policy design exercise may reduce the risk of low sensitiveness and motivation of local decision-makers to lead a behavioural change.

This paper describes the current situation on the island of Sicily and the projections related to climate change impacts, alongside the policy context of adaptation and risk management. The methodology section highlights the workflow, the duration and the tools utilised to guide the participatory process. The subsequent section describes the analysis of the results by sector and discusses the findings and their managerial and policy implications.

2. The Vulnerability of Islands to Climate Change

The effects of global CC are expected to vary in both magnitude and timing as well as by geographic region [9]. The impacts are going to depend on the region. Island communities are among the first and most adversely affected by the impacts of global CC [10] because they share relatively larger coastal zones and feature valuable ecosystems and natural environments, with a high level of species endemism, unique functional traits and evolutionary patterns [11].

The scientific literature on CC provides a comprehensive understanding of the direct impacts of a changing climate on islands, from the tropics to the polar regions [12].

However, the well-known problem is that "climate models often provide coarse spatial resolution for the case of small islands" [13]. These direct impacts include changes in the atmosphere and the ocean's physical and chemical parameters, leading to sea-level rise, ocean warming acidification, and changes in extreme event patterns [13].

Estimates indicate that certain islands may disappear because of sea-level rise, while others will face a considerable reduction in coastal areas, beaches, and land surface [9,14]. Other cascading consequences to which islands are particularly exposed are marine flooding [13], shifts in species ranges due to (ocean and air) temperature, and precipitation changes, leading to drier conditions and an increased frequency of heat waves and forest fires [15].

These physical changes pose a challenge to the sustainability of tourism, energy, fisheries, aquaculture, and maritime transport, which are essential for islands, as sea-related economic activities have always been key to their socioeconomic development [8,16,17]. At the same time, these activities on islands face different and often more significant structural challenges regarding, for example, the cost of products and services than in other coastal regions [18]. Moreover, the public support and generation of funds needed to maintain economic and social development follow different dynamics on islands than on the European mainland.

Islands are also subject to more challenging adaptation processes than the mainland due to their geographic remoteness, low economic diversification, and difficulties enjoying the scale advantages of human and economic agglomerations [19]. At the same time, island communities are deeply connected in ways that facilitate islanders' abilities to respond to CC on their terms. The social homogeneity and cohesion, their condition as living labs, and their openness to explore new development trajectories have proven to be effective in inducing greater flexibility and decision-making efficiency and favouring the implementation of environmentally oriented policies that reduce both the exposure to external economic fluctuations and the vulnerability to climatic disasters and CC [12].

However, with few exceptions, the progress of islands towards decarbonisation and fast and smart adaptation to CC shows poor results [12]. This is so for three main reasons. First, best practices at the island level are not well documented and disseminated to benchmark for the rest of the islands [20]. Second, academics and governments still cannot provide the massive amount of local information each island needs to implement policies more efficiently [16,21,22]. Third, the existing studies fail to explain when and how adaptive capacity at the local level translates into effective adaptation action [21].

In this respect, the consensus clearly emphasises that adaptation is fundamentally a local issue, and local involvement, participation and ownership are a central precondition for successful implementation. Moreover, studies agree that adaptation is implemented more effectively and efficiently when stakeholder perceptions and concerns about climate risks increase [20]. Hence, this work responds to these implementation gaps by providing a methodological framework for building up the basis for the analysis and ranking of adaptation policies that account for the specificities and identify the peculiar challenges and opportunities faced by the island under study in an ineludible step toward this goal. The wide range of quantitative and qualitative information sources and experiences of the local stakeholders' contributed to raising awareness and reaching a collective view. In this vein, the study may be seen as an analysis model that other islands and sectors can easily implement.

3. Climate Change and Adaptation Response on the Island of Sicily

Located in the south of Italy, the island of Sicily is the largest and one of the most densely populated islands in the Mediterranean Sea (see Figure 1). With its surrounding islands, Sicily's island forms an autonomous Italy region [8,22]. The island is primarily mountainous: 61% of the region consists of hills, 25% mountains, and 14% plains [22]. There is seismic and volcanic activity that is quite intense. It hosts Europe's highest active volcano, Mount Etna (3.350 m). The climate is subtropical and Mediterranean.

Underground water and springs are plentiful. The rainfall is generally relatively poor, especially at low altitudes and on the coast, where the landscape is semi-arid. Over 1000 m of altitude, snowfall can be abundant and frequent. For example, the Etna Volcano also has snow in the summer due to the Atlantic currents, affecting the climate, especially between the end of July and August. Over the years, the natural vegetation of the island of Sicily has been dramatically reduced by human influence, and forest land occupies only 4% of the territory nowadays [8,22–24].

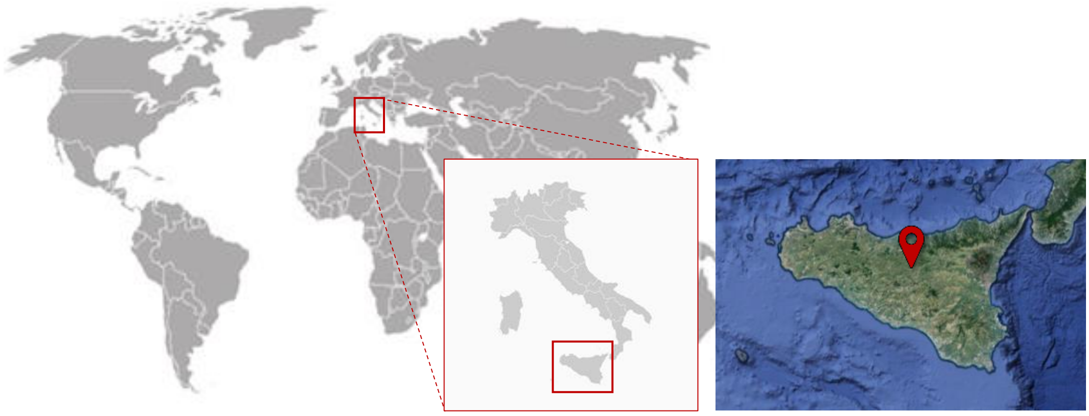

Figure 1. The geographic location of the island of Sicily.

The island of Sicily's sunny, dry climate scenery and the rich and unique natural and cultural heritage—tangible, such as arts, architecture, and craftsmanship, and intangible, such as cuisine, music, and literature—represent a relevant tourism resource and attraction for tourist flows to the island all year round, even if the peak season is from May to September. Tourism is considered an important activity of great potential on the island of Sicily. However, it represents a small share of regional GDP [24], mainly due to the limited touristic capacity of the island and overall infrastructure [25]. Tourist infrastructure is the island's main weakness, constraining tourism's economic exploitation [26].

Regarding energy, the island of Sicily is interconnected through high-voltage links with the Italian mainland and Malta. Malta meets an essential share of its total electricity demand via imports from the island of Sicily. More than 65% of electricity is supplied through a high-voltage interconnector established in 2015. The Sicilian power supply system features traditional thermal, hydro, biomass, PV, and wind plants. The island of Sicily has significant solar potential, with high levels of horizontal irradiation. Expanding the interconnection capacity has enabled exports from the island to the mainland and contributed to the fall in electricity prices [23].

Maritime transport is essential for the island of Sicily, particularly for the island's connection to the mainland, with minor routes connecting to small surrounding islands.

Making investments in upgrading and maintaining infrastructure is a priority concern to improve the tourism and transport sector, as the current state hinders the efficient movement of people and goods. As a "convergence" region, the island of Sicily has received EU funding to improve mobility, focusing on railways, ports, and interconnecting parts through highway or road networks [27].

3.1. Future Climate and Macroeconomic Impacts: Reference Scenario

The island of Sicily's CC projections was reviewed by several sources, including MED-CORDEX and CMIP5 Ensemble [6,7,28]. Climate models indicate that the island is mainly affected by sea-level rise, extreme temperatures and drier conditions. Future climate conditions will thus have profound implications in terms of more prolonged droughts and heatwaves, higher energy demand, beach losses, and increased forest fire risk. For example, in the worst scenario (status quo), the sea level is projected to increase by 63 cm by the end of the century (2100), leading to an average beach surface loss of about 60% [6]. In the current climate, days with thermal discomfort on the island occur two months per year. Still, heatwaves could become the norm by the end of the century, with temperatures exceeding 35 °C for more than four months if no actions are implemented [29].

Moreover, the island is expected to be severely affected by meteorological droughts, exceeding the "very dry" conditions and fire danger thresholds [3,30,31]. This could lead to unprecedented increases in water demand by island residents, tourists and agriculture.

Table 1 summarises the essential CC impacts on the island, along with the sources they were extracted from. Considering that these changes are anticipated to be more pronounced during the warm part of the year, the impacts on tourism and energy demand will be more significant [8]. This information was synthesised and utilised as input for the policy design exercise with stakeholders, explained in the following sections. All climate impacts are estimated for two IPCC emissions scenarios: RCP2.6, a scenario that aims to keep global warming likely below 2 °C, above preindustrial levels, and RCP8.5, a baseline scenario without additional efforts to constrain emissions. Two-time horizons are considered: the near (2040–2060) and the distant (2080–2100) future, which reflect changes above the reference period.

Table 1. Projections of climate-related impacts on land ecosystems and sectoral activities on the island of Sicily.

Indicator	Reference (1986–2005)	RCP2.6 (2045–2060)	RCP2.6 (2080–2100)	RCP8.5 (2045–2060)	RCP8.5 (2080–2100)	References
Mean sea level rise		▲11 cm	▲23 cm	▲31 cm	▲63 cm	Leon et al., 2021 [8]; Lionello et al., 2019 [22]; Mariano et al., 2021 [6]; Primo et al., 2019 [28] Lionello, P.; Conte, D.; Reale, M., 2019 [32]
Reduced beach area		▼24%	▼34%	▼47%	▼61%	
Phanerogam surface *(Posidonia)*	966 km²	966 km²	966 km²	966 km²	693 km²	
Fire weather index (FWI) [a]	Low risk	Medium risk	Medium risk	High risk	Very high risk	Bacciu et al., 2021 [3] Conte et al., 2020 [33]; Jorda et al., 2020 [5]
Humidity index Number of days per year with humidex greater than 35 °C	52 d/y	68.5 d/y	70.1 d/y	74.1 d/y	118.7 d/y	
Available water- SPEI [b] Standardised precipitation-evapotranspiration index	0.00 Normal	−0.6 Normal	−0.6 Normal	−1.4 Medium dry	−2.3 Extremely dry	De la Vara et al., 2020 [34]; Soto-Navarro et al., 2020 [7]; Zittis, 2018 [30]; Zittis et al., 2019 [31] and 2021 [29].
Cooling degree days (CDDs) Number of degree-days with air temperature higher than 20 °C	210 DD	326 DD	314 DD	454 DD	746 DD	
Port damages		▼0.04%	▼0.04%	▼0.10%	▼0.12%	

In terms of decreased GDP						Kaján and Saarinen, 2013 [35]; Leon et al., 2021 [8]; Vrontisi et al., 2022 [25]
Electricity consumption Desalination and cooling	1720.19 GWh/year	▲10.5%	▲3.1%	▲25.3%	▲43.5%	
Tourism expenditure % change from reference case	av.p/person (EUR 1180)	▼7.2%	▼10.0%	▼13.8%	▼38.4%	

[a] An FWI system provides numerical non-dimensional ratings of relative fire potential for a generalised fuel type (mature pine stands) based solely on weather observations. The scale ranges from 0 to 1, from the lowest interval of 0–0.2 (very low danger) to the highest of 0.8–1.0 (very high). The categories vary greatly among subareas (NUT3). [b] SPEI is a representative indicator of increased water demand, indicating available water stored in dams or underground resources; it ranges from −2 (extremely dry) to 2 (extremely humid).

In their studies, Leon et al. (2021) [8] and Vrontisi et al. (2022) [25] examined the impact of CC on the Sicilian regional economy for different future climate scenarios. This macroeconomic analysis simulates future changes in GDP, private consumption, investments, exports and imports, sectoral activities, and employment [25]. Looking further into the results for the island of Sicily, the studies reveal an increased energy demand for cooling buildings and for the production of more water, which is necessary to maintain the living conditions of the domestic population and tourists.

This research highlights that the potential increased electricity demand could be partly satisfied by imports, while the domestic electricity network will probably handle the rest. This will require additional cooling equipment and higher utilisation of existing cooling systems. Hence, further investments to increase capacity are needed for the island, and the sectors actively engaged in this process, such as construction and market services, will increase [25].

According to Vrontisi et al. (2022) [25], reducing tourist expenditure will decrease the island's private consumption, investments, and trade deficits. The latter will originate with decreased imports (due to an overall decrease in domestic demand) and increased exports. Reduced demand for labour in tourism-related industries is expected to exert negative pressure on wages, which will benefit other sectors - mainly those that employ labour intensively.

The study concludes that CC hurts the regional economy because the macroeconomic impacts are more sensitive to higher emission patterns (RCP8.5), decreased tourism, and an increased need for electricity. The simulation results indicate that tourism is amongst the sectors that will experience the steepest decline in activity levels. In contrast, the electricity and construction sectors could record increased activity levels [35].

The cumulative reduction of GDP over the period 2040–2100 is estimated to be 0.54% in RCP2.6 and 2.6% in RCP8.5. Increased investment in the energy sector will lead to higher capital prices and result in a loss of competitiveness. In addition, the high investment in energy needed for additional cooling outweighs smaller consumption losses [25].

3.2. Adaptation Policy Context

Adapting to CC can be based on uncoordinated ad hoc choices and the actions of individuals and stakeholders or collective decisions, with numerous efforts coordinated at various levels—local, regional, national, or supranational [36]—that respond to sectoral vulnerabilities [37,38]. Adaptation also requires multidisciplinary knowledge and shared responsibility coordinated between governmental and non-governmental actors in different policy areas [39].

Italy has been dedicated to supporting and providing a robust analytical basis for the National Integrated Energy and Climate Plan (2018). The plan includes a BASE scenario that describes an evolution of the energy system with current policies and measures and a PNEC scenario that quantifies the strategic objectives for 2030. In this vein, using renewables and promoting energy efficiency are the leading measures envisaged to achieve the climate objectives of the country. The latest National Plan of Adaptation to Climate Change (PNACC), launched in July 2017, identifies and discusses the main objectives to be pursued and the necessary steps for each socio-economic sector of interest. From the sector analysis, over 350 actions are proposed in a single database containing detailed analytical information for each step and different selection keys to allow easy search and consultation.

At the regional level, in 2019, the Regional Department of Agriculture defined the guidelines to launch a regional strategy for adapting agriculture to CC. It was realised within the LIFE project “Adaptation to climate change impacts on the Mediterranean islands’ agriculture—ADAPT2CLIMA” as an associate beneficiary [40]. In the same year, the Sicilian Region defined a regional action strategy to combat desertification [41], a document developed with the support of the Technical Committee Scientific ex-art. 3 of the l.r. 8 May 2018 n. 8. The overall objective of the strategy is to define a unified governance model based on multi-sectoral and multi-level approaches, ensuring a guidance framework concerning the spatial planning and hydrogeological risks of the priority agricultural, forestry, and resource sectors. The actions to implement the strategy were based on the National Action Plan (NAP) Drought and Desertification Control Programme and the national adaptation strategy for climate change (SNAC).

Moreover, the actions reflect the sustainable development objectives defined by UN Resolution 25 September 2015 in Transforming Our World: Agenda 2030 for Sustainable Development. Agenda 2030 is a programme of action with 17 selected goals to reach sustainable development, further articulated into 169 economic, environmental, social, and institutional sub-objectives. This document stresses the need for an integrated vision of the different dimensions concerning economic development, environmental protection, and human and social rights. The actions aim to arrest biodiversity loss, protect environmental resources and services, and fight and mitigate CC effects to protect and improve terrestrial and aquatic ecosystems.

There is limited information on CC impacts in the island context (i.e., Sicily and Sardinia). No adaptation plans were implemented in the past to identify necessary and specific measures for the local context. Regional governments are characterised by a weak understanding and awareness of the features and dissimilarities of CC impacts on islands compared to the mainland [8]. In addition, some documents highlighted inadequate allocation of funds from the national to the local level, a lack of locally relevant and practical information about potential impacts, limited financial resources for both medium-sized organisations and local governments, and low climate culture of the organisations [40,41].

As previously highlighted, in recent years, thanks to the island of Sicily’s participation in the European project ADAPT2CLIMA, the effectiveness of some of the PNACC actions was analysed in a simulated scenario of decreasing climate-related vulnerability of the agriculture sector. The process helped to understand the importance of stressing more specific actions at the island level. Available solutions for the mainland are designed for homogeneous areas, and their implementation may not be efficient in particular contexts. Other limitations and barriers to implementing such measures on the island are related to national organisations and local governments’ capacities and different priorities [40].

4. Methodology

The participatory process was conducted in four steps, strictly oriented toward stakeholders’ engagement and promoting local adaptation action [42]. Presenting and discussing the background material was step 1. It laid the groundwork for the policy design exercise as it defined the picture of future climate scenarios for the island and their potential impact on the local socio-economic system. An extensive review of the available literature was required before this stage. Additional effort was dedicated to translating scientific results, complex data, and maps into infographics and fact sheets, with images and words to facilitate the comprehension of non-experts' and their interpretation of the information. The information was presented to stakeholders at an introductory event in which we also explained the analysis to be carried out.

Step 2 was devoted to the stakeholders' analysis of a catalogue of adaptation and risk management options, including 72 programmes (24 per sector). The programmes were adapted from the available literature on CC adaptation. At this stage, pre-defined criteria were established to evaluate these programmes' appropriateness and sustainability potential in the study context. This step was conducted at the sector level by organising workshops. Stakeholders were experts from local universities and research centres, public offices and agencies, and local sectoral associations. The sample included the stakeholders who agreed to cooperate on a volunteer basis.

Designing sector adaptation pathways was step 3. This was done through an online tool, similar to a questionnaire, that collected individual preferences for adaptation programmes that represented, according to stakeholders, a priority concern for the island in the short term (until 2030), mid-term (mid-century–until 2050), and long term (end of the century until 2100). Four possible scenarios of policy ambition (APTs) were constructed, aiming to obtain different packages of ranked programmes. Frequency analysis was applied to the stakeholders' responses. Results, aggregated by sector, were presented in a plenary session to identify cross-sector win-win situations (i.e., actions that would yield positive adaptation across some or all sectors) and, when possible, their decarbonisation performance (i.e., how each pathway will address measuring decarbonisation targets for the region).

Step 4 covered the pathway sustainability evaluation, allowing for a comparison between the final APTs and time frames in a radar graph. Figure 2 presents the methodological framework designed for the participatory process, the flow of information, and the sequence of methods performed to support the creation of local pathways.

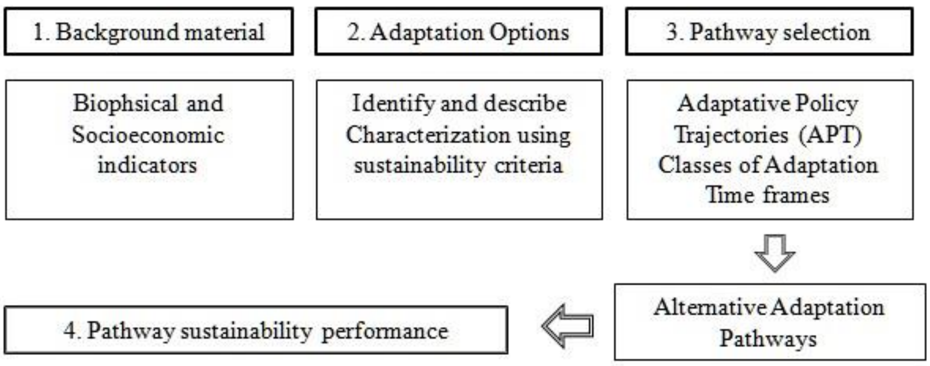

Figure 2. Methodological framework.

In total, 32 stakeholders were involved in this process. The profile involved policy- and decision-makers and practitioners, representing 44% of the sample; non-governmental and civil society organisations (16%); science experts (25%); and private parties, business operators, and sector regulators (15%). This process took two years, from June 2018 to March 2021. This was mainly because the COVID-19 pandemic appeared in the middle and stopped the process, which required a new and different start. The original plan was to hold only physical workshops and face-to-face questionnaires. In reality, a significant part of the process was redone and organised through online sessions, some in plenary with all stakeholders and others as sectoral workshops. This change also required dedicated resources to create a robust online support tool to collect individual views efficiently. The rationale of the COVID-19 contingency plan was to make it as easy as possible for stakeholders to carry out the proposed work without seriously compromising the scientific quality of the outcomes.

4.1. Catalogue of Adaptation and Risk Management Options

As mentioned before, the second step required the catalogue of programmes to be constructed, hence the policy options for the stakeholder analysis. In this vein, the Intergovernmental Panel on Climate Change (IPCC) proposes the use of RCP scenarios, which express starting atmospheric conditions for the CC models; SSPs that compile predefined packages of future socioeconomic contexts; and SPAs that include climate policy goals, policy regimes and measures, and implementation limits and obstacles [43,44].

A review of European adaptation literature and best practices was undertaken to create an outstanding catalogue to guide stakeholders' discussions on local benefits. The first significant source to start building this list was the Climate-ADAPT database (2022) [45], and the second was specific CC policy studies [46–51].

The main challenge in this phase was downscaling the programmes to the local scale. Indeed, several failures remain, as the proposed programmes neither ascertain the specific way in which a policy can be implemented nor the particular technologies nor investments needed (i.e., the beach protection programme through coastal defence infrastructure does not identify which specific structure is the most appropriate, which can vary from one point of the coast to another).

The adaptation and risk options/programmes were classified following Suckall et al. (2018) [52]. They considered three main strategic vectors for climate adaptation and resilience of any sector:

(i) Vulnerability reduction (VR): Programmes to reduce socio-economic vulnerability based on the five capitals of the sustainable livelihoods approach [47].
(ii) Disaster risk reduction (DRR): Programmes developed through the Hyogo and Sendai frameworks [52,53].
(iii) Socio-ecological resilience (SER): Programmes that affect socio-ecological resilience, including millennium ecosystem assessment (MEA) and Common International Classification of Ecosystem Services (CICES) [46,47].

Table 2 presents the distribution of the proposed programmes by sector and strategic vector, with the primary sources they were adapted from. The Supplementary Material includes the final catalogue of the 72 adaptation and risk management options utilised in this study and their characterisations.

Table 2. The number of adaptation programmes under analysis by a strategic vector (columns) and sector (rows).

	Vulnerability Reduction (VR)	Disaster Risk Reduction (DRR)	Socio-Economic Resilience (SER)
Maritime transport	10 programmes	8 programmes	6 programmes
Energy	10 programmes	8 programmes	6 programmes
Tourism	10 programmes	8 programmes	6 programmes
Reference	Bitner-Gregersen et al. (2018) [47]; De Bruin et al. (2009) [53]; De Sisternes et al. (2016) [54]; Lehr et al. (2012) [55]; Scott et al. (2013) [56]; Taneja, et al. (2012) [57]	Alfieri, L. et al. (2012) [58]; Ayoub et al. (2018) [59]; Crainic et al. (2009) [60]; Chhetri. et al. (2015) [61]; Cuce at al. (2016) [62]; Hammett and Mixter (2017) [63]; de Bruin (2009) [53]; Stahlhut et al. (2008) [64];	Apsley et al. (2009) [67]; Arias-Gaviria (2019) [46]; Bitner-Gregersen et al. (2018) [47]; Iglesias and Abanades (2017) [48]; Lund and Chiasson (2007) [68]; McNally and Natanzi

	Erol-Kantarci et al. (2011) [65]; Chen et.al (2015) [66]; Zhang al. (2017) [51]	(2018) [49]; Water Research Laboratory (2022) [69]

With the programmes being pre-defined, the stakeholders in each sector group contributed to their final characterisation. The sectoral groups were thus invited to analyse the pertinence of each programme and its sustainability potential. They could also propose new programmes not initially included in the catalogue at this stage.

Following Haque (2016) [70] and Verkerk et al. (2017) [71], five criteria were defined to evaluate the programmes, as shown in Table 3. The first criterion refers to cost efficiency (1 = low cost-efficiency; 4 = high cost-efficiency). It relates to the programme's ability to address current or future climate hazards/risks in the most economical way. The programme's ability to reduce emissions and minimise trade-offs with mitigation objectives was also considered relevant, together with the analysis of the current capacity on the island to implement the programmes (technical applicability). According to the stakeholders' views, the criterion of social acceptability refers to the potential acceptance of the program by civil society and policymakers. This information was utilised for the sustainability analysis of the final pathways, which is explained in the following sections.

Table 3. Criteria and scale are utilised to evaluate the sustainability potential of programmes.

Criterion	**Description**	**Measurement**
Cost-efficiency	Ability of proposed programme to efficiently address current or future climate hazards/risks in most economical way	1 = very low cost-efficiency; 4 = very high cost-efficiency
Environmental protection	Ability to protect environment, now and in the future	1 = very low environmental protection; 4 = very high environmental protection
Mitigation (GHG emissions) win–win and trade-off	Current ability to meet (win–win) or not (trade-off) island's mitigation objectives	1 = very high trade-off with mitigation goals; 4 = very high mitigation win–win and low trade-off
Technical applicability	Current ability to technically implement proposed option/programme	1 = very low technical applicability; 4 = very high technical applicability
Social acceptability	Social acceptability of option/measure	1 = very low social acceptability; 4 = very high social acceptability

4.2. Designing Sector Adaptation Pathways

Adaptation pathways usually capture policy preferences in a given time and context [52]. In this study, four adaptation pathway trajectories (APTs) were delineated as scenarios of policy ambition in terms of investment and commitment [71,52]. Therefore, it was assumed that stakeholders' preferences for programmes could be grouped from minimal to high-cost scenarios and from requiring a small to a significant change above the status quo [52].

Table 4 summarises the four APTs scenarios considered. Each APT has a specific narrative, adapted from Kebede et al. (2018) [72], Suckall et al. (2018) [52], and Hall et al. (2016) [73]. Minimum intervention APT A corresponds to a general approach in which climate actions continue to follow the tendency of historical levels of investment, where policies respond more exclusively to urgent needs protecting citizens and lives at a lower cost. Economic capacity expansion APT B focuses on planning the increasing investment in infrastructure capacity for the long-term resilience of the sector. Efficiency enhancement APT C may include actions to optimise the performance and efficiency of the current system, targeting both supply and demand and the deployment of technological innovations. Finally, system restructuring APT D groups highly transformational actions with a high level of investment and an increased commitment to significant policy change.

Table 4. The APT A,B,C,D, explanation.

APT A **Minimum intervention** (low investment/low commitment)	Assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts. Addresses those areas where maximum impact can be achieved for the lowest cost.
APT B **Economic capacity expansion** (high investment/low commitment)	Focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy. Requires a high level of investment to prepare the economy for future change but does not aim to reorient the economy or create significant change.
APT C **System efficiency enhancement** (medium investment/medium commitment)	Based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system, looking at ways of distributing labour, balancing livelihood choices, and best-utilising ecosystem services to enhance livelihoods and well-being under climate change.
APT D **System restructuring** (high investment/high commitment)	Embraces fundamental pre-emptive change at every level to completely transform the current socio-ecological and economic systems and thus change the social and physical functioning of archipelago/island sectors. Has a guiding belief that significant/radical landscape and societal modifications are justified to create long-term system restructuring despite the short-term costs among some social groups or economic sectors.

In the next phase (step 3), stakeholders were presented with a full explanation of the APTs to encourage thinking about different portfolios of ranked adaptation programmes. If one stakeholder could not analyse one APT scenario, it would be omitted, which was not the case. Hence, stakeholders selected the programmes they considered priority actions in each time frame (short-term, up to 2030; mid-century, 2030–2050; end-century, 2050–2100), as shown in Figure 3. The process was carried out for each APT scenario and sector independently, supported by an online tool that facilitated the exercise. The analysis was carried out by stakeholders individually. If a stakeholder was part of all three sector groups, they made 216 choices. All programmes selected within each time frame/APT were subject to frequency analysis.

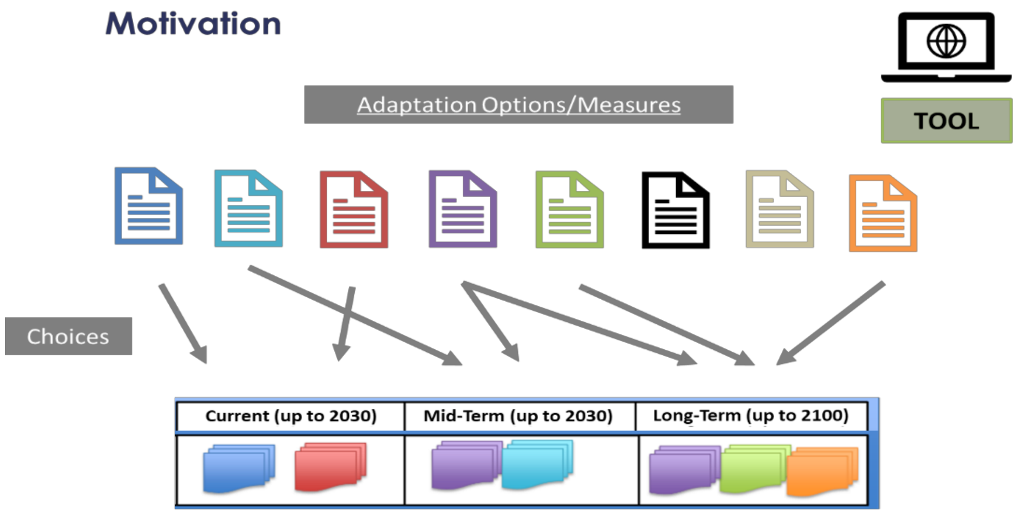

Figure 3. Theoretical representations of stakeholders' choices in the policy design exercise.

Hence, the final APTs obtained for each sector were formed with the most frequently chosen programmes. If a program was selected by at least 50% of the stakeholders in a specific time frame and APT, it was included in the pathway. The results were refined during a meeting with all sector representatives to capture inconsistencies and mutual benefits.

5. Results

The results are presented in two outputs per sector: (i) selected adaptation pathways (APTs) and (ii) sustainability evaluation. The first refers to the composition of the four final pathways per sector (from APT A to APT D) by incorporating the most frequent responses in each time frame. As expected, each APT comprises programmes representing a particular combination of priorities and commitment, which generally leads to a specific involvement level and policy ambition. Secondly, each pathway's sustainability potential is analysed by aggregating the average scores of the five sustainability criteria explained in Section 3.1.

5.1. Maritime Transport

The final adaptation pathways for the maritime transport sector are presented in Table 5. Pathways are significantly heterogeneous across the four APTs. Generally, the programme "Integrate ports in urban tissue" (MT7, socio-ecological resilience) received the highest level of concordance at 83%, followed by "Intelligent transport systems" (MT21, risk reduction) and "Refrigeration, cooling and ventilation systems" (MT13, vulnerability reduction), both at 75%.

APT A (low commitment) is characterised by the presence of programmes related to infrastructure protection (MT6), awareness campaigns (MT9), preparedness for delays and cancellations due to climate events (MT22), re-design of ports (MT18), and service management (MT 23) to confront climate-related impacts and maintain ports' operability in worsening future climate scenarios. Meanwhile, APT C and D add more ambitious programmes and propose more marine-friendly coastal protection infrastructures that can act as a source of wave energy production (MT3,4), thus combining adaptation with emissions reduction.

As expected, programmes to reduce vulnerability (VR) and increase resilience capacity (SER) have a more significant presence in APT C and D. Finally, climate-proof ports and activities (MT17) were the programmes more frequently chosen by stakeholders in all APTs, indicating that this should be considered a priority in all policy scenarios. Creating an intelligent transport system (MT21) only appears in the low investment scenario (APT

A). According to stakeholders, the island has sufficient technical capacity to implement this programme in its current situation.

Table 5. Alternative adaptation pathways for the maritime transport sector.

ID	Programmes	Strategic vector	APT A			APT B			APT C			APT D		
			S	M	L	S	M	L	S	M	L	S	M	L
MT1	Insurance mechanisms for ports	VR					B						D	
MT2	Financial incentives to retreat from high-risk areas						B						D	
MT10	Social dialogue for training in the port sector			A			B			C			D	
MT9	Awareness campaigns for behavioural change			A			B			C			D	
MT11	Diversification of trade using climate resilient commodities									C				
MT12	Climate resilient economy and jobs									C				
MT13	Refrigeration, cooling and ventilation systems									C			D	
MT14	Restrict development and settlement in low-lying areas									C			D	
MT16	Increase operational speed and flexibility in ports						B							
MT15	Sturdiness improvement of vessels						B							
MT17	Climate proof ports and port activities	DRR		A			B			C			D	
MT18	Consider expansion/retreat of ports in urban planning			A			B			C			D	
MT20	Early Warning Systems (EWS) and climate change monitoring									C				
MT19	Reinforcement of inspection, repair and maintenance of infrastructures									C				
MT21	Intelligent Transport Systems (ITS)			A										
MT22	Prepare for service delays or cancellations			A										
MT24	Post-Disaster recovery funds			A									D	
MT23	Backup routes and infrastructures during extreme weather			A									D	
MT4	Combined protection and wave energy infrastructures	SER								C			D	
MT3	Marine life friendly coastal protection structures			A			B			C			D	
MT6	Coastal protection structures			A			B			C				
MT5	Hybrid and full electric ship propulsion						B			C				
MT7	Integrate ports in urban tissue									C				
MT8	Ocean pools									C				

Note: VR, vulnerability reduction; DRR, disaster risk reduction; SER, socio-ecological resilience. Each APT (A, B, C, D) is represented in 3 time-frames: S, short-term (up to 2030); M, medium-term (up to 2050); and L, long-term (until 2100). Coloured boxes show the final programs that formed each APT: blue: APT A; green: AT B; orange: APT C; purple: APT D.

Figure 4 presents the results of the sustainability evaluation. The radar graph utilises the mean scores of the five sustainability criteria for the group of programmes that formed each APT and time frame. Only short- and long-term results are shown in the graphic.

In general, all four APT scenarios exhibit similar rankings; relatively high social acceptability and technical applicability of the programmes selected and low performance in terms of environmental protection. This means that stakeholders tend to choose programmes they consider to generate the maximum impact for the lowest cost in the island's current situation and better prepare the sector to deal with climate events. For example, APT C has the best sustainability performance, considering the five criteria in the longer term. It received the highest average scores in the cost-efficiency, environmental protection, and mitigation potential scales. This is because APT C includes programmes such as MT5 that propose the electrification of vessels. At the same time, APT A and B are more devoted to preparing vessels for sea storms (MT15) or using information systems to alert ships of CC hazards earlier (MT21), in which there is no direct environmental protection but by sector.

The same occurs in the short term, where APT D has the best sustainability performance, as it includes more adaptation programmes with the potential to reduce emissions (i.e., MT4).

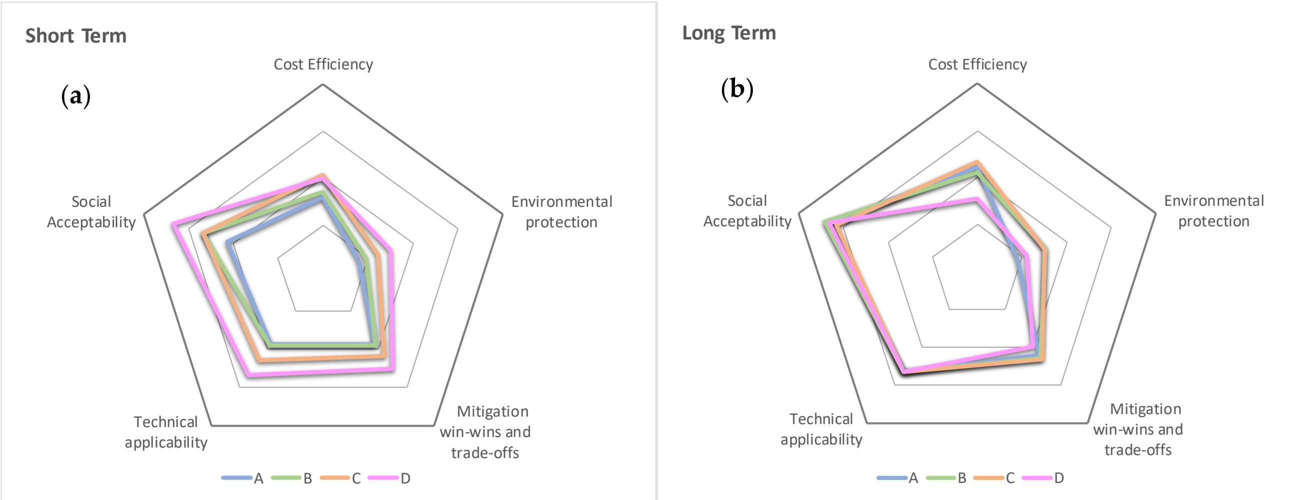

Figure 4. APT sustainability evaluation. (**a**) Sustainability evaluation of APTs in the short term; (**b**) sustainability evaluation of APTs in the long term. Note: The sustainability potential of each programme was measured by a 4-point scale and considering five criteria: cost-efficiency, environmental protection, mitigation (GHG emissions) win-win and trade-off, technical applicability, and social acceptability (see Section 3.1).

5.2. Energy

Table 6 presents the final adaptation pathways for the energy sector on the island of Sicily. Overall, APTs are characterised by heterogeneity concerning programmes and strategic vectors of significant concern. As expected, programmes aiming to increase social-ecological resilience are concentrated in more ambitious policy scenarios (APTC-D). At the same time, APTA is more devoted to preparedness and recovery in extreme events (DRR) cases. Hence, using waste heat from power plants for heating pools (E8) is the programme most frequently chosen within APT C and D, while in APT A, more operational actions were often selected by stakeholders, such as E22 (energy independency, 67%), E23 (energy recovery microgrid, 56%), E21 (study and develop energy grid connections, 56%), and E17 (review building codes of the energy infrastructure, 56%). On its side, APT C is characterised by a broader awareness of the need to reduce vulnerability and increase social-ecological resilience in the medium- and long-term.

All APTs propose the creation of green jobs and businesses (E9) and the review of building codes and generators (E17) for all time frames to reduce the vulnerability of the sector (VR). However, stakeholders consider the commitment to raise public information and knowledge about climate actions in the energy sector as secondary (E10), given the low frequency of responses. The promotion of educational gardens (E7) is not a priority since it was not chosen by any APT.

Table 6. Alternative adaptation pathways for the energy sector.

ID	Programmes	Strategic vector	APT A			APT B			APT C			APT D		
			S	M	L	S	M	L	S	M	L	S	M	L
E2	Financial support for smart control of energy in houses and buildings	VR					**B**						**D**	
E1	Financial support for buildings with low energy needs						**B**						**D**	
E9	Green jobs and businesses			**A**			**B**			**C**			**D**	
E10	Public information service on climate action			**A**			**B**			**C**			**D**	
E11	Small scale production and consumption									**C**				
E12	Risk reporting platform									**C**				
E13	Energy storage systems									**C**			**D**	
E14	Collection and storage of forest fuel loads									**C**			**D**	
E16	Demand Side Management (DSM) of Energy						**B**							
E15	Seawater Air Conditioning (SWAC).						**B**							
E17	Review building codes of the energy infrastructure	DRR		**A**			**B**			**C**			**D**	
E18	Upgrade evaporative cooling systems			**A**			**B**			**C**			**D**	
E20	Grid reliability									**C**				
E19	Early Warning Systems (EWS)									**C**				
E21	Study and develop energy grid connections			**A**										
E22	Energy-independent facilities (generators)			**A**										
E23	Energy recovery micro grids			**A**									**D**	
E24	Local recovery energy outage capacity			**A**									**D**	
E4	Underground tubes and piping in urban planning	SER		**A**			**B**			**C**			**D**	
E3	Energy efficiency in urban water management			**A**			**B**			**C**			**D**	
E5	Biomass power from household waste						**B**			**C**				
E6	Urban green corridors									**C**			**D**	
E8	Heated pools with waste heat from power plants									**C**				
E7	Educational garden plots									**C**				

Note: VR, vulnerability reduction; DRR, disaster risk reduction; SER, socio-ecological resilience. Each APT (A, B, C, D) is represented in 3 time-frames: S, short-term (up to 2030); M, medium-term (up to 2050); and L, long-term (until 2100). Coloured boxes show the final programs that formed each APT: blue: APT A; green: APT B; orange: APT C; purple: APT D.

Figure 5 presents the sustainability analysis results by calculating the mean scores of the five sustainability criteria for every group of programmes that formed the APTs. Although stakeholders were aware of the most beneficial and balanced adaptation programmes across the sustainability criteria, the priorities in policy design are dominated more by the aim of public acceptance and the maximum impact for the lowest cost.

For example, when stakeholders evaluated the sustainability potential of the energy programmes, the collection and storage of forest fuel loads (E14) received higher average scores than the operationalisation of energy microgrids (E23), which aim to prepare systems for power outages caused by knock-out events and excess demand (e.g., during heat waves). However, the latter was chosen as a priority measure in APT A by 56% of the stakeholders, while E14 was only by 22% in the APTD. This can be explained by the vast amount of resources and cross-sectoral collaboration required in maintaining woods, increasing the spacing between trees and reusing materials for energy (pellets, biogas).

Although few in number, other programmes such as E8 (heated pools with waste heat from power plants) were considered with excellent sustainability potential and were highly preferred in the policy design, given their potential to increase tourist attraction to the destination. This type of result enriched by the cross-sectoral discussion highlights the relevance of cost efficiency and social acceptance for stakeholders.

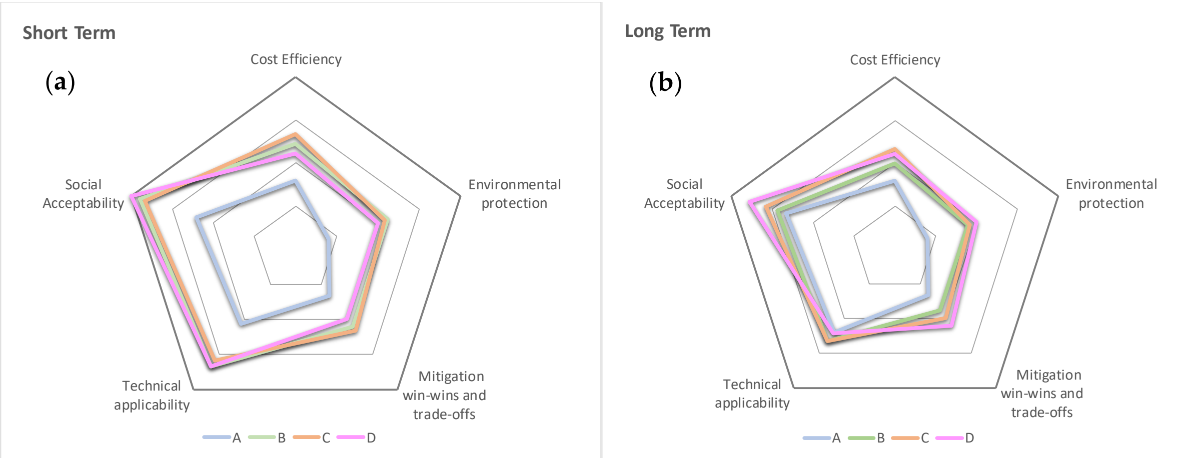

Figure 5. APT sustainability evaluation. (**a**) Sustainability evaluation of APTs in the short term; (**b**) sustainability evaluation of APTs in the long term. Note: Sustainability of proposed programs was measured on a 4-point scale considering five criteria: cost-efficiency, environmental protection, mitigation (GHG emissions), win-win and trade-off, technical applicability, and social acceptability (see Section 3.1).

5.3. Tourism

Table 7 presents the final structure and composition of the APTs for the tourism sector. Moreover, significant attention is drawn in this sector toward a more practical and operational approach to adapting existing processes and management. Programmes related to modelling and forecasting (T4), tourism diversification (T9), and drought management (T18) were chosen in all four APTs by more than half of the stakeholders, which means that they are priority concerns.

Specifically, concerning vulnerability reduction (VR) objectives, the results indicate that stakeholders are centred on natural, social, and physical capital rather than financially related programmes. Especially in APT C, the goal is to address a circular economy system and more sustainable tourist activities.

Table 7. Alternative adaptation pathways for the tourism sector.

ID	Programmes	Strategic Vector	APT A			APT B			APT C			APT D		
			S	M	L	S	M	L	S	M	L	S	M	L
T1	Economic Policy Instruments (EPIs)	VR					B						D	
T2	Financial incentives to retreat from high-risk areas						B						D	
T9	Activity and product diversification			A			B			C			D	
T10	Public awareness programmes			A			B			C			D	
T11	Local circular economy									C				
T12	Tourist awareness campaigns									C				
T13	Local sustainable fishing									C			D	
T14	Water restrictions and grey-water recycling									C			D	
T15	Beach nourishment						B							
T16	Desalination						B							
T18	Drought and water conservation plans	DRR		A			B			C			D	
T17	Coastal protection structures			A			B			C			D	
T19	Mainstreaming Disaster Risk Management (DRM)									C				
T20	Using water to cope with heat waves									C				
T22	Health care delivery systems			A										
T21	Fire management plans			A										
T24	Pre-disaster early recovery planning			A									D	
T23	Post-Disaster recovery funds			A									D	
T4	Monitoring, modelling and forecasting systems	SER		A			B			C			D	

T3	Adaptation of groundwater management			**A**			**B**			**C**			**D**	
T6	River rehabilitation and restoration						**B**			**C**				
T5	Dune restoration and rehabilitation						**B**			**C**				
T7	Adaptive management of natural habitats									**C**				
T8	Ocean pools									**C**				

Note: VR, vulnerability reduction; DRR, disaster risk reduction; SER, socio-ecological resilience. Each APT (A, B, C, D) is represented in 3 time-frames: S, short term (up to 2030); M, medium-term (up to 2050); and L, long term (until 2100). Coloured boxes show the final programs that formed each APT: blue: APT A; green: APT B; orange: APT C; and purple: APT D.

To manage disaster risks (DRR), the results highlight a significant preference for coastal protection (T17) and water conservation plans (T18). Within the programmes addressing socio-ecological resilience (SER), the adaptive management of natural habitats was considered a priority for most stakeholders in APT C, indicating that this is crucial for promoting efficiency in adaptation investment.

Figure 6 presents the sustainability analysis results by calculating the mean scores of the five sustainability criteria. The four APT scenarios have similar sustainability results from the short to long term, with social acceptability and technical applicability showing the best results for all APTs. In APT A, stakeholders prioritise programmes that provide the sector with security and new directions to maintain its economic performance (e.g., coastal protection structures, diversification of the tourism economy, etc.). Scenarios APT B and APT C show more balanced results for all sustainability criteria. Finally, high investment and commitment to CC (APT D) requires implementing more ambitious programmes in terms of environmental protection and win-win mitigation scenarios without forgetting the social and technical aspects (e.g., greywater recycling, T14).

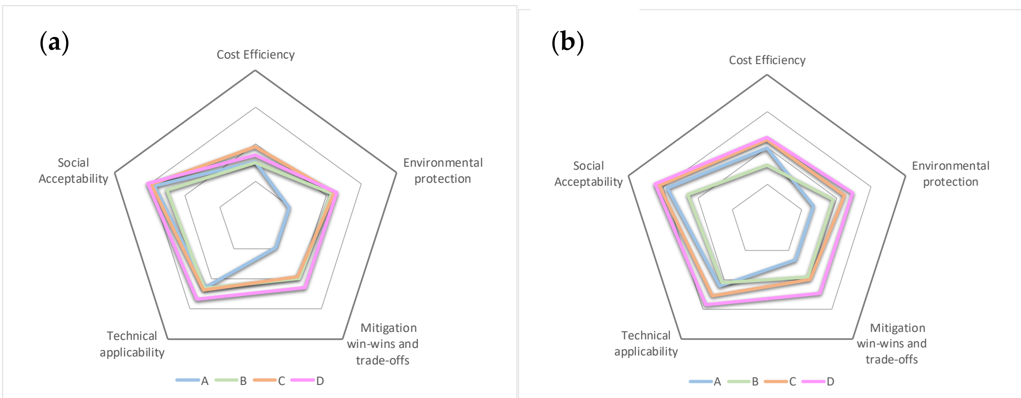

Figure 6. APT sustainability analysis. (**a**) Sustainability evaluation of APTs in the short term; (**b**) sustainability evaluation of APTs in the long term. Note: Sustainability of proposed programs was measured by a 4-point scale considering five criteria: cost-efficiency, environmental protection, mitigation (GHG emissions) win-win and trade-off, technical applicability, and social acceptability (see Section 3.1).

6. Policy Discussion

With policymakers ultimately being the ones who are expected to make correct use of this research, we attempted to maximise its policy orientation by reaching a compromise between simplicity and scientific relevance that proved to be highly appreciated [70,71]. We analysed and ranked CC adaptation programmes for tourism, energy and maritime transport and proposed alternative adaptation pathways for the case of the island of Sicily through the lens of high-level sectoral representatives, academics, and experts. These primary outlines are considered the first and most essential attitudes to be prepared at the local level for future climate scenarios. When top-down governance systems prevail, as with the island of Sicily, there is often a lack of communication-related to climate change impacts and a lack of empowerment of local decision-makers, which increases the risk of adaptation [72–74]. In this vein, the policy implication of the study is twofold. First, the production of precise and adapted information at a local level by enabling cooperation between science and society to raise awareness about the urgent need to deal with climate change issues in more efficient terms; second, the engagement process carried out can be seen as a step towards speeding up the transition from identifying adaptive capacities to designing adaptation policies in terms of long-term sustainability and social-ecological resilience.

The participatory process also provided information about critical areas that need to be addressed at a local level, such as the incomplete understanding of vulnerability dimensions and leeway for adaptation [12,21,42,75]. It also allowed us to discuss priority risks, other islands, and new opportunities for the island of Sicily from a multidisciplinary perspective [24,25,75]. Some climate risks for the island of Sicily are expected to be lower than for other European islands farther from the mainland [76,77]. In addition, although the island of Sicily is significantly exposed to marine habitat degradation, there is more potential to offer viable substitutes for marine and tourist activities, thanks to the island's extraordinary endowment of assets. Indeed, the island of Sicily presents a balanced array of tourist offerings [26], including a wide range of cultural, social, landscape, gastronomic, and historical resources that ensure the tourism activity is not strictly dependent on the marine environment, as well as being more resilient [4,44] to the risk of seawater heating [35].

More details about spatial hotspots were revealed, which allows for an in-depth characterisation of the adaptation programmes (i.e., to which tourism products the island should be diversified). Moreover, some priority measures proposed for the energy sector were considered beneficial for tourism, such as enabling energy microgrids and using waste heat from power plants for heating pools. Hence, considering that transparency and case-specific information is crucial for ensuring a higher commitment to effective adaptation planning [52], this study has significantly contributed to building up the basis for improved climate actions at a local level.

The most challenging task was putting the stakeholders into the context of different scenarios of policy ambition. This task was highly demanding but significantly improved the stakeholders' experience with the process. An excellent understanding was achieved when the APTs' rationale was scaled down with shorter descriptions, images, and real-world examples [52]. The results demonstrate that stakeholders correctly understood the diverse policy directions when making their choices. For instance, they selected more programmes that provide general solutions for protecting citizens and capital needs; highly diversified activities; and responses to potential damage to economic activities in the low-commitment scenario, APT A. In APT B (economic capacity expansion), we see that many resources (investments) are used to deal with climate risks and thus expand the capacity of protection from risk. For example, coastal flooding is dealt with by building ever larger heavy protections that prevent the impact of physical force. In APT C, more efficient solutions are selected, implying fewer resources but requiring more engagement. In APT D (system restructuring), where high investment and engagement are necessary, we frequently find measures with the potential to enhance socio-ecological resilience.

This means that stakeholders recognise the need to protect human and social capital but also the quality of the environmental services that support these activities. With the policy scenarios and measures being understood by almost all, stakeholders' concerns revolved around affordability and the significant costs associated with the required structural changes, which certainly depend on national decisions [78–81]. This may be why stakeholders tend to concentrate on more ambitious adaptation programmes in the longer term.

7. Conclusions

This article used a mixed-method approach through literature review and participatory assessment based on multicriteria analysis [70,73] to identify and rank alternative adaptation pathways [71,72] in an island context. The methodology is framed in the socio-economic context of the island of Sicily, a large island without implemented adaptation plans.

In this regard, this study has been able to crystallise measures that, according to the stakeholders, have the potential to increase the climate-related resiliency capacities of the energy, tourism, and maritime transport sectors. The methodological framework was ambitious and led to valuable results, bearing in mind that this was the first step towards local adaptation solutions. Therefore, the proposed pathways should be considered a focal point for future discussion between researchers, practitioners and the island’s citizens. Hence, there is room for future contributions in these subfields of research.

From the methodological perspective, there is a possibility to use this evidence to bridge the gap between academic research and practical policy design beyond the sectors and the island analysed. In this respect, a relevant issue is whether findings reported in the literature can constitute a common groundwork for raising alternative solutions to climate actions locally. Moreover, when the information at a local level is full of subjectivity, experts’ participation is crucial, and multi-criteria analyses have proven sufficient robustness in many decision-making fields [42].

The study’s results highlight the great importance that local stakeholders attach to programmes for their ability to meet social and capital needs in future climate scenarios with a contained investment. The participatory process also revealed a breach between what stakeholders would prioritise when designing adaptation pathways and their opinion about the policies across the sustainability criteria. Although stakeholders were aware of the most beneficial and balanced adaptation programmes, the priorities when designing climate policies are dominated more by the aim of public acceptance and the maximum impact for the lowest cost.

The study focuses on three sectors, but there was room to discuss adaptation with a multisector perspective. In this regard, common adaptation needs to arise, mainly to confront sea-level rise and increased frequency of extreme temperatures, a major concern of the local stakeholders and a critical risk for the island according to climate projections. This concern was materialised in the stakeholders’ choices, with a higher preference for infrastructure protection measures (MT4, MT6), the improvement of cooling (MT13) and energy storage systems (E13), and improved healthcare delivery systems (T22), among others. Surprisingly, the energy sector was the only one where stakeholders considered raising public information and awareness not to be a priority, suggesting that society (consumers) is far from influencing policymaking.

Some study limitations emerged regarding the geographical, sectoral scope and the dimension and composition of the sample of stakeholders involved. Indeed, the number of experts was limited, and the composition was homogeneous. There were not the same numbers of categories, practitioners, academics, public authorities, and sector experts for each sector analysed. At the same time, the number of stakeholders in each industry was not equal. This suggests the need to conduct further analysis to overcome these aspects. Moreover, the consideration of other sectors that are also relevant for the islands (i.e., fisheries, aquaculture, agriculture) could enrich the analysis and expected benefits of climate actions.

Future research could consider a deeper analysis of the structural relations between sectors and the extension of the multicriteria analysis since sectoral changes induced by certain hazards would modify the exposure and vulnerability of other sectors. A solution may be using different hierarchy trees, each defined for a particular combination of climate risks and sectors and adequately treating the systemic loops between them.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land11081206/s1. Catalogue of adaptation options for the island of Sicily (Italy).

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